

LIMIS

'6th



The 6th International Symposium on  
Laser Interaction with Matter



# LIMIS

August 10-12, 2022    Ningbo, China



:: Hosts



:: Co-organizers



:: International Co-organizer

**SPIE.**

# Program



The 6th International Symposium on  
Laser Interaction with Matter

August 10-12, 2022 Ningbo, China

**LIMIS**  
6th

	August 10	August 11	August 12	Hall
<b>Registration</b>	9:00-21:00	7:00-18:00	8:00-14:00	Hotel Lobby
<b>Workshop</b>	14:00-18:00			4F, Qizhi Hall
<b>Opening Ceremony</b>		8:30-8:45		4F, New Century Hall
<b>Plenary Session</b>		8:45-12:30	8:30-12:10	4F, New Century Hall
<b>SC1: Laser irradiation effect and mechanism</b>				4F, New Century Hall 2
<b>SC2: Plasmas and optics physics</b>				4F, Siji Hall
<b>SC3: Laser spectrum technology and applications</b>		14:00-17:30	13:30-17:30	4F, Shangli Hall
<b>SC4: High power lasers</b>				4F, New Century Hall 1
<b>SC5: Micro-nanophotonics</b>				4F, Qizhi Hall
<b>Poster Session</b>		17:30-18:30		4F, Rest Area
<b>Banquet</b>		18:30-20:30		4F, New Century Hall

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# Committee

## Hosts

State Key Laboratory of Laser Interaction with Matter  
Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

## Co-organizers

Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences  
Northwest Institute of Nuclear Technology  
Nanjing University of Science and Technology

## International Co-organizer

**SPIE.**

## Honorary Chairs

### Jianlin Cao

State Key Laboratory of Applied Optics

### Ruxin Li

Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

## Symposium Co-chairs

### Dianyuan Fan

Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

### Yuxin Leng

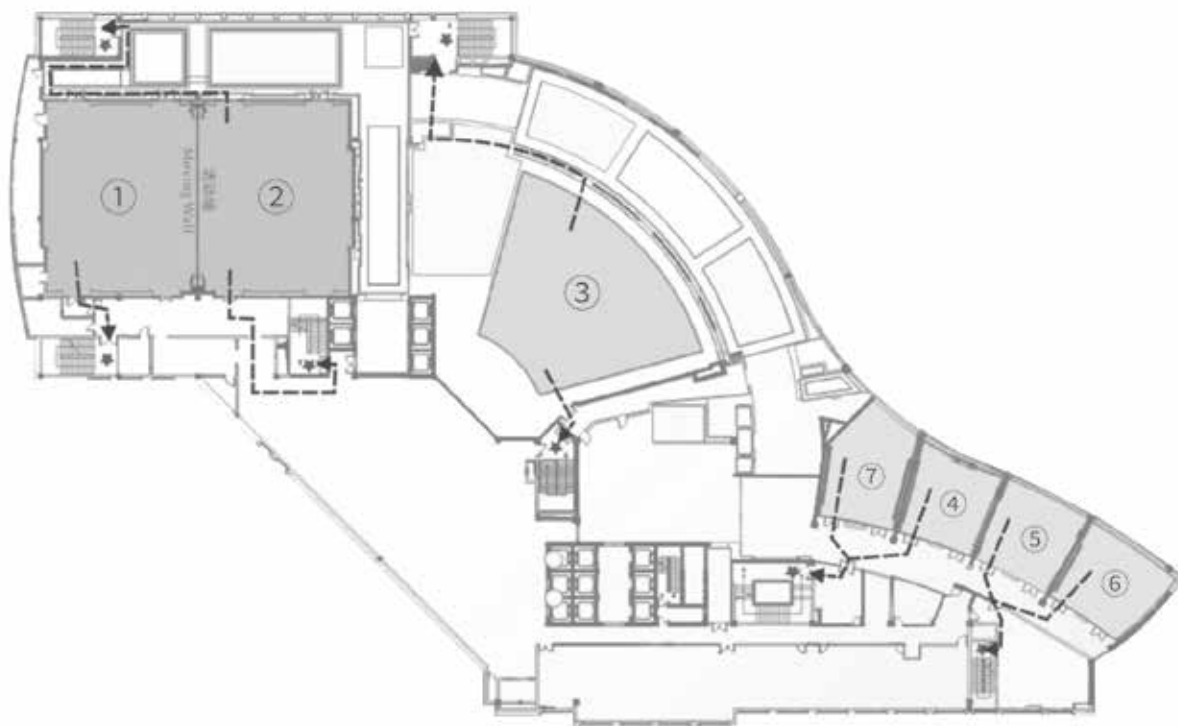
Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

### Guobin Feng

Northwest Institute of Nuclear Technology, State Key Laboratory of Laser Interaction with Matter

# Sponsors





## Conference Map

Opening Ceremony & Plenary Session & Banquet

SC1: Laser irradiation effect and mechanism

SC2: Plasmas and optics physics

SC3: Laser spectrum technology and applications

SC4: High power lasers

SC5: Micro-nanophotonics & WorkShop

① & ② 开元厅 New century Hall 1 & 2

② 开元厅1 New century Hall 2

⑤ 思义厅 Siyi Hall

④ 尚礼厅 Shangli Hall

① 开元厅1 New century Hall 1

⑦ 启智厅 Qizhi Hall

# General Information

The 6th International Symposium on Laser Interaction with Matter will be held on 10-12 August (registration on 10 August) in Ningbo, China. Jointly organized by State Key laboratory of Laser Interaction with Matter and Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, LIMIS is expected to attract about 250 participants from all over the world, including about 70 invited speakers.

Conference venue: New Century Grand Hotel, Ningbo  
Hotel Address: No. 666, Shounan Middle Road, Yinzhou District, Ningbo, Zhejiang, China

## Speaker Preparation

Time of an oral talk will be 15 min, including Q & A. For all oral speakers, please arrive the session room 30 min before your talk to upload and check the PPT.

## Poster Preparation

Authors are required to stand by their posters during the poster session for discussion. Please make sure to print your mobile tel. and email in the poster, because the conference staff will contact the winner of Best Poster Award, which will be selected on-site the poster session.

Poster session: August 11, 17:30-18:30

Poster board size: 0.95 m (length) \* 2.47 m (height), recommended poster size: 0.8m \* 1.2 m

Set-up time: August 11, 8:00-15:30

\*No show of the oral/poster presentations will be remarked and these papers will not be published in SPIE Digital Library.

LIMIS will select Best Papers and Best Posters.

**Best Papers Awards** The candidates will be selected from all contributed submissions. All candidates be scheduled to show on the afternoon of August 11 by oral. The winner will be selected by session chairs on-site.

**Best Posters Awards** Each session will select Best Poster. The winner will be selected by session chairs on-site the conference during the poster session.



# Workshop on Ultrashort Intense Lasers and Atmospheric Applications

14:00-18:00, August 10, 2022 Qizhi Hall

Inspiring by the technique of Chirped Pulse Amplification (CPA) invented in 1985, ultrashort intense laser has been well developed in the past three decades. Following the development of intense femtosecond lasers, growing attention has been devoted to the atmospheric applications through optical Kerr effect induced laser filamentation. The workshop of Ultrashort Intense Lasers and Atmospheric Applications will discuss the frontiers ranging from ultrashort laser pulse generation, amplification, atmospheric propagation and its interaction with matters.

## Invited Talk

### **The technology of laser propagation in atmosphere**

*Wenyue Zhu*, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

### **High-power GHz femtosecond fiber lasers and their applications**

*Xiaoming Wei*, South China University of Technology

### **High power SPM-assisted broadband all-fiber Raman laser at 1180 nm**

*Kun Liu*, China Electronics Technology Group Corporation

### **Low coherent “KunWu” laser facility and recent LPI Experiments on it**

*Yanqi Gao*, China Academy of Engineering Physics

### **Ultra-intense and ultra-short lasers in SIOM, from 1PW to 100PW**

*Yi Xu*, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

### **Characterization of electromagnetic pulses generated from plasma associated with ultrashort laser-solid interaction in the atmosphere**

*Chuliang Zhou*, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

### **Recent progress on femtosecond laser filamentation at SIOM**

*Tiejun Wang*, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences







# The 6th International Symposium on Laser Interaction with Matter

August 10-12, 2022 Ningbo, China

## **Plenary Session 1** Site:4F, Kaiyuan Hall August 11, 2022

Presider: Yuxin Leng, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

08:30-08:45

**Opening Ceremony**

08:45-09:25

**Metaphotonics and metasurface**

*Yuri S. Kivshar, Australian National University*

09:25-10:05

**Light-Matter Interaction at the Nanoscale: from 2D Materials to Nanolasers**

*Cunzheng Ning, Shenzhen Technology University*

10:05-10:30

**Coffee Break&Group Photo**

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## **Plenary Session 2**

Presider: Cunzheng Ning, Shenzhen Technology University

10:30-11:10

**Recent progress on Ultra-shot laser driven X-ray sources and its applications in LFRC**

*Yuqiu Gu, Research Center of Laser Fusion, China Academy of Engineering Physics*

11:10-11:50

**Progress on high power pulsed gas laser in SKLLIM**

*Ke Huang, Northwest Institute of Nuclear Technology, The State Key Laboratory of Laser Interaction with Matter*

11:50-12:30

**Wall-bounded combustion: Thermochemical and fluid dynamical analysis using advanced laser diagnostics**

*Andreas Dreizler, Technische Universität Darmstadt*



# The 6th International Symposium on Laser Interaction with Matter

August 10-12, 2022 Ningbo, China

## Plenary Session 3 Site:4F, Kaiyuan Hall August 12, 2022

President: Wentao Wang, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

08:30-09:10

### When laser meets mechanics — Recent advances in laser induced shocks and damages in IMECH

*Hongwei Song, Institute of Mechanics, Chinese Academy of Sciences*

09:10-09:50

### Strong Light-Matter Coupling in Halide Perovskite Microcavity for Room-temperature Polaritonics

*Qihua Xiong, Tsinghua University*

09:50-10:10

Coffee Break

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## Plenary Session 4

President: Qihua Xiong, Tsinghua University

10:10-10:50

### Free-electron lasing on a laser wakefield accelerator at SIOM

*Wentao Wang, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*

10:50-11:30

### Femtosecond Coherent Anti-Stokes Raman Scattering (CARS) Measurements

*Robert P. Lucht, Purdue University*

11:30-12:10

### Current Status of the Shanghai Superintense Ultrafast Laser Facility (SULF)

*Xiaoyan Liang, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*

# Plenary Session

## Metaphotonics and metasurfaces

### Yuri Kivshar

*Nonlinear Physics Center, Research School of Physics,  
Australian National University, Australia*



**Abstract:** I aim to introduce and discuss the recently emerged field of all-dielectric resonant metaphotonics that provides practical alternatives for nanoscale optics by employing resonances in high-index dielectric nanoparticles and metasurfaces. I will discuss the physics of dielectric Mie-resonant metamaterials for efficient spatial and temporal control of light by employing multipolar resonances and bound states in the continuum to achieve high Q factors, with applications to chiral and nonlinear photonics, nanolasers, and sensing. I will also emphasize my strong collaboration with several leading groups in China.

**Biography.** Yuri Kivshar received PhD degree in 1984 in Kharkov (Ukraine). From 1989 to 1993 he worked at several research centers in USA and Europe, and in 1993 he moved to Australia where he established Nonlinear Physics Center at the Australian National University. His research interests include nonlinear physics, metamaterials, and nanophotonics. He is Fellow of the Australian Academy of Science, OSA, APS, SPIE, and IOP. He received many awards for his research including Lyle Medal (Australia), Lebedev Medal (Russia), The State Prize in Science and Technology (Ukraine), Harrie Massey Medal (UK), Humboldt Research Award (Germany), SPIE Mozi Award (USA), and more recently Max Born Award (Optica, former OSA)

## Light-Matter Interaction at the Nanoscale: from 2D Materials to Nanolasers

### Cunzheng Ning

Shenzhen Technology University and Tsinghua University



**Abstract:** Light matter interactions span over many orders of magnitude in many characteristic quantities such as space extension, time scales, and energy/power levels. While most talks of the conference deal with large extremes of these quantities, my talk will focus on the other extreme: the extremely small scales or nanoscale. More specifically, my talk will overview the progress in the last 10+ years in taking advantages of nanoscale light-matter interactions to make smallest possible lasers. These lasers include nanolasers based on plasmon-photon interactions or coupling between a silicon nanobeam with 2D mono-molecular layer materials.

**Biography:** Cun-Zheng Ning received his PhD from the University of Stuttgart, Germany. His research interest has included laser physics, stochastic resonances, geometric phases in non-Hermitian systems, semiconductor physics, nanophotonics and nanolasers. He was a tenured full professor at Arizona State University (2006-2021), Professor and Director of Tsinghua International Center for Nano-Optoelectronics, Tsinghua University (2014-2022). He is now a Chair Professor and Dean, College of Integrated Circuits and Optoelectronic Chips at Shenzhen Technology University. He discovered the geometric phase in self-pulsing lasers, the first example of Berry's phase in non-Hermitian and nonlinear systems. Together with Gang Hu, they discovered a phenomenon of "stochastic resonance without external signal", or now known as "Stochastic Coherence". Together with Martin Hill, they demonstrated one of world's first plasmonic semiconductor laser. More recently, he invented and demonstrated the first white laser, which won "The Best of Tech" in 2015 as the "Top 10 Engineering Inventions of the Year" by Popular Science magazine. The first room-temperature laser based on 2D material by his group was selected as China's top 10 most important progress in optics in 2017. For his various achievements, he has won several international awards including NASA and NASA Contractor Awards, CSC Technical Excellence Award, IEEE/Photonics Society Distinguished Lecturer Award, and Humboldt Research Award. Dr. Ning is a Fellow of the Optical Society (OSA), IEEE, and the Electromagnetic Academy, and a member of US Inventors Academy.

## Recent progress on Ultra-shot laser driven X-ray sources and its applications in LFRC

### Yuqiu Gu

Laser fusion research center, CAEP



**Abstract:** As an intense laser (intensity  $>10^{18}$ W/cm<sup>2</sup>) interacting with a target (solid, liquid, or gas), its energy will efficiently transfer to relativistic electrons with very high current density, then produce short pulse x-ray, proton beams, or neutron sources through several different physical mechanisms. In this talk, the x-ray source researches in LFRC based on short pulse laser will be reviewed. Our purpose of developing laser-driven x-ray sources is mainly based on its merits of short pulse and small emitting spot. Based on high power pico-second laser beams coupled with large energy nanosecond laser system laser systems, the characters and radiography capabilities of micro-spot x-ray sources were studied extensively. Based on high repetition femtosecond laser system, a micro-spot hard x-ray source produced by tens MeV electron beam hitting on a high-Z converting target was also researched and demonstrated to non-destruction inspection. A high energy CT using this hard x-ray source was performed, which shows that the resolution of reconstruction can reach 100  $\mu$ m at 10% contrast.

**Biography:** Prof. Yuqiu Gu is an established Senior Researcher in experimental high energy density physics, author of more than 150 papers published in international peer-reviewed journals. He took part in LFRC in 2000 and used to be the head of department of high energy density physics and now is associated chief scientist of LFRC.

## Progress on high power pulsed gas laser in SKLLIM

### Ke Huang

Northwest Institute of Nuclear Technology, The State Key Laboratory of Laser Interaction with Matte



**Abstract:** Gas lasers with abundant wavelength and high output power or high pulse energy have broadly used in scientific research, industry, and medical treatment. In UV region, excimer laser is a promising candidate for ICF/IFE driver due to its remarkable advantages in high coupling efficiency, uniform ablating and high instability threshold. A 100J/10ns/18 beams angular-multiplexed XeCl MOPA system was completed In SKLLIM, and mainly concentrated on laser plasma interaction and high energy density physics. The conceptual design of 10KJ laser system featured by LTD driver has been made recently and the LTD module is being developed. Up to now, chemical or molecule gas laser is still the main way to acquire high pulse energy in mid-infrared band far-infrared band. Such as electric discharge initiated hydrogen and deuterium fluoride chemical lasers has been reached to 100J level. And benefited from the advance of pulse power and gas purification technology, the high energy laser system operated with high repetition rate comes true. In SKLLIM, 300W HF laser up to 200Hz running has been achieved recently, and the output power of CO<sub>2</sub> laser with narrow bandwidth increased enormously as the candidate of VUV photoresist driver source. Moreover, new type gas lasers come forth continually for thermal management superiority, such as optical pumping alkali metal vapor laser, nanoparticle gas laser, hollow core fiber gas laser, and so on. All these new developments show that the study on gas laser is a vital field. A breakthrough spring up will be hopeful.

**Biography:** Ke Huang received PhD degree in nuclear technology and applications from Northwest Institute of Nuclear Technology and is employed as a research associate at SKLLIM, NINT since 2010. In 2018, he worked at Quantum Optical Institute Hannover University In Germany as a visiting scholar. His professional interests focus on high power pulsed laser technology and applications, current projects include state key laboratory foundations and national research programs. Recent years, he published more than 60 papers, authorized 9 patents and was honored with three ministerial incentives.

## Wall-bounded combustion: Thermochemical and fluid dynamical analysis using advanced laser diagnostics

**Andreas Dreizler**

*Technical University of Darmstadt, Germany*



**Abstract:** Interactions of premixed flames with walls are of importance in several thermochemical processes of practical relevance, such as gas turbines or internal combustion engines. Even though flame-wall interactions (FWI) are restricted to regions very close to solid walls of a combustion chamber, they are crucial for overall heat losses, unburned hydrocarbon emissions and formation of wall deposits. Increasing power densities, associated with the recent trend of downsizing, cause a rising surface-to-volume ratio, which motivates detailed studies of FWI. Due to small characteristic scales in space and time, an experimental investigation of FWI is challenging. In the past decades, the focus was on heat transfer characteristics, whereas studies of thermochemical and fluid-dynamical states and their differences to unbounded flames have been analysed only in a few cases.

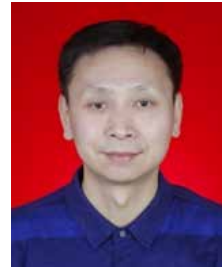
Modelling of turbulent flames close to walls is similarly a challenge. Although direct numerical simulations (DNS) based on detailed chemical reaction mechanisms and transport models enable an in-depth analysis of near-wall combustion, DNS is prohibitive for more realistic geometries and combustion of hydrocarbon fuels. Reduced-order models, such as large eddy simulation, are needed to account for the impact of the wall on flame structures and hence the thermochemical state.

Development of suitable mathematical models and validation of numerical simulations using improved near-wall combustion models needs suitable benchmark experiments and comprehensive experimental data. In this context, this contribution focusses on measuring important properties of an atmospheric premixed flame in a sidewall-quenching (SWQ) geometry, including laminar and turbulent flow conditions, using advanced multi-parameter laser diagnostics.

## When laser meets mechanics — Recent advances in laser induced shocks and damages in IMECH

**Hongwei Song**

*Institute of Mechanics, CAS*



**Abstract:** Working as a stable and controllable thermal-mechanical loading methodology with high efficiency, high power laser has been increasingly employed by researchers in mechanics. This report introduces recent advances in laser induced shocks and damages in IMECH. Short-pulsed lasers are utilized to generate high pressure shocks to investigate mechanical behaviors of novel materials under extremely high strain rate, the dynamics of bubbles evolution in the water, and high speed dust erosion on photovoltaic cells. Continuous wave lasers are utilized to induce damages under multifields environments, and coupled fluid-thermal-ablation analysis is developed to investigate the interaction mechanisms of laser and composite subjected to high speed airflow. The possibility of combining short-pulsed and continuous wave lasers to induce damages with high efficiency is also discussed.

**Biography:** Prof. Song Hongwei received the B.A. degree in polymer composites and the Ph.D. degree in engineering mechanics from Harbin Institute of Technology in 1996 and 2001, respectively. After his postdoctoral research in Tsinghua University, Prof. Song started to work on high power laser induced thermal and mechanical effects since 2004 in Institute of Mechanics, CAS. In 2008 he was awarded Lu Jiaxi Young Talent Award from CAS. He is now the director of the Coupling Mechanics of Thermal Structures Laboratory at IMECH, CAS. His research interests include laser induced thermal-mechanical effects and damages, multi-fields coupling effects of hypersonic flight, light-weight thermal structures etc.



## Strong Light-Matter Coupling in Halide Perovskite Microcavity for Room-temperature Polaritonics

**Qihua Xiong**

*Department of Physics, Tsinghua University*



**Abstract:** Halide perovskite semiconductors exhibit exceptional optical gain properties, large oscillator strength and high external quantum efficiency, thus they have shown tremendous potentials in a wide range of photonic and optoelectronic applications, such as solar cells, light-emitting diodes, photodetectors, and nanophotonics. In 2D hybrid perovskites and some 3D all inorganic perovskite systems, robust exciton formation at room temperature has been recognized, suggesting a bright future for strong light-matter coupling towards room-temperature polaritonics. We will present an exciting journey in the discovery of exciton polariton in perovskite semiconductor microcavities, resulted from a strong light-matter coupling. Particularly we will discuss recently progress in polariton laser and condensate, nonlinear properties and quantum optics control based on artificial potential landscapes, demonstrating the significant promise in future photonics, polaritonics and integrated photonic devices based on those new quasiparticles.

## Free-electron lasing on a laser wakefield accelerator at SIOM

**Wentao Wang**

*Shanghai Institute of Optics and Fine Mechanics Chinese Academy of Sciences*



**Abstract:** X-ray free-electron lasers can generate intense and coherent radiation at wavelengths down to the sub-ångström region, and have become indispensable tools for applications in structural biology and chemistry, among other disciplines. Several X-ray free-electron laser facilities are in operation; however, their requirement for large, high-cost, state-of-the-art radio-frequency accelerators has led to great interest in the development of compact and economical accelerators. Laser wakefield accelerators can sustain accelerating gradients more than three orders of magnitude higher than those of radio-frequency accelerators, and are regarded as an attractive option for driving compact X-ray free-electron lasers. However, the realization of such devices remains a challenge owing to the relatively poor quality of electron beams that are based on a laser wakefield accelerator. After ten years of efforts, Prof. Ruxin Li's research team present an experimental demonstration of undulator radiation amplification in the exponential-gain regime by using electron beams based on a laser wakefield accelerator. The amplified undulator radiation, which is typically centred at 27 nanometres and yields a maximum radiation energy of about 150 nanojoules. The results constitute a proof-of-principle demonstration of free-electron lasing using a laser wakefield accelerator, and pave the way towards the development of compact X-ray free-electron lasers based on this technology with broad applications.

## Femtosecond Coherent Anti-Stokes Raman Scattering (CARS) Measurements

**Robert P. Lucht**

*Purdue University*



**Abstract:** Femtosecond (fs) coherent anti-Stokes Raman scattering (CARS) offers several major potential advantages compared with nanosecond (ns) CARS; i.e., CARS as usually performed with nanosecond pump and Stokes lasers. These potential advantages include an elimination of collisional effects in the signal generation and the capability of performing real-time temperature and species measurements at data rates of 1 kHz or greater as compared to 10-50 Hz for ns CARS.

We have investigated the effects of moderate chirp in the pump and Stokes beams on the Raman excitation efficiency and signal generation for CPP fs CARS. We were able to model the decrease in the bandwidth of the Raman excitation efficiency using our parallelized time-dependent density matrix code. Our results indicate that inducing moderate levels of chirp appears to actually enhance slightly the temperature accuracy and precision of the CPP fs CARS technique.

We have investigated high-pressure effects for  $N_2$ ,  $CO_2$ ,  $O_2$ ,  $CH_4$  and  $C_2H_4$  in a new high-pressure, high-temperature cell at pressures from 1 to 10 bar. We observed that at high pulse energies that the spectra of all of these species were very pressure dependent, even though the characteristic collisional times were much longer than the chirped probe pulse time duration of  $\sim 3$  ps. We measured the spectra of the pump and Stokes beams before and after the cell and observed a drastic change in the spectrum for high cell pressures due to self-phase modulation (SPM). We have been able to model these effects and to determine the nonlinear phase induced on the pump and Stokes beam as they traverse the gas cell

**Biography:** Robert Lucht is the Ralph and Bettye Bailey Distinguished Professor of Combustion in Mechanical Engineering at Purdue University and the Director of Zucrow Laboratories. He has authored or co-authored over 190 articles in archival journals, and advised or co-advised nearly 40 PhD students. He is a Fellow of the Optical Society of America, the American Society of Mechanical Engineers, the Combustion Institute, and the American Institute of Aeronautics and Astronautics (AIAA). In 2008 he received the AIAA Aerodynamic Measurement Technology Award.

## Current Status of the Shanghai Superintense Ultrafast Laser Facility (SULF)

### Xiaoyan Liang

*Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*



**Abstract:** The Shanghai Super-intense Ultrafast Laser Facility (SULF) has been built in 2020, which contains two laser beam lines and three physical research platforms. The SULF-10 PW laser can operate at repetition rate of 1 shot per three minutes with peak power above of 10 PW, while the focused intensity is above  $10^{22}$ W/cm<sup>2</sup>. The SULF-1PW can provide the peak power of 1 PW at repetition rate of 0.1Hz. From 2021, the two lasers have been operating for the physical research experiments and are open to all the related users.

**Biography:** Xiaoyan Liang is currently a professor in Shanghai Institute of Optics and Fine Mechanics (SIOM), China. She received the Ph.D. in Laser Optics in 2001 from Institute of Physics, Chinese Academy of Science. From 2001 to 2003 she was a postdoctoral fellow in department of physics, University of Kaiserslautern in Germany, where her research was on solid state lasers and widely tunable optical parametric oscillator. She joined SIOM in 2003, and her current research interests involve exploring of ultra-intense and ultra-fast lasers. As a deputy chief engineer, she joined the building of Shanghai Super-intense Ultrafast Laser Facility (SULF).

<b>SC1: Laser irradiation effect and mechanism</b> <b>2022/8/11 4F, New Century Hall 2</b>	
Presider: Minsun Chen, National University of Defense Technology	
14:00-14:25 (Invited)	<b>Femtosecond laser interaction with transparent conductive oxide thin film</b> Yuanan Zhao, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences
14:25-14:50 (Invited)	<b>Fundamentals, Instruments and Applications of Laser-Induced Breakdown Spectroscopy</b> Lianbo Guo, Huazhong University of Science and Technology
14:50-15:15 (Invited)	<b>Interaction of femtosecond laser with crystal materials</b> Qiang Wu, Nankai University
15:15-15:40 (Invited)	<b>High harmonic generation from gases driven by ultrashort vortex laser with nonzero orbital angular momentum</b> Cheng Jin, Nanjing University of Science and Technology
15:40-15:55 Coffee Break	
Presider: Hongwei Song, Institute of Mechanics, Chinese Academy of Sciences	
15:55-16:10	<b>LIMIS2021-2021-000002</b> <b>Feasibility analysis of double-sided laser irradiation for testing mechanical properties of materials at elevated temperatures</b> Jiawei Wang, Northwestern Polytechnical University
16:10-16:25	<b>LIMIS2021-2021-000026</b> <b>Research progress of CW laser ablation of metal materials in low pressure environment</b> Yue Zhao, Nanjing University of Science and Technology
16:25-16:40	<b>LIMIS2021-2021-000143</b> <b>Surface formation mechanism of CVD diamond processed by picosecond laser</b> Quanli Zhang, Nanjing University of Aeronautics and Astronautics
16:40-16:55	<b>LIMIS2021-2022-000020</b> <b>Modeling the microwave transmittance of glass fiber reinforced plastics subjected to laser ablation</b> Guo Li, Institute of Applied Physics and Computational Mathematics
16:55-17:10	<b>LIMIS2021-2022-000021</b> <b>The acceleration phenomenon of shock wave induced by millisecond-nanosecond combined-pulse laser on silicon</b> Jingyi Li, Changchun University of Science and Technology

**SC1: Laser irradiation effect and mechanism  
2022/8/12 4F, New Century Hall 2**

Presider: Xiuli He, Institute of Mechanics, Chinese Academy of Sciences

13:30-13:55 (Invited)	<b>Two-Dimensional Conjugated Porous Frameworks as Promising Optical Limiting Materials</b> Heping Ma, Xi'an Jiaotong University
13:55-14:20 (Invited)	<b>Multi-physical response of PV cell to laser illumination</b> Chenwu Wu, Institute of Mechanics, Chinese Academy of Sciences
14:20-14:45 (Invited)	<b>Near-infrared/mid-infrared laser irradiation effects on polyethylene film</b> Minsun Chen, National University of Defense Technology
14:45-15:00	<b>LIMIS2021-2022-000011</b> <b>Coherence beam scattering from cylindrical objects with rough surfaces</b> Shubing Ye, Xidian University
15:00-15:15	<b>LIMIS2021-2021-000138</b> <b>Interaction of nanosecond extreme ultraviolet laser with solid targets</b> Huaiyu Cui, Harbin Institute of Technology
15:00-15:15 Coffee Break	
Presider: Yuanan Zhao, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences	
15:30-15:55 (Invited)	<b>Heat and mass transfer, melt pool dynamics in laser advanced manufacturing</b> Xiuli He, Institute of Mechanics, Chinese Academy of Sciences
15:55-16:20 (Invited)	<b>Local thermodynamic equilibrium considerations of silicon plasma during nanosecond and picosecond laser ablation</b> Kai Han, National University of Defense Technology
16:20-16:35	<b>LIMIS2021-2022-000010</b> <b>Modeling of Optical Rough Target Surface Based on Power Spectral Density and Monte Carlo Method</b> Zengyan Wu, Xidian University
16:35-16:50	<b>LIMIS2021-2022-000018</b> <b>Study on the correlation of output current in each quadrant for a silicon-based quadrant detector in the bias voltage irradiated by laser</b> Hongxu Liu, Changchun University of Science and Technology

## Femtosecond laser interaction with transparent conductive oxide thin film

Yuanan Zhao

*Shanghai Institute of Optics and Fine Mechanics, CAS*

**Abstract:** In this presentation, a multiscale model was proposed to describe the dynamic behavior of electrons in the interaction process between femtosecond laser pulse and TCOs film. Using this model, we can predict the transition behavior of electrons in the ITO film under femtosecond laser irradiation and the changes in optical properties caused by the transition. Firstly, we investigated the dynamic behavior of electrons in ITO film under femtosecond laser irradiation, involving the applications of epsilon-near-zero (ENZ) film in the ultrafast photonics applications. A conversion behavior from saturable absorption (SA) to reverse saturable absorption (RSA) at 1030 nm with increasing incident laser intensity, whereas only SA behavior at 1440 nm were observed. The ground-state free electrons bleaching in the conduction band and three-photon absorption play a vital role in this conversion. Secondly, the pulsed laser ablation of ITO film induced by femtosecond laser was investigated. Several distinct types of final micro/nanostructures were observed and may attributed to superficial amorphization, spallation ablation, stress-assisted delamination, boiling evaporation, and phase explosion. This significant morphological difference is caused by the change of free electron temperature. The above work opens up new opportunities for understanding the mechanism of the interaction between fs pulse and TCOs film, especially the analysis of the dynamic transition behavior of free carrier and bound electrons.

## Fundamentals, Instruments and Applications of Laser-Induced Breakdown Spectroscopy

Lianbo Guo<sup>\*</sup>, Zhenlin Hu, Shengqun Shi

*Wuhan National Laboratory for Optoelectronics (WNLO), Huazhong University of Science and Technology*

**Abstract:** With NASA's Perseverance rover and CNSA's Zhurong rover working on Mars, Laser-induced breakdown spectroscopy (LIBS), as the future superstar of analytical atomic spectrometry, gets more and more attention worldwide. Our group has done a series of researches focused on the fundamentals, methods, instruments and applications of LIBS. In the basic research, we achieved self-absorption reduction fundamentally using LIBS assisted by laser-stimulated absorption (LSA-LIBS) and microwave-assisted excitation in LIBS (MAE-LIBS). Image-assisted LIBS (IA-LIBS) was suggested for the matrix effect correction. We first proposed laser opto-ultrasonic dual (LOUD) detection. These results of basic researches were adopted for LIBS instrument development. In the LIBS applications, we focused on multi-functional, online, and offline detection for wire + arc additive manufacturing (WAAM), as well as rapid biomedical detection. The results illustrated that LIBS has the unique advantages of fast, high integration and high efficiency, with a pretty broad application prospect in the field of 3D printing and biomedical analysis.

**Keywords:** Laser-Induced Breakdown Spectroscopy; Self-Absorption Effect; Rapid Detection

## Interaction of femtosecond laser with crystal materials

**Qiang Wu**

*Nankai University*

**Abstract:** The femtosecond laser has greatly promoted the development of physics, chemistry, biology and other disciplines. Because of the characteristics of ultrashort pulse duration and ultrahigh peak power, many formulas in textbooks can no longer describe the interaction of femtosecond laser with matter. Therefore, some new theories are developed and many new applications have been acquired based on that.

In this presentation, I will introduce our research, which focuses on the interaction of femtosecond laser with crystals and pay more attention to the dynamic elementary excitations. It is the interdisciplinary of ultrafast photonics, ultrafast optics, Terahertz optics, photoelectric materials and devices, micro-nano optics, and condensed physics. We are not only concerned about new physical problems, developing new theories and equations, but also working hard to advance our new discoveries into practical applications. There are two research projects for our research: 1. Femtosecond laser processing crystals: physical mechanisms, material fabrication, and photoelectric devices; 2. Physics and applications of THz phonon polariton in ferroelectric crystals produced by femtosecond laser pulses.

## High harmonic generation from gases driven by ultrashort vortex laser with nonzero orbital angular momentum

**Cheng Jin**

*Nanjing University of Science and Technology*

**Abstract:** Through high harmonic generation (HHG) driven by intense ultrashort vortex infrared lasers, a nonzero orbital angular momentum (OAM) can be imprinted onto the extreme ultraviolet (XUV) light pulses. In this talk, we first choose the Laguerre-Gaussian (LG) beam as the driving vortex laser and simulate the generation of vortex XUV harmonics in the gas medium as well as their propagation in vacuum till reaching the far field. The single-atom response is computed by the quantitative rescattering (QRS) model. We find that the intensity and phase of generated high harmonics are very sensitive to the position of gas jet with respect to the laser focus. The topological charge of the  $q$ th harmonic is found to be  $q$  times that of the driving beam. Each harmonic in the far field appears as a single ring in the transverse plane with an invariant diameter which is scalable with the fundamental topological charge only when the gas jet is placed after the laser focus. The underlying phase-matching mechanism is analyzed by examining the spatial map of the coherence length and by calculating the evolution of harmonic emission in the medium. Second, we use the Bessel-Gaussian (BG) beam to drive the HHG and control its divergence in the far field. The vortex attosecond pulses can be synthesized by spectrally filtering the high harmonics. Finally, we generate the XUV light with superimposed OAM modes by mixing two different LG modes as the driving beam. We reveal the complexity nature of phase-matching conditions in the gas medium, especially their dependence on the azimuthal angle. We demonstrate that the OAM spectra of the HHG can be tailored by varying the harmonic order, the position of the gas jet, and the energy ratio of two LG beams.

## Two-Dimensional Conjugated Porous Frameworks as Promising Optical Limiting

**Heping Ma**

*Xi'an Jiaotong University*

**Abstract:** Phthalocyanine is a planar macrocycle with an inherent  $18\pi$ -electron conjugated structure, which



is able to suffer fast charge redistribution under intense laser radiation. Additional advantages of phthalocyanine are its good thermal stability and ease of functionalization on its molecular structure such as coordinated with most of metal ions.

In this presentation, five 2D transition-metal-containing polyphthalocyanine conjugated porous frameworks were reported, and their nonlinear optical properties are studied for the first time. We chose transition metals (TM) ranging from Fe, Co, Ni, Cu to In to combine in phthalocyanine centers to tune their delocalized electronic structure. The coupling of localized d-electrons in metal and delocalized 2D  $\pi$ -conjugated structure of MPc-CPF exhibit excellent nonlinear optical performance.

## Multi-physical response of PV cell to laser illumination

Chenwu Wu

*Institute of Mechanics, CAS*

**Abstract:** Laser power beaming is believed to be a promising conceptualized technology for wireless power transmission in terrestrial or space application and paid much attention in research. Such a system mainly includes a Laser device to convert electricity into monochromatic light beam of high quality and a Photovoltaic (PV) cell panel to convert the incident Laser energy into electricity. The efficiency as well as reliability during photoelectric conversion is dominated by the multi-physical response of PV cell to laser illumination, including carrier excitation, carrier transportation, thermal dissipation, thermal expansion and even thermo-mechanical damage that are in particular discussed in this article. Further, aiming at performance improvement on the system, a strategy of hybrid laser beaming is developed and multi-scale theoretical model is proposed on typical PV cell subjected to laser of different operation mode to explore the potential optimized pathway.

## Near-infrared/mid-infrared laser irradiation effects on polyethylene film

Minsun Chen

*National University of Defense Technology*

**Abstract:** Experimental researches of the near-infrared laser with 1085nm wavelength and the mid-infrared laser with 3.8 microns wavelength irradiate on the transparent polyethylene film with a thickness of about 25 microns are carried out. Results show that the burn through time approximate exponentially decreases from 5.76s to 0.85s, for the average power density of the mid-infrared laser increases from  $2.9\text{W}/\text{cm}^2$  to  $37.2\text{W}/\text{cm}^2$ , and the damage energy density is about  $22.2\text{J}/\text{cm}^2$ . The polyethylene film can be burned through by near-infrared laser irradiation with an average power density of  $338.8\text{W}/\text{cm}^2$  for 18.6s, and the corresponding damage energy density is up to  $6301.7\text{J}/\text{cm}^2$ . The failure time exponentially decreases from 18.6s to 0.75s with the incident laser density increases from  $338.8\text{W}/\text{cm}^2$  to  $428.5\text{W}/\text{cm}^2$ , and the corresponding damage energy density approximate exponentially decreases from  $6301.7\text{J}/\text{cm}^2$  to  $321.4\text{J}/\text{cm}^2$ . The damage of near-infrared laser has obvious threshold effect. The polyethylene film would not be burned through until the laser power density reaches a certain high value, so the damage threshold of polyethylene film by near-infrared laser is 1 ~ 2 orders of magnitude higher than that by mid-wavelength infrared laser. The results are in good agreement with the absorption ratio of polyethylene film at wavelength of 3800 nm and 1085 nm measured under weak light.

# Heat and mass transfer, melt pool dynamics in laser advanced manufacturing

Xiuli He

*Institute of Mechanics, Chinese Academy of Sciences*

**Abstract:** Laser manufacturing is a dynamic and complex process with multiple fields, multiple scales and multiple parameters. During the process, the heat and mass transfer plays an important role, affecting the thermal history and composition of the material, thereby affecting the final microstructure and properties. Heat and mass transfer, and melt pool dynamics in laser advanced manufacturing have been investigated. The distribution of temperature, fluid flow, alloying elements, and the evolution of liquid-gas interface were simulated systematically. Dimensionless numbers were used to analyze the driving forces of fluid flow, and the dynamic behavior of the molten pool was studied under different driving forces. The heat and mass loss caused by evaporation and ejection at high temperature was analyzed.

## Local thermodynamic equilibrium considerations of silicon plasma during nanosecond and picosecond laser ablation

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*2. State Key Laboratory of Pulsed Laser Technology*

*3. Hunan Provincial Key Laboratory of High Energy Laser Technology,*

**Abstract:** The validity of local thermodynamic equilibrium (LTE) in laser-induced plasma (LIP) is a significant concern in the community of plasma diagnosis and pulsed laser ablation. The work demonstrated an optical emission spectroscopic method to estimate the thermodynamic state of the evolving plasma. Compared with the prior LTE criteria, this technique provides spatially and temporally resolved LTE evaluation and offers the insight that how far the plasma deviates from the LTE.

In this work, we established a high spatio-temporal (50  $\mu\text{m}$ -2 ns) resolution spectrum measurement system to record the optical emission spectra of silicon plasma, which generated by nanosecond laser (532 nm, 8 ns) ablation and picosecond laser (532 nm, 20 ps) ablation at  $10^{-3}$  Pa. Then, a spectral analysis program was designed to fit a series of discrete spectral intensity line data into a smooth curve using a model based on the universal electron energy distribution function (EEDF). The program calculate the degree of plasma deviating from LTE according to the bias between the actual EEDF returned from best-fitting and the Maxwellian distribution. Combining the spectral measurements and data analysis, we obtain the spatial and temporal evolution of the thermodynamic state of LIPs, and discuss the effect of different laser pulse widths on LTE.

The results showed that the nanosecond laser-induced plasma is in LTE at  $\Delta t < 100$  ns near the target surface ( $z < 1.5$  mm) and at  $\Delta t > 240$  ns in the area of  $z > 7$  mm, where the energy exchange between ions/neutrals and electrons is sufficient. For picosecond laser ablation, because the pulse duration is close to electron-lattice energy transfer time(1~10 ps), the plasma fails to achieve LTE in the first hundred nanoseconds, and only the plasma in the area of  $z > 4$  mm when  $\Delta t > 180$  ns fulfills LTE. This technique suggests a clear boundary where LTE exists and provides valuable insight to the physical mechanism of pulsed laser ablation.

**Keywords:** Local thermodynamic equilibrium, Laser-induced breakdown spectroscopy, Laser-induced plasma, Picosecond laser ablation, Nanosecond laser ablation.

LIMIS2021-2021-000002

## Feasibility analysis of double-sided laser irradiation for testing mechanical properties of materials at elevated temperatures

Jiawei Wang<sup>1,2</sup>, Weiping Liu<sup>2</sup>, Yuwei Lv<sup>2</sup>, Chenghua Wei<sup>2</sup>, Shuang Zhang<sup>2</sup>, Guobin Feng<sup>2</sup>, Bin Li<sup>1</sup>

*1 Northwestern Polytechnical University*

*2 State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology*

**Abstract:** A method of double-sided laser irradiation is presented for temperature control in high temperature mechanical properties test of composite materials. Based on the finite element method (FEM), a numerical model of temperature distribution of materials was established. The effects of specification, laser heating area and laser intensity, laser heating time on temperature uniformity during heating were analyzed. The results show that the laser heating area, thickness of the specimen, laser intensity and laser heating time have a decisive effect on the temperature uniformity. The limit temperature control precision reaches 2% for carbon fiber reinforced polymer(CFRP), and the heating time can be controlled in minutes. The method is especially suitable for composite materials that cannot be heated by electric induction in the traditional heating experiment of high heating rate. Furthermore, an experimental scheme of double-sided irradiation heating using a single laser beam was designed. Experiment results illustrated that the temperature control precision was high before the material appears obvious flame. This method has the advantages of rapid heating rate, high testing efficiency and high testing temperature. It can make a reference for mechanical properties test of composite materials at elevated temperature with rapid heating rate.

**Keywords:** double-sided laser irradiation; mechanical properties test; continuous laser; elevated temperature.

LIMIS2021-2021-000026

## Research progress of CW laser ablation of metal materials in low pressure environment

Yue Zhao, Kun Xu, Bing Han\*, Zhonghua Shen\*\*, Zewen Li, Yunxiang Pan

*Nanjing University of Science and Technology*

**Abstract:** Laser ablation process in low pressure environment is different from that in atmospheric environment. In different environments, surface tension of liquid metal will be different and make an impact on the melt flow. Different ambient pressure will also make the evaporation temperature and condensation coefficient of liquid metal different. This review introduces the morphology of the molten region on the surface of copper foil and TC4 sheet after laser ablation in low pressure environment. There are few splashes on the surface of molten region and ring ripples are observed on surfaces after laser irradiation. The size and morphology of molten region are Obviously different from those in atmospheric environment. A 2D transient model considering temperature dependent surface tension and condensation coefficient is also established to investigate the melt flows in molten pool during laser irradiation at low pressure. According to the numerical results, the melt flows are driven by Marangoni force during laser irradiation. During cooling process, Marangoni force and capillary force will produce ripple structure on the surface in molten region. The competition between these two forces transports the melt back and forth between the center and edge of the molten pool

during cooling process. This makes the edge of the molten pool undulate continuously and 'frozen' by the cooling process, which produces the ripple structures.

**Keywords:** Low pressure, Laser ablation, Melt flow, Surface tension, Ripple structure

**LIMIS2021-2021-000143**

### Surface formation mechanism of CVD diamond processed by picosecond laser

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*Nanjing University of Aeronautics and Astronautics*

**Abstract:** The heat affected zone in the laser processing lead to the deterioration of the diamond surface. To optimize the processing parameters and improve the surface quality, the ablation threshold of a single pulse and the influence of laser power on the surface characteristics of CVD diamond are investigated. The results show that the thermal effect of picosecond laser leads to the gasification of a large amount of material, where less accumulated products in the processing area appears. The high temperature produced by laser and the local anisotropy of polycrystalline CVD diamond result in irregular gullies on the machined surface. In addition, the three-dimensional morphology of the machining groove indicates that with the increase of laser energy, the uneven diffusion of heat flow at the edge of the groove is exacerbated, resulting in the reduction of the straightness of machining grooves. The depth and width of the machining groove change approximately linearly in a single scanning process.

**Keywords:** CVD diamond, Picosecond laser, Surface topography, Ablation threshold

**LIMIS2021-2022-000020**

### Modeling the microwave transmittance of glass fiber reinforced plastics subjected to laser ablation

Guo Li<sup>1,\*</sup>, Peng Hu<sup>1</sup>, Weiping Liu<sup>2</sup>, Hua Su<sup>2</sup>, Faliang Chen<sup>2</sup>

*1. Institute of Applied Physics and Computational Mathematics, CAEP*

*2. State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology*

**Abstract:** The microwave transmittance of glass fiber reinforced plastics subjected to continuous-wave laser ablation is studied in the framework of continuum mechanics. Firstly, a one-dimensional physical model involving laser absorption, heat conduction, pyrolysis of resin, thermal radiation and convection heat transfer is established to get the temperature field. We proposed an experiment-based absorption coefficient to capture the bulk-to-surface absorption transition during laser ablation. Secondly, the complex dielectric constant is modeled using a solid state kinetic model describing the graphitization of pyrolysis products, and the microwave reflection and transmittance are then calculated based on the distribution of dielectric constant. The agreement of temperature and microwave transmittance with the experiment results suggest the reasonableness of the numerical model. Based on the model, the influence of laser power density, material thickness and tangential airflow velocity on the microwave transmittance are studied. It is shown that laser ablation can induce remarkable decreasing of microwave transmittance above the power density threshold, for which the absorption due to graphitization is dominate. With increasing material thickness, the microwave transmittance changes non-monotonically due to the competition between different physical mechanism. The existence of tangential airflow can prevent the decreasing of microwave transmittance especially for weaker laser. These results show that the transfer of microwave in ablated GFRP can be effectively predicted despite of the complexity of the underlying physics.

**Keywords:** glass fiber reinforced plastics, laser ablation, microwave transmittance, physical model.

LIMIS2021-2022-000021

## The acceleration phenomenon of shock wave induced by millisecond-nanosecond combined-pulse laser on silicon

Jingyi Li\*, Yahui Li, Chenxiao Zhao, Wei Zhang, Guangyong Jin

*Changchun University of Science and Technology*

**Abstract:** Silicon is an indispensable raw material in the manufacture of electronic devices, and it is widely used in aerospace field. With the rapid development of aerospace field, the spreading space debris blocks orbit of earth increasingly, laser propulsion can be used as a method to remove space debris in earth orbit. The velocity variation law of shock wave induced by millisecond-nanosecond (ms-ns) combined-pulse laser has been investigated experimentally. The pulse delay and laser energy are important experimental variables. The method of laser shadowgraphy is used in the experiment. Experimental results show that when the pulse delay is 2.4 ms, the ms and ns laser energy density is  $301 \text{ J cm}^{-2}$  and  $12 \text{ J cm}^{-2}$ , respectively, the velocity of shock wave is 1.1 times faster than that induced by single ns pulse laser. It is inferred that the shock wave propagates in the plasma is faster than that in air. When the ms and ns laser energy density is 414.58 and  $24 \text{ J cm}^{-2}$ , the velocity of shock wave shows rising trend with pulse delay in a range of  $1.4 \text{ ms} > \Delta t > 0.8 \text{ ms}$ . It is indicated that with the increase of ns laser energy, the laser energy absorbed by laser-supported absorption wave increases. The mechanism of inverse bremsstrahlung absorption acts with target surface absorption simultaneously during the ns laser irradiation. Thus, the phenomenon of the double shock wave is induced. The results of this research can provide a reference for the field of laser propulsion.

**Keywords:** shock wave, laser-supported absorption wave, plasma

LIMIS2021-2022-000011

## Coherence beam scattering from cylindrical objects with rough surfaces

Shubing Ye, Changqing Cao\*

*Xidian University*

**Abstract:** The characteristic of laser speckle plays an important role in the research of target detection, recognition, tracking, interaction and so on. At present, in the research on the scattering characteristics of rough objects, most of literatures are the research on the scattered field characteristics of spheres under the incidence of plane waves. In practical applications, the scattering phenomena and theoretical deduction processes of rough objects with different shapes are different, so the conclusion cannot directly describe the scattering characteristics of cylinders. In addition, there are few studies about coherent light incident, and the conclusions obtained cannot directly reflect the characteristics of scattered fields under coherent light incidence.

This paper studies the scattered field statistical properties of the rough cylinder irradiated by coherent light, and the physical approximation method and the angular spectrum expansion method are used. Firstly, the coherence beam is expanded into a linear superposition of multiple plane waves by using the angular spectrum expansion method. And combined with the research foundation of the plane wave incident on arbitrarily shaped objects with rough surfaces, the function of scattered light field and the backscatter coefficient are derived theoretically. The influences of the beam radius, scattering angle, roughness parameter and size of the cylinder on the backscatter coefficient are discussed and analyzed. Results show that, the function of scattered light field has closely relationship with the roughness, scattering angle and cylindrical dimension. Additionally, the rougher of cylinder surface, the fewer of coherent scattering components. The backscatter-

ing coefficient decreases with the increase of incident angle. The ratio of beam waist radius to cylinder radius, the closer the result is to a plane wave.

**LIMIS2021-2021-000138**

### **Interaction of nanosecond extreme ultraviolet laser with solid targets**

**Huaiyu Cui, Lei Li, Dongdi Zhao, Bo An, Zhigang Fan and Yongpeng Zhao**

*Harbin Institute of Technology*

**Abstract:** Nanosecond extreme ultraviolet (EUV) laser is quite a unique radiation source in the field of laser surface processing since its long duration and short wavelength introduces thermal and non-thermal effect involved in the laser-matter interaction. In this report, various materials were irradiated by the nanosecond EUV laser. The laser induced plasma was detected and the interaction process was analyzed and discussed. The results will help to control the scale and morphology of the self-formed structures induced by the nanosecond EUV laser.

**LIMIS2021-2022-000010**

### **Modeling of Optical Rough Target Surface Based on Power Spectral Density and Monte Carlo Method**

**Zengyan Wu, and Changqing Cao\***

*Xidian University*

**Abstract:** Due to the high coherence of the laser light, random and irregularly distributed laser speckles will be formed in space when the light hits the rough surface. The information of scatterers carried by laser speckles is an important basis for target detection, identification, feature analysis, and micro-motion detection. But so far, the modeling of rough surface and speckle field is too simplified in the research process, and only the rough surface is regarded as a collection composed of many independent reflection units. This simple model does not consider the relationship between roughness and is very different from the actual situation.

Based on the rough surface scattering theory, this paper studies the statistical characteristics of rough target laser speckle. A non-cooperative target speckle field model is established based on rough surface power spectral density function and Monte Carlo method. The two-dimensional power spectral density function of Gaussian optical rough surface is quantitatively determined. And based on the Monte Carlo method, random fields and statistical parameters are introduced into the rough surface spectrum to simulate the random characteristics of the rough surface to invert the non-cooperative target speckle field. The simulation results show that the target rough surface is related to the root mean square and the correlation length, which are the statistical parameters of the longitudinal fluctuation degree and the horizontal fluctuation frequency of the target rough surface, respectively. The larger the RMS set in the power spectral density function, the more severe the longitudinal fluctuation of the target rough surface; the larger the correlation length, the greater the period of fluctuation. This work helps to further study the time-domain scattering characteristics and speckle statistical characteristics of more complex rough targets, and provides a theoretical basis for radar system design and the mechanism of laser irradiation effect.

## Study on the correlation of output current in each quadrant for a silicon-based quadrant detector in the bias voltage irradiated by laser

Hongxu Liu\*, Guangyong Jin, Di Wang  
*Changchun University of Science and Technology*

**Abstract:** Silicon-based photodetector have become an important part in various laser applications. The influence in the process of laser interacted with a silicon-based quadrant detector include not only laser parameters, but also external circuit parameters. Using 1064nm millisecond pulsed laser to interact on one quadrant of a silicon-based quadrant detector, the output current of each quadrant of the silicon-based quadrant detector under different bias voltage is compared and studied. The research shows that, in the process of laser irradiation on a silicon-based quadrant detector, the change of output current in the quadrant where the laser beam is located can be divided into three stages: initial stage, maintenance stage and recovery stage. The output current in the maintenance stage decreases as time, and the output current in the recovery stage fluctuates. Combined with the change trend of output current in each quadrant, it is found that those phenomenon are related to the interaction between the quadrants. It is also found that the law between the output current and the bias voltage changes obviously in the maintenance stage and recovery stage with the increase of the bias voltage. The reason is that, the internal electric field increases with the bias voltage, and the influence on the output current increases.

**Keywords:** laser irradiate, quadrant detector, bias voltage, output current

<b>SC2: Plasmas and optics physics</b> <b>2022/8/11 4F, Siyi Hall</b>	
President: Xuewen Fu, Nankai University	
14:00-14:20 (Invited)	<b>Monoenergetic High-energy Ion Source via Femtosecond Laser Interacting with a Microtape</b> Bin Qiao, Peking University
14:20-14:40 (Invited)	<b>Ultra-brilliant Gamma-ray radiation in near-critical-density plasmas</b> Tongpu Yu, National University of Defense Technology
14:40-15:00 (Invited)	<b>Attosecond transient absorption in molecular frame</b> Peng Peng, ShanghaiTech University
15:00-15:20 (Invited)	<b>A High Efficiency and Collimated Terahertz Pulse from Ultra-short Intense Laser and Cone Target</b> Jinqing Yu, Hunan University
15:20-15:35 Coffee Break	
President: Ye Tian, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences	
15:35-15:55 (Invited)	<b>Two-color near-field ultrafast electron microscopy</b> Xuewen Fu, Nankai University
15:55-16:15 (Invited)	<b>High-energy, ultrafast UV light generation through laser-gas interactions in hollow-core photonic crystal fiber</b> Meng Pang, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences
16:15-16:30	<b>LIMIS2021-2021-000077</b> <b>Dynamics of attosecond electrons in the solid-plasma surface under relativistic light field</b> Chuliang Zhou, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences
16:30-16:45	<b>LIMIS2021-2022-000006</b> <b>High pressure melting and sound speed in laser shock compression forsterite</b> Liang Sun, Laser Fusion Research Center, China Academy of Engineering Physics
16:45-17:00	<b>LIMIS2021-2021-000074</b> <b>Above 100 MeV proton beam generation from near-critical-density plasmas irradiated by a Laguerre-Gaussian laser pulse</b> Yan-Ting Hu, National University of Defense Technology



17:00-17:15	<b>LIMIS2021-2021-000129</b> <b>Intense Single-cycle Terahertz Generation on Metal Wires</b> Yushan Zeng, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences
17:15-17:30	<b>LIMIS2021-2022-000035</b> <b>Photo-Induced Ultrafast Symmetry Switch and Coherent Control in SnSe</b> Yadong Han, Institute of Fluid Physics, China Academy of Engineering Physics
<b>SC2: Plasmas and optics physics</b> <b>2022/8/12 4F, Siyi Hall</b>	
Presider: Taiwu Huang, Shenzhen Technology	
13:30-13:50 (Invited)	<b>Interaction of laser-accelerated ion beam with dense ionized matter</b> Yongtao Zhao, Xi'an Jiaotong University
13:50-14:10 (Invited)	<b>Laser drive novel pathway to inner core states of planets</b> Mu Li, Shenzhen Technology University
14:10-14:30 (Invited)	<b>The Progress of 3D Reconstruction Algorithm and Application to Plasma Diagnosis</b> Zhenxing Wang, Xi'an Jiaotong University
14:30-14:45	<b>LIMIS2021-2021-000088</b> <b>The Hugoniot of polycrystalline diamond at TPa pressure with indirectly laser-driven shock wave</b> Peng Wang, Laser Fusion Research Center, China Academy of Engineering Physics
14:45-15:00	<b>LIMIS2021-2022-000004</b> <b>Research on fractal and angular momentum of electromagnetic solitons</b> Zhongpeng Li, Xi'an Jiaotong University
15:00-15:15 Coffee Break	
Presider: Yongtao Zhao, Xi'an Jiaotong University	
15:15-15:35 (Invited)	<b>Strong laser-driven QED effects and their applications</b> Jianxing Li, Xi'an Jiaotong University
15:35-15:55 (Invited)	<b>Toward kW, few-cycle ultra-intense Ti: sapphire lasers</b> Huabao Cao, Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences
15:55-16:15 (Invited)	<b>Laser-driven ultra-high dose rate protons: an experimental platform for radiobiological research of the FLASH effect</b> Jianhui Bin, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

16:15-16:35 (Invited)	<b>Branched flow of intense laser and particle beams in uneven plasmas</b> Taiwu Huang, Shenzhen Technology University
16:35-16:50	<b>LIMIS2021-2022-000033</b> <b>Ultrafast nonlinear optics in Porphyrin- Based Surface-Supported Metal-Organic Framework Nanofilms</b> Junhong Yu, China Academy of Engineering Physics
16:50-17:05	<b>LIMIS2021-2021-000165</b> <b>Controllable birefringent lens based on magnetized plasma</b> Kaiqiang Pan, Laser Fusion Research Center, China Academy of Engineering Physics
17:05-17:20	<b>LIMIS2021-2022-000030</b> <b>Few-cycle vortex beam generated from self-compression of mid-infrared femtosecond vortices in thin plates</b> Litong Xu, University of Chinese Academy of Sciences
17:20-17:35	<b>LIMIS2021-2021-000032</b> <b>The effect of an applied magnetic field on Kelvin-Helmholtz instability driven by laser under multi-mode disturbance</b> Wei Sun, Department of Nuclear Physics, China Academy of Engineering Physics
17:35-17:50	<b>LIMIS2021-2021-000101</b> <b>Measurements of X-ray spectra and absolute energies from laser produced Al plasmas</b> Yanpeng Liu, Northwest Institute of Nuclear Technology

## Monoenergetic High-energy Ion Source via Femtosecond Laser Interacting with a Microtape

**Bin Qiao**  
*Peking University*

**Abstract:** Laser-driven ion acceleration is conceived to be one of the main applications of many extreme light facilities that are being projected, built, or already in operation around the world. It opens a way for a future new generation of compact accelerators providing high-quality ion beams for many applications in medicine, industry, science and others. Several acceleration methods, including target normal sheath acceleration (TNSA), shock wave acceleration (SWA), and radiation pressure acceleration (RPA), have been proposed and identified in experiments. However, so far, the obtained ion beams have not achieved the required high qualities yet, such as high energy, narrow energy spread, large particle number, etc. In this talk, I shall report a novel method to achieve monoenergetic proton beams with energy spread at 1% level and peak energy of hundred MeV by irradiating the edge of a microtape with a readily available fs petawatt laser [1,2]. Our three-dimensional particle-in-cell simulations demonstrate that a monoenergetic proton beam with peak energy  $> 100$  MeV, energy spread about 1% and particle number  $\sim 10^9$  can be stably obtained with a femtosecond laser pulse characterized by intensity  $> 10^{20}$  W/cm<sup>2</sup> [1,2]. The proposed scheme opens a new route for the development of future compact ion sources.

## Ultra-brilliant Gamma-ray radiation in near-critical-density plasmas

**Tongpu Yu**  
*National University of Defense Technology*

**Abstract:** X/γ-ray sources are broadly useful tools for scientific researches and practical applications. They are normally produced based upon conventional accelerators with huge size and high expense. However, X/γ-ray sources from laser-plasma interactions open up new opportunities due to their compact sizes and high tunabilities, making them be capable of realizing pico-meter spatial and sub-femtosecond temporal resolutions.

Near-critical-density plasma as an important media plays a key role in laser-driven ion acceleration, bright x/γ-ray radiation and dense electron-positron pair production. Here, we introduce our recent work at National University of Defense Technology on ultra-brilliant X/γ-ray emission via nonlinear Compact scattering and dense electron-positron pair production based on multi-photon Breit-Wheeler process. Full three-dimensional (3D) Particle-in-Cell (PIC) simulations show that attosecond GeV gamma-ray bunch train can be generated via the nonlinear Compton scattering of energetic electrons driven by the LG laser pulse with zero angular momentum.

## Attosecond transient absorption in molecular frame

**Peng Peng**  
*ShanghaiTech University*

**Abstract:** We demonstrated coherent control of molecular absorption line shape and optical gain in XUV. The control is achieved by creating a quantum coherence in the ground electronic state of hydrogen molecules.

These observations provide new insights into control of spectral line shapes and open the way for achieving lasing-without-inversion in the XUV spectral range.

## **A High Efficiency and Collimated Terahertz Pulse from Ultra-short Intense Laser and Cone Target**

**Jinqing Yu**  
*Hunan University*

**Abstract:** We propose a new method to manipulate the divergence angle and the energy conversion efficiency of the THz source. An extreme strong and collimated THz source can be generated through the interaction between relativistic femto-second laser pulse and cone target. By using the cone target, one can improve the conversion efficiency from laser to hot electrons and the cut-off energy of the electron, both of which contribute to stronger THz source with better collimation. Particle-in-cell (PIC) simulations were performed to demonstrate this method. In the simulation with a laser pulse of 1.9J and a cone target with an open angle of  $10^\circ$ , an extreme terahertz source of 44mJ was generated. This THz source was collimated to a pointing angle of  $\sim 20^\circ$ . Unlike the traditional coherent transition radiation for terahertz generation, the cone target takes the advantage of generating terahertz source of higher conversion efficiency and better collimation. Therefore, the method for the generation of intense terahertz pulse whose energy is higher than 40mJ, would promote the THz science into extreme region with compact laser system of  $\sim 100$ TW.

## **Two-color near-field ultrafast electron microscopy**

**Xuwen Fu**  
*Nankai University*

**Abstract:** In the past decade, four-dimensional electron microscopy (4D-EM), which enables the direct observation of transient structures, morphologies and even carrier transport of materials in real time and space, has attracted increasing interest to the research community due to its powerful capability in the interdisciplines of physics, chemistry, material science, and biology. In this presentation, I will firstly give a brief introduction of the development of 4D-EM and the state-of-the-art of its applications in scientific research, including our latest developments of liquid-phase 4D transmission electron microscopy and laser-free 4D transmission electron microscopy. After that, I will present our recent progress in two-color near-field ultrafast electron microscopy and its application in study of insulator-to-metal phase transition dynamics in individual VO<sub>2</sub> nanowires. We took advantage of a femtosecond temporal gating of the electron pulse mediated by an infrared laser pulse, and exploited the sensitivity of inelastic electron-light scattering to changes in the material dielectric function. By spatially mapping the near-field dynamics of an individual VO<sub>2</sub> nanowire, we observed that ultrafast photo-doping drives the system into a metallic state on a time scale of  $\sim 150$  fs without yet perturbing the crystalline lattice. The high versatility and sensitivity of our method would allow capturing the electronic dynamics of a wide range of nanoscale materials with ultimate spatio-temporal resolution.

## **High-energy, ultrafast UV light generation through laser-gas interactions in hollow-core photonic crystal fiber**

**Meng Pang**  
*Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*

**Abstract:** High-performance femtosecond lasers at ultraviolet wavelengths have a few important applications in mass spectroscopy, combustion diagnosis and defect detection of semiconductors. However, tradition-

al ultraviolet light-sources have several challenges such as low pulse repetition rate, low pulse energy and lack of wavelength tunability. In this talk, I will demonstrate our recent theoretical and experimental studies on gas-filled hollow-core fiber which can generate ultraviolet femtosecond light with high pulse energy and kHz-level pulse repetition rate. A theoretical and numerical platform of nonlinear pulse propagation was established, being used to study the underlying mechanisms of sub-cycle pulse compression and ultraviolet dispersive-wave emission processes in gas-filled hollow-core fiber waveguides. In experiments, we optimized recently the frequency-conversion efficiency of the system and improved the system stability, leading to the generation of uJ-level ultraviolet pulses with tunable wavelengths from ~200 nm to ~350 nm.

## Interaction of laser-accelerated ion beam with dense ionized matter

**YongtaoZhao**

*Xi'an Jiaotong University*

**Abstract:** Ultra-high-intensity lasers have opened up perspectives in many fields of research and application. By irradiating a thin foil with ultra-high-intensity lasers, an ultrahigh accelerating field (1 TV/m) can be formed and multi-MeV ions with high intensity ( $10^{10}$  A/cm<sup>2</sup>) in short timescale (~ps) are produced. Such beams provide experimental opportunities to investigate the beam-driven complex collective phenomena, and also provide options in radiography, high-yield neutron sources, high-energy-density matter generation, and ion fast ignition. An accurate understanding of laser-accelerated-ion-beam induced energy deposition and nuclear reaction in dense matter is crucial for all these applications. Here we will mainly report the following progress on the investigation of Interaction between laser-accelerated intense ion beams with dense ionized matter.

1) Observation of a high degree of stopping for laser-accelerated intense proton beams in dense ionized matter [Nat.Commun.11(2020)5157]. 2) Nuclear reaction induced by laser accelerated intense proton beam in dense boron plasma. 3) Investigation of radiation properties of warm dense matter based on combination of high power laser with large scale accelerators.

## Laser drive novel pathway to inner core states of planets

**Mu Li**

*Shenzhen Technology University*

**Abstract:** Off-Hugoniot states of Materials at terapascal pressure have been pursued for years, in this talk, a combination of isentropic and shock compression method has been experimentally demonstrated on SGII laser facility and provides Mbar pressure regime with much higher pre-compression relative to static pre-compression. This technique presents a possible way to reach high density states (especially for higher bulk modulus materials) that is regarding to planetary science, testing first-principles theories of condensed matter.

## The Progress of 3D Reconstruction Algorithm and Application to Plasma Diagnosis

**Zhenxing Wang**

*Xi'an Jiaotong University*

**Abstract:** The tomography reconstruction technique is an effective method for obtaining complex dynamic properties of plasma in a three-dimensional (3D) space. Based on the multiple views of plasmas, this technique can invert the distribution of the measured object in a 3D space without the symmetrical assumption, which could deviate from symmetry significantly. In this presentation, we will show the progress of the recon-

struction algorithms and their application to studies of 3D plasma diagnosis. First, an improved deep learning-based reconstruction algorithm is presented, aiming to improve the reconstruction speed and guarantee the reconstruction accuracy at the same time. Second, the effect of optical absorption by plasmas is taken into account, which could correct the errors due to the optical thin hypothesis and exists in the majority of experiments. Third, the algorithm is adopted to obtain the dynamic behaviors of plasmas as well as the temperature distributions. The results indicate the effectiveness and efficiency of the reconstruction algorithm and offer advantages for investigating the complex behaviors of plasmas.

## Strong laser-driven QED effects and their applications

**Jian-Xing Li**

*Xi'an Jiaotong University*

**Abstract:** Relativistic spin-polarized electron and positron beams are indispensable for future electron-positron colliders to test modern high-energy physics theory with high precision. However, present techniques require very large scale facilities for those experiments. We put forward a novel efficient method for generating ultrarelativistic polarized electron and positron beams employing currently available laser fields. Moreover, polarization is also a crucial intrinsic property of a gamma-photon. Currently, polarized gamma-rays are most efficiently generated via linear Compton scattering and bremsstrahlung, however, with a rather low flux, and high gamma-photon statistics is usually obtained during a large amount of laser shots. Here, we employ non-linear Compton scattering in the quantum radiation-dominated regime to generate unprecedented high-polarization (90-95%) and high-flux multi-GeV circularly-polarized and linearly-polarized gamma-rays.

## Toward kW, few-cycle ultra-intense Ti: sapphire lasers

**Huabao Cao**

*Xi'an Institute of Optics and Precision Mechanics of Chinese Academy of Sciences*

**Abstract:** Ultra-short Ultra-intense lasers can achieve extreme states of matters in the laboratory. They are crucial tools for study of light-matter interactions, including laser acceleration, laser fusion, plasma physics, high-energy physics, et al. Currently, most of modern high peak-power and short-pulse laser systems rely upon titanium sapphire as amplifier material due to its broad emission spectrum, high thermal conductivity, and the relatively low-quality requirements of the pump pulses. However, gain narrowing and thermal issue limit the achievable pulse duration and average power. The gain narrowing in Ti:Sapphire limits the pulse duration to  $\sim 30$  fs. At the other hand, despite of the high thermal conductivity of sapphire crystals, the high thermal load without efficient cooling limits the repetition rate to  $< 10$  Hz. We propose two techniques to overcome the gain narrowing effect and improve the cooling mechanism, respectively. These developments are the Polarization Encoded Chirped Pulse amplification (PE-CPA), that allows to conserve the bandwidth during amplification, and the combination of the Thin Disk technique applied to Ti:Sapphire crystal with Extraction During Pumping (EDP-TD) for efficient cooling and energy extraction. The experimental results demonstrated that the PE-CPA could effectively preserve the bandwidth during the amplification and the EDP-TD could greatly promote the repetition rate to 100 Hz for 100s of TW-level lasers. The combination of these techniques may pave the way to PW class Ti:Sapphire lasers with tens of Joule few cycle laser pulses and at 100 Hz repetition rates.

## Laser-driven ultra-high dose rate protons: an experimental platform for radiobiological research of the FLASH effect

Jianhui Bin

*Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*

**Abstract:** Radiotherapy is the current standard of care for more than 50% of all cancer patients. Improvements in radiotherapy (RT) technology have increased tumor targeting and normal tissue sparing, especially with the recent interest in ultra-high dose rates required for FLASH-RT effects. We present a new experimental platform that is the first one to deliver petawatt laser-driven proton pulses of 2 MeV energy at 0.2 Hz repetition rate by means of a compact, tunable active plasma lens beamline to biological samples. Cell monolayers grown over a 10 mm diameter field were exposed to clinically relevant proton doses ranging from 7 to 35 Gy at ultra-high instantaneous dose rates of 107 Gy/s. Dose-dependent cell survival measurements of human normal and tumor cells exposed to LD protons showed significantly higher normal cell than tumor cell survival for total doses of 7 Gy and higher, which was not observed to the same extent for X-ray reference irradiations at clinical dose rates. These findings provide preliminary evidence that compact LD proton sources enable a new and promising platform for investigating the physical, chemical and biological mechanisms underlying the FLASH effect.

## Branched flow of intense laser and particle beams in uneven plasmas

Taiwu Huang

*Shenzhen Technology University*

**Abstract:** Branched flow is an appealing phenomenon that describes the formation of aesthetically beautiful treebranch-like filaments as waves propagating in an uneven medium. The recent observation of laser light branching on thin soap films has brought this interesting phenomenon to optics. Branched flow is usually considered a linear phenomenon in that the flow does not alter the medium properties. However, with the increase of laser intensity, the nonlinear coupling between laser and background electrons can significantly affect the laser propagation. Here we found that for intense lasers, with intensities ranging from  $10^{14}$  to  $10^{20}$  W/cm<sup>2</sup>, propagating in plasma with randomly uneven density distribution, photoionization by the laser can locally enhance the density variations along the laser paths and thus the branching of the laser. However, too-intense lasers can smooth the uneven electron density and suppress branching. Our work extends the existing studies of optical branching to the nonlinear regime. Branched flow of intense light in plasma opens an interesting new regime of laser-matter interaction.

In addition to intense laser branching, we also show that when a high-current relativistic electron beam propagates into a porous foam target with randomly uneven density distribution, the relativistic electron beam can also form pronounced branch patterns, which presents a completely new transport regime of high-current electron beam in plasmas. Such branch formation is physically attributed to the self-generated disordered electromagnetic fields related to the unevenness of background plasma, and is distinct from the current filamentation instability.

LIMIS2021-2021-00077

## Dynamics of attosecond electrons in the solid-plasma surface under relativistic light field

Chuliang Zhou, Yafeng Bai, Ye Tian\*

*Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*

**Abstract:** The subcycle interaction of light and electrons has been one of the key frontiers in free-electron lasers, attosecond science and dynamical investigation of matter. Capturing the underlying subcycle dynamics of electrons with an optical field promises fascinating vistas with unprecedented temporal resolution. Yet the rigorous synchronization requirement has kept its realization out of reach. Here, by direct spatial observation of periodic electron bunch fringes, we demonstrate a laser streaking concept for revealing the dynamics of free electrons emitted from a plasma mirror under sub-relativistic laser intensity. Field-induced electron beam deflection demonstrates subcycle charge dynamics with a streaking speed of  $\sim 60 \mu\text{rad as}^{-1}$ . This provides us with an attosecond-resolution metrology to obtain more direct evidence about the light-field-induced electron dynamics in the plasma mirror. Our results offer unprecedented characterization of attosecond dynamics and open the way to extensive experimental investigations of the interaction of attosecond electrons with intense lasers.

**Key words:** attosecond electron pulse trains, laser streaking, laser-plasma interaction

LIMIS2021-2022-000006

## High pressure melting and sound speed in laser shock compression forsterite

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*2. Sichuan University*

*3. Center for High Pressure Science and Technology Advanced Research (HPSTAR)*

**Abstract:** Forsterite ( $\text{Mg}_2\text{SiO}_4$ ) and enstatite ( $\text{MgSiO}_3$ ) are representative of silicates found in the interiors of large planets, such as super-Earths and large-scale impact events. Their high-pressure phase transitions and melting behaviors are important in understand the interior structures as well as the impact phenomena during planetary formation and evolution. Directly probing materials under such extreme conditions are now attainable only through dynamic compression techniques. The high-pressure melting behaviors of forsterite has been investigated up a shock pressure of 950 GPa under laser-driven shock compression experiments. Although the complex structural and chemical changes for shocked forsterite are interpreted for the discontinuities founded in laser shock compression along Hugoniot path, a direct measurement of melting behaviors is essential for deeply understanding the phase separations and melting boundary, such as incongruent crystallization of forsterite, phase transition of MgO. The adiabatic sound speed is key parameter for constrain melting boundary and phase transition in dynamical shock experiments.

Here, we report a high pressure Hugoniot of forsterite at 1200 GPa by laser indirectly shockwave loading using the high power laser facility SGIII-prototype in China. We also present the first sound speed data of shocked forsterite to 800 GPa by lateral release technique. The agreement between experiments obtained provides a reliable knowledge of phase relations during shock compression. Furthermore, the observed melt-



ing behaviors provides a critical constrain on melt transition and will affect prospect of driving a dynamo in massive rocky planets.

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## LIMIS2021-2021-000074

### Above 100 MeV proton beam generation from near-critical-density plasmas irradiated by a Laguerre-Gaussian laser pulse

Yan-Ting Hu and Tong-Pu Yu<sup>\*</sup>  
*National University of Defense Technology*

**Abstract:** High-quality protons have many potential applications in tumor therapy, proton radiography, fast ignition and nuclear physics. Over the past decades, significant progress has been made in generating such proton beams with lasers. However, it is still challenging to achieve a compact proton beam with energy of hundreds of MeV under currently available laser intensities. Here, we propose a novel scheme to produce above 100 MeV protons in the nonuniform near-critical-density (NCD) plasmas driven by a Laguerre-Gaussian (LG) laser pulse. When a linearly-polarized LG laser pulse with an intensity of  $\sim 10^{20}$  W/cm<sup>2</sup> enters the NCD plasma with a trapezoidal density profile, a donut-like double-channel structure with an electron column on the axis is produced behind the laser pulse, together with a unique, strong magnetic field, and this field has the form of a toroidal vortex. At the end of the density plateau, the magnetic field begins to expand in both forward and lateral directions. During the process, the magnetic field pressure pushes electrons and ions to form a density jump along the laser axis and induces electric fields in longitudinal and transverse directions. These electric fields collimate and accelerate protons to high energies. Finally, we obtained a well-defined proton beam with cut-off energy at least 3.5 times larger than that of the normal Gaussian laser could be obtained, making the proton beams a potential source for tumor therapy in the future.

**Keywords:** laser-plasma interaction, Laguerre-Gaussian laser pulse, near-critical-density plasma, magnetic field, ion acceleration

## LIMIS2021-2021-000129

### Intense Single-cycle Terahertz Generation on Metal Wires

Yushan Zeng, Liwei Song, Ye Tian  
*Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*

**Abstract:** Intense Terahertz radiation generation is attracting more attention, as vast light-matter control applications can be opened in this special band of the electromagnetic wave spectrum. We investigate the generation and guidance of millijoule-level intense Terahertz radiation generation from a femtosecond-laser-driven wire, and demonstrate peak electric field with GV/m field strength using near-field enhancement at the nanotip of the wire. For further applications, the Terahertz-induced fourth-order harmonic is also studied via pump-probe spectroscopy, demonstrating ultrafast non-destructive symmetry manipulation of a silicon crystal by using a 500 kV/cm Terahertz electric field.

## Photo-Induced Ultrafast Symmetry Switch and Coherent Control in SnSe

Yadong Han, Junhong Yu, Hang Zhang, Jianbo Hu

*Institute of Fluid Physics, China Academy of Engineering Physics*

**Abstract:** SnSe was recently reported to achieve a ZT value (i.e., the dimensionless figure of merit to characterize the heat-to-power conversion efficiency) of approximately 2.6 at 923 K along a particular crystallographic direction (the b axis) with the lattice transformed in the high-temperature Cmcm phase, setting the benchmark for high thermoelectric performance. Understanding the thermoelectric performance of thermoelectric materials has been mostly achieved under thermal equilibrium conditions via conventional strategies, such as: tuning the temperature, the pressure, or chemical doping. Nevertheless, such methods, which are limited in thermal equilibrium conditions, have intrinsic difficulties to understand the physical properties in thermoelectric materials, thus impeding the further improvement of thermodynamic performance. To address this issue, we investigate ultrafast carrier and phononic dynamics in SnSe via femtosecond pump-probe spectroscopy. We observed an ultrafast photoinduced switch of point-group symmetry from Pnma to Cmcm in a few hundreds of femtoseconds with an ultralow carrier density threshold ( $1.26 \times 10^{17} \text{ cm}^{-3}$ ). Furthermore, we have for the first time demonstrated that phonon dynamics in thermoelectric materials can be manipulated in the time domain. Our work, which demonstrates the ability to access the Cmcm phase without thermally heating the lattice and to discriminatorily manipulate phononic processes in SnSe, would allow scientists in the field to go beyond the current thermal-equilibrium-based thinking and foster novel design ideas to improve the performance of thermoelectric materials.

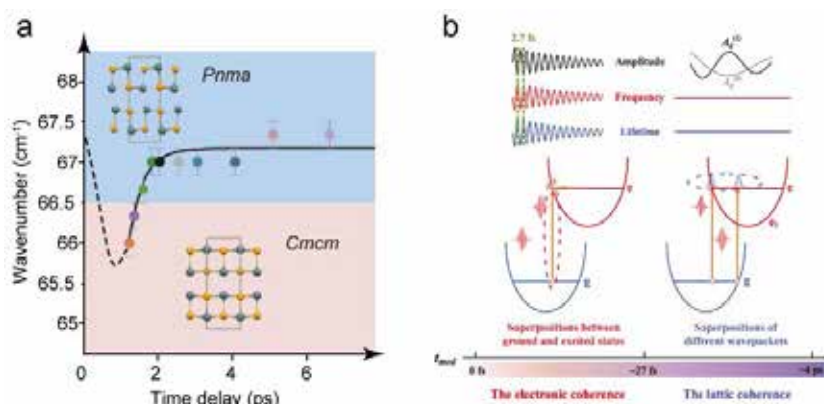


Figure 1. (a) The transient frequency of the coherent Ag(1) mode is extracted from the CWT chronogram, providing clear evidence of the point-group symmetry switch from Pnma to Cmcm.. (b) Schematic illustration of the overall phononic control mechanisms and results.

Keyword: Ultrafast spectrum; Tin selenide; Lattice dynamic; Carrier dynamic

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**LIMIS2021-2021-000088**

**The Hugoniot of polycrystalline diamond at TPa pressure with indirectly laser-driven shock wave**

**Peng Wang<sup>1,2</sup>, Chen Zhang<sup>1</sup>, Shaoen Jiang<sup>1</sup>, Xiaoxi Duan<sup>1</sup>, Huan Zhang<sup>1</sup>, LiLing Li<sup>1</sup>, Weiming Yang<sup>1</sup>, Yonggang Liu<sup>1</sup>, Yulong Li<sup>1</sup>, Liang Sun<sup>1</sup>, Hao Liu<sup>1</sup>, Feng Wang<sup>1</sup>, Zhebin Wang<sup>1</sup>**

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**Abstract:** High-density carbon (HDC) is one of the most potential ablator material in laser fusion, with a density of triple that of CH, high energy absorption efficiency, and short laser pulse. Due to the fabrication process, the initial state of HDC is different from that of single-crystal diamond, with lower density and smaller grain size, and these factors could affect the shock process in laser fusion. We use indirectly laser-driven shock waves to measure the shock Hugoniot of HDC in a 10-kJ laser facility at pressures related to the shock in laser fusion. Stiffness of the HDC Hugoniot due to lower initial density is confirmed. Two porous models are used to describe the Hugoniot of HDC, which behave better than the commonly used SESAME database. The discussion of the Grüneisen parameter used in McQueen model shows that the temperature effect, which is usually neglected, might need to be taken into account under this condition. The results could help researchers understand the initial density effects of HDC in laser fusion.

**LIMIS2021-2022-000004**

**Research on fractal and angular momentum of electromagnetic solitons**

**Zhongpeng Li**

*Xi'an Jiaotong University*

**Abstract:** The specific polarization of radially polarized lasers with cylindrical structures and longitudinal electric fields at their focal spots are of interest, as are the fundamental characteristics of electromagnetic (EM) solitons. We report the fractal features of EM solitons induced via a radially polarized laser on the basis of three-dimensional (3D) particle-in-cell (PIC) simulations, and find that the intriguing structure is indirectly originates from the Weibel instability of the electron ring. Apart from this, the optical vortex has been widely studied owing to its specific characteristics such as orbital angular momentum, hollow intensity distribution and topology charge. We report the generation of EM solitons with angular momentum and reveal that the physical essence is the conversion from spin angular momentum to orbital angular momentum. The research on the topology and angular momentum of EM solitons unveil the peculiar properties such as spatial and broken polarization symmetry and provide a deep insight into laser plasma interactions.

Key words: electromagnetic solitons, fractal, angular momentum conversion

**LIMIS2021-2022-000033**

**Ultrafast nonlinear optics in Porphyrin- Based Surface-Supported Metal–Organic Framework Nanofilms**

**Junhong Yu,<sup>1,2</sup> Yadong Han,<sup>1,2</sup> Longyu Wang,<sup>1</sup> Yibing Liu,<sup>1</sup> Hang Zhang,<sup>1,2</sup> Xuan Chen<sup>3</sup>, Xuezhi Liu<sup>3</sup>, Zhengbang Wang,<sup>3,#</sup> Jianbo Hu<sup>1,2,#</sup>**

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*2. Southwest University of Science and Technology*

*3. Hubei University*

**Abstract:** Optical logic gates call for materials with giant optical nonlinearity to break the current performance bottleneck. Metal-organic frameworks (MOFs) provide an intriguing route to achieve superior optical nonlin-

earity benefitting from the structural diversity and design flexibility. However, the potential of MOFs for optoelectronics has been largely overlooked and its applications in optical logics have not been exploited. Here, through temporally manipulating the nonlinear optical absorption process in porphyrin-based MOFs, we have successfully developed AND and XOR logic gates with an ultrafast speed approaching 1 THz and an on-off ratio above 90%. On this basis, all-optical information encryption is further demonstrated using transmittance as primary codes, which shows vast prospects in avoiding the disclosure of security information. To the best of our knowledge, this is the first exploration of MOFs for applications in ultrafast optical logic devices and information encryption.

**LIMIS2021-2021-000165**

### **Controllable birefringent lens based on magnetized plasma**

**Kaiqiang Pan, Dong Yang, Xiantu He**

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**Abstract:** In this paper, we investigate the controllable birefringent lens based on magnetized plasma via three dimensional(3D) particle-in-cell(PIC) simulations. It is shown that, when a linearly-polarized laser obliquely irradiates on the interface between the vacuum and a magnetized plasma, the laser will be double refracted into two circularly-polarized lasers, one of them is left-circular, the other is right-circular. By changing the intensity of the internal magnetic field and the plasma density, we can totally split the two circularly-polarized lasers with a large angle between the propagation directions. It is also shown that, the ellipticity of the circularly-polarized lasers can be controlled by the intensity of the internal magnetic field. The birefringent lens can be used to generate circularly-polarized lasers or elliptically-polarized lasers which satisfy our needs.

**Keywords:** Laser plasma interaction; magnetized plasma; birefringence; particle-in-cell

**LIMIS2021-2022-000030**

### **Few-cycle vortex beam generated from self-compression of midinfrared femtosecond vortices in thin plates**

**Litong Xu<sup>1</sup>, Dongwei Li<sup>2</sup>, Junwei Chang<sup>2</sup>, Tingting Xi<sup>1</sup>, Zuoqiang Hao<sup>2</sup>**

*1. University of Chinese Academy of Sciences*

*2. Shandong Normal University*

**Abstract:** Vortex beams with phase singularities have attracted great attention for their applications in optical tweezer, microscopy, optical communications and so on. When combined with the ultrashort and ultraintense nature of femtosecond pulse, they provide opportunities for new applications in high field physics, such as vortex THz generation, proton acceleration and attosecond vortices. Femtosecond vortex beams can be generated from a femtosecond gaussian beam with phase encoding elements, including spatial light modulator, spiral phase plate and q-plate. Nevertheless, few-cycle or attosecond vortex beams are hard to be realized by these methods due to chromatic aberrations. They may be obtained by post-compression of supercontinuum vortices. However, the post compression technique will cause inevitable energy loss. As an alternative way, self-compression is of particular interest for its convenience to generate few-cycle pulses with high conversion efficiency. Recently, few-cycle pulses have been generated via self-compression of mid-infrared laser pulses using the thin-plate scheme (Opt. Lett. 46, 5075). Considering that the thin-plate scheme can also avoid multiple filamentation and preserve the initial vortex structure in the output supercontinuum, which

was demonstrated in our previous work (Photon. Res. 10, 802), it should be a promising candidate for the generation of few-cycle vortex beams. Here for the first time we demonstrate theoretically the generation of few-cycle vortex beam via self-compression of mid-infrared femtosecond vortex beam using the thin-plate scheme. Due to the strong negative group velocity dispersion of fused silica, the pulse with a central wavelength of 3  $\mu\text{m}$  is compressed from 3 mJ/90 fs to 2.75 mJ/15.1 fs, corresponding to about 1.5 optical cycles with a peak power of 0.18 TW. At the same time, the thin-plate scheme prevents destructive multifilamentation, so that the few-cycle pulse preserves its vortex characteristics. As a result, few-cycle vortex beam is obtained, and the conversion efficiency is as high as 91.5% due to weak ionization. Our work will be particularly helpful to the generation of isolated attosecond vortices, opening a new perspective in ultrafast science. (<https://arxiv.org/abs/2204.11147>)

**Keywords:** Filamentation; Supercontinuum; Ultrafast optics; Vortex beams.

**LIMIS2021-2021-000032**

### The effect of an applied magnetic field on Kelvin-Helmholtz instability driven by laser under multi-mode disturbance

Wei Sun<sup>1</sup>, Chong Lv<sup>1</sup>, Zhao Wang<sup>1</sup>, Jiayong Zhong<sup>2</sup>

1. China Institute of Atomic Energy

2. Beijing Normal University

**Abstract:** Kelvin-Helmholtz instability (KHI), as a basic physical process of fluids and plasmas. It is widely present in nature, astrophysics, and high energy density physical phenomena. This paper, using the radiation magnetohydrodynamic code to conduct a two-dimensional numerical simulation of the KHI generated by the laser-driven modulation target for the laboratory. Here, the evolution process of KHI vortices under different initial disturbance modes and with or without horizontal external flow-direction magnetic field is investigated and compared from the perspectives of vortices, longitudinal total kinetic energy, magnetic pressure, and magnetic tension. The simulation shows that the external magnetic field in the horizontal flow direction inhibits the evolution of single-mode KHI vortices and the merging of multi-mode KHI vortices. The research results can provide theoretical guidance of the KHI experiment in a high-energy-density laser device under a strong magnetic environment.

**Keywords:** the external magnetic field, Kelvin-Helmholtz instability, multi-mode disturbance

**LIMIS2021-2021-000101**

### Measurements of X-ray spectra and absolute energies from laser produced Al plasmas

Yanpeng Liu, Quanxi Xue, Xueqing Zhao

State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology

**Abstract:** The X-ray property of Al plasmas was studied experimentally by using the excimer laser facility in the State Key Laboratory of Laser Interaction with Matter. Radiated fluxes were recorded within two X-ray diodes, and the relative spectral distributions were recorded within an X-ray flat-field grating spectrograph, respectively. Experimental results indicated that the major X-ray photons were between 60 eV and 360 eV. By employing the spectral integration method, the measured data were appropriately processed to obtain absolute energies of the X-ray that radiated from Al plasmas.

**Keywords:** Measurement; X-ray spectrum; X-ray energy; Aluminum plasma.

**SC3:Laser spectrum technology and applications  
2022/8/11 4F, Shangli Hall**

Presider: Jingfeng Ye, Northwest Institute of Nuclear Technology, State Key Laboratory of Laser Interaction with Matter

14:00-14:25 (Invited)	<b>Photothermal gas sensing: from single frequency to frequency comb</b> Wei Ren, The Chinese University of Hong Kong
14:25-14:50 (Invited)	<b>Atmospheric remote sensing based on tunable diode lasers</b> Liang Mei, Dalian University of Technology
14:50-15:15 (Invited)	<b>Recent Advances in Quartz-enhanced Photoacoustic Spectroscopy</b> Lei Dong, Shanxi University
15:15-15:40 (Invited)	<b>On-chip dual-comb generation via sideband thermal compensation for spectroscopy</b> Ke Yin, National University of Defense Technology
15:40-15:55 Coffee Break	
Presider: Wei Ren, The Chinese University of Hong Kong	
15:55-16:10	<b>LIMIS2021-2021-000046</b> <b>Wideband tunable Tm-doped fiber laser and its hyperspectral applications</b> Mengmeng Tao, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences; State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology
16:10-16:25	<b>LIMIS2021-2021-000086</b> <b>A minizturised all-optical photoacoustic sensor for CH<sub>4</sub> gas detection</b> Zhenfeng Gong, Dalian University of Technology
16:25-16:40	<b>LIMIS2021-2021-000017</b> <b>Application of laser induced plasma spectroscopy in air pollution monitor</b> Zhixing Gao, China Institute of atomic energy
16:40-16:55	<b>LIMIS2021-2022-000037</b> <b>Unsupervised learning based noise reduction algorithm in 2D Rayleigh images</b> Minnan Cai, Xiamen University
16:55-17:10	<b>LIMIS2021-2022-000032</b> <b>Research on Measurement Method of Three-dimensional Temperature Field Based on High Temperature Radiation Spectrum of Water Vapor</b> Gongxi Zhou, Institute of Mechanics, Chinese Academy of Sciences

**SC3: Laser spectrum technology and applications**  
**2022/8/12 4F, Shangli Hall**

Presider: Qili Liu, Institute of Mechanics, Chinese Academy of Sciences

13:30-13:55 (Invited)	<b>Trace multi-component gas detection by enhanced Raman spectroscopy</b> Pinyi Wang, Chongqing University
13:55-14:10	<b>LIMIS2021-2021-000009</b> <b>Image distortion effect and distortion correction method in two-color LIF approach for droplet temperature measurement</b> Jiangning Zhou, China Aerodynamic Research and Development Center
14:10-14:25	<b>LIMIS2021-2022-000031</b> <b>Mid infrared laser absorption tomography for in situ quantitative thermochemistry measurements of hybrid rocket motors</b> Sihan Fang, Institute of Mechanics; University of Chinese Academy of Sciences
14:25-14:40	<b>LIMIS2021-2022-000053</b> <b>Weak absorption detection method under broadband interference based on linear wavelength modulation spectroscopy</b> Renjie Li, Institute of Mechanics, Chinese Academy of Sciences
14:40-14:55	<b>LIMIS2021-2022-000027</b> <b>A Method for Improving the Accuracy of Calibration-Free Laser-Induced Breakdown Spectroscopy by Exploiting Self-Absorption</b> Zhenlin Hu, Huazhong University of Science and Technology
14:55-15:10 Coffee Break	
Presider: Pinyi Wang, Chongqing University	
15:10-15:35 (Invited)	<b>Mid-Infrared Laser Sensors for Chemistry and Environment</b> Aamir Farooq, King Abdullah University
15:35-16:00 (Invited)	<b>Applications of Laser Diagnostics in High-Speed Airbreathing Engines</b> Qili Liu, Institute of Mechanics, Chinese Academy of Sciences
16:00-16:15	<b>LIMIS2021-2022-000043</b> <b>Room-temperature Topological Photocurrent Injection and Manipulation at Two-Dimensional Interface</b> Zeyu Zhang, Hangzhou Institute for Advanced Study, University of Chinese Academy of Sciences



## Photothermal gas sensing: from single frequency to frequency comb

**Wei Ren**

*The Chinese University of Hong Kong*

**Abstract:** Trace gas sensing plays an important role in energy production, environmental monitoring, transportation, agriculture, safety, and security. Laser spectroscopy provides many possibilities for trace gas sensing in multi-disciplinary research and applications. Among different spectroscopic methods, photothermal spectroscopy (PTS) is a highly sensitive and selective technique to measure the optical absorption and thermal characteristics of a gas sample. It becomes extremely attractive if this technique is merged with optical hollow-core fibers. In this talk I will discuss our recent innovations in PTS, showing the potentiality of remote interrogation and integrated photonics systems. In particular, the most recent results on dual-comb photothermal spectroscopy (DC-PTS) are presented and discussed.

## Atmospheric remote sensing based on tunable diode lasers

**Liang Mei**

*Dalian University of Technology*

**Abstract:** Atmospheric lidar techniques featuring high space- and time-resolution, and high sensitivity have been widely used for atmospheric aerosol, trace gases, temperature and wind speed measurements. Traditionally, the atmospheric lidar technique, based on the time-of-flight principle, employs ns-scale pulsed Nd:YAG laser lasers as light sources and photomultiplier tubes as detectors. In recent years, we have developed a new lidar technology – the Scheimpflug lidar (SLidar) for atmospheric remote sensing, which is based on the Scheimpflug principle. The newly developed SLidar technique can thus utilize continuous wave diode lasers as light sources and image sensors as detectors, featuring short blind range, compact structure, low maintenance and high cost performance, etc. In recent years, the SLidar technique has been applied to the fields of atmospheric environment monitoring, three-dimensional (3D) target imaging, fluorescence (hyperspectral) lidar detection, ecological studies, combustion diagnosis, and water-body optical measurements, etc. This presentation will report our recent progress of the Scheimpflug lidar technique in the applications of atmospheric aerosol and trace gas monitoring.

## Recent Advances in Quartz-enhanced Photoacoustic Spectroscopy

**Lei Dong**

*Shanxi University*

**Abstract:** Trace gas detection technology plays an important role in many fields such as environmental monitoring, industrial process control, defence and security, medical diagnostics. The innovation and development of new trace gas sensing technology can provide highly sensitive and selective gas detection modules. Gas sensing method based on photoacoustic spectroscopy is featured as good selectivity, high accuracy, long life, fast response time, and low maintenance cost. This presentation mainly summarizes the latest advance in quartz-enhanced photoacoustic spectroscopy. The modelling, simulation and design of customized quartz tuning forks (QTFs) for trace gas sensing are present. Novel spectrophone configuration, combining a QTF and a multipass cell, is studied. Several application examples for environmental monitoring, non-invasive medical diagnostics, supervisory control of power industries are introduced. Finally, the development trend of quartz-enhanced photoacoustic technique is discussed.



## On-chip dual-comb generation via sideband thermal compensation for spectroscopy

Ke Yin, Runlin Miao, Tian Jiang

*National University of Defense Technology*

**Abstract:** Microcombs—generated by coherently pumping the nonlinear microresonators —have emerged as a state-of-the-art scheme at the chip scale. Dual-comb spectroscopy technology further takes advantage of the miniature system and has been demonstrated as a powerful tool for the real-time, broadband optical sampling of molecular spectra by down-converting it to the RF domain. Here, based on the novel microcomb generation method via rapid frequency sweep and sideband thermal compensation, the soliton dual-microcomb generation beyond 200 nm optical spectra has been demonstrated with two microresonators of moderate quality factors ( $1 \times 10^6$ ), and the free-running system could stably stay for several hours with no active locking technique. Compared to the dual-comb with a weak thermal compensation effect, our dual-comb shows much lower-noise microwave beat notes ( $< 10$  kHz) and smaller Allan deviation ( $1.0 \times 10^{-4}$  @ 1 ms) by increasing sideband power. Moreover, the dual-comb has been utilized in the gas absorption detection of  $H_{12}CN$  for demonstration with high signal-to-noise ratios and fast acquisition rates. The dual-microcomb spectrum is unaligned by an AOM, and the repetition rate difference of 28 MHz could map over 100 microcomb lines from a 5.4-THz optical spectrum (1505 to 1590 nm) span into a 1.5-GHz RF bandwidth with 101.8 GHz resolution without any coherent averaging at a fast acquisition time of 10  $\mu$ s. Compared to the absorption spectrum obtained by conducting wavelength scanning, the dual-comb spectroscopy has a standard deviation of 0.0208. When further equipped with field-programmable gate arrays and the coherent averaging algorithm, it will also have the potential for real-time and time-resolved spectral acquisition on microsecond time scales. Our work also lays a technical foundation for other applications such as dual-comb ranging and microwave photonics.

## Trace multi-component gas detection by enhanced Raman spectroscopy

Pinyi Wang

*Chongqing University*

**Abstract:** Trace multi-component gas detection is widely required in many fields, such as environmental safety monitoring, air pollution detection, industrial process control, and equipment fault diagnosis. Among different spectroscopic technologies, Raman spectroscopy is a unique gas sensing tool that provides multi-faceted qualitative information and accurate quantitative indication of a gaseous mixture using a single-wavelength laser. However, the intensity of Raman scattering is intrinsically weak, and signal enhancement is consequently indispensable. This presentation will mainly report our recent progress in the gas's Raman signal enhancement methods, including the principle and applications of resonant cavity enhanced technology, multipass cavity enhanced technology, and hollow-core fiber enhanced technology. With signal enhancement methods, Raman spectroscopy is powerful for gas sensing, which can simultaneously detect multi-component gas with high selectivity, high sensitivity, and high accuracy.

## Mid-Infrared Laser Sensors for Chemistry and Environment

Aamir Farooq

*King Abdullah University of Science and Technology (KAUST)*

**Abstract:** The mid-IR wavelength region is considered to be the 'molecular fingerprint' as it provides access to fundamental vibrational bands of many molecules and the possibility of developing highly sensitive and interference-free optical sensors. With the relatively recent availability of stable quantum cascade lasers (QCLs) and interband cascade lasers (ICLs) emitting in the mid-IR, our group has been at the forefront of exploiting

the capabilities of these sources for chemical kinetics research and environmental monitoring. We designed and developed a novel chirped-pulse strategy to perform spectrally-resolved, calibration-free and ultrafast temperature measurements in a shock tube, and later applied this technique to measure the first-stage temperature rise during low-temperature oxidation studies in an RCM. Thereafter, we combined the benefits of chirped-pulse and cavity-enhancement to measure trace amounts of carbon monoxide. Recently, we demonstrated chirped-pulse temperature measurements with water vapor as the absorbing gas. Commercially-available continuous-wave QCLs are not yet able to reach wavelengths beyond 13  $\mu\text{m}$ . However, the 12 – 15  $\mu\text{m}$  region has strong vibrational bands of many important molecules; particularly, this region contains the bending vibrational modes of aromatics. Therefore, we designed and developed our own laser source to access the long-wavelength region of mid-IR. We employed non-linear spectroscopy, i.e., difference-frequency-generation, between a  $\text{CO}_2$  gas laser and an external-cavity QCL to generate laser light in the target region. This laser system has been demonstrated for measurements of benzene, toluene, and HCN.

## Applications of Laser Diagnostics in High-Speed Airbreathing Engines

Qili Liu

*Institute of Mechanics, Chinese Academy of Sciences*

**Abstract:** Spacecrafts for near-earth orbit transportation use high-speed airbreathing propulsion systems to provide long-range flight capabilities in the near space. Flame stabilization in hypersonic flows is an important scientific and technical challenge with its main implications in supersonic and hypersonic airbreathing engines. High-repetition-rate laser diagnostic technologies can resolve the flow and flame structure with high temporal resolution to understand the rate-limiting parameters of fluid-combustion interactions in the harsh flow environments like supersonic combustors. Planar laser-based measurement methods (e.g., planar laser-induced fluorescence PLIF, particle imaging velocimetry PIV, etc.) can provide multi-dimensional informations to depict the high-speed turbulent combustion phenomenon, which include but not limit to velocity, temperature, and distributions of species. In premixed flame structures, OH radicals are produced in production regions, while CH radicals are produced in reacting layers, and  $\text{CH}_2\text{O}$  in preheat regions. Therefore, OH/CH/ $\text{CH}_2\text{O}$  PLIF methods are used to characterize the high-speed combustion in terms of preheat region, reacting layer, production region, respectively. High-speed PIV can visualize the evolutions of large-scale coherent structures and eddies. Simultaneous measurements of PIV and PLIF can provide fine flame structures in turbulent flows to reveal the flow-flame interactions, which are critical to engine operation stabilities. Such laser-based diagnostic technologies have been widely applied to high-speed combustion engines for fundamental studies of combustion sciences and engineering optimization of combustor devices.

LIMIS2021-2021-000046

## Wideband tunable Tm-doped fiber laser and its hyperspectral applications

Mengmeng Tao<sup>1,2</sup>, Yamin Wang<sup>2</sup>, Haolong Wu<sup>2</sup>, Jingfeng Ye<sup>2</sup>, Bo Tao<sup>2</sup>, Guohua Li<sup>2</sup>, Xisheng Ye<sup>1</sup>, and Weibiao Chen<sup>1</sup>

1. Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

2. State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology

**Abstract:** In our previous works, a wideband tunable Tm-doped fiber laser around 2  $\mu\text{m}$  is developed based on a tunable FP filter. The emitting wavelength covers a wide range from about 1850 nm to over 1890 nm where plenty of H<sub>2</sub>O absorption lines can be found at room temperature. Hyperspectral absorption spectroscopy validations are carried out with this laser system for continuous detection of water absorption lines. More than 30 absorption peaks are clearly identified in the tuning range and all match with the theoretical ones derived from the HITRAN2012 database. However, tests show that for broadband wavelength tuning, the dynamic linewidth of the laser expands. Besides, the strong absorption lines in this band at room temperature would also affect the applications in high temperature sensing. For high temperature sensing, here, the emitting wavelength of the Tm-doped fiber laser is shifted to 1910~1970 nm band through optimization of the cavity parameters. And, a Tm-doped fiber amplifier is developed to boost the output power to over 300 mW. At room temperature, more than 50 strong absorption lines are identified for H<sub>2</sub>O. And, analysis shows that the linewidth of the laser output is about 0.06 nm, and keeps stable in dynamic tuning operation. Then, temperature sensing of alcohol flames through hyperspectral absorption is investigated with this laser source.

**Keywords:** hyperspectral absorption, wavelength tuning, narrow linewidth.

LIMIS2021-2021-000086

## A minizturised all-optical photoacoustic sensor for CH<sub>4</sub> gas detection

Zhenfeng Gong<sup>\*</sup>, Guojie Wu, Junsheng Ma, Haie Li, Ke Chen, Liang Mei

Dalian University of Technology

**Abstract:** In this paper, a miniaturized all-optical single-fiber photoacoustic (PA) sensor was demonstrated. The sensor was integrated by a cantilever made of silicon material, a single optical fiber together with a silicon dioxide sensor head. The excitation light source of the PA signals and the detecting light source of the Fabry-Perot (F-P) fiber-optic acoustic sensor were coupled in a single fiber through a wavelength division multiplexer (WDM). The silicon dioxide sensor head had a truncated cone-shaped cavity, which served both as the F-P cavity and PA cell. Due to this special structure, the volume of the PA cell and the entire sensor head were  $\sim 1.1 \mu\text{L}$  and  $\sim 17 \mu\text{L}$ , respectively. The miniaturized single-fiber PA sensor was applied for methane (CH<sub>4</sub>) detection. The MDL is calculated to be 51.1 ppm with the integration time of 1 s. The proposed sensor is completely suitable for remote, long-distance and space-limited trace gas detection.

## Application of laser induced plasma spectroscopy in air pollution monitor

Zhixing Gao<sup>1\*</sup>, Hongyu He<sup>1</sup>, Fengming Hu<sup>1</sup>, Jing Li<sup>1</sup>, Zhao Wang<sup>1</sup>, Jian Gao<sup>2</sup>

*1. China Institute of atomic energy*

*2. Chinese Research Academy of Environmental Sciences*

**Abstract:** Laser induced plasma spectroscopy (LIPS, also LIBS) is a promising technique for the challenging issues associated with the real-time and in-situ monitoring the major elements of aerosol particulate matters. A prototype of Aero-LIPS had been set up with the techniques of aerosol beam focusing, enhanced plasma emission collector and conditional data filter to demonstrate the potential application of air pollution composition monitoring. The prototype can identify more than 40 elements from aerosols and continuously monitor 20 elements with the time resolution of 10 minutes. In the field test of an Asian dust event, the major elements, such as Ca, Mg, Al, Si, Cl, P, S, etc. have been real-time monitored, which took 77.9% part of the total particulate matter mass. The evolutions of temporal elemental concentrations went well along with the particle matter concentration. However, the monitored element only weight 10.6% of smog particles in total. It is interesting that the persist lines of U and Th have been detected from Asian dust aerosol while their concentration in local air should range in the level nano-grams per cubic-meter. It indicates that the enhanced-LIPS has a potential to monitor the nuclear facility emission for Nuclear Security and Safeguards.

## Unsupervised learning based noise reduction algorithm in 2D Rayleigh images

Minnan Cai, Jiawei Peng, Wenjiang Xu\*

*Xiamen University*

**Abstract:** This work reports a novel image denoising and reconstruction algorithm based on unsupervised learning for removing Mie scattering interference in Rayleigh images. We first superimposed numerically simulated noise-free Rayleigh images and noisy Mie images acquired in experiment to generate noisy Rayleigh images as training data. The proposed unsupervised model was then trained using the feature-unpaired data. Finally, extensive evaluations were conducted to demonstrate a convincing denoising result, which displayed an excellent reconstruction quality with a peak-signal-to-noise of ~41dB and an overall reconstruction error of ~0.5%. The results showed the potential of our algorithm as an alternative method, which requires no additional molecular filter as in conventional Rayleigh imaging, for noise reduction in two dimensional Rayleigh measurement of combustion.

Keywords: unsupervised learning, denoising, Rayleigh measurement.

Main figures:

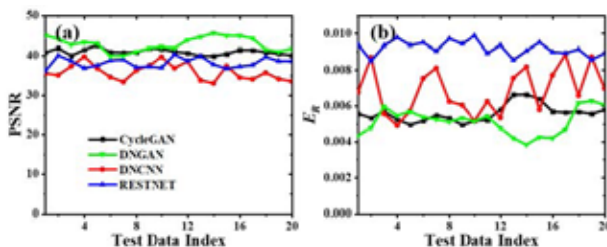


Figure 1. Performance variation of proposed unsupervised model and three other networks on the test data-set (flame C) (a) variation of PSNR, (b) variation of ER

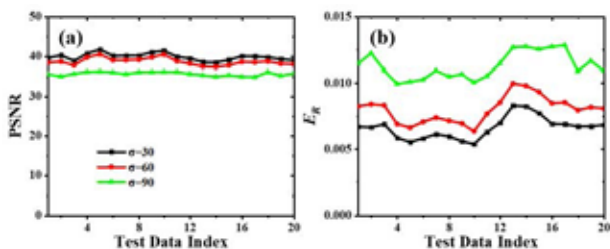


Figure 2. The denoising quality remain similar as in previous figures, though extra noise added.

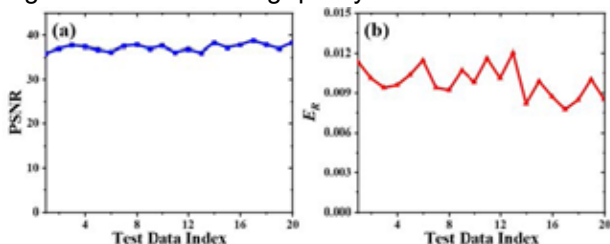


Figure 3. Performance variation of unsupervised model on the test data of flame B

LIMIS2021-2022-000032

## Research on Measurement Method of Three-dimensional Temperature Field Based on High Temperature Radiation Spectrum of Water Vapor

GONGXI ZHOU<sup>1,2</sup>, FEI LI<sup>2</sup>, XIN LIN<sup>2</sup>, DONGDONG MENG<sup>2</sup>, XILONG YU<sup>1,2</sup>

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*2. Institute of Mechanics, Chinese Academy of Sciences*

### Abstract:

#### 1. Introduction

The combustion process is a complex, violent, luminous and heat-generating chemical process. The study of combustion mechanism and combustion process is conducive to the control of combustion, the suppression of pollutants and the improvement of combustion efficiency. Combustion temperature distribution is the most basic and most important parameter in the combustion process, and combustion is often controlled and optimized by measuring them. Therefore, the research of temperature measurement technology has always been a hot issue that has attracted much attention.

The high-speed collisions between particles at high temperatures excite the respective degrees of gas molecules. At the same time, due to the short life of high-energy molecules, emission spectra of corresponding frequencies are generated when they transition from high energy levels to low energy levels. The emission spectrum data contains information such as temperature and concentration of high-temperature gas molecules. The usual method is to determine the temperature by comparing the mid-infrared simulation spectrum database of CO<sub>2</sub> and other components in the flame with the line type and intensity of the experimental spectrum, but this requires high precision for the spectrometer and spectrum simulation.

H<sub>2</sub>O occupies a large proportion of combustion products, and its visible light and near-infrared radiation spectrum is very sensitive to temperature. Therefore, the selection of H<sub>2</sub>O radiation spectrum to determine the flame temperature eliminates the dependence on the more technically demanding mid-infrared spectrometer. In addition, the algebraic reconstruction algorithm has successfully achieved the high spatial resolution reconstruction of the flame three-dimensional structure [1-4]. In this experiment, the introduction of the electronically controlled translation stage realizes the data acquisition of multiple points on the cross-section, and combined with the algebraic iterative algorithm makes it possible to realize the three-dimensional temperature field.

## 2. Experiment introduction

In order to achieve precise control of the pure oxygen methane flame and obtain a stable flame structure, a pure tangential swirl burner is used to generate the target flame. The experimental device is shown in Figure 1. Methane and oxygen enter the combustor through four pipes as shown in the figure. The spark plug is installed on the axis of the combustor to ignite the methane-oxygen mixture through electric discharge, and then a stable flame is formed in the quartz tube at the outlet.

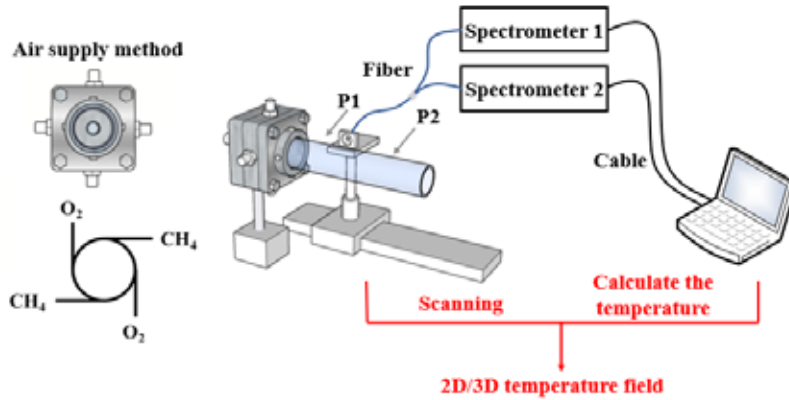


Figure 1 Tangential swirl burner, the red arrows are the two measurement positions

Two optical fiber spectrometers with test bands of 200~1000nm and 950~1700nm were installed on the outside of the quartz glass tube. It is worth noting that the two spectrometers use a Y-type fiber with one input end and two output ends, combined with a rotary and axial displacement stage to realize scanning along the axis and circumferential direction of the quartz tube.

## 3. Data analysis

### 3.1 High-temperature radiation simulation spectra of water molecules

Accurate spectral simulation is the key to constant temperature. Based on the HITEMP spectral database, we simulated the high temperature radiation spectrum of  $H_2O$ . Figure 2(a) shows the high-temperature radiation spectrum data of  $H_2O$  at a temperature of 3000k (the ordinate is processed in logarithm). It can be found from the figure that different wavebands of water molecules have very different emission intensities at the same temperature. As shown in Figure 2(b), we are fortunate to find that the ratio of the total emission intensity between 1400~1500nm and 920~1000nm changes drastically with temperature changes, making it possible to accurately determine the temperature.

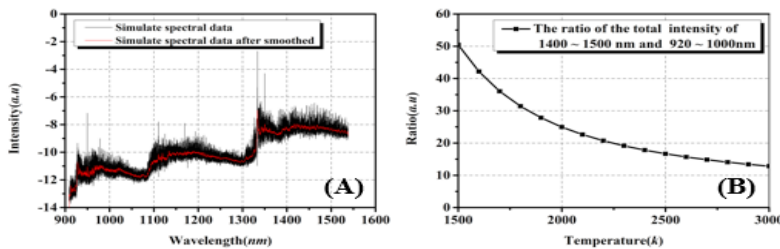


Figure 2 (A) radiation spectra of water molecules at 3000K and smoothed curves, (B) the ratio of the total intensity of 920~1000nm and 1400~1500nm.

### 3.2 Experimental spectral data

The spectrum measurement of the pure oxygen methane flame produced by the tangential swirl burner introduced in Chapter 1 was carried out. Two portable optical fiber spectrometers combined with a Y-type optical fiber were used in the experiment to ensure that the two spectrometers can receive the optical signal from the same position of the flame. Figure 3 shows the spectral data of different positions of the pure oxygen flame of methane when the equivalence ratio is 1.0. It can be seen from the figure that the intensity change ratios of different bands at different positions are very different. The intensity change at the two positions at

920~1000nm is very small, while the intensity difference between 1000~1700nm is very obvious.

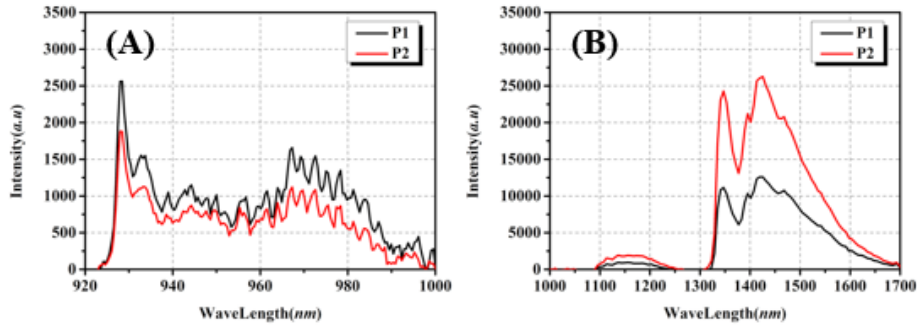


Figure 3 (A)(B) is the spectral data at P1 and P2 in Figure 1

We performed six spectral measurements using three sets of equivalence ratios (1.0, 0.8, and 1.2) at two different locations. Comparing the ratio of the total emission intensity between 920~1000nm and 1400~1500nm in the obtained spectrum data with the ratio curve of the simulated spectrum data in Fig. 2(B), the temperature data of the two measurement positions can be obtained as approximately 2750~2900K and 2200~2400K.

Table 1 The ratio of the total intensity of the spectrum at the two points P1 and P2 and the corresponding temperature

Position	Position 1	Position 2
Equivalence ratio 1.0	15.9364(2758K)	24.8383(2234k)
Equivalence ratio 0.8	14.6700(2862K)	22.8994(2278K)
Equivalence ratio 1.2	15.2153(2813K)	21.6731(2311K)

#### 4. Discussion of experimental results

The temperature of the flame can be directly determined by using the ratio of the total radiant intensity of the visible light and the near-infrared part of the water molecules. Combining with algebraic iterative algorithm, the flame three-dimensional temperature field reconstruction with high spatial and temporal resolution can be realized. This temperature measurement method has simple equipment and strong robustness, and will play an important role in temperature measurement of engine combustion chambers.

### LIMIS2021-2021-000009

#### Image distortion effect and distortion correction method in two-color LIF approach for droplet temperature measurement

Jiangning Zhou, Quan Zhou, Wenbin Yang, Yimin Yin, Shuang Chen, Jinhe Mu  
*China Aerodynamic Research and Development Center*

**Abstract:** Two-color laser induced fluorescence approach has been widely used in temperature field analysis of complex two phase flow such as droplet and spray. However, due to great refractive index difference in two phase flow, strong image distortion of measurement result may happen however is rarely considered. In this work, influences of this image distortion in droplets on temperature field measurement are analyzed. Based on refraction and reflection theories, a simplified distortion model is built and discussed in sphere droplet case. Then distortion and LIF intensity changes of droplets at different refractive index atmosphere are analyzed in experiment, which can be well described by our distortion model. From both theoretical and experimental results, greater image distortion can be observed in two phase flow with larger refractive index



difference and areas with larger thickness and larger tangential angle of two phase flow boundary. Besides, temperature measurement data loss can be observed at low refractive index atmosphere due to total reflection effect. Based on distortion model, corresponding distortion correction method is proposed based on this distortion model.

**Keyword:** Fluorescence, Temperature, Image distortion, Laser Induced Spectroscopy

### LIMIS2021-2022-00031

#### Mid-infrared laser absorption tomography for in-situ quantitative thermochemistry measurements of hybrid rocket motors

Sihan Fang<sup>1,2</sup>, Xin Lin<sup>1</sup>, Zezhong Wang<sup>1</sup>, Zelin Zhang<sup>1</sup>, Jiaxiaolin Luo<sup>1,2</sup>, Renjie Li<sup>1,2</sup>, Fei Li<sup>1</sup>, Xilong Yu<sup>1,2</sup>

1. Institute of Mechanics, Chinese Academy of Sciences

2. School of Engineering Science, University of Chinese Academy of Sciences

**Abstract:** Further development of hybrid propulsion systems requires a deeper understanding of the complex physicochemical mechanisms governing its combustion performance. A tunable diode laser absorption tomography (TDLAT) technique was developed for investigating the thermochemical processes at the nozzle exit of an oxygen/high-density polyethylene (HDPE) hybrid rocket motor. Firing tests were conducted for different oxidizer mass fluxes ranging from 2.15 to 4.10 g/(cm<sup>2</sup>·s). A distributed feedback (DFB) laser was tuned to cover three H<sub>2</sub>O absorption lines near 2.5 μm, using scanned-wavelength direct absorption (DA) mode with 2.0 kHz repetition rate. Under an assumption of cylindrical symmetry, a Radon transformation was applied to yield radially- and time- resolved absorption coefficient, from which the radial distribution of temperature and H<sub>2</sub>O partial pressure were reconstructed. Based on the Taylor series method (TSM), measurement uncertainty was analyzed in detail considering line-strength uncertainty, Voigt fitting residuals and Radon transformation. Finally, the radial distribution and dynamic variations of both temperature and H<sub>2</sub>O partial pressure were obtained in all firing tests, both the constructed results show measurement sensitivity to chemical kinetic progress and oxidizer mass flux changes. Our experimental results highlight the capability of TDLAT to characterize combustion processes of hybrid rocket motors.

**Keywords:** tunable diode laser absorption tomography (TDLAT), H<sub>2</sub>O partial pressure, Radon transformation, combustion process, hybrid rocket motors

### LIMIS2021-2022-00053

#### Weak absorption detection method under broadband interference based on linear wavelength modulation spectroscopy

Renjie Li<sup>1,2</sup>, Jing Li<sup>2,3</sup>, Yan Liu<sup>2,3</sup>, Fei Li<sup>1</sup>, Xin Lin<sup>1</sup>, Xilong Yu<sup>1,2</sup>, Dongdong Meng<sup>1,\*</sup>

1. Institute of Mechanics, Chinese Academy of Sciences

2. University of Chinese Academy of Sciences

3. Institute of Engineering Thermophysics, Chinese Academy of Sciences

**Abstract:** In complex environments, the measurement of trace gases is inevitably greatly affected by broadband absorption (such as water absorption in combustion exhaust). Based on the study of high-order harmonics in linear wavelength modulation spectroscopy, a method for detecting target gases (trace, weak absorption) in the presence of broadband absorption interference is proposed. Theoretical analysis and numerical simulation work give the applicable conditions of this method. The effectiveness of this method is verified by NO<sub>2</sub> measurement of combustion exhaust gas. This study proves the application potential of this



method for the measurement of trace gases under broadband absorption interference.

**Keywords:** Linear wavelength modulation spectroscopy; Weak absorption detection; Broadband interference

**LIMIS2021-2022-000027**

## **A Method for Improving the Accuracy of Calibration-Free Laser-Induced Breakdown Spectroscopy by Exploiting Self-Absorption**

**Zhenlin Hu, Lianbo Guo\***

*Wuhan National Laboratory for Optoelectronics (WNLO), Huazhong University of Science and Technology*

**Abstract:** The existence of the self-absorption effect results in a nonlinear relationship between spectral intensity and elemental concentration, which dramatically affect quantitative accuracy of laser-induced breakdown spectroscopy (LIBS), especially calibration-free LIBS (CF-LIBS). In this work, the CF-LIBS with columnar density and standard reference line (CF-LIBS with CD-SRL) was proposed to improve the quantitative accuracy of CF-LIBS analysis by exploiting self-absorption. Our method allows using self-absorbed lines to perform the calibration-free approach directly and doesn't require self-absorption correction algorithms. To verify this method, the experiment was conducted both on aluminium-bronze and aluminium alloy samples. Compared with classical CF-LIBS, the average errors (AEs) of CF-LIBS with CD-SRL were decreased from 3.20%, 3.22%, 3.15% and 3.01% to 0.95%, 1.00%, 1.16% and 1.78%, respectively for four aluminium-bronze alloy samples. The AEs were decreased from 0.66%, 0.70%, 0.89% and 1.30% to 0.43%, 0.61%, 0.77% and 0.33%, respectively for four aluminium alloy samples. The experimental results demonstrated that CF-LIBS with CD-SRL provided higher quantitative accuracy and stronger adaptability than classical CF-LIBS, which is quite helpful for the practical application of CF-LIBS.

**Keywords:** Laser-Induced Breakdown Spectroscopy; Calibration-Free LIBS ;Self-Absorption

**LIMIS2021-2022-000043**

## **Room-temperature Topological Photocurrent Injection and Manipulation at Two-Dimensional Interface**

**Zeyu Zhang**

*Hangzhou Institute for Advanced Study, University of Chinese Academy of Sciences*

**Abstract:** The dissipationless surface state of topological insulators (TIs) can protect the seamless integration of the spin and charge by means of topologically protected spin-momentum locking. The room-temperature detection of the spin-momentum locked Dirac spin current in TIs, however, suffers from trivial thermal disturbances and contact perturbations. Here, by breaking the mirror symmetry of  $\text{Bi}_2\text{Se}_3$  thin films on mono layer GaSe, helicity-dependent and topologically-protected chiral Dirac currents have been launched and contactless-detected by terahertz emission spectroscopy without external magnetic field at room temperature. The non-trivial spin-momentum locked current has been verified by the circular photogalvanic effect measurement in 28QL  $\text{Bi}_2\text{Se}_3/\text{GaSe}$ , and the helicity-dependent and topologically-protected photocurrent is amplified by 10 times. By varying the pump wavelength, the photo-induced surface current in 28QL  $\text{Bi}_2\text{Se}_3/\text{GaSe}$  is directly linked to the Dirac cone state in  $\text{Bi}_2\text{Se}_3$ , indicating the non-trivial surface current is dominated in the injection. Our work would not only present a robust platform for quantum transport of the spin-momentum locking surface current in 3D TIs at room temperature, but also invigorate other quantum phase room temperature emergent phenomena in 3D TI-2D semiconductor heterostructures.

**SC4:High power lasers  
2022/8/11 4F, New Century Hall 1**

Presider: Fei Chen, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences; State Key Laboratory of Laser Interaction with Matter

14:00-14:25 (Invited)	<b>Renaissance of high energy gas lasers in diode pumping age</b> Hongyan Wang, National University of Defense Technology
14:25-14:50 (Invited)	<b>Experimental Study on Combustion-driven HF and HBr Chemical Laser</b> Liping Duo, Dalian Institute of Chemical Physics, Chinese Academy of Sciences
14:50-15:15 (Invited)	<b>High efficiency optical resonators for miniaturized deuterium fluoride gas flow chemical laser</b> Xiaoming Ren, The 718th Research Institute of China Shipbuilding Industry Corporation
15:15-15:40 (Invited)	<b>Research Progress and Prospects of the Diode Pumped Metastable Rare Gas Lasers</b> Zining Yang, National University of Defense Technology
15:40-15:55 Coffee Break	
Presider: Hongyan Wang, National University of Defense Technology	
15:55-16:20 (Invited)	<b>Pin-like Laser Beam</b> Ze Zhang, Aerospace Information Research Institute, Chinese Academy of Sciences
16:20-16:45 (Invited)	<b>Study on the optimization design of high power CO<sub>2</sub> laser based on simulation technology</b> Kuo Zhang, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences
16:45-17:00	<b>LIMIS2021-2021-000013</b> <b>Study on characteristics of mid-infrared high-energy Fe<sup>2+</sup>:ZnSe laser at room temperature</b> Fei Xu, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences
17:00-17:15	<b>LIMIS2021-2021-000028</b> <b>Advanced diagnostic technique of diode pumped alkali Lasers</b> Huizi Zhao, National University of Defense Technology
17:15-17:30	<b>LIMIS2021-2021-000063</b> <b>Toward high peak-power mid-infrared laser with oxide LGN crystals</b> Jinsheng Liu, Shanghai Jiao Tong University

**SC4:High power lasers  
2022/8/12 4F, New Century Hall 1**

Presider: Duluo Zuo, Huazhong University of Science and Technology

13:30-13:55 (Invited)	<b>The experimental study of laser-induced damage in photodetectors by ultrashort pulse laser</b> Pingxue Li, Beijing University of Technology
13:55-14:20 (Invited)	<b>Recent progress on Quasi-Parametric Chirped-Pulse Amplification (QPCPA)</b> Jingui Ma, Shanghai Jiao Tong University
14:20-14:45 (Invited)	<b>UV-enhanced intense sub-cycle waveform</b> Shaobo Fang, Institute of Physics, Chinese Academy of Sciences
14:45-15:00	<b>LIMIS2021-2021-000019</b> <b>Analysis on performance of single-wavelength pumped two-photon Rb vapor laser</b> Yanhui Ji, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences
15:00-15:15	<b>LIMIS2021-2021-000015</b> <b>High energy mid-infrared actively Q-switched fiber laser</b> Yanlong Shen, Northwest Institute of Nuclear Technology
15:15-15:30 Coffee Break	
Presider: Jingui Ma, Shanghai Jiao Tong University	
15:30-15:55 (Invited)	<b>Experimental and Theoretical Investigations on the Kinetics of Optically Pumped Rare Gas Laser of Argon</b> Duluo Zuo, Huazhong University of Science and Technology
15:55-16:20 (Invited)	<b>Research progress of high-power chirped and tilted fiber Bragg gratings</b> Meng Wang, National University of Defense Technology
16:20-16:45 (Invited)	<b>Research on pulse modulation technology of CO<sub>2</sub> laser</b> Qikun Pan, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences
16:45-17:10 (Invited)	<b>Lasers in the 1.5<math>\mu</math>m wavelength region with high average power and high peak power based on Optical Parametric Oscillators</b> Zhiyong Li, Aerospace Information Research Institute, Chinese Academy of Sciences
17:10-17:25	<b>LIMIS2021-2021-000107</b> <b>To see through a hole for laser beam quality diagnostics</b> Kunpeng Luan, Northwest Institute of Nuclear Technology

## Renaissance of high energy gas lasers in diode pumping age

Hongyan Wang

*National University of Defense Technology*

**Abstract:** Gas lasers have been long the chief players in high energy lasers due to their superior performance of single aperture high energy output with excellent beam quality. However, in the past decade, its glory is shaded due to the prosperity of diode pumped all solid state lasers. Is ASSLs are the end of the HEL history? Many believe the answer is surely yes. However, to say an end is always arbitrary, particularly in oriental culture. And in the past decade, we have witnessed a slow but definitely trend, that, gas lasers are meet new opportunities, the dawn could be seen now with fast development of diode pumped alkali lasers and its successors. With diode pumped alkali laser as an example, we prospected the scientific foundation of diode pumped gas lasers and its future development.

## Experimental Study on Combustion-driven HF and HBr Chemical Laser

Liping Duo

*Dalian Institute of Chemical Physics, Chinese Academy of Sciences*

**Abstract:** The combustion-driven HF and HBr chemical laser based on NF<sub>3</sub>/D<sub>2</sub> combustion has been experimentally studied. We focus on the study of the single-line output of HF chemical laser weakly absorbed by atmosphere. The methods for measurement of various excited particles, branching ratio of vibration quantum states, temperature of optical cavity medium and the small signal gain of HF and HBr chemical laser are established. The experimental results of the spectra lines of HF chemical laser show that the vibration levels can be changed by the relative collision energy based on reaction kinetic of F + H<sub>2</sub>, and the rotation quantum states can be tuned by the temperature of optical cavity medium. The design of the supersonic mixing nozzle which is the main section of gain generator was optimal. The regulation of HF chemical laser output line was studied experimentally and the output power of up to 1200W of the single-line HF chemical laser at weak absorption in atmosphere is obtained.

The experimental research platform of HBr chemical laser in medium infrared region is built and the output progress of HBr chemical laser is explored. The oscillation resonance of a combustion-driven HBr chemical laser operating at 4-5 $\mu$ m was realized and the output power was obtained from several to a hundred watts, and achieved up to 1000W recently.

## High efficiency optical resonators for miniaturized deuterium fluoride gas flow chemical laser

Xiaoming Ren, Qing Li, Xiankui Liu

*The 718th Research Institute of China Shipbuilding Industry Corporation*

**Abstract:** Aiming at the kilowatt-level compact deuterium fluoride gas flow chemical laser, in order to obtain high energy extraction efficiency and high beam quality mid-infrared continuous laser output in a miniaturized gain generator (size of gain medium: 30mm x 40mm x 125mm), we have investigated a variety of optical resonators numerically and experimentally. Stable resonators such as a proposed five-mirrors reflector plane parallel resonator with high stability, unstable resonators with reduced output coupling such as the super Gaussian reflectivity unstable resonator, the off-axis hybrid unstable resonator etc. Among all the kinds of

unstable resonators, we achieved mid-infrared continuous laser output with average power of 550W, beam quality  $\beta$  value of 1.8 ( $\beta$  value in the stable direction is 1.5,  $\beta$  value in the unstable direction is 1.9), and spectral coverage of 3680 nm to 4089 nm based on an off axis hybrid unstable resonator with Z-fold in gas flow direction which is flat concave stable resonator in gas flow direction, and Z-folded to reduce the gain size in the direction of the stable resonator and it is a positive branch confocal unstable resonator in the direction of vertical flow. The physical process of far-field spot from high order transverse mode oscillation to fundamental transverse mode oscillation in the direction of stable resonator is studied theoretically and experimentally. The calculated results agree well with the experimental results.

**Keywords:** Optical resonators, deuterium fluoride chemical laser, beam quality.

## Research Progress and Prospects of the Diode Pumped Metastable Rare Gas Lasers

**Zining Yang**

*National University of Defense Technology*

**Abstract:** The diode pumped metastable rare gas lasers (DPRGLs) have aroused increasing attention in recent years. Because of the similarities in atomic configurations, the DPRGLs to some extent inherit the physical advantages of the DPALs, and with simpler engineering requirements due to inert gas operation. In this paper, we present our recent research progress on DPRGLs, including the modeling and simulation results, the experimental performance of the high frequency DC discharge type DPRGL system, and the first internationally demonstrated novel-type DPRGL system. Some difficulties of the DPRGLs development at the current stage are summarized and analyzed, and further development for power scaling of DPRGLs are prospected.

## Pin-like Laser Beam

**Ze Zhang**

*Aerospace Information Research Institute, Chinese Academy of Sciences*

**Abstract:** We design and demonstrate what we called shape-preserving “optical pin beams” (OPBs) that possess stable wavefronts against diffraction and ambient turbulence during free-space long distance propagation. We show that a laser beam passing through properly assembled phase elements paired with opposite transverse wavevectors can morph quickly into a stable optical field, exhibiting “self-focusing” dynamics during propagation without optical nonlinearity. The overall shape of such OPBs remains invariant, while their width can in principle be inversely proportional to the propagation distance, in contradistinction to conventional Bessel beams and radially symmetric Airy beams. Utilizing a single photoetched mask, we demonstrate efficient generation and robust propagation of the OPB through atmospheric turbulence beyond kilometer distances. We envisage exciting opportunities arising from such OPBs, especially when propagation through turbulent environments is unavoidable.

## Study on the optimization design of high power CO<sub>2</sub> laser based on simulation technology

**Kuo Zhang**

*Changchun institute of optic, fine mechanic and physics, Chinese Academy of Sciences*

**Abstract:** High energy pulse CO<sub>2</sub> laser has a widely application in Military, scientific research and industry. Transversely excited atmospheric (TEA) CO<sub>2</sub> laser is a principal technique to obtain pulse laser with high energy in the 9–11 $\mu$ m wavelength range. In the operation of a TEA CO<sub>2</sub> laser, high voltage is applied to the

working gas to discharge, the working gas quickly circulates to dissipate heat and recover itself. The process of generating laser includes high voltage discharge, high-speed flow and high stability of optical and mechanical structure. Especially laser pulse control components such as park-gap switch or thyatron, the fan drives the working gas flow quickly, and complex flow field is formed in the discharge area, which makes it difficult to analyze and optimize the components performance. Therefore, we proposed a simulation method based on finite element technology, The complex flow field structure in the components is obtained by reverse engineering. Some critical boundary inputs are experimentally determined. The multi-physics coupling calculation is conducted to obtain the effect of key parameters on the laser performance. The method will be meaningful for optimization of high energy pulse TEA CO<sub>2</sub> laser.

## The experimental study of laser-induced damage in photodetectors by ultrashort pulse laser

Pingxue Li

*Beijing University of Technology*

**Abstract:** The photodetectors are widely used in industrial detection, satellite remote sensing, bio-medical treatment and other fields due to its high resolution, good sensitivity and fast imaging speed. It is of great theoretical and practical significance to study the performance of photodetectors under laser irradiation, but there are few studies on the laser irradiation effects irradiated by the ultrafast fiber laser.

In this work, we had carried out the experimental study of the performance changes on silicon-based photodetectors by hundred picoseconds laser irradiation. The silicon-based PIN photodiode and CMOS were irradiated by the hundred picoseconds, high-repetition fiber laser (pulse width of 226.5 ps and repetition rate of 9.6 MHz and 2.4 MHz) and the hundred picoseconds solid-state regenerative amplifier (pulse width of 302 ps and repetition rate of 500 Hz). The performance changes were monitored by oscilloscope, and the damage threshold was calculated. The appearance of the physical damage to the photodetectors was observed by SEM. It was found that the hundred picoseconds laser caused electrical degradation and thermal effects on silicon-based photodetectors, and the phenomena was different with different energy and laser repetition frequency. With the increase of laser energy, the electrical properties gradually lost, resulting in laser ablation on the photodetectors surface. These works provided theoretical basis and experimental basis for laser interaction with silicon-based materials and silicon-based detectors.

## Recent progress on Quasi-Parametric Chirped-Pulse Amplification (QPCPA)

Jingui Ma

*Shanghai Jiao Tong University*

**Abstract:** This report will introduce recent research progress on Quasi-Parametric Chirped-Pulse Amplification (QPCPA)—an efficient, broadband, and robust amplification scheme proposed in 2015 for generating high power laser. The core of QPCPA is to dissipate the idler wave for facilitating signal amplification by obstructing the back conversion process. Recently, we have demonstrated an idler-absorption-dissipated QPCPA system with an ultrahigh conversion efficiency of 55% for 810 nm signal pulses pumped at 532 nm. This QPCPA system also shows unique parametric fluorescence characteristics. The high efficiency and low noise make it a promising candidate for boosting laser peak power well beyond petawatt level. On the other hand, we have developed a non-absorption approach to constructing QPCPA, in which the idler is dissipated by SHG. Such a SHG-dissipated QPCPA can avoid the thermal load caused by idler absorption and thereby is promising in the average-power scalability.

## UV-enhanced intense sub-cycle waveform

**Shaobo Fang**

*Institute of Physics, Chinese Academy of Sciences*

**Abstract:** Ultrabroadband generation of white-light continuum spanning from ultraviolet to near-infrared is demonstrated by using induced-phase modulation between multi-color femtosecond pulses. Here, we generate 0.6-mJ white-light pulses with an ultra-broad bandwidth, analysis of the calculated spectrum fits the experimental results well, and the pulse is quasilinearly chirped and compressible. The resulting intense robust supercontinuum, supporting 1.6-fs transform-limited pulses corresponding to sub-optical-cycle, could be a promising light source for an ever greater degree of tailored optical waveform coherent control in new parameter spaces.

## Experimental and Theoretical Investigations on the Kinetics of Optically Pumped Rare Gas Laser of Argon

**Duluo Zuo**

*Huazhong University of Science and Technology*

**Abstract:** Optically pumped metastable rare gas laser (OPRGL) is considered as an attractive candidate for high energy laser. But the reported output power up till now is still much lower than the expectation. To understand the reason and try to make a break, the kinetics of OPRGL is experimentally and theoretically investigated.

RF discharge and repetitively pulsed DC discharge were adopted for the generation of the metastable particles Ar (1s5) in our laboratory. Emission spectroscopy was applied to diagnose the plasma. The temporal resolved spectra of the emissions from pulsed DC discharge showed that there were possibly two processes in the generation of the metastable particles, the one is the direct excitation by electron collision, the other is the decay from highly excited states. Particle density of metastable Ar (1s5) about  $10^{13} \text{ cm}^{-3}$  was obtained from the pulsed DC discharge, much higher than that obtained from the RF discharge.

A fluid model was established for the simulation of the kinetic processes of OPRGL, in which 17 kinds of particles were considered with 194 reactions, and the plasma processes, pumping processes, and laser processes can be simulated simultaneously. It is shown by the simulation that metastable particle density as high as  $10^{14} \text{ cm}^{-3}$  can be obtained when the gas mixture is electrically strongly pumped by a pulsed circuit of LC generators with peaking capacitors. When power density of pumping laser higher than  $10 \text{ kW/cm}^2$  is available, high conversion efficiency will be possible.

The experiments are now in progressing, a break to the status of OPRGL is expected from the final results.

## Research progress of high-power chirped and tilted fiber Bragg gratings

**Meng Wang**

*National University of Defense Technology*

**Abstract:** Stimulated Raman scattering (SRS) is one of the main limiting factors for power scaling of high-power fiber laser. So far, many methods for SRS suppression in fiber laser systems have been proposed, including increasing fiber mode field area, using spectral selective fiber, using spectral filter devices and so on. In 2017, we first proposed and reported the application of chirped and tilted fiber Bragg grating (CTFBG) for SRS suppression in fiber laser. Since CTFBG can couple the core mode of forward transmission to the cladding mode of backward transmission, a good broadband band-rejection filtering function can be realized by reasonable design, which can couple the Stokes light of core to the cladding and then leak to



the air, so as to filter and suppress the SRS. With the characteristics of all-fiber structure, flexible design and good stability, CTFBG has attracted extensive attention at home and abroad in recent years. It has realized kW-level CTFBG with low insertion loss, high rejection ratio and broadband rejection, and has played an important role in the SRS suppression in high-power fiber laser system. This report briefly introduces the working principle, design or simulation and the research progress of CTFBG, especially the progress made by the high-energy laser team of National University of Defense Technology in the design, preparation and application of high-power CTFBG, and looks forward to the next development.

## Research on pulse modulation technology of CO<sub>2</sub> laser

**Qikun Pan, Fei chen, Jin Guo**

*Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences*

**Abstract:** CO<sub>2</sub> gas laser has the characteristics of good beam quality, high power and good spectral purity. It has important applications in national defense, industry, scientific research fields. Intracavity Q-Modulated pulsed CO<sub>2</sub> laser has the characteristics of high peak power, and is widely used in the fields of laser remote active detection, laser plasma physics, laser processing of non-metallic materials and so on. This report will introduce the research status of our team in the fields of CO<sub>2</sub> laser pulse modulation in recent years, including electro-optic Q-switching, acousto-optic Q-switching, mechanical Q-switching and gain switch Q-switching CO<sub>2</sub> lasers. The CO<sub>2</sub> laser pulse width of 20ns-500ns has been realized using different pulse modulation technology. And the peak power of the CO<sub>2</sub> laser from kW to MW has been obtained at different repetition frequencies. Combined with grating tuning technology, we have achieved more than 60 pulsed CO<sub>2</sub> laser spectral lines. The advantages and disadvantages of various Q-switching technologies of CO<sub>2</sub> lasers are discussed, which may be useful to the development of pulsed CO<sub>2</sub> laser technology.

## Lasers in the 1.5μm wavelength region with high average power and high peak power based on Optical Parametric Oscillators

**Zhiyong Li**

*Aerospace Information Research Institute, Chinese Academy of Sciences*

**Abstract:** Optical Parametric Oscillators (OPO) are well suited for the generation of 1.5μm eye-safe lasers. We established eye safe laser systems based on KTP and PPMgLN. The KTP-OPO is designed for high energy with a adjustable repetition rate from 0.5 Hz to 100 Hz. The pulse energy is 141 mJ at the repetition rate of 100 Hz while the pulse width is 7.6 ns. The PPMgLN-OPO is designed for high repetition rate which could be varied from 1 kHz to 50kHz while the peak power (30 kW), pulse width (4.6 ns) maintains the same. The heat consumptions in the laser systems, which are varied with repetition rate, are dealt by adoption the time division of optical pulses. Both laser systems will be good candidates for eye-safe LIDAR's optimizations.



LIMIS2021-2021-000013

### Study on characteristics of mid-infrared high-energy Fe<sup>2+</sup>:ZnSe laser at room temperature

Fei Xu<sup>1,2</sup>, Qikun Pan<sup>1,\*</sup>, Fei Chen<sup>1</sup>*1.Changchun Institute of optics, Fine Mechanics and Physics, Chinese Academy of Sciences**2.University of Chinese Academy of Sciences*

**Abstract:** The Fe<sup>2+</sup>:ZnSe laser has a broad bandwidth tunability and high energy output characteristics that have shown unique advantages in ultra-intense and ultra-short lasers. It is one of the research hotspots of novel mid-infrared solid-state lasers with wide-ranging application prospects in the fields of atmospheric monitoring, space remote sensing, laser medicine, and laser radar. In this paper, based on the configuration coordinate model of Fe<sup>2+</sup>, the influence of laser upper-level lifetime and excited-state absorption are introduced. A four-level theoretical model revealing the laser kinetics of a gain-switched pulsed Fe<sup>2+</sup>:ZnSe laser is established. The time-domain evolution characteristics and pulse waveform of the particle number density at each laser level are obtained based on the Runge–Kutta method. The Fe<sup>2+</sup>:ZnSe laser is a high gain laser, which has great potential in high energy output, especially pumped by short pulsed lasers. The output energy of Fe<sup>2+</sup>:ZnSe laser could be scaled up by increasing the pump energy. While limited by low damage threshold of the Fe<sup>2+</sup>:ZnSe crystal, the pump energy density can't be increased freely. Well, increase the diameter of pump spot at safe pump energy density can improve the output energy, but transversal parasitic oscillation problem also occurs under large pump spot. Transversal parasitic oscillation (TPO) suppression of Fe<sup>2+</sup>:ZnSe laser is one of the most important scientific problems. Transversal Parasitic Oscillation of Fe<sup>2+</sup>:ZnSe laser is analyzed theoretically. A method to effectively suppress TPO of high gain Fe<sup>2+</sup>:ZnSe laser is obtained. This method increases the effective utilization rate of Fe<sup>2+</sup>:ZnSe crystal. Corresponding experiments were made on Fe<sup>2+</sup>:ZnSe laser pumped by a non-chain pulsed HF laser. The efficiency of Fe<sup>2+</sup>:ZnSe laser successfully improved by optimizing pump spot size and energy distribution uniformity. At room temperature, the output energy of single-pulse Fe<sup>2+</sup>:ZnSe laser reached 502mJ and stable repetitively pulsed operation of the Fe<sup>2+</sup>:ZnSe laser with an average power of 21.7W was achieved at a repetition rate of 50 Hz.

**Keyword:** Mid-infrared laser, Fe<sup>2+</sup>:ZnSe laser, Transversal parasitic oscillation, Laser kinetics

LIMIS2021-2021-000028

### Advanced diagnostic technique of diode pumped alkali Lasers

Huizi Zhao, Hao Tang, Rui Wang, Liang Li, Zining Yang\*, Weiqiang Yang, Hongyan Wang\*

*National University of Defense Technology*

**Abstract:** Diode pumped alkali vapor lasers (DPAL) have become one of the most promising high energy lasers in the past decades. However, direct active medium diagnostic data are still limited to support engineering power scaling, which will show importance in much higher pump intensity and larger apertures, we reviewed alkali lasers' diagnostic development, particularly, the atomic number density, ionization degree, and temperature measurement in our group were systematically presented. Future development of diagnostic techniques was prospected.

## Toward high peak-power mid-infrared laser with oxide LGN crystals

Jinsheng Liu and Jingui Ma

*shanghai Jiao Tong University*

**Abstract:** The frontiers of strong-field physics and attosecond science starve for mid-infrared (mid-IR) ultrashort intense laser sources. Such demand is fundamentally attributed to the wavelength-dependent ponderomotive potential  $U_p \propto I\lambda^2$  ( $I$  and  $\lambda$  are the intensity and wavelength of the driving laser). High- $U_p$  sources at moderate intensity and a longer wavelength open the door to previously inaccessible regimes of light-matter interactions and in particular they allow experimental investigations of the  $\lambda$ -scaling laws of strong-field physics (e.g., high-harmonic generation cutoff  $\propto \lambda^2$ , minimum attosecond pulse duration  $\propto \lambda^{-1/2}$ ). The physical interests for intense mid-IR lasers have forced considerable efforts to develop such sources. Unfortunately, it is hard to produce intense mid-IR lasers directly from commercial laser oscillators or amplifiers, due to the lack of gain medium. Current mainstream method is to convert mature near-IR intense lasers to the mid-IR region by difference-frequency generation (DFG), optical parametric amplification (OPA) or optical parametric chirped pulse amplification (OPCPA). To date, these nonlinear frequency conversion processes with some semiconductor crystals can support the generation of low-power mid-IR pulse in an extended spectral range. However, how to generate intense mid-IR pulses has remained open for investigation. The key to solve this problem is to find a suitable nonlinear crystals that simultaneously possess wide transparency range (from near-IR into mid-IR beyond  $\sim 5 \mu\text{m}$ ), high laser damage thresholds, adequate nonlinear coefficient, and large crystal aperture. We find that the langasite oxide  $\text{La}_3\text{Ga}_{5.5}\text{Nb}_{0.5}\text{O}_{14}$  (LGN) crystal that was previously known for its piezoelectric and electro-optic properties is a promising candidate for converting near-IR to mid-IR pulses beyond  $5 \mu\text{m}$  [1]. LGN is transparent for both 800 nm and  $1 \mu\text{m}$  lasers, and its IR transmission edge can extend to  $7.4 \mu\text{m}$ . As an oxide, its damage threshold is much higher than semiconductor crystals. Moreover, LGN can be grown to a size of 5 inch by the Czochralski method, so it is quite suitable in generation of highpower mid-IR laser.

We experimentally evaluated the mid-IR performance of LGN crystals by intrapulse DFG [2]. With LGN crystals, both Type-I and Type-II intrapulse DFGs have converted the three-cycle pulses at 800 nm to the three-cycle mid-IR pulses tunable from 3 to  $7 \mu\text{m}$ . We have studied the dependence of conversion efficiency on polarization angle and crystal length, and achieved a conversion efficiency higher than 1%. We have also demonstrated that the bandwidth and central wavelength of the mid-IR spectra can be tuned by adjusting the crystal length and phase-matching angle. To the best of our knowledge, these results represent the first experimental demonstration of LGN in generating mid-IR ultrashort pulses. The generated broadband mid-IR pulses from intrapulse DFG can seed the LGN-based OPCPA system for further amplification. By the aid of numerical simulation, we validated the feasibility in developing sub-seven-cycle, terawatt-class OPCPA system at  $5.2 \mu\text{m}$  through three-stage LGN-based OPCPA pumped by  $1 \mu\text{m}$  [3]. This OPCPA system based on an octave-spanning ultrafast Ti:sapphire laser and a state-of-the-art thin-disk Yb:YAG laser offers the performance of high peak-power, a high repetition rate, and a stable carrier-envelope phase, which will be a promising drive source in strong-field physics and attosecond science.

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## LIMIS2021-2021-000019

### Analysis on performance of single-wavelength pumped two-photon Rb vapor laser

Yanhui Ji,<sup>1,2</sup> Yang He<sup>1</sup>, Haohua Wan,<sup>1,2</sup> Fei Chen<sup>1\*</sup>

1. State Key Laboratory of Laser Interaction with Matter, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences

2. University of Chinese Academy of Sciences

**Abstract:** Combining the kinetic processes in two-photon absorbing alkali vapor laser (TPAL), a three-dimensional physical model with a cyclic iterative approach for simulating the output characteristics of single-wavelength pumped Rb-TPALs is established. The theoretical calculation of the dependence of the laser power on the pump power was found to be in good agreement with the experimental results. Our study makes a significant contribution to the literature by simulating the blue laser characteristics of single-wavelength pumped Rb-TPAL. The effects of the parameters of the high-power continuous-wave LD-pumped Rb-TPAL (temperature, vapor cell length, pump waist, vapor cell transmission, and output mirror reflectance) on the blue laser power, efficiency, and pumping threshold, were studied. Furthermore, the reason behind the limited efficiency of Rb-TPAL has been determined and an approach has been proposed to improve the efficiency of Rb-TPAL. It has been found that an optimal combination of temperature and cell length can maximize the output power of the blue laser: with an increase in the optimal temperature, the corresponding cell length decreases, and a higher output power is achieved. The pump beam waist has been found to have a significant effect on the output power: when the pump beam waist is located on the center of the vapor cell, the Rb-TPAL realizes the maximum blue laser power, based on the selection of the appropriate pump beam waist radius. With the increase in transmittance, the output power of the blue laser has been observed to increase. Furthermore, it has been concluded that the addition of the resonator cavity promotes the enhancement of the blue laser power that is maximized based on an optimal reflectivity of the output mirror. Although the efficiency of the blue laser has been found to be low, this problem can be solved by introducing mid-infrared light to enhance the transition rate from  $5^2\text{D}_{5/2}$  to  $6^2\text{P}_{3/2}$ . In conclusion, we believe that the model and simulation results can provide an effective way to design a high power TPAL system.

**Keyword:** single-wavelength pump; two-photon absorption; alkali vapor laser; blue laser;

## LIMIS2021-2021-000015

### High energy mid-infrared actively Q-switched fiber laser

Yanlong Shen, Yousheng Wang, Feng Zhu, Liu Zhao, Zhengge Chen, Hao Wang

State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology

**Abstract:** High energy pulsed fiber lasers at mid-infrared (Mid-IR)  $3\mu\text{m}$  waveband have attracted lots of interest recently due to their potential applications such as laser surgery, laser spectroscopy, laser irradiation effect, gas monitoring and IR-laser pumping. Among the three principal pulsed regimes, i.e., Q-switching, gain-switching and mode-locking, Q-switching has the capability of producing high energy laser pulses. Com-

pared to passive Q-switching scheme, active Q-switching enjoys the advantages of producing laser pulses with shorter pulse width, much higher peak power, and specifically well-controlled pulse repetition rate. Here, we report on a high energy Q-switched single-oscillator Er-doped fiber laser at 2.8  $\mu\text{m}$  based on an electro-optical modulator. The energy of laser pulses reaches as high as 1.8 mJ with a pulse width of  $\sim 100$  ns, corresponding to a calculated peak power of 18 kW. The central wavelength of pulsed output is 2.79  $\mu\text{m}$ .

**LIMIS2021-2021-000107**

### **To see through a hole for laser beam quality diagnostics**

**Kunpeng Luan, Shaowu Chen, Pengling Yang, Dahui Wang, Bo Tao**

*Key Laboratory of Laser Interaction with Matter, and Northwest Institute of Nuclear Technology*

**Abstract:** With the development of laser technologies, high energy lasers have been widely used in the field of industrial processing, high-intensity physics, biomedicine, etc. In the applications which need to focus the high energy of laser in the far field, the laser beam quality is especially important. There exist considerable demands of real-time beam quality diagnostics and measurements for high energy laser systems. And laser beam characterization has attracted researchers' much attention. Till now, several kinds of standards have been found for laser beam quality diagnostics, such as M2-factor, far-field divergence angle, Strehl ratio, and power in bucket (PIB). Among them, PIB standard fits well for the characterization of high energy laser in the far field, because PIB definitely shows the laser power or intensity within the specific circle region on the far-field target, and the relation between the laser power distribution and laser spot radius.

This paper demonstrated a method for measuring the PIB factor of laser beam, based on sparse sampling of the laser power distribution with aperture array and compressive sensing (CS) technic to recover the high resolution laser spot. First, several circle apertures were laid on a metal plate. When the plate was rotating, the apertures sparsely sampled the power of different parts of the laser beam in turn. Second, the measurement matrix which shows the relation between the sampled signal and original laser intensity spot was found. The inverse problem was solved with regularization algorithm and a calculated high-resolution laser spot was achieved. Finally, the PIB factor was estimated and PIB curve calibration was actualized based on the power sampling signal. In the experimental system, only one photo-electricity detector was used, improving the measurement compatibility and stability. The sparse sampling way and application of CS technic, enabled both a much bigger real-time sampling spatial region, and a less stringent dynamic range requirement on detectors. The method fits well for real-time PIB factor measurements of a laser spot with a size of several centimeters or larger in the far field.

<b>SC5:Micro-nanophotonics</b> <b>2022/8/11 4F, Qizhi Hall</b>	
Presider: Qing Zhang, Peking University	
14:00-14:25 (Invited)	<b>Self-chaotic semiconductor microcavity lasers due to mode interaction</b> Yongzhen Huang, Institute of Semiconductors, Chinese Academy of Sciences
14:25-14:50 (Invited)	<b>Spontaneous Quasi-Phase Matching in a Micro-Racetrack Resonator</b> Yuping Chen, Shanghai Jiao Tong University
14:50-15:15 (Invited)	<b>Semiconductor nanowire lasers: efforts towards practical applications</b> Xin Guo, Zhejiang University
15:15-15:40 (Invited)	<b>The high-performance micro-nano lasers based on low dimensional perovskites</b> Zhengzheng Liu, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences
15:40-15:55 Coffee Break	
Presider: Juan Du, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences	
15:55-16:20 (Invited)	<b>Low-threshold stimulated emission and optical spectroscopies of solution-processed 2D-3D hybrid perovskite thin films</b> Qing Zhang, Peking University
16:20-16:45 (Invited)	<b>Dual-wavelength switchable single-mode lasing from a lanthanide-doped resonator</b> Limin Jin, Harbin Institute of Technology, Shenzhen
16:45-17:00	<b>Single-cell tracking with intracellular laser particles</b> ShuiJing Tang, Harvard Medical School; Peking University
17:00-17:15	<b>LIMIS2021-2022-000046</b> <b>Surface Ligand Engineering for CsPbBr<sub>3</sub> Quantum Dots Aiming at Aggregation Suppression and Amplified Spontaneous Emission Improvement</b> Fengxian Zhou, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences; Hangzhou Institute for Advanced Study
17:15-17:30	<b>LIMIS2021-2021-000119</b> <b>Low-threshold near-IR multi-wavelength lasing in metallo-dielectric cavity</b> Jialu Xu, Tsinghua University

**SC5:Micro-nanophotonics  
2022/8/12 4F, Qizhi Hall**

Presider: Limin Jin, Harbin Institute of Technology, Shenzhen

13:30-13:55 (Invited)	<b>Magic-angle lasers in nanostructured moiré superlattice</b> Renmin Ma, Peking University
13:55-14:20 (Invited)	<b>Dissipative Kerr solitons in the high-Q microresonators</b> Chunhua Dong, University of Science And Technology of China
14:20-14:45 (Invited)	<b>Two-dimensional exciton-polaritons</b> Wenjing Liu, Peking University
14:45-15:00	<b>LIMIS2021-2021-000152</b> <b>High Optical Gain and Low Threshold of One-step Air-Processed All-Inorganic CsPbX<sub>3</sub> Thin Films towards Enhanced and Stable Full Colored Amplified Spontaneous Emission</b> Dingke Zhang, Chongqing Normal University
15:00-15:15 Coffee Break	
Presider: Chunhua Dong, University of Science And Technology of China	
15:15-15:40 (Invited)	<b>TBD</b> Yongsheng Zhao, Institute of Chemistry, Chinese Academy of Sciences
15:40-16:05 (Invited)	<b>Highly confined polaritons in two-dimensional materials</b> Xiaoxia Yang, The National Center for Nanoscience and Technology
16:05-16:30 (Invited)	<b>New microlaser functionalities inspired by quantum symmetry</b> Zhifeng Zhang, Nanjing University
16:30-16:45	<b>LIMIS2021-2021-000147</b> <b>High-performance cavity-enhanced quantum memory with warm atomic cell</b> Lixia Ma, Shanxi University
16:45-17:00	<b>LIMIS2021-2021-000018</b> <b>Stimulated Scattering in Supermode Microcavity Single- or Dual-Mode Lasing?</b> Zhang Pei-Ji, Peking University

## Self-chaotic semiconductor microcavity lasers due to mode interaction

Yong-Zhen Huang

*Institute of Semiconductors, Chinese Academy of Sciences*

**Abstract:** Chaotic semiconductor lasers have been widely investigated for generating true unpredictable random numbers, mainly for semiconductor lasers under external optical feedback. Under continuous perturbations of an external optical injection or delayed optical feedback, semiconductor lasers can exhibit strong nonlinear dynamics, such as periodic oscillations and chaos. However, chaos derived from delayed optical feedback has obvious correlation peaks relative to the external feedback loop time, which reduces the randomness and security in random number generation. Here, we designed and demonstrated a circular-sided hexagonal microcavity laser exhibited period-oscillation states and chaotic state without external optical feedback. Dual-transverse-mode lasing with a small frequency interval close to the relaxation oscillation frequency is essential for internal mode interaction under strong carrier oscillation caused by beating mode intensity. circular sides and a ring electrode pave the way for mode engineering in the microcavity. The chaotic output of the microcavity laser was used for random number generation at 10 Gb/s.

## Spontaneous Quasi-Phase Matching in a Micro-Racetrack Resonator

Yuping Chen

*Shanghai Jiao Tong University*

**Abstract:** Quasi-phase matching (QPM) technology is the most popular and significant approach for efficient nonlinear frequency conversion. However, the realization of periodic poling for QPM has become a challenging issue for the requirement of CMOS-compatibility and large-scale fabrication. Here, we propose a poling-free mechanism to realize QPM in a micro-racetrack resonator on x-cut lithium niobate on insulator, named spontaneous quasi-phase matching (SQPM). By engineering the dispersion and orientation of the crystal, the domain reversal could arise spontaneously as the TE polarized light propagates circularly in the racetrack structure. The SQPM second harmonic generation with a normalized conversion efficiency of 2.25%/W (169th-order QPM) has been achieved in experiment, which can be further optimized by an improved fabrication accuracy or a well-designed free spectral range. This SQPM mechanism could provide a flexible and extensible platform for the efficient nonlinear optics process.

## Semiconductor nanowire lasers: efforts towards practical applications

Xin Guo

*Zhejiang University*

**Abstract:** As nanoscale coherent light sources, semiconductor nanowire lasers have drawn intense attention in recent years, however, practical applications of these tiny lasers remain challenging. In this talk, I introduce several proposals for developing practical nanowire lasers. Firstly, I introduce a wavelength-tunable single-nanowire laser with high tuning rate and excellent reversibility via temperature-dependent Varshni shift of the bandgap. Secondly, by integrating a CdS nanowire onto a SiN photonic chip to form a hybrid Mach-Zehnder structure for mode selection, I show a highly compact on-chip single-mode CdS nanowire laser. Thirdly, I introduce a proposal to cool nanowire lasers in liquids to bestow the nanowire lasers with greater versatility.



# The high-performance micro-nano lasers based on low dimensional perovskites

Zhengzheng Liu

Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

**Abstract:** Micro-nano light sources have played an important role in the fields of optoelectronic integration, sensing, optical communication, etc. The emerging metal halide perovskite nanomaterials are one of the ideal gain media for the future integrated micro-nano laser devices in the fields of optoelectronics due to their advantages of high gain, low defect density, narrow emission peak, high photoluminescence quantum yield, etc. In view of this, we have fabricated high quality perovskites with different structures and realized the sub-wavelength single-mode nanolasers from low-dimensional perovskites. Firstly, we successfully realized the single-mode laser from 3D perovskite nanocubes with sizes of ( $\sim 400$  nm)<sup>3</sup>, which displayed low threshold and narrow linewidth. The lasing mechanism was also revealed by transient absorption spectroscopy. In addition, through molecular engineering, the 2D and 0D perovskite micro/nanoplates were synthesized. Based on their intrinsic structures, the single-mode lasers were demonstrated in submicron scale with good performance. To further improve the lasing behavior, we prepared quasi-2D perovskite thin film by solution method, and analyzed the optical gain mechanism and luminescence characteristics. Inspired by the gain characteristic, we successfully overcome the trade-off between small size and good performance for miniaturized lasers and shrank the quasi-2D perovskites laser to the deep-subwavelength scale ( $\sim 50$  nm) using only a layer of ultraviolet glue and a glass substrate in the vertical dimension. These results are expected to provide insights into next-generation integrated laser sources.

## Low-threshold stimulated emission and optical spectroscopies of solution-processed 2D-3D hybrid perovskite thin films

Qing Zhang

Peking University

**Abstract:** Recently, two dimensional (2D) perovskites have attracted much attention for the low-temperature solution-processable fabrication, interesting exciton feature, naturally-formed quantum well structure and good stability. Herein, I will present recent progresses on stimulated emission properties of the solution-processed 2D perovskite  $((\text{BA})_2(\text{MA})_{n-1}\text{Pb}_n\text{I}_{3n+1})[1]$  and 2.5D perovskite  $(\text{Cs}_{0.87}(\text{FAMA})_{0.13}\text{PbBr}_3)/[(\text{NMA})_2\text{PbBr}_4][2]$ . An n-engineered lasing behavior (threshold, color), Auger recombination, electron-hole coupling are revealed for 2D perovskites. A record net optical gain ( $3030$  cm<sup>-1</sup>) of green spectral range is achieved via using 2.5D perovskites. Furthermore, we proposed an anti-solved recrystallization method to reduce the density of pin-holes of the mixed cation 2.5D perovskite and realized room temperature amplified spontaneous emission with threshold as low as  $1.44$   $\mu\text{J}/\text{cm}^2$ .

## Dual-wavelength switchable single-mode lasing from a lanthanide-doped resonator

Limin Jin

Harbin Institute of Technology, Shenzhen

**Abstract:** Multi-wavelength lasing, with dynamic switching functionality, high spectral purity and contrast, plays an essential role in photonic devices. Lanthanide(Ln<sup>3+</sup>)-doped upconversion nanocrystals(UCNCs) featured with plentiful energy levels act as ideal candidates for the gain medium. However, it remains a daunting challenge to develop a tunable Ln<sup>3+</sup>-based single-mode laser across a wide wavelength range due to the absence of a feasible mode-selection mechanism. Here, we have demonstrated the first active control of unidirectional single-mode lasing with switchable wavelength spanning beyond a record range ( $\sim 300$  nm).



This is accomplished through the integration of two size-mismatched coupled microdisks cavity and inversely designed dual-mode UCNCs incorporated with selective sensitizer-pair and activator ions. By asymmetric pumping, a reversible and crosstalk-free violet-to-red single-mode operation were formed respectively from such UCNCs-based system through changing the pumping wavelengths from 980 nm to 808 nm. The results enlighten the reversal engineering design of luminescent materials and microcavity. With remarkable doping flexibility, our approach would pave an avenue to a class of UCNCs-based photonic devices for on-chip optical filter, switch, sensor and other devices.

## Magic-angle lasers in nanostructured moiré superlattice

**Renmin Ma**

*Peking University*

**Abstract:** Conventional laser cavities require discontinuity of material property or disorder to localize a light field for feedback. Recently, an emerging class of materials, i.e. twisted van der Waals materials have been explored for the applications in electronics and photonics. Here, we propose and develop magic-angle lasers where the localization is realized in a periodic twisted photonic graphene superlattices. We reveal that the confinement mechanism of magic angle lasers does not reply on a full band gap but on the mode coupling between twisted two layers of photonic graphene lattice. Without any fine tuning in structure parameters, a simple twist can result in nanocavities with strong field confinement and high quality factor. Furthermore, the emissions of magic-angle lasers allow direct imaging of the wavefunctions of magic-angle states. Our work provides a robust platform to construct high quality nanocavities for nanolasers, nanoLEDs, nonlinear optics and cavity quantum electrodynamics at the nanoscale.

## Dissipative Kerr solitons in the high-Q microresonators

**Chunhua Dong**

*University of Science and Technology of China*

**Abstract:** The dissipative Kerr solitons offer broadband coherent and low-noise frequency combs and stable temporal pulse trains, having shown great potential applications in spectroscopy, communications, and metrology [1-4]. Here, we have demonstrated the dissipative Kerr soliton generation in a microrod resonator or silicon nitride ( $\text{Si}_3\text{N}_4$ ) microrings, by utilizing an auxiliary-laser assisted thermal response control. We have studied the evolution of the soliton generation processes during the scanning of the pump laser detuning, especially the breathing dissipative Kerr soliton, which shows uncertainties of around megahertz (MHz) order of the breathing period. This instability is the main obstacle for future applications. By applying a modulated signal to the pump laser, the breathing frequency can be injection locked to the modulation frequency and tuned over tens of MHz with frequency noise significantly suppressed. Our demonstration offers an alternative knob for the control of soliton dynamics in microresonators and paves a new avenue towards practical applications of breathing solitons.

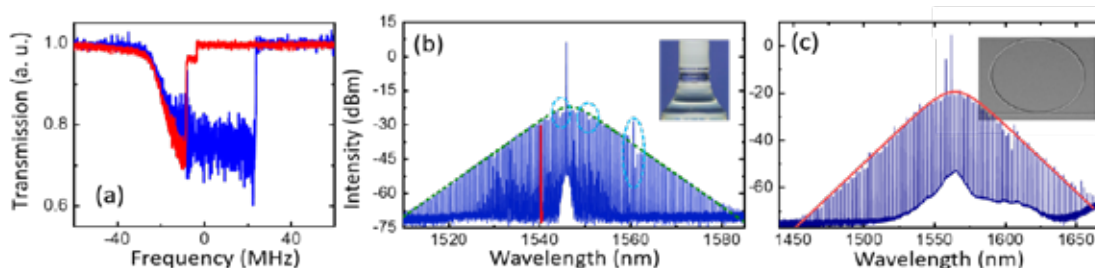


Fig. 1. (a) The typical transmission of the pump laser without (blue) or with (red) the auxiliary laser. (b) Optical spectrum of the single DKS in the high-Q microrod resonator, the green dot line shows the spectral sech<sup>2</sup> envelope. The wavelength of pump laser and auxiliary laser are 1546nm and 1540.3nm (indicated by the red line), with the power of 100mW and 350mW, respectively. Obvious avoided mode crossings (AMXs) are shown in the blue circles. (c) The optical spectra of single soliton state in the high-Q Si<sub>3</sub>N<sub>4</sub> microring with the smooth envelope fitted by sech<sup>2</sup> function (red curve).

## Two-dimensional exciton-polaritons

**Wenjing Liu**

*Peking University*

**Abstract:** Exciton-polaritons are half-light half-matter quasiparticles resulted from the strong coupling between excitons and photons. Exhibiting both high spatial and temporal coherence and strong inter-particle interactions, exciton polaritons serve as a unique platform for studying macroscopic quantum phenomena such as Bose-Einstein condensation and optical nonlinearities. Optical field engineering through photonic microcavities and nanostructures allows precise tailoring of the spin, momentum, angular momentum and topological properties of photons, thereby providing a great freedom for manipulating photon-exciton interactions. This talk will discuss recent progresses of exciton-polariton studies in two-dimensional photonic nanostructures including plasmonic metasurfaces and photonic crystals.

**TBD**

**Yongsheng Zhao**

*Institute of Semiconductors, Chinese Academy of Sciences*

## Highly confined polaritons in two-dimensional materials

**Xiaoxia Yang**

*National Center for Nanoscience and Technology*

**Abstract:** Highly confined polaritons can confine and manipulate light at deep subwavelength nanoscale, which can be used in subdiffraction imaging, sensing and engineering of spontaneous emission [1,2]. However, the trade-off between the degree of confinement and the excitation efficiency of phonon polaritons makes it difficult to detect ultra-highly confined modes. High-resolution electron energy loss spectroscopy (EELS) offers a way to excite and detect these highly confined modes by providing large momentum compensation [3,4]. We use monochromatic EELS (about 7.5meV energy resolution) in a scanning transmission electron microscope to measure phonon polaritons in monolayer h-BN which is predicted to have ultrahigh confinement, directly demonstrating the existence of these modes as the phonon Reststrahlen band (RS) disappears. We find phonon polaritons in monolayer h-BN to exhibit high confinement (>487 times smaller wavelength than that of light in free space) and ultraslow group velocity down to about 10-5c. The large momentum compensation provided by electron beams additionally allows us to excite phonon polaritons over nearly the entire RS band of multilayer h-BN. These results open up a broad range of opportunities for the engineering of metasurfaces and strongly enhanced light-matter interactions [5].

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## New microlaser functionalities inspired by quantum symmetry

**Zhifeng Zhang**

*Nanjing University*

**Abstract:** Due to the mathematical equivalence between quantum mechanics and paraxial optics, integrated photonics becomes an ideal test bed of quantum theories challenging to be realized in condense matter systems such as parity-time (PT) symmetry. By the careful engineering of the complex indices at the microscale, such non-Hermitian PT symmetric system can be conveniently constructed on a photonic platform. This exploration enables the new paradigm in developing photonic devices with unique functionalities. In this presentation, I will introduce our recent works in developing new microlasers inspired by quantum symmetries for the next generation information system. We demonstrated microlasers emitting twist light on demand, providing an additional degree of freedom, namely, orbital angular momentum (OAM), for high dimensional optical communication systems. Additionally, inspired by super symmetry in quantum mechanics, we developed an OAM microlaser array with robust single mode lasing and enhanced lasing power. Our exploration not only strengthen the understanding of fundamental physics, but also provides new paradigm in designing photonic devices for real applications.

LIMIS2021-2021-000154

### Single-cell tracking with intracellular laser particles

Shui-Jing Tang<sup>1,2</sup>, Paul H. Dannenberg<sup>1,3</sup>, Andreas C. Liapis<sup>1</sup>, Yun-Feng Xiao<sup>2\*</sup>, and Seok-Hyun Yun<sup>1,3\*</sup>*1. Harvard Medical School and Wellman Center for Photomedicine, Massachusetts General Hospital**2. Peking University**3. Harvard-MIT Health Sciences and Technology, Massachusetts Institute of Technology*

**Abstract:** The ability to track individual cells is crucial to the study of cellular heterogeneity and its consequences, particularly in organismic development and complex diseases such as cancer. Recently, microlaser particles have emerged as unique optical probes for single-cell tagging [1-3]. In comparison to conventional photoluminescent probes, such as fluorescent molecules and dye-doped microbeads, the laser particles emit narrowband coherent light, which makes LPs an attractive choice for spectrally-multiplexed tagging of cells. However, due to the inherent directionality of laser emission and because the laser's orientation varies randomly over time inside living cells, these labels suffer from "lighthouse-like" blinking, leading to frequent loss of cell traces.

Here, we demonstrate blinking-free single-cell tracking with intracellular laser particles engineered to emit nearly homogeneously in all directions. The omnidirectional laser emission is achieved by incorporating light scattering into the microdisk cavity, which reduces the intensity fluctuations by two orders of magnitude, enabling blinking-free tracking of single cells under the same conditions where existing technology suffers from frequent tracking failure. At the same time, the extremely narrow spectral bandwidth (< 0.3 nm) of laser particles allows for spectrally-multiplexed large-scale tracking of single cells. We believe more than thousands or even millions of cells in a heterogeneous population can be tracked using the omnidirectional laser particles in the future in in-vitro experiments, in a live animal, or across different single-cell analysis instruments, for example, from microscopy to single-cell sequencing.

**Keywords:** whispering-gallery microcavity, intracellular microlaser, cell tracking, light scattering

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LIMIS2021-2022-000046

### Surface Ligand Engineering for CsPbBr<sub>3</sub> Quantum Dots Aiming at Aggregation Suppression and Amplified Spontaneous Emission Improvement

Fengxian Zhou<sup>1,2</sup>, Xiong Qian<sup>1</sup>, Jun Wang<sup>1,2</sup>, Qian Li<sup>1,2</sup>, Zhiping Hu<sup>2</sup>, Juan Du<sup>1,2</sup>.*1. Shanghai Institute of Optics and Fine Mechanics (SIOM) Chinese Academy of Sciences**2. Hangzhou Institute for Advanced Study (HIAS) Chinese Academy of Sciences*

**Abstract:** In recent years, it has been reported that using ligands modification to passivate the surface is one reasonable approach to improve the optical properties and stability of perovskite QDs, and the improvement

effect has been frequently evaluated by the applications of perovskite LEDs. However, simple and effective way to restrain aggregation phenomenon of perovskite QDs is still challenging, and the effect of ligands modification on the improvement of stimulated emission is rarely studied. In this work, a facile and effective ligand-engineering strategy is adopted to fabricate CsPbBr<sub>3</sub> QDs passivated by short capping ligands octylamine (OLA). The OLA-CsPbBr<sub>3</sub> QDs show excellent photochemical properties and enhanced stability. No aggregation or degradation phenomenon could be observed even after being exposed in the air for 100 days, and the OLA-CsPbBr<sub>3</sub> QDs films can keep 96.8% of initial PL intensity even stored under ambient condition for 5 weeks. Finally, amplified spontaneous emission (ASE), which is usually considered to be classified as lasing without optical cavity, is investigated to study the stimulated emission property after ligand engineering. An improved ASE with lower threshold (only 24% of the OAm-CsPbBr<sub>3</sub> QDs threshold) and better photostability has been observed from OLA-capped CsPbBr<sub>3</sub> QDs.

**Keyword:** CsPbBr<sub>3</sub> quantum dots, perovskite, stability, ligands, amplified spontaneous emission

**LIMIS2021-2021-000119**

### Low-threshold near-IR multi-wavelength lasing in metallo-dielectric cavity

Jialu Xu<sup>1,2</sup>, Taiping Zhang<sup>1,2</sup>, Yongzhuo Li<sup>1,2</sup>, Jianxing Zhang<sup>1,2</sup>, Qiang Kan<sup>4</sup>, Ruikang Zhang<sup>4</sup>,  
CunZheng Ning<sup>\*1,2,3</sup>

1. Tsinghua University

2. Tsinghua International Center for Nano-Optoelectronics

3. Arizona State University

4. Institute of Semiconductors, Chinese Academy of Sciences

**Abstract:** Plasmonic metallo-dielectric nanolasers at communication wavelengths are highly desirable as on-chip sources in the photonic integrated circuits due to their ultra-small physical volume, high modulation speed, and feasibility of electrical pumping. However, the reported plasmonic nanolasers cannot meet the requirement of power consumption less than 10 fJ/bit for on-chip interconnect due to the high thresholds on the order of MW/cm<sup>2</sup> or even GW/cm<sup>2</sup> at room temperature. Here, we demonstrate a plasmonic nanoasaser with threshold as low as 50 kW/cm<sup>2</sup> around 1550 nm based on InGaAsP MQWs metallo-dielectric cavity. The estimated power consumption of 5.19 fJ/bit~5 fJ/bit makes our nanolasers suitable for on-chip or off-chip optical interconnects. Moreover, our devices show robust performance with tilted sidewall and surface roughness. On the other hand, due to the subwavelength dimension of metallo-dielectric cavity ( $\sim(\lambda/n)^3$ ), the carrier density can easily reach an ultra-high level under relatively low pump power. An ultra-wide gain spectrum (>400 nm) and a large mode interval (~100 nm) can be achieved to support stable multiple lasing modes simultaneously in a single device. Up to 5 wavelengths with a working range of 350 nm is realized in our work. Such nanolasers exhibit great potential on the applications of wavelength division multiplexing systems.

**Keywords:** Low threshold, multi-wavelength lasing, plasmonic nanolaser, metallo-dielectric cavity

**LIMIS2021-2021-000152**

### High Optical Gain and Low Threshold of One-step Air-Processed All-Inorganic CsPbX<sub>3</sub> Thin Films towards Enhanced and Stable Full Colored Amplified Spontaneous Emission

Dingke Zhang

Chongqing Normal University

**Abstract:** Inorganic cesium lead halide perovskite that has the advantages of potential stability improvement and remarkable optical gain properties are attractive for the realization of on-chip coherent light sources.

Unfortunately, conventional solution-processed CsPbX<sub>3</sub> films suffer unavoidable pinhole defects and poor surface morphology, severely limiting their performance on amplified spontaneous emission (ASE) and lasing application. Here, from the perspective of precursor solution chemistry, we involve ionic liquid solvent methylammonium acetate (MAAc) to develop compact, pinhole-free and smooth thin films of CsPbX<sub>3</sub> in a one-step air-processing process without anti-solvent treatment. Optically pumped ASE with a straightforward visible spectral tunability (418-725 nm) is successfully achieved under both nanosecond and one/two-photon femtosecond laser excitation at room temperature, which is promising in developing single-source-pumped full-color visible lasers. For the representative CsPbBr<sub>3</sub> films among them, the threshold reaches down to 11.4 μJ cm<sup>-2</sup> under the condition of nanosecond laser pumping, which is comparable to that of one-photon femtosecond pumping. Most importantly, the films showed excellent optical stability: no signs of degradation under more than 210 minutes pulsed laser pumping, stable ASE emission spectra under the humidity of 95%

**Keywords:** Amplified spontaneous emission, caesium lead halide perovskites, methylammonium acetate, wavelength tunable

**LIMIS2021-2021-000147**

## High-performance cavity-enhanced quantum memory with warm atomic cell

**Lixia Ma**

*Shanxi University, China*

**Abstract:** High-performance quantum memory for quantized states of light is a prerequisite building block of quantum information technology. Despite great progresses of optical quantum memories based on interactions of light and atoms, physical features of these memories still can not satisfy requirements for applications in practical quantum information systems, since all of them suffer from trade off between memory efficiency and excess noise. Here, we report a high-performance cavity-enhanced electromagnetically-induced-transparency memory with warm atomic cell in which a scheme of optimizing the spatial and temporal modes based on the time-reversal approach is applied. The memory efficiency up to  $67 \pm 1\%$  is directly measured and a noise level close to quantum noise limit is simultaneously reached. The deterministic fidelity of  $0.98 \pm 0.01$  beyond the corresponding classical benchmark fidelity of 0.73 is obtained for an optical coherent state. The realized quantum memory platform has been capable of preserving quantized optical states, and thus is ready to be applied in quantum information systems, such as distributed quantum logic gates and quantum-enhanced atomic magnetometry.

**Keyword:** quantum memory, electromagnetically-induced-transparency

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## Stimulated Scattering in Supermode Microcavity Single- or Dual-Mode Lasing ?

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1. Peking University

2. Shanxi University

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4. Present address: T. J. Watson Laboratory of Applied Physics, California Institute of Technology

**Abstract:** Microlasers in near-degenerate supermodes lay the cornerstone for studies of non-Hermitian physics, novel light sources, and advanced sensors. Recent experiments of the stimulated scattering in supermode microcavities reported beating phenomena, interpreted as dual-mode lasing, which, however, contradicts their single-mode nature due to the clamped pump field. Here, we investigate the supermode Raman laser in a whispering-gallery microcavity and demonstrate experimentally its single-mode lasing behavior with a side-mode suppression ratio (SMSR) up to 37 dB, despite the emergence of near-degenerate supermodes by the backscattering between counterpropagating waves. Moreover, the beating signal is recognized as the transient interference during the switching process between the two supermode lasers. Self-injection is exploited to manipulate the lasing supermodes, where the SMSR is further improved by 15 dB and the laser linewidth is below 100 Hz.



## SC1: Laser irradiation effect and mechanism

LIMIS2021-2021-000001	<p><b>Numerical simulation of surface topography evolution during pulsed CO<sub>2</sub> laser ablation of fiber</b> Chang Hu<sup>1</sup>, Han Wu<sup>1</sup>, Xiuquan Ma<sup>1,2*</sup> 1.Huazhong University of Science and Technology; 2.Guangdong intelligent robotics institute</p>
LIMIS2021-2021-000004	<p><b>Positron generation via ultra-intense laser head-on collision with an electron beam</b> Jian-Xun Liu<sup>1,2*</sup>, Jin-Jian Lv<sup>1</sup>, Wei-Qiang Deng<sup>1</sup>, Jun-Kai Liu<sup>1</sup>, Tong-Pu Yu<sup>2*</sup> 1.Early Warning Academy; 2. National University of Defense Technology</p>
LIMIS2021-2021-000005	<p><b>Analysis of the damage mechanism of gray point induced by 800 nm femtosecond laser pulse on IT-CCD camera</b> Yubin Shi<sup>†</sup>, Jianmin Zhang, Wangqi Xue, Zuodong Xu, Dahui Wang, Yunpeng Li, Pengcheng Dou, Guobin Feng Northwest Institute of Nuclear Technology</p>
LIMIS2021-2021-000006	<p><b>A study on laser welding aluminum alloy reinforced by adding <math>\alpha</math>-Si<sub>3</sub>N<sub>4</sub> particles</b> Tianyu Xu, Shaowei Zhou, Xiuquan Ma<sup>*</sup> Huazhong University of Science and Technology</p>
LIMIS2021-2021-000007	<p><b>Irradiation effects of continuous laser on liquid tank: a nucleate boiling study</b> Lu-guang Jiao<sup>1</sup>, Guo-min Zhao<sup>2</sup>, Zao-fu Yang<sup>1</sup>, Min-sun Chen<sup>2</sup> 1. Beijing Institute of Radiation Medicine, China; 2. National University of Defense Technology</p>
LIMIS2021-2021-000023	<p><b>Application of boundary element method with convolution core in solving carrier evolution equation</b> Yunfeng Zhang, Junfeng Shao<sup>†</sup>, Chunrui Wang, Fei Chen, Jin Guo State Key Laboratory of Laser Interaction with Matter, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Science</p>
LIMIS2021-2021-000024	<p><b>Mechanism of Combined Laser on Damage Effectiveness</b> Te Ma<sup>1,2</sup>, Hongwei Song<sup>1,2</sup>, Wu Yuan<sup>1,2</sup> 1.Key Laboratory for Mechanics in Fluid Solid Coupling Systems, Institute of Mechanics, Chinese Academy of Science; 2.School of Engineering Science, University of Chinese Academy of Sciences;</p>
LIMIS2021-2021-000025	<p><b>Multiphysics analysis for laser ablation behavior of C/SiC composites subjected to high-speed airflow</b> Zhe Wang<sup>1,2</sup>, Ruixing Wang<sup>1*</sup>, Hongwei Song<sup>1,2</sup> 1.Institute of Mechanics, Chinese Academy of Sciences; 2.School of Engineering Sciences, University of Chinese Academy of Sciences</p>
LIMIS2021-2021-000030	<p><b>The damage threshold of filter film induced by femtosecond and picosecond laser pulses</b> Yunzhe Wang<sup>1,2</sup>, Xiangzheng Cheng<sup>3</sup>, Junfeng Shao<sup>1</sup>, Changbin Zheng<sup>1</sup>, Anmin Chen<sup>4</sup>, Luwei Zhang<sup>1†</sup> 1.State Key Laboratory of Laser Interaction with Matter, Changchun Institute of Optics, Fine Mechanics and Physics of Chinese Academy of Sciences; 2.University of Chinese Academy of Sciences; 3.Key Laboratory of Electro-Optical Countermeasures Test &amp; Evaluation Technology; 4.Jilin University</p>



LIMIS2021-2021-000031	<p><b>Effect of femtosecond laser polarization on damage threshold of Ta<sub>2</sub>O<sub>5</sub>/SiO<sub>2</sub> thin film</b>          Luwei Zhang<sup>1</sup>, Xiaodong Jia<sup>3</sup>, Yunzhe Wang<sup>1,2</sup>, Yin Zhang<sup>1,2</sup>, Anmin Chen<sup>4</sup>, Junfeng Shao<sup>1</sup>, Changbin Zheng<sup>1*</sup>          1.State Key Laboratory of Laser Interaction with Matter, Changchun Institute of Optics, Fine Mechanics and Physics of Chinese Academy of Sciences; 2.University of Chinese Academy of Sciences; 3.High Speed Aerodynamics Institute Aerodynamics Research and Development Center; 4.Jilin University</p>
LIMIS2021-2021-000036	<p><b>Porcine skin damage effects from infrared fiber laser at the wavelength of 1070 nm</b>          Lu-guang Jiao*, Jiarui Wang, Chao Wang, Zaifu Yang*          Beijing Institute of Radiation Medicine</p>
LIMIS2021-2021-000039	<p><b>Numerical simulation and experimental study on Temperature evolution of 1064 nm continuous laser ablation silicon based PIN detector</b>          Le Gao<sup>1</sup>, Zhi Wei<sup>1*</sup>, Di Wang<sup>1</sup>, Guangyong Jin<sup>1</sup>, Jianxiang Ma<sup>1</sup>, Chao liang<sup>1</sup>, Jinyuan Yu<sup>1</sup>          Jilin Key Laboratory of Solid-State Laser Technology and Application, Changchun University of Science and Technology</p>
LIMIS2021-2021-000043	<p><b>Effect of laser beam diameter on near infrared laser damage threshold of Ge optical materials</b>          Wangqi Xue, Jianmin Zhang, Yubin Shi, Zuodong Xu, Yunpeng Li, Pengcheng Dou, Guobin Feng          Northwest Institute of Nuclear Technology</p>
LIMIS2021-2021-000061	<p><b>Energy deposition in the initial stage of laser damage on KDP crystal induced by processing surface defects</b>          Hao Yang<sup>1,2,3</sup>, Jian Cheng<sup>*1,3</sup>, Zhichao Liu<sup>2</sup>, Qi Liu<sup>1</sup>, Linjie Zhao<sup>1</sup>, Jian Wang<sup>2</sup>, Mingjun Chen<sup>*1</sup>          1. School of Mechatronics Engineering, Harbin Institute of Technology; 2.Research Center of Laser Fusion, China Academy of Engineering Physics</p>
LIMIS2021-2021-000081	<p><b>Evolution of micro-ingredients in Glass Fiber Reinforce Epoxy Composite Induced by Laser Ablation Carbonization</b>          Yuwei Lv, Yongxiang Zhu, Taotao Wu, Chenghua Wei, Jiawei Wang, Lijun Wang, Yongchao Han, Ran Zhang, Guobin Feng          State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology</p>
LIMIS2021-2021-000094	<p><b>Numerical simulation of ultrashort pulse laser ablation based on COMSOL</b>          Li Peng<sup>1,2,3</sup>, Shi Chen<sup>1,2,3*</sup>, Hua Zhang<sup>1,2,3</sup>, Xiaoguang Li<sup>1,2,3</sup>, Mingqiang Li<sup>1,2,3</sup>          1.Shenzhen Key Laboratory of Ultraintense Laser and Advanced Material Technonlgy; 2.Center for Advanced Material Diagnostic Technology; 3.Shenzhen Technology University</p>
LIMIS2021-2021-000103	<p><b>Irradiation effects of continuous laser on liquid tank: a nucleate boiling study</b>          Chuhui Zhang, Lu Jian*, Hongchao Zhang, Gao Lou          Nanjing University of Science and Technology</p>

LIMIS2021-2021-000106	<p><b>Experimental study on crosstalk phenomenon of pulsed laser irradiation on array CCD</b> Lan Li*, Meng Yao, Jifei Ye, Sai Li, Ying Wang Space Engineering University</p>
LIMIS2021-2021-000121	<p><b>Influence of K9 Optical Elements Processing Method on Laser Damage Characteristics</b> Hongjun Wang, Lin Wu, Ailing Tian, Bingcai Liu, Xueliang Zhu, Chen Wei* Xi'an technological university</p>
LIMIS2021-2022-000002	<p><b>Measurement of laser energy distribution on the target surface of CCD detector by image fusion method</b> Zhou Xuanfeng*, Zhang Defeng, Wang Yanbin, Xiao Wenjian, Jiang Chenglong State Key Laboratory of Complex Electromagnetic Environment Effects on Electronics and Information System</p>
LIMIS2021-2022-000003	<p><b>Generation of uranium aerosol with laser ablation to simulate nuclear facilities emission</b> Hongyu He, Zhixing Gao*, Yun He, Xiaohua Zhang, Qiushi Liu, Bing Guo China Institute of Atomic Energy</p>
LIMIS2021-2022-000008	<p><b>Effect of Multiple Pulsed Laser Irradiations on Resistance of Silicon Cells</b> Longcheng Huang, Jifei Ye, Sai Li*, Lan Li, Diankai Wang Space Engineering University</p>
LIMIS2021-2022-000012	<p><b>Experimental study of electromagnetically enhanced laser propulsion performance</b> Hang Song, Jifei Ye*, Chao Zhu, Nanlei Li Space Engineering University</p>
LIMIS2021-2022-000015	<p><b>Plasma plume characteristics of an aluminum target irradiated by a nanosecond pulsed laser with oblique incidence</b> Chenghao Yu, Jifei Ye, Weijing Zhou*, Hao Chang, Xiao Han, Luyun Jiang Space Engineering University</p>
LIMIS2021-2022-000017	<p><b>Study on laser propulsion performance based on ADN liquid propellant</b> Hong-Jie KONG, Ji-Fei YE*, Chen-Tao MAO Space Engineering University</p>
LIMIS2021-2022-000022	<p><b>Study on Polarization Reflectivity Measurement of Metallic Coating Mirrors Based on Laser Dynamics Analysis</b> Siyu Huang, Fengzhou Fang* Tianjin University</p>
LIMIS2021-2022-000023	<p><b>Study on amplification of nanoseconds level laser momentum transfer induced mechanical wave on Ag coating mirror</b> Chunyang Gu, Fengzhou Fang* Tianjin University</p>
LIMIS2021-2022-000024	<p><b>Numerical simulation of the expansion velocity of laser-induced plasma generated in transparent materials</b> Jixing Cai*, Congrui Geng, Hongtao Mao, Hao Yu, Yunpeng Wang Changchun University of Science and Technology</p>

LIMIS2021-2022-000034	<p><b>Study on the damage of silicon cells irradiated by nanosecond pulse laser</b> Sai Li* Space Engineering University</p>
LIMIS2021-2022-000044	<p><b>Fabrication of regular micro crack array on the surface of hard brittle material with 46.9nm soft X-ray laser</b> Bowen Liao<sup>1</sup>, Huaiyu Cui<sup>2*</sup>, Han Wu<sup>1</sup> 1.School of Mechanical Science and Engineering, Huazhong University of Science and Technology, China; 2.School of Astronautics, Harbin Institute of Technology, China</p>
LIMIS2021-2022-000045	<p><b>Optical limiting and charge transfer properties of lead phthalocyanine derivatives in solution</b> Xinchen Du<sup>1,2</sup>, Yunfeng Zhang<sup>1</sup>, Chunrui Wang<sup>1*</sup>, Fei Chen<sup>1*</sup>, Junfeng Shao<sup>1</sup>, Rui Wang<sup>1</sup> 1.Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences; 2.University of Chinese Academy of Sciences</p>
LIMIS2021-2022-000051	<p><b>Three-photon-induced singlet excited-state absorption for tunable ultrafast optical-limiting in distyrylbenzene: a first-principles study</b> Danyang Zhang Anhui Normal University</p>
LIMIS2021-2022-000052	<p><b>Laser induced spatial self-phase modulation of nano-suspension</b> Haoran Du<sup>1,2</sup>, Ze Zhang<sup>1*</sup>, Lu Gao<sup>2*</sup> 1.Institute of Space Information Innovation, Chinese Academy of Sciences; 2.China University of Geosciences</p>

## SC2: Plasmas and optics physics

LIMIS2021-2021-000016	<p><b>FDTD algorithm improved for investigating laser interaction with matter</b> Huicheng Guo, Henglei Du, Chengpu Liu* Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences</p>
LIMIS2021-2021-000083	<p><b>Laser intensity and incidence angle dependent attosecond light pulse generation from relativistic laser-plasma surfaces</b> Guangjin Ma<sup>3*</sup>, Jingbiao Chen<sup>1</sup>, Jin He<sup>1*</sup>, Laszlo Veisz<sup>2</sup> 1.Peking University Shenzhen Institute &amp; PKU-HKUST Shenzhen-Hong Kong Institution; 2. Umeå University, Sweden; 3.Songshan Lake Materials Laboratory</p>
LIMIS2021-2021-000087	<p><b>Ultra-stable operation of 100J-class commercial ns Lasers with pulse-shaping capabilities for Dynamic Shock Compression and High Energy OPCPA pumping</b> S. Branly, F. Mollica, O. Zabiolle, Jiaru Lu Amplitude Laser</p>
LIMIS2021-2021-000112	<p><b>Dense Short Muon Source Driven by Ultra-Intense Circularly Polarized Laser Pulse</b> Rong Sha, Tongpu Yu* National University of Defense Technology</p>

LIMIS2021-2021-000114	<p><b>Research on the Lightweight Design and Processing Technology of Optical Parts</b>  DONG Xiao, ZHANG Wenming, WU Xiaoming, LAN Qihong, Qi Feng  Luoyang Institute of Electro-Optical Equipment, AVIC</p>
LIMIS2021-2021-000125	<p><b>Generation of brilliant <math>\gamma</math>-ray vortex from a light-fan-in-channel target</b>  Hao Zhang, Jie Zhao, Yanting Hu, Qianni Li, Yu Lu, Yue Cao, Debin Zou, Fuqiu Shao, Tongpu Yu*  National University of Defense Technology</p>
LIMIS2021-2021-000126	<p><b>The metallic planar target irradiated by the laser for the scaled explosion</b>  Chenguang Li, Guangwei Meng  Institute of Applied Physics and Computational Mathematics</p>
LIMIS2021-2021-000133	<p><b>Study on time-space resolved diagnostics technology of low-temperature rarefied plasma</b>  Hao Wang, Quanxi Xue, Yanpeng Liu, Xueqing Zhao, Yanlong Shen, Chao Huang, Aiping Yi, Ke Huang  Northwest Institute of Nuclear Technology</p>
LIMIS2021-2021-000166	<p><b>Effects of many-body interactions on the transient optical properties of lead halide perovskites</b>  Guangbiao Xiang  Shandong Normal University</p>
LIMIS2021-2022-000005	<p><b>Computational and experimental studies of fused-silica damage and ablation threshold by 35fs laser pulse</b>  Lin Zhang, Shengbo Xing, Han Wu*, Ma Xiuquan  Huazhong University of Science and Technology</p>
LIMIS2021-2022-000026	<p><b>Pulse-shape effects on high-order-harmonic generation from a periodic potential field</b>  Jie Li, Wen-Hui Guan, Shuo Yuan, Ji-Cai Liu  North China Electric Power University</p>
LIMIS2021-2022-000047	<p><b>Ultrafast Photo Current Amplification and Room temperature Valley Manipulation in Monolayer WSe<sub>2</sub>/Si Heterostructure</b>  Fanchen Song<sup>1,2,3†</sup>, Xinzhi Zu<sup>1,2,3†</sup>, Qinxue Yin<sup>1,2</sup>, Zeyu Zhang<sup>1,2,3*</sup>, Tingyuan Jia<sup>1,2,3</sup>, Chenjing Quan<sup>1,2,3</sup>, Chunwei Wang<sup>1,2,3</sup>, Sihao Huang<sup>1,2,3</sup>, Zhengzheng Liu<sup>1,2,3</sup>, Hongwen Xuan<sup>4*</sup>, Juan Du<sup>1,2,3*</sup> and Yuxin Leng<sup>1,2,3</sup>  1. State Key Laboratory of High Field Laser Physics and CAS Center for Excellence in Ultra-intense Laser Science, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences; 2. School of Physics and Optoelectronic Engineering, Hangzhou Institute for Advanced Study, University of Chinese Academy of Sciences; 3. Center of Materials Science and Optoelectronics Engineering, University of Chinese Academy of Sciences  4. GBA branch of Aerospace Information Research Institute, Chinese Academy of Sciences</p>
LIMIS2021-2022-000048	<p><b>Research on plasma characteristics of fused silica induced by millisecond pulsed laser</b>  Jixing Cai<sup>†</sup>, Zequn Zhang, Hao Yu, Yunpeng Wang, Hongtao Mao  Changchun University of Science and Technology</p>
LIMIS2021-2022-000054	<p><b>Laser active detection technology based on cat's eye effect</b>  zhe lv<sup>1,2</sup>, kuo zhang<sup>1*</sup>  1.Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences; 2.University of Chinese Academy of Sciences</p>

### SC3: Laser spectrum technology and applications

LIMIS2021-2021-000014	<p><b>Study on Thermosensitive Phosphor Temperature Measurement Technology for Surface Temperature Measurement of High Power Laser Irradiated Materials</b></p> <p>Sheng Wang*, Jingfeng Ye, Lijun Wang, Weiping Liu, Jun Shao, Taotao Wu, Guohua Li Northwest Institute of Nuclear Technology</p>
LIMIS2021-2021-000055	<p><b>Study on Time- Resolved Measurement of Chemical Components in Strong Impact Vibration Environment</b></p> <p>Zhenjie Wu, Zhenrong Zhang, Jingfeng Ye Northwest Institute of Nuclear Technology, State Key Laboratory of Laser Interaction with Matter</p>
LIMIS2021-2021-000057	<p><b>PLIF thermometry using OH origin from photo dissociation of water</b></p> <p>Guohua Li<sup>1,2</sup>, Jingfeng Ye<sup>1,*</sup>, Zhenrong Zhang<sup>1</sup>, Sheng Wang<sup>1,2</sup>, Jun Shao<sup>1,2</sup>, Bolang Fang<sup>1</sup>, Zhiyun Hu<sup>1</sup>, Jinhua wang<sup>2</sup>, Zuohua Huang<sup>2,*</sup> 1. State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology; 2. State Key Laboratory of Multiphase Flow in Power Engineering, Xi'an Jiaotong University</p>
LIMIS2021-2021-000060	<p><b>Study on Image Processing Based on Photo-dissociation Hydroxyl Characteristic Information for Flow Field Parameters Measurement</b></p> <p>Jun Shao, Jing-feng YE, Zheng-rong Zhang, Sheng Wang, Guo-hua Li, Meng-meng Tao, Ai-ping Yi, Li-jun Wang, Jun-zheng Wu* State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology</p>
LIMIS2021-2021-000082	<p><b>Numerical investigation of nonlinear broadened OFC based on the CS-DSB modulation frequency shift recirculation loop</b></p> <p>Meili Shen, Zhuohang Zhang, Jianghua Zhang, Jie Yang, Xin Zheng Defense Innovation Institute, Academy of Military Science PLA China</p>
LIMIS2021-2021-000116	<p><b>Characterizing Combustion of a Hybrid Rocket Engine Using Mid-Infrared Tunable Diode Laser Absorption Tomography</b></p> <p>Ze Zhong Wang, Xin Lin, Zelin Zhang, Sihan Fang, Xilong Yu Institute of Mechanics, Chinese Academy of Science</p>
LIMIS2021-2021-000130	<p><b>Research of High-Precision Spatial Positioning Method of Optical Fiber Fire Extinguishing Device for Special Vehicles Based on Raman Spectroscopy Technology</b></p> <p>Yang Wu*, Peng Mi Shanghai Electric Control Research Institute</p>
LIMIS2021-2022-000019	<p><b>Identification for concealed liquid components with SORS</b></p> <p>Qiushi Liu, Mingjiang Ma, Chong Lv, Guoqing Yang, Zhixing Gao, Hongyu He, Baozhen Zhao, Xiaohua Zhang* China Institute of Atomic Energy</p>

LIMIS2021-2022-000036	<b>Measurement of kerosene cracking gas based on TDLAS Technology</b> Guo Jianyu, Rao Wei* ,Song Junling,c University of Aerospace Engineering
LIMIS2021-2022-000038	<b>Achieving Low Threshold and High Optical Gain Amplified Spontaneous Emission in MAPbI<sub>3</sub> Perovskite Films via Symmetric Waveguide Effect</b> Xin Zeng, Zhengzheng Liu, Dingke Zhang, Juan Du and Jie Yang Chongqing Normal University

### SC4: High power lasers

LIMIS2021-2021-000012	<b>Ultra-high speed launch of laser driven pellet</b> Ban Xiaona <sup>1</sup> , Yang Weiming <sup>2</sup> ,Zhang Pinliang <sup>3</sup> ,Zhang Chen <sup>2</sup> ,Wang Zhao <sup>1</sup> ,Tian Baoxian <sup>1</sup> , Wang Zhebin <sup>2</sup> ,Gao Zhixing <sup>1</sup> ,Li Jing <sup>1</sup> ,Hu Fengming <sup>1</sup> 1. Department of Nuclear Physics, China Institute of Atomic Energy; 2. Laser Fusion Research Center, CAEP; 3. Beijing Institute of Spacecraft Environment Engineering
LIMIS2021-2021-000021	<b>The Study On The Corona Discharge for Voltage Balance In Multi-gap Gas Switch</b> Wenbo Yan, Chao Huang, Aiping Yi, Gaopeng Li, Quanxi Xue, Yanlong Shen, Ke Huang, Zhengge Chen, Yousheng Wang State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology
LIMIS2021-2021-000033	<b>Theoretical study of a new kind of gas-flowing Diode Pumped Cesium Laser</b> Guofei An, Jiao Yang, Kepeng Rong, Jiawei Guo, Qing Luo, Xiaoxu Liu, You Wang* Southwest Institute of Technical Physics
LIMIS2021-2021-000041	<b>Mode switchable LMA fiber laser using multi-channels phase control</b> Wenguang Liu*, Changjin Li, Pengfei Liu, Jiangbin Zhang, Qiong Zhou National University of Defense Technology
LIMIS2021-2021-000042	<b>The Influence of filler wire on the process of aluminum alloy by serial dual-beam laser welding</b> Shanguo Han <sup>1,2,3*</sup> , yongqiang Yang <sup>1*</sup> , Ziyi Luo <sup>2</sup> , Detao Cai <sup>2</sup> , Yafei Xue <sup>2</sup> , Shida Zheng <sup>2</sup> 1.School of Mechanical & Automotive Engineering, South China University of technology; 2.Guangzhou China-Ukraine Institute of welding, Guangdong Academy of Sciences; 3.Yangjiang China-Ukraine E.O Paton Institute of Technology

LIMIS2021-2021-000052	<p><b>New theoretical model guided optical pumped semiconductor laser chip design method</b> Kang Li, Zining Yang, Wenda Cui, Hongyan Wang* National University of Defense Technology</p>
LIMIS2021-2021-000069	<p><b>Bend loss owing to absorption of coating</b> Pengfei Liu<sup>1,2*</sup>, Jianqiu Cao<sup>1,2</sup>, Jiangbin Zhang<sup>1,2</sup>, Qiong Zhou<sup>1,2</sup>, Wenguang Liu<sup>1,2</sup> 1.National University of Defense Technology; 2.State Key Laboratory of Pulsed Power Laser Technology</p>
LIMIS2021-2021-000073	<p><b>Super-resolution reconstruction for far-field beam profile based on deep learning</b> Xianchen Xie, Bolang Fang, Haichuan Zhao, Dahui Wang, Pengling Yang State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology</p>
LIMIS2021-2021-000089	<p><b>A Method for High Precision Attenuation of the High Energy Laser Beam Based on Fresnel Reflection</b> Tianyang Xue State Key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology</p>
LIMIS2021-2021-000098	<p><b>Study on conjugated polarization beam combination amplification of ultraviolet femtosecond laser</b> Ji Zhang*, Zhang Xiaohua China Institute of Atomic Energy</p>
LIMIS2021-2021-000131	<p><b>Study on Fracture of Carbon Fiber Composite Strip under Preloading and CW Laser irradiation</b> Guobin Zhang, Yunxiang Pan*, Zhonghua Shen*, Yiming Chen, Zewen Li Nanjing University of Science and Technology</p>
LIMIS2021-2021-000132	<p><b>35kW-peak-power eye-safe laser with high average power, tunable repetition rate and short pulse width for Lidar</b> Juntao Tian, Zhiyong Li*, Rongqing Tan, Songyang Liu, Jinzhou Bai, Wenning Xu, Lili Zhao, Mingjun Wu Aerospace Information Research Institute, Chinese Academy of Sciences</p>
LIMIS2021-2021-000134	<p><b>Stimulated Brillouin scattering suppression in fiber amplifiers with multi-point pump</b> Haichuan Zhao*, Mengmeng Tao, Hongwei Chen, Zhenbao Wang, Yong Wu, Junjie Wu, Lei Zhang, Ping Wang, Gang Feng, Pengling Yang State key Laboratory of Laser Interaction with Matter, Northwest Institute of Nuclear Technology;</p>
LIMIS2021-2022-000001	<p><b>Theoretical investigation of vector modes in a conventional photonic lantern</b> Xuanfeng Zhou*, Wang Yanbin, Wenjian Xiao, Men Xinghuo, Zhou Hanbing State Key Laboratory of Complex Electromagnetic Environment Effects on Electronics and Information System</p>



LIMIS2021-2022-000041	<p><b>Simultaneous observation of visible upconversion and near-infrared downconversion in the Yb<sup>3+</sup>/Ho<sup>3+</sup>/Tm<sup>3+</sup>-tri-doped SrF<sub>2</sub> nanocrystals under 980 nm excitation</b></p> <p>Linxuan Wang, Liang Li, Maohui Yuan*, Zining Yang, Hongyan Wang* National University of Defense Technology</p>
LIMIS2021-2022-000042	<p><b>Kilowatt-level 100 kHz nanosecond pulsed laser amplifier via a 205-watt seeding</b></p> <p>Tian-Li Yang<sup>1,2,3</sup>, Jing Yang<sup>1,2,4*</sup>, Wang-Zhe Zhou<sup>1,2,3</sup>, Xiao-Jun Wang<sup>1,2,4</sup>, Bing-Jie Liu<sup>4</sup>, Qin-Jun Peng<sup>1,2,4</sup></p> <p>1.Key Lab of Solid State Laser, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences; 2.Key Lab of Function Crystal and Laser Technology, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences; 3.University of Chinese Academy of Sciences; 4.Institute of Optical Physics and Engineering Technology, Qilu Zhongke</p>
LIMIS2021-2022-000050	<p><b>FADOF-based High-power Narrow-linewidth Diode Laser for Alkali Laser Pumping</b></p> <p>Hao Tang, Huizi Zhao, Liang Li, Zining Yang, Weiqiang Yang, Hongyan Wang* National University of Defense Technology</p>

### SC5: Micro-nanophotonics

LIMIS2021-2021-000050	<p><b>Design optimization of electrode region of Silicon-organic Hybrid integrated Mach-zehnder modulator</b></p> <p>Runzhong Gao, Lijun Guo* Changchun University of Science and Technology</p>
LIMIS2021-2021-000139	<p><b>Solid-state sources for single photons with orbital angular momentum on a semiconductor chip</b></p> <p>Bo Chen, Jin Liu*, Xuehua Wang* Sun Yat-sen University</p>
LIMIS2021-2021-000141	<p><b>Inkjet Printed Full-color Quantum Dot Layer for Active-Matrix Micro-LED Display</b></p> <p>Jun Wang<sup>1,2</sup>, Fengxian Zhou<sup>1,2</sup>, Zhiping Hu<sup>1,2,*</sup></p> <p>1. Hangzhou Institute for Advanced Study, UCAS; 2. State Key Laboratory of High Field Laser Physics and CAS Center for Excellence in Ultra-Intense Laser Science, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Science</p>
LIMIS2021-2021-000142	<p><b>Soliton microcombs in the silicon nitride microresonators</b></p> <p>Shuai Wang, Rui Niu, Jing Li, Zhengyu Wang, Jinlan Peng, Changling Zhou, Guangcan Guo, Chunhua Dong* University of science and technology of China</p>
LIMIS2021-2021-000144	<p><b>Mid-infrared broadband optical parametric oscillator centered at 4.78 μm in MgF<sub>2</sub> resonators</b></p> <p>Wei Wu<sup>1,2</sup>, Yi Wang<sup>1,2</sup>, Qibing Sun<sup>1,2</sup>, Keyi Wang<sup>2</sup>, Yu Yang<sup>2</sup>, Leiran Wang<sup>1,2</sup>, Wei Zhao<sup>1,2</sup>, Wenfu Zhang<sup>1,2</sup></p> <p>1. Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Science; 2.University of Chinese Academy of Sciences;</p>

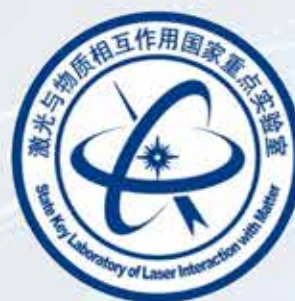


LIMIS2021-2021-000148	<p><b>High quality factor 1-D optomechanical crystal cavity on chip</b> Wangyu, Shenzhen, Dongchunhua* University of science and technology of China</p>
LIMIS2021-2021-000149	<p><b>A High-Accuracy Measurement Method of Laser Radar Cross Section based on Micro-nanophotonics</b> Qu Weidong<sup>1*</sup>, Shao Ming<sup>1</sup>, Cheng Xiangzheng<sup>1</sup>, Liu Yang<sup>2</sup> 1.State Key Laboratory of Complex Electromagnetic Environment Effects on Electronics and Information System; 2.State Key Laboratory of Laser Interaction with Matter, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Science</p>
LIMIS2021-2021-000150	<p><b>Non- Hermiticity Solely Induced Topological Laser</b> Zhang Lingxuan<sup>1</sup>, Qi Bingkun<sup>2</sup>, Zhang Wenfu<sup>3*</sup> Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Science, China; 2.epfl, Switzerland</p>
LIMIS2021-2021-000153	<p><b>Strong coupling of a plasmonic nanoparticle to a semiconductor nanowire</b> Xin Guo*, Limin Tong*, Yingying Jin, liu Yang Zhejiang University</p>
LIMIS2021-2021-000156	<p><b>Enhanced amplified spontaneous emission of Ag-mesoporous SiO<sub>2</sub> core-shell nanowire composite embedded perovskite in SiO<sub>2</sub> mesopores</b> Zijun Zhan<sup>1*</sup>, Cheng Chen<sup>2</sup> 1.Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Science; 2.Shandong Normal University</p>
LIMIS2021-2021-000158	<p><b>Etchless Perovskite Microdisk lasers Based on Bound States in the Continuum</b> Haijun Tang, Qinghai Song* Harbin Institute of Technology, Shenzhen</p>
LIMIS2021-2021-000159	<p><b>Surface-Emitting Perovskite Random Lasers for Speckle-Free Imaging</b> Liu Yilin, Xiao Shumin*, Song Qinghai* Harbin Institute of Technology, ShenZhen</p>
LIMIS2021-2021-000160	<p><b>Topological controllable perovskite vortex laser array with all-dielectric metasurfaces</b> Hui Zhang, Qinghai Song Harbin Institute of Technology, ShenZhen</p>
LIMIS2021-2021-000163	<p><b>Cascaded photon-phonon coupling in an optomechanical system</b> Shen Zhen University of Science and Technology of China</p>
LIMIS2021-2022-000049	<p><b>Energy funneling manipulation and enhanced amplified spontaneous emission in quasi-2D perovskite</b> Sihao Huang, Zhengzheng Liu, Juan Du* State Key Laboratory of High Field Laser Physics and CAS Center for Excellence in Ultra-Intense Laser Science, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Science</p>



# State Key Laboratory of Laser Interaction with Matter

The State Key Laboratory of Laser Interaction with Matter (SKLLIM) was jointly established by the Northwest Institute of Nuclear Technology and the Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, with the approval of the Ministry of Science and Technology of the People's Republic of China in 2009. Focusing on the forefronts of scientific researches in information, materials and energy, the objective of the SKLLIM is to conduct innovative fundamental and applied researches in laser-matter interaction. The SKLLIM has explored 4 research scopes, including laser irradiation effect and mechanism, high power laser plasma physics, laser combustion diagnostics technology, and high power repetitive gas laser technology. Now, the SKLLIM has 58 staffs, including two academicians of the Chinese Academy of Sciences and 21 professors or researchers. Since its establishment, the SKLLIM has participated in more than 120 projects from international cooperation, National Natural Science Foundation of China, National 863 Program of China, and so on; the faculties have achieved 5 awards at the national and ministerial levels, and more than 50 national patents; more than 500 papers have been published in domestic and overseas academic journals. As the Guest Researcher, Professor Yury Andreev was awarded for the international cooperation by the Chinese Academy of Sciences in 2013. The SKLLIM has always attached much attention to academic communications. As the initiator and the permanent organizer, it has successfully hosted the series International Symposium on Laser Interaction with Matter (LIMIS2010, LIMIS2012, LIMIS2014, LIMIS2016 and LIMIS2018) with the cooperation from many co-sponsors. The SKLLIM will try to make more contribution to the development of laser-matter interaction in the various research fields and the front-cross subjects. Holding the cooperative philosophy of mutual complementation, the SKLLIM warmly welcome domestic and overseas scientists and researchers to strengthen collaboration and address problems of common concern.



# The most complete and advanced Femtosecond & Nanosecond laser portfolio

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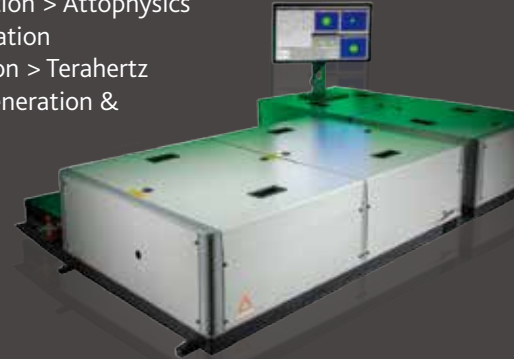
**Ti:Sa Solution: from TW Level to Multi-PW Level System Laser 4.0 HE**

**Arco:** #Ti: Sapphire #Amplifiers #Ultra Intense Femtosecond Laser  
**Key parameters:** Up to 40 W, Single Shot to Multi-kHz, CEP

**Pulsar PW:** #Ultra Intense #Ultrafast Laser #Reliability #Sub 20 fs

**Applications (Arco and Pulsar PW):**

- > High Harmonic Generation > Attophysics
- > Spectroscopy > Filamentation
- > Laser Wakefield Acceleration > Terahertz
- > Plasma Physics > Particle Generation & Acceleration X-Ray Imaging
- > Proton Therapy



Arco

## Nanosecond Advanced Lasers

**NEW Elite:** #Innovation #Performance #Best Value

**Key parameters:** 100 J @ 1053 nm & 75 J @ 527 nm  
Single Beam

**Premiumlite:** #High Repetition #High Energy  
#DISK Technology

**Key parameters:** Up to kJ level, Up to 750 W

**Applications (Elite and Premiumlite):**

- > Pumping of PW-class Laser Systems > Laser Dynamic Shock Compression > LIDT Metrology (IR, green) > High Energy Frontier Science > Ti:Sapphire Pumping for PW and Multi-PW Laser Systems
  - > Laser Driven Shock Applications
- Options:** #Attenuators #Spectral Smoothing Device



Elite



Premiumlite

## Yb HR: HHG Source, High Flux, High Proton Energy, Most Efficient

**Tangor & Tangerine:** #Customization Function FemtoBurst™

#Trigger on Demand - FemtoTrig™ #SuperSync Control

**Key parameters:** Up to 300 W, Down to 15 fs, CEP

**Applications:** > Micromachining > Ultrafast Spectroscopy  
> High Harmonic Generation > Attoscience



Tangor 300

## Yb HE: Industrial Ytterbium Solution from few mJ to hundreds of mJ

**Magma:** #High Energy #Ultrafast Laser #Customizable Configuration

**Key parameters:** Up to 500 mJ, Down to 500 fs, Multi-kHz

**Applications:** > THz > ICS > Filamentation > Photocathode



Magma



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# 角分辨光谱解决方案

## 产品介绍



以机械臂转动沿角向逐角度扫描为特征的角分辨技术



基于傅里叶变换,以沿直线逐角度扫描为特征的角分辨技术



基于傅里叶变换,以平面全角度瞬态采集为特征的角分辨技术

## 产品功能

- ◎ 角分辨透反射光谱检测
- ◎ 角分辨荧光光谱检测
- ◎ 角分辨偏振光谱检测

## 产品特点

- ◎ 自动化运行,便捷操作
- ◎ 实现不同角度的入射和接收光谱检测
- ◎ 实现一套系统,多种测试功能
- ◎ 扩展包括:偏振、外接光源、分子取向、光栅形貌

## 产品参数

测量模式	参数
波段	7种测量模式
适配样品尺寸	220~2500nm
波长分辨率	$\mu\text{m}$ ~mm
角度范围	0.5nm (视光栅而定)
角度分辨率	0~360°
光源	0.5°
扩展性	氙灯(紫外),卤素灯(可见)
扩展性	可外接光源、偏振配件等

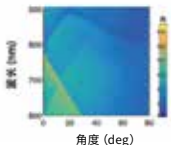
注:具体的参数与配置有关,详情可咨询工程师

## 典型案例

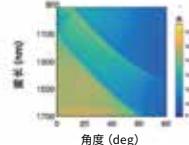
### SPR 金属传感



SPR 金属材料结构示意图



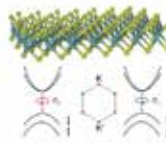
角度 (deg)



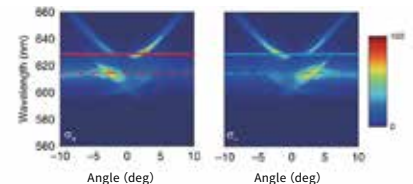
角度 (deg)

角分辨反射光谱图

### 二维材料能谷激子角分辨辐射调控



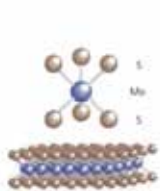
二维材料结构示意图<sup>2</sup>



不同偏振态下二维材料角分辨色散图<sup>2</sup>

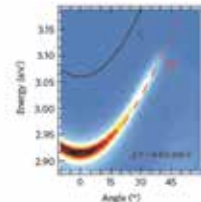
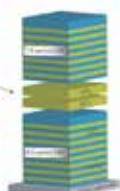
2. Wang et al. Light: Science & Applications (2020) 9:148

### 光学微控角分辨光谱探测



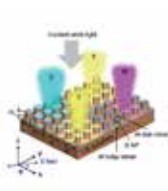
MoS<sub>2</sub>纳米材料与平板微腔<sup>1</sup>

1. X. Liu, et al., Nat. Photon. 9, 30 (2014)



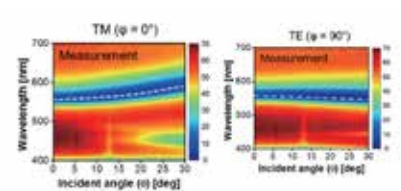
光学微腔角分辨色散图<sup>1</sup>

### 超构材料角分辨光谱



超构材料(结构色滤光片)结构示意图<sup>1</sup>

1. Wenjing Yue, et al., Laser Photonics Rev. 11, No.3(2017)



不同偏振态下超构材料角分辨色散图<sup>1</sup>

## 典型应用领域

光子晶体、纳米材料、表面等离子体、光学镀膜、光栅衍射效率、衍射光波导、超构材料、微腔光子器件、结构色、超表面透镜、钙钛矿

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## Topcis

SC1: Laser irradiation effect and mechanism

SC2: Plasmas and optics physics

SC3: Laser spectrum technology and applications

SC4: High power lasers

SC5: Micro-nanophotonics



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