Q-BASIS 2023

Quantum Beam Application for Sciences and Industres2023

24-27 April 2023

SANKEN, Osaka University, Japan

24 - 27 April 2023

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CALL FOR PAPERS

SCOPE

- High-power lasers, quantum beams and applications
- Laser and quantum beams for imaging, inspection and production
- Laser electron acceleration and FELs
- Ion beam generation and medical applications
- Material science and engineering with quantum beams
- Chemistry, biology and medicine with quantum beams
- Novel particle acceleration principles and applications
- Numerical experiments in quantum beam researches
- U.S. - Japan Forum for Advanced Accelerators

Invited Speakers

Mei Bai, SLAC, Stanford Univ. (USA)
Laurent Berthe, PIMM, CNRS (France)
Liming Chen, Shanghai Jiao Tong Univ. (China)
Min Chen, Shanghai Jiao Tong Univ. (China)
Marie-Emmanuelle Couprie, SOLEIL Synchrotron (France)
Eric Esarey, Lawrence Berkeley National Lab. (USA)
Domenico Furfari, Airbus Operations GmbH (Germany)
Spencer Gessner, SLAC, Stanford Univ. (USA)
Noboru Hasegawa, KPSI, QST(Japan)
Yusuke Ito, Univ. Tokyo (Japan)
Takayasu Kawasaki, KEK (Japan)
Thomas Kluge, Helmholtz-Zentrum Dresden-Rossendorf (Germany)
Masahiko Koizumi, Osaka Univ. (Japan)
Rodrigo Lopez-Martens, LOA, Ecole Polytechnique (France)
Fesseha Mariam, Los Alamos National Lab. (USA)
Haruo Miyadera, Toshiba Energy Systems & Solutions Corporation (Japan)
Takeharu Nagai, Osaka Univ. (Japan)
Tomas Mocek, HiLASE (Czech Rep.)
Keiichi Nakagawa, Univ. Tokyo (Japan)
Kei Nakamura, Lawrence Berkeley National Lab. (USA)
Makoto Ochiai, Toshiba Energy Systems & Solutions Corporation (Japan)
Yoshie Otake, RIKEN (Japan)
Tomokazu Sano, Osaka Univ. (Japan)
Takashi Sekine, Hamamatsu Photonics K.K. (Japan)
Antoine Snijders, Lawrence Berkeley National Lab. (USA)
Kentaro Uesugi, JASRI (Japan)
Yasunobu Yamashita, Osaka Univ. (Japan)

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Tomas Mocek, HiLASE (Czech Rep.)
Domenico Furfari, AIRBUS Operations GmbH (Germany)
Omar Hatamleh, NASA Johnson Space Center (USA)
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Rodrigo Lopez-Martens, LOA, Ecole Polytechnique (France)
Marie-Emmanuelle Couprie, SOLEIL Synchrotron (France)
Leonida A. Gizzi, INO-CNR / INFN (Italy)
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François Sylla, SourceLAB-Laser Plasma Technologies (France)

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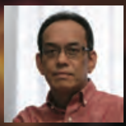

Masaki Kando,
KPSI, QST (Japan)

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April 24 (MON)

Time	Session / Chair	No.	Speaker	Affiliation	Title of talk
10:00 - 10:30 (each 5 - 10min)	Opening (Chaired by Y. SANO, T. HOSOKAI and M. KANDO)		Conference Chair		Opening, welcome to Q-BASIS 2023
			Tohru SEKINO	SANKEN, Osaka U., Japan	Welcome to SANKEN, Osaka University
			Hiroyuki KAMAI	MEXT, Japan	Greetings from MEXT (Ministry of Education, Culture, Sports, Science and Technology)
10:30 -11:00 Invited	Application of high-power lasers (Chaired by Y. SANO)	24A-01	Domenico FURFARI	Airbus, Germany	The use of Lights for Structural Performance Enhancement of Metallic Airframes. LEOPARD, a Laser Shock Peening industrial solution for Maintenance Repair Overhaul Use
11:00 -11:30	Break				
11:30 -12:00 Invited	Application of high-power lasers (Chaired by K. NOMURA)	24A-02	Laurent BERTHE	PIMM, CNRS, France	New advance on laser shock generation and related applications : Laser shock peening, laser adhesion test and damaging
12:00 - 12:30 Invited		24A-03	Noboru HASEGAWA	KPSI, QST, Japan	Development of a laser hammering system for tunnel and bridge concrete inspection using the high-power lasers
12:30 - 14:00	LUNCH TIME **12:30 ～ Group Photo**				
14:00 -14:30 Invited	Laser-material interaction for science and industry (Chaired by T. MOCEK)	24P-01	Kenichi ISHIKAWA	U. of Tokyo, Japan	Building Artificial Intelligence, Science and Theory for Smart Laser Manufacturing
14:30 - 15:00 Invited		24P-02	Yusuke ITO	U. of Tokyo, Japan	Ultrafast processing of transparent materials by selective absorption of continuous-wave laser into transiently excited electrons
15:00 -15:30 Invited		24P-03	Tomokazu SANO	Osaka U., Japan	Femtosecond Laser-Shock Processing: Fundamentals and Applications
15:30 - 16:00	Break				
16:00 -16:30 Invited	Quantum beams for material science and industry (Chaired by T. SANO)	24P-04	Makoto OCHIAI	Toshiba ESS, Japan	Achievements and future expectations of laser applications for energy solutions
16:30 - 17:00 Invited		24P-05	Kentaro UESUGI	JASRI, Japan	High speed 2D/3D X-ray imaging at SPring-8
17:00 -17:30 Invited	High-power laser development and applications (Chaired by S. TOKITA)	24P-06	Tomas MOCEK	HiLASE, Czech Rep.	Advanced DPSSL technologies and applications at HiLASE
17:30 -18:00 Invited		24P-07	Takashi SEKINE	Hamamatsu Photonics, Japan	A 100 J, 10 Hz operation with LD pumped Yb:YAG ceramics laser

April 25 (TUE)

Time	Session / Chair		Speaker	Affiliation	Title of talk
9:00 - 9:30 Invited	Quantum beam applications for imaging and inspection (Chaired by T. KANAI)	25A-01	Haruo MIYADERA	Toshiba ESS, Japan	Muon imaging and applications
9:30 - 10:00 Invited		25A-02	Fesseha MARIAM	LANL, USA	The LANL Proton radiography Facility and Investigations toward Achromatic Imaging
10:00 - 10:30 Invited		25A-03	Yoshie OTAKE	RIKEN, Japan	RIKEN Accelerator-driven compact neutron system and its applications and achievements
10:30 - 11:00	Break				
11:00 -11:30 Invited	Quantum beams for medical and biological science & engineering (Chaired by M. NOZAKI)	25A-04	Masahiko KOIZUMI	Osaka U., Japan	Radiation Sensitization for Radiation Therapy
11:30 -12:00 Invited		25A-05	Thomas KLUGE	HZDR, Germany	High Energy Proton Acceleration at DRACO-PW and Radiobiological Applications for Medical Tumor Therapy Research
12:00 - 12:30		25A-06	Kiminori KONDO	KPSI, QST, Japan	Development of laser driven injector for a compact heavy ion radiotherapy system
12:30 - 14:00	LUNCH TIME （Organization Committee Meeting of US-Japan Forum for Advanced Accelerators）				
14:00 -14:30 Invited	Quantum beams for medical and biological science & engineering (Chaired by K. KONDO)	25P-01	Antoine SNIJDERS	LBNL, USA	The BELLA PW laser proton beamline: a new platform for ultra-high dose rate radiobiological research
14:30 - 15:00 Invited		25P-02	Kei NAKAMURA	LBNL, USA	Proton beamlines for radiation biology application at the BELLA PW facility
15:00 -15:30 Invited		25P-03	Takayasu KAWASAKI	KEK, Japan	Terahertz radiation to amyloid fibrils
15:30 - 16:00	Break				
16:00 - 16:30 Invited	Quantum beams for medical and biological science & engineering (Chaired by T. KLUGE)	25P-04	Keiichi NAKAGAWA	U. of Tokyo, Japan	Single-shot ultrafast imaging for observation of non-repetitive laser-induced plasma and shockwaves
16:30 - 17:00 Invited		25P-05	Takeharu NAGAI	Osaka U., Japan	Use of quantum beams in improving the properties of glowing pants
17:00 -17:20		25P-06	Tomonao HOSOKAI	Osaka U., Japan	Drug discovery with high-energy electron beams
17:20 - 17:40 Invited		25P-07	Yasunobu YAMASHITA	Osaka U., Japan	Chemotherapy triggered by electron beams

Banquet	19:00 - 21:00	Senri Hankyu Hotel

April 26 (WED)

Time	Session / Chair		Speaker	Affiliation	Title of talk
9:00 - 9:10	Joint session with U.S. - Japan Forum for Advanced Accelerators (Chaired by M. YOSHIDA and M. BAI)	26A-01	Mitsuhiro YOSHIDA	KEK, Japan	Introductory talk
9:10 - 9:30 Invited		26A-02	Mei BAI	Stanford, USA	Grand challenges of future colliders
9:30 - 10:00 Invited		26A-03	Eric ESAREY	LBNL, USA	Laser plasma accelerator research at the BELLA Center
10:00 - 10:30 Invited		26A-04	Robert Joel ENGLAND	Stanford, USA	Particle Acceleration Using Laser-Driven Photonic Structures
10:30 - 11:00	Break				
11:00 -11:30	Laser electron acceleration and FEL (Chaired by R. LOPEZ-MARTENS)	26A-05	Masaki KANDO	KPSI, QST, Japan	Current status of the MIRAI free-electron laser project using laser accelerated electron beams in Japan
11:30 -12:00 Invited		26A-06	Marie-Emmanuelle COUPRIE	SOLEIL, France	The COXINEL seeded Free Electron Laser driven by the HZDR Laser Plasma Accelerator
12:00 -12:20 Invited		26A-07	François Sylla	SourceLAB, France	KAIO-BEAMLINE, à modular high repetition rate laser electron accelerator for broad range of applications
12:20 - 15:30	Lunch （Q-BASIS 2024 Kickoff Meeting） / **Poster presentations at SANKEN CReA (Chaired by Y. Gu and A. Rondepierre)**				
15:30 - 16:00 Invited	Laser electron acceleration and FEL (Chaired by M. COUPRIE)	26P-01	Rodrigo LOPEZ-MARTENS	LOA, France	Lightwave control of relativistic plasmas
16:00 -16:30 Invited		26P-02	Liming CHEN	SJTU, China	Ultra-high charge electron acceleration and nuclear applications
16:30 - 17:00 Invited		26P-03	Min CHEN	SJTU, China	Recent progresses of laser plasma based electron acceleration and radiation at Shanghai Jiao Tong university
17:00 -17:20	Closing (Chaired by Y. SANO, T. HOSOKAI and M. KANDO)		Conference Chair		Closing, announcement of Q-BASIS 2024

Poster presentations at SANKEN CReA (Chaired by Y. Gu and A. Rondepierre)

Poster No.	Presenter	Title
PO-01	Boyuan Li	Efficient high-order harmonic generation via surface plasma compression with lasers
PO-02	Alexandre Rondepierre	Challenges to make LPA viable for industrial XFEL sources
PO-03	Wenchao Yan	Fold-rotational Symmetric Radiation Vortex stem from Nonlinear Thomson Scattering of Intense Laser with Circular Polarization Topology
PO-04	Duthika Dilrangi Perera	Development of a compact electron source using self-modulated laser wakefield acceleration driven by a Sub-TW class laser
PO-05	Sadaoki Kojima	Induction heating for desorption of surface contamination for high-repetition laser-driven heavy-ion acceleration
PO-06	Masayasu Hata	Numerical simulation of laser ion injector for quantum scalpel project
PO-07	Matthew S Freeman	LPA-Driven Electron Radiography at OMEGA EP
PO-08	Jinfeng Yang	Ultrafast electron microscopy with relativistic femtosecond electron pulses
PO-09	Tsuneto Kanai	Temperature-driven, Sub-100-fs Mode-locked Fiber Oscillators Based on the Symmetry-Broken Nonlinear Polarization Evolution Method
PO-10	James Kevin Koga	Simulation of self-focusing ultrashort femtosecond lasers in air for the detection of viruses and VOCs
PO-11	Hitoshi Soyama	Laser Cavitation Peening Using a Nd:YAG Laser with and without Q-switch
PO-12	Daiki Okazaki	Development of a 6-mJ, 100-Hz, femtosecond Yb:CaF2 regenerative amplifier for driving 4-micron KTA parametric amplifiers
PO-13	Shigeki Tokita	Temperature-driven, Sub-100-fs Mode-locked Fiber Oscillators Based on the Symmetry-Broken Nonlinear Polarization Evolution Method
PO-14	Kazufumi Nomura	In-line Detection of Internal Defects in Fillet Welded Sheet of Lap Joint by Laser Ultrasonic and Its Robotic Application Using Microchip Laser
PO-15	Haruya Matsumoto	Development of a Start-to-End simulation code for the laser-driven ion injector
PO-16	Tatsuhiko Miyatake	Optimization of laser irradiation conditions for high-brightness beam generation in laser-driven ion beams
PO-17	Kai Huang	Temporal measurement of laser wakefield electrons via electro-optic sampling
PO-18	Yuta Suzuki	Development of a high-power terahertz source baced on laser-produced plasma for electron acceleration
PO-19	Yoshio Mizuta	Laser peening with microchip laser mounted on a controlled robotic arm
PO-20	Shigeru Yamamoto	Undulator light source with a compact, slender and lightweight frame based on a magnet technology developed for very-short-period undulators
PO-21	Yoshihide Honda	Current status and prospect of RLQBS in SANKEN
PO-22	Thanh-Hung Dinh	Development of a compact 50 TW laser for energetic quantum beam generation toward practical applications
PO-23	Alexei Zhidkov	Plasma Effects on Electron Beam Bunching in External Periodic Fields
PO-24	Naveen Chandra Pathak	Focusing and reduction of correlated energy spread of chirped electron beams in passive plasma lens.
PO-25	Yanjun Gu	Study of gas jet stability for LWFA in the context of shock injection
PO-26	Zhan Jin	An Overview of Laser Wakefield Acceleration Platform in Spring-8
PO-27	Shingo Sato	Characterization of Plasma Targets for Electron Beam Generation in Laser Wakefield Acceleration Systems
PO-28	Illia Zymak	The electron beam diagnostic system for MeV range high repetition rate LWFA sources
PO-29	Masao Gohdo	The electronic structure of the solvated electron investigated by pulse radiolysis
PO-30	Nobuhiko Nobuhiko	Beam pointing control of laser wakefield accelerator by shaping near field profile of laser pulse
PO-31	Yusa Muroya	Picosecond pump-probe study on radiation-induced primary reaction processes of solutions at extreme conditions

April 27 (THU)

Optional tour	Bus Tour Schedule 10:30 Departure from Senri Hankyu Hotel 11:50 – 12:45 Lunch(Japanese style) 13:30 Arrival at RIKEN SPring-8 Campus (VisitingSPring-8, SACLA and LAPLACIAN) 16:00 Departure form RIKEN SPring-8 Campus 18:00 Arrival at Senri Hankyu Hotel 18:30 Arrival at Shin-Osaka Station *Arrival time may be delayed due to traffic conditions.	RIKEN SPring-8 Center

Invited Talk and Oral Presentation

The use of Lights for Structural Performance Enhancement of Metallic Airframes. LEOPARD^{TM}, a Laser Shock Peening industrial solution for Maintenance Repair Overhaul Use

Domenico Furfari(1), Richard Redon(2), Romain Ecault(3), Olivier Collin(3)
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(2) Airbus Central Entities SaS, Blagnac, France
(3) Airbus Operations SaS, Toulouse, France
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Keywords: Laser Shock Peening, Fatigue, Maintenance Repair Overhaul, crack growth, residual stress, design, repair, maintenance, aircraft structure

One application of High Power Laser is the use of pulsed lasers to generate high pressure as a consequence of plasma formed at the near surface of a material subjected to the laser beam struck. The rapidly expanding plasma generates pressure shock waves traveling into the material causing plastic deformation and the elastic bulk material surrounding the affected material forms residual stress fields.
The residual stresses induced by the Laser Shock Peening (LSP) process can be used to improve the economical and ecological impact of an aging fleet as well as of future aircraft [1]. The final stress state of an aircraft component subjected to the superimposition of external load and internal stresses by the LSP can affect the fatigue, wear, and corrosion behavior of the structural components.
Laser Shock Peening is one of many surface technologies commonly used in the aeronautical industry to ensure salvage in hot spots for fatigue and crack growth performance. The mechanical performance in terms of fatigue and crack propagation in aircraft components containing residual stresses induced by LSP is well known and many potential applications have been reviewed in several publications [2], [3].
In [4] and [5] an example of application of LSP in fatigue critical components of military aircraft as a retrofit maintenance task in a fixed established repair station is described. The application of LSP in Commercial Aircraft while in Maintenance Repair and Operations (MRO) is particularly challenging because of the rigid and complex mirror-based beam delivery system characteristic of commonly used LSP systems in production envinroment (i.e. stationary equipment). When a commercial aircraft is in an MRO station for a scheduled maintenance task or for repairs and modifications, unscheduled Aircraft on Ground (AoG) must be avoided and stationary LSP system are not compatible with such envinroment. To realize LSP as a retrofit solution in commercial aircraft in MRO a simple setup and easy transportable equipment is needed. For this scope a low energy portable LSP equipment has been developed by Airbus. The first commercially available industrial solution named LEOPARD^{TM} will be presented.
It has been reported that compressive residual stress above 1mm depth in Al Alloys is possible if a high energy laser peening system is used [6]. A deeper than 1mm compressive residual stress induced by low energy LSP system ($\leq$200mJ, pulse width of $\leq$20nsec) and associated small laser spot size (e.g. 0.7mm diameter) in Al7xxx series aluminum has been demonstrated and the results is shown in the fig.1.
1mm compressive residual stress depth using low energy system would be enough to extend the fatigue life of aircraft component made of AA7175-T7351 as shown in fig.2 which summarize the fatigue test results of four point bending coupon subjected to LSP treatment compared with bare material and shot peening.
Residual stresses induced by the LSP process can also be used to shape components and this technique is referred to as Laser Peening Forming. In the past decade, it has been demonstrated that microchip pulsed laser characterized by low energy peaks (e.g. <15mJ) and very short pulse duration (e.g. in the range of 1nsec) would be enough to generate compressive residual stresses into metallic material for structural application to improve the fatigue behavior [7], [8]. Microchip lasers enable the development of very compact laser peening devices named hand held and palm top size laser peening systems. Such small and compact laser peening devices open the door for implementation of laser peening forming with a fully integrated digitized industrial setup solution that will be presented by the authors.

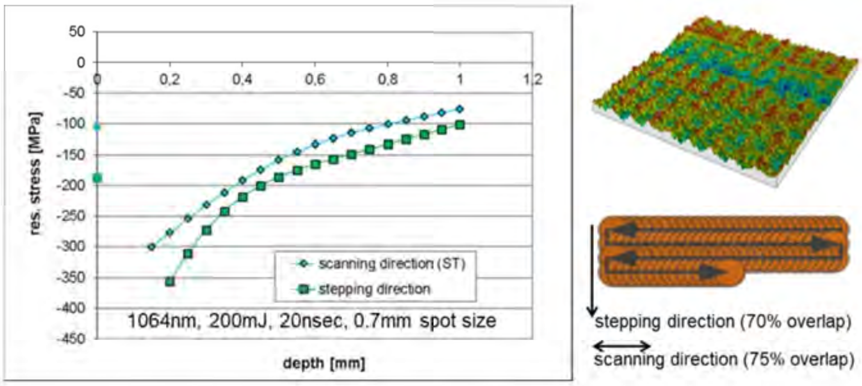

Fig.1 Residual Stress profile in Al7xxx series after LSP by low energy system

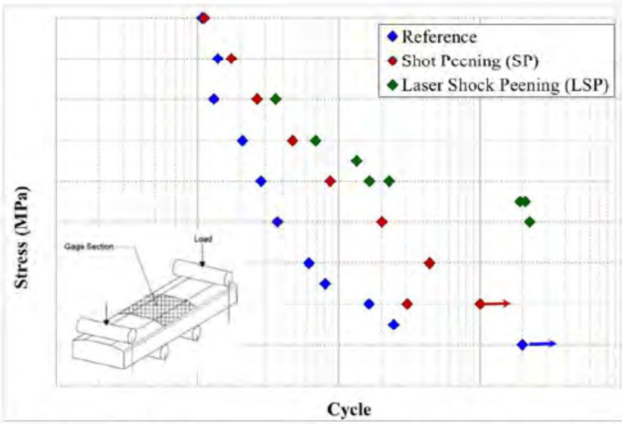

Fig.2 Wöhler curves of coupons made of 7175-T7351 material in as machined condition (reference), after shot peening and LSP

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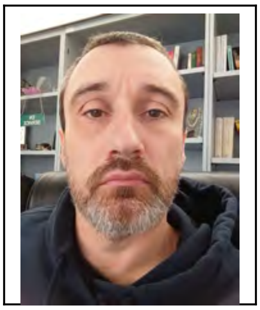
Title: New advance on laser shock generation and related applications : Laser shock peening, laser adhesion test and damaging.



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Keywords: Shocks, laser, Plasma, Material, Material processing

Shocks produced by laser plasma consists in irradiating material with focused beam in the range of GW/cm2 and ns pulse duration. For applications, target is covered by a transparent medium to confine plasma and reach higher pressure than in direct regime. In reaction of plasma release, induced stresses in material are in the range of GPA and strain rate of $1e^6 s^{-1}$. Such sollicitations can be used to reinforce surfaces (Laser Shot Peening) , adhesion test of interfaces (LASer Adhestion Test), controlled damaging productions and material study in extreme conditions. This presentation presents recent results on current issues concerning laser interaction in confined regime (Plasma pressure control, loading for small spot diameter [1,2]), design process by numerical simulations (In elasto-plastic regime) and development growing Technology Readiness Level for applications (LSP with High repetition rate [3], Laser beam quality impact on processes, flexible solid confinement [4]). Some perspectives, new applications and open issues are also presented for discussions [5].

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24A-03

Development of a laser hammering system for tunnel and bridge concrete inspection using the high-power lasers.

Noboru Hasegawa[1], Masaharu Nishikino[1,2], Hajime Okada[1,2], Shuji Kondo[1,2], Katsuya Sakamoto[2], Shigeru Kogure[2], Satoshi Tomoto[3], Yuki Yamada[3] and Hikaru Nakamura[4]

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Keywords: Inspection of infrastructures, laser hammering, high power laser application

Periodic maintenances are required for safety use of concrete infrastructures such as tunnels and bridges. Currently, new inspection machines are being considered to solve an insufficiency of inspectors in near future. For the inspection of tunnel lining concrete, laser hammering system[1)] has been developed and trial work was already started with a construction consultant company[2)] (figure 1). On the other hand, for the inspection of bridge concrete, new technologies are still in the development stage because it requires long-distance measurement (several tens of meters). In this talk, we introduce the recent development of laser hammering system for tunnel and bridge.

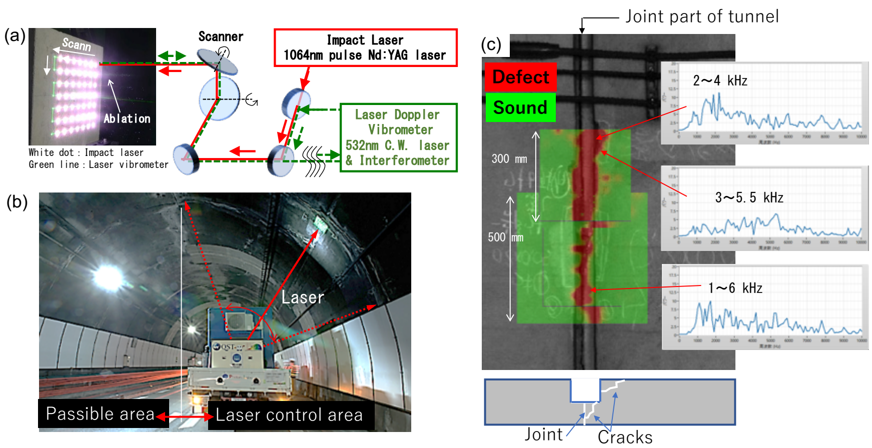

Fig.1 (a) Scheme of Laser hammering system (LHS). (b) Tunnel inspection by LHS. (c) Inspection result of tunnel joint part.

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Building artificial intelligence, science and theory for smart laser manufacturing

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Keywords: Ultra-short pulse laser, Laser material processing, Cyber-physical system

Laser processing is a versatile technique with numerous adjustable parameters, such as wavelength, pulse duration, and pulse energy. Currently, these parameters are optimized through human experience and intuition. However, to address the growing need for mass customization in the emerging super smart society, we aim to replace these methods with data-driven approaches [1], artificial intelligence (AI), and scientifically grounded theories that highly integrate cyberspace and physical space (CPS). To facilitate smart production, we develop CPS laser manufacturing that propose optimal processing parameters based on simulations in cyberspace.

Laser processing is a complex, cutting-edge field that spans multiple scales and disciplines. For example, how atoms, molecules, and materials behave under intense laser irradiation is at the forefront of atomic, molecular, optical, and condensed matter physics, involving highly nonlinear, dynamical processes. One of our focuses is to understand and simulate these strong laser-matter interactions by employing various techniques, including AI and even starting from the first principles of quantum mechanics. We have established a nationwide STELLA network of approximately 100 researchers, comprising both theoreticians and experimentalists, with the latter specializing in advanced data collection and operando measurement techniques.

The deep learning simulators within our network are capable of accurately and efficiently replicating the laser drilling process in physical space. We are currently developing a range of innovative methods to precisely calculate the laser-driven electron dynamics and energy transfer from the laser to the materials. Furthermore, by combining first-principles and molecular dynamics calculations, we can quantitatively reproduce the ejection of atoms from laser-irradiated surfaces. On a macroscopic scale, our research also involves the study of multiphysics modeling for complex thermal multiphase flows.

This project is supported by MEXT Quantum Leap Flagship Program (MEXT Q-LEAP) Grant Number JPMXS0118067246.

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Ultrafast processing of transparent materials by selective absorption of continuous-wave laser into transiently excited electrons

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Keywords: Transient and selective laser processing, Ultrashort pulse laser, Imaging, Material processing

Femtosecond laser processing of transparent dielectric materials such as glass and sapphire is expected to be applied in various applications in the fields of photonics, electronics, and bioengineering. These applications require precision fabrication of holes with a diameter on the order of 10 μm and a depth of over 100 μm with high speed. However, there are two major problems in femtosecond laser drilling of transparent dielectric materials: low processing speed and low quality of the generated surface [1]. Because the depth of the hole drilled by one femtosecond laser pulse is limited to be approximately 1 μm, hundreds of pulses must be focused to create a hole with a depth of over 100 μm. Furthermore, every time laser pulse is focused, a strong stress wave is generated inside the material, creating cracks which inhibit the precision processing.

In this talk, we first discuss the mechanisms of emergence of the problems, and then introduce a novel processing method, transient and selective laser (TSL) processing, which solves both the problems [2]. In TSL processing, an ultrashort laser pulse is firstly delivered to the material to generate filamentary region (filament) where electrons are excited locally and transiently. Then, a continuous-wave (CW) laser beam, which has a wavelength transparent to the material, is coaxially delivered to the sample, so that the filament is selectively heated (Fig. 1(a)). Because the heating process occurs rapidly, the material is immediately evaporated, and thus ultrafast processing is achieved (Fig. 1(b)). Furthermore, TSL processing can achieve crackles processing because it requires only one shot of ultrashort laser pulse, resulting in the reduction of generation of stress waves. The further detail of the technique and physics behind the processing will be explained in the talk.

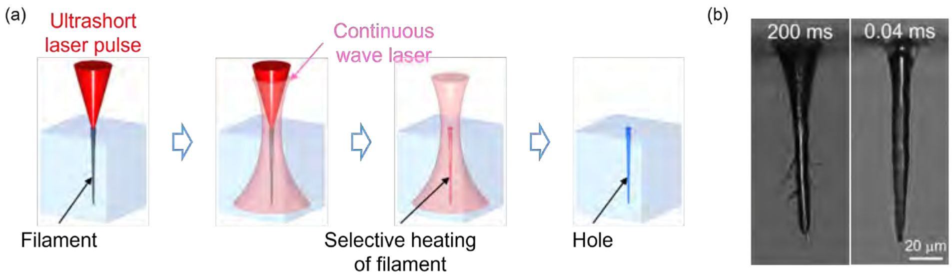

Fig.1 (a) Illustration of transient and selective laser (TSL) processing, (b) comparison of conventional (left) and proposed methods (right).

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24P-03

Femtosecond Laser-Shock Processing: Fundamentals and Applications

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Keywords: Femtosecond laser, femtosecond laser-driven shock wave, Dry laser peening

Femtosecond laser-shock processing or Dry laser peening (DLP) enables improving fatigue performance of metallic materials using femtosecond laser pulses without a sacrificial overlay in air. Direct irradiation of a solid surface with a femtosecond laser pulse drives an intense shock wave that propagates into the solid. Such a shock wave driven by the femtosecond laser pulse deforms a material plastically. Heat-affected and melted zones formed by a femtosecond laser pulse are much smaller than those produced by a nanosecond laser pulse due to its extremely short pulse width. Therefore, peening without a sacrificial overlay in air is possible using femtosecond laser pulses. The objective of this study is to verify the effectiveness of the dry laser peening for laser-welded 2024 aluminum alloy containing welding defects by investigating the mechanical properties. Changes of hardness, residual stress and fatigue properties of laser-welded 2024 aluminum alloys between before and after the DLP were investigated in this study. As a result of plane bending fatigue test of the laser-welded joints, the fatigue life of the DLPed specimen was improved as much as 15 times in comparison with the as-welded specimen at stress amplitude of 120 MPa. This DLP is found to be effective to other kinds of aluminum alloys such as 6061 and 7075 aluminum alloys, therefore this process has a potential to be applied to variety of industrial fields such as automotive, rail, aircraft, and space industries.

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Achievements and future expectations of laser applications for energy solutions

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Keywords: Laser peening, Laser-ultrasonics, Microchip lasers, Heavy-ion radiotherapy, Superconducting rotating gantry

We, Toshiba Energy Systems & Solutions Corporation, provides energy solutions for sustainable society and life. We offer various solutions in all aspects of energy systems such as "Generation", "Transmission", "Storage" and "Smart utilization" with our technologies, products, and services.
In power generation field, we have recently been focusing on renewable energy and CO_2 capture and storage/utilization and so on. However, we originally have delivered more than 2,000 units /over 200GW of turbine generators to 43 countries around the world and most of them continue to support our daily lives today. As for nuclear, we have constructed 26 light water reactors in Japan and working on the decommissioning of Fukushima area, as well as the development of next generation reactors and small modular reactors.

In particular, operation and maintenance services for power plants are one of the important technological fields we have been working on. We have developed and used some laser applications as an inspection, maintenance and repair technology for major components of power plants such as nuclear reactor internals and turbine generators for more than 20 years. We have contributed to the stable and safe operation of power plants by utilizing not only the basic characteristics of lasers, such as high power density and high directivity, but also the characteristics that can be applied to remote and narrow areas even in underwater environments. Our representative technologies include laser peening that prevents the initiation of cracks on important structures and laser-ultrasonic that detects small cracks to enable efficient repair. We are currently working on ubiquitous inspection and measurement systems, such as laser-ultrasonics using microchip lasers, as well as stress corrosion cracking prevention and fatigue strength improvement using laser peening.

We conduct advanced research not only for future energy, but also for contributing to society with technology related to promoting carbon neutrality, improving infrastructure resilience and enhancing Quality of Life (QoL).
In the QoL field, we are working on "non-surgical cancer treatment," and have contributed to develop heavy ion therapy systems including superconducting rotating gantries and beam irradiation functions.

In the future, we will continue to work on technology development related to carbon neutrality, resilience, and QoL by utilizing quantum applied technologies such as superconductivity, accelerators, and lasers.

High speed 2D/3D X-ray imaging at SPring-8

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Keywords: Synchrotron Radiation X-ray, High speed imaging, micro-tomography

Synchrotron Radiation X-rays have high brilliance. It is suitable for high-resolution and high-speed X-ray imaging. Recently effective spatial resolution of 100nm and high-speed imaging of over 20kHz (Figure 1) have been possible, and phase contrast measurement with concentration resolution of mg/cm3 or higher is also possible using optical systems for phase measurement.

At SPring-8, these X-ray imaging techniques are available to users by taking advantage of the features of multiple beamlines. The measurement targets are various, including biological samples, rocks and minerals, and metallic materials. Recently, many dynamic observations such as the fracture process of metallic materials when external force is applied or the structural change of batteries during charging and discharging have been performed.

These measurement techniques and several measurement examples are shown at the conference.

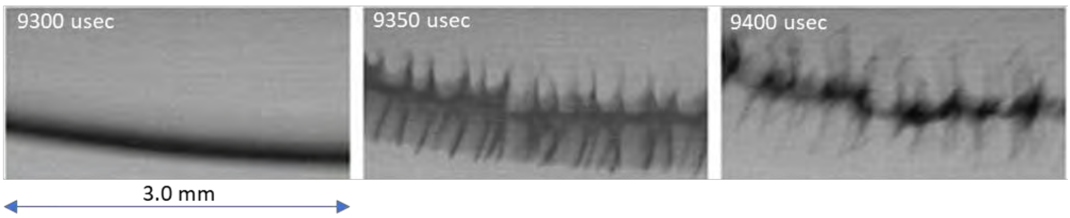

Fig.1 An example of high-speed X-ray imaging: A fuse blowing due to an overcurrent was captured. BL20B2 Experimental hatch 1 is used. Using a multilayer monochromator at 40 keV X-rays. The pixel size and frame rate are 3.0um/pixel and 20kHz, respectively.

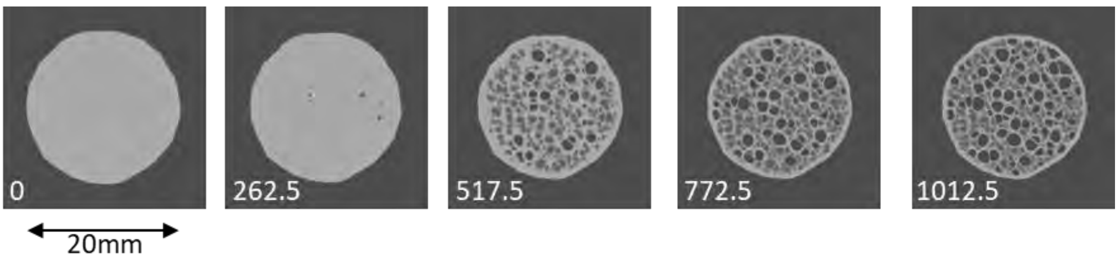

Fig.2 The time lapse CT images of tensile loading of rubber. The number at the left bottom shows the time in sec from the begging of CT scan.

Advanced DPSSL technologies and applications at HiLASE

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Keywords: diode pumped solid state laser, high average power laser, material processing

Recent advances in high average power laser technologies and applications at the HiLASE CoE will be presented. We have demonstrated efficient and stable operation of diode pumped solid state laser system BIVOJ delivering 145 J, 10 ns, 1030 nm pulses at 10 Hz thus confirming the power scalability of multi-slab cryogenic gas-cooled Yb:YAG amplifier technology. Recently, we have achieved kilowatt-class high energy frequency conversion at 515 nm and half-kilowatt-class at 343 nm, respectively. We have developed advanced thin-disk laser platform PERLA generating 1-ps pulses with an average power of a few hundred watts, exceptional beam quality and power stability. Both laser systems are used for diverse hi-tech industrial and scientific applications.

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Repetitive 100 J class LD pumped cryogenic Yb:YAG ceramics Laser

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Keywords: Laser diode, Solid-state laser, Yb:YAG ceramics, Helium gas cooling

High energy with repetitive pulsed diode-pumped solid-state lasers(DPSSLs) with over 1 kW average power are developed for industrial and academic applications fields such as laser processing, laser acceleration, laser fusion and so on[1-7]. As a feasibility study of 10 kW average power with 1 kJ at 10 Hz pulsed laser, we are developing 250 J at 10 Hz laser with laser diode(LD) pumped cryogenically cooled Yb:YAG ceramics laser(Fig. 1). As a results, we have demonstrated a 253 J laser energy output with 0.2 Hz repetition rate(Fig. 2)[6]. And now, we are focused on the development for 10 Hz operation with 250 J energy. This research aim to clarify the possibility and technical issues to realize 1 kJ at 10 Hz output with cryogenic helium gas cooled Yb:YAG ceramics.

Fig.1 LD pumped 250 J Yb:YAG ceramics laser.

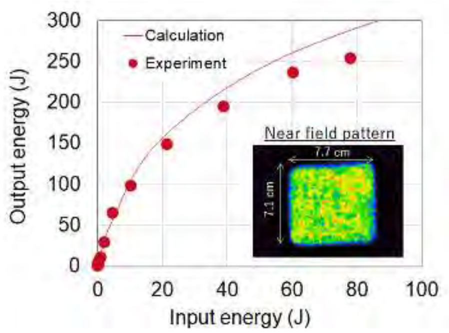

Fig.2 characteristics of 250 J DPSSL.

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Muon Imaging and Applications

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Keywords: Cosmic-ray muon, muon imaging, muon tracker

Cosmic-ray muons are created when highly energetic particles collide with the Earth's upper atmosphere. Initially, pions and kaons are produced which decay into muons, and at ground level, the muon flux is 10^4 /m^2/min. Cosmic-ray muon transmission imaging was invented in the 1950s [1] and applied to an Egyptian pyramid [2], and other large-scale objects. A more sensitive technique, muon scattering imaging, was invented at Los Alamos National Laboratory, which measures the scattering angles of muons [3]. The muon scattering imaging is selective to high-Z dense materials and is used to detect shielded packages of nuclear materials in a background of normal cargo [4]. Though the muon scattering tomography is a relatively new imaging method, many applications have been explored [5], and some muon trackers are already commercialized. Other nuclear applications include measurement of a reactor [6] and a dry cask: the world' s first muon reactor imaging was carried out in collaboration with Toshiba Coperation and LANL at Toshiba Nuclear Critical Assembly in 2013, where a reactor core and other reactor components were clearly imaged with a four-week measurement using LANL's Mini Muon Tracker of 1.2×1.2 m^2 detection area as shown in Fig. 1 [7].

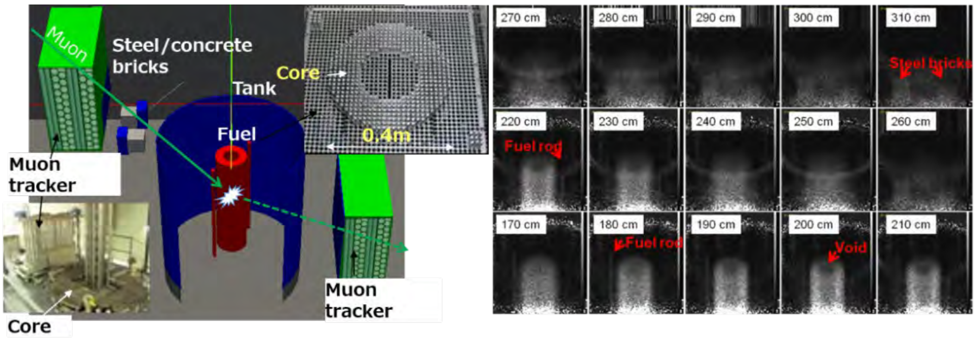

Fig.1 Geometry of reactor imaging at Toshiba NCA (left). Slices through the tomography in 10-cm steps along a line connecting the detector centers (right)

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The LANL Proton radiography Facility and Investigations toward Achromatic Imaging

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Proton radiography (pRad) at LANL is an imaging modality best suited for imaging dense materials up to 50 g/cm-2 at time scales of 100 ns. The temporal structure of the LANSCE 800 MeV proton beam allows the flexibility for multi-frame imaging over the duration of dynamic processes lasting up to 20 microsec or more. The LANL pRad facility has so far provided invaluable data on dynamic processes such as explosives and explosives-driven shock in materials. However, it is limited by chromatic effects that degrade the resolution of off-energy protons. Work currently underway aims to eliminate or mitigate these chromatic effects using a second-order achromatic magneto-optic imager. Our team aims to design, fabricate and test such an imager using low-energy electron beams (~25MeV) at the Idaho Accelerator Center. If successful, this will serve as a prototype that can be scaled up for use with 800-MeV protons. We will discuss the benefits and complexities of achromatic imaging over existing capabilities.

25A-03

RIKEN Accelerator-driven compact neutron system and its applications and achievements

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Keywords: Compact neutron system, non-destructive test, infrastructure, Quantum beams, Salt meter

We have been developing and upgrading Compact Neutron Systems and their applications at RIKEN since 2013[1]. There are two major goals of RANS project. One of the objectives is to construct a floor-standing type of compact neutron systems that enables non-destructive evaluation and analysis of materials and components using low-energy neutrons, which has not been possible until now on-site, and to demonstrate its achievements, thereby contributing to industrial applications and human resource development. Another major objective is to develop and demonstrate outdoors new, transportable, compact neutron systems for preventive maintenance of bridges and other large infrastructure structures, thereby contributing to extending the service life of social capital. Neutron scattering experiments such as imaging, neutron diffraction, and small-angle scattering have been performed on RANS and RANS-II, including for external user applications. As an urgent issue to prevent bridge accidents, we have developed an ultra-compact neutron salt meter, RANS-μ, for salt damage, which is one of the three most common causes of bridge accidents and have already conducted measurements on actual bridges[2]. In addition, we have succeeded in visualizing sedimentation by scattered neutron imaging, which visualizes the internal degradation of bridge decks from the road surface [3]. Efforts toward the practical application of RANS project will also be presented.

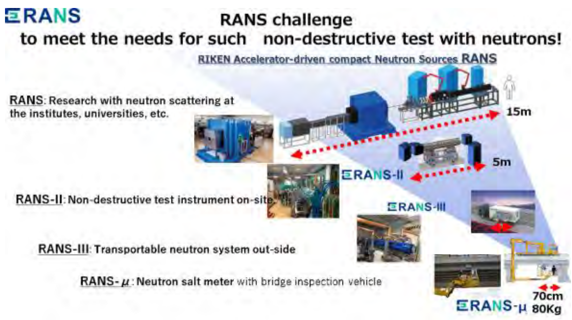

Fig.1 RANS challenge, RANS, RANS-II, III, μ

Fig.2 RANS-μ at a bridge

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Radiation Sensitization for Radiation Therapy

Masahiko Koizumi, Kazumasa Minami

Sensitization of radiotherapy is necessary to improve the clinical outcome of radiotherapy, i.e., tumor control and reduced damage to normal tissue.

In other words, it is necessary to increase the sensitivity of radiotherapy that means the effectiveness of radiotherapy in controlling tumors at equivalent doses.

For this purpose, three types of sensitizations can be considered: physical sensitization, chemical sensitization, and biological sensitization.

Physical sensitization is the enhancement of physical effects by focusing on the physical properties of the radiation itself.

Physical sensitization includes spatial and temporal sensitization.

Spatial intensification is to increase the concentration of the dose to the tumor site. Recent developments in radiotherapy equipment have focused on increasing the concentration of the dose and spatial physical sensitization. These include stereotactic irradiation (SRI) and intensity-modulated irradiation (IMRT) in external irradiation, and image-guided radiotherapy (IGRT) to accommodate occasional positional changes.

Temporal sensitization is also aimed at enhancing the effect of radiation irradiation by controlling it over time. The effect is enhanced by irradiating the same dose for a shorter period of time. In other words, the effect is enhanced by increasing the dose rate. In terms of dose rate, methods to increase the conventional dose rate of about 2 Gy/minute have been favored, and this has become known as ultra-high dose rate irradiation (Ultra HDR), which is now attracting attention as FLASH Therapy. The conventional fractionated irradiation method has been used for a long time, in which fractionated irradiation is performed across days to wait for recovery of normal cells and tissues and to extend the interval between irradiations.

Temporal and spatial physical sensitization is in any case aimed at enhancing the therapeutic effect = tumor control - normal exposure.

Chemical sensitization is a chemical method of sensitization by means of drugs. It is a chemical method to enhance the effect of the treatment by administering a chemical substance (drug) at or above the equivalent dose. The drug is namely “radiosensitizer”. Tumor control in radiotherapy is mainly focused on the indirect effects of DNA double-strand breaks caused by reactive oxygen species (ROS) damage. The tumor environment is hypoxic, and in a hypoxic environment, subsequent tumor control is reduced due to inferior ROS damage. The radiosensitizers that supplement this, i.e., cover the hypoxic environment by introducing oxidizing substances that substitute for ROS, have proven to be useful. These are called hypoxia sensitizers. Although chemical sensitizers, i.e. radiosensitizer have been tried for a long time, not many attempts have been made for clinical use in humans because of the increased risk of adverse events such as neurotoxicity. Recently, our laboratory has been investigating the use of a photosensitizing agent called Lavurchin, which is a photosensitizing substance produced by a deep-sea red alga. Other chemotherapeutic agents provide additive sensitization, which is used in combination therapy to enhance the therapeutic effect.

The last type of bio sensitization is one in which biological effects are used to enhance the radiotherapy efficacy ratio. Recently, immune effects have been attracting attention, and immune checkpoint inhibitors (ICIs) with CTLA-4 and PD-L1 antibodies by Dr. Allison and Dr. Honjo, who received the Nobel Prize in 2018, have significantly improved tumor control. The ICIs work well with RT to restore the original anti-tumor immunity of the body by initiating an immune response through antigen presentation by the tumor-inflammatory effect of RT and removing the immunosuppressive effects that cause the anti-tumor effect in the process. It is known that RT + ICI can enhance the abscopal effect, which has been increasingly investigated in recent years.

As described above, radio sensitization, i.e., enhancement of the simple irradiation effect of radiation by increasing the ratio of physical, chemical, and biological effects, has been gaining momentum. This is leading to the clinical application of radio sensitization, which increases the efficacy ratio of radiotherapy, i.e., tumor control is enhanced and normal tissues are better protected.

25A-05

Title: High Energy Proton Acceleration at DRACO-PW and Radiobiological Applications for Medical Tumor Therapy Research

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Keywords: Ultra-short pulse laser, Proton acceleration, Tumor therapy

In this talk I will report on the latest progress in the laser proton acceleration program at HZDR that is dedicated to apply next generation laser plasma based ion acceleration to tumor therapy. We performed the world's first model-conform dose-controlled animal irradiation with laser accelerated protons. I will outline the enhancements of the laser system and process understanding that lead to this milestone and touch on the next steps towards laser-plasma accelerators that are applicable for medical and biological tumor irradiation studies.

25A-06

Development of laser driven injector for a compact heavy ion radiotherapy system

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Keywords: Heavy ion radiotherapy, Laser driven ion acceleration, Injector, Quantum Scalpel

One of the most important advantage of laser driven acceleration, the size of the energetic accelerator could be much smaller than the conventional accelerator. Then the researcher of laser driven ion acceleration mentions that the possibility of the compact and the low cost particle cancer therapy machine, which will enable to bring the innovation in the radiotherapy. However, a few decades have passed from the start of the real experimental laser driven ion acceleration study. Not only ion acceleration, but also electron acceleration is not used as the real accelerator for some application. In Japan, JST-MIRAI large scale project has started from Nov. 2017, which is total ten years project. This project includes the development of not only electron accelerator for the compact XFEL but heavy ion injector for the heavy ion cancer therapy machine. The laser driven heavy ion injector could be installed for the next generation heavy ion cancer therapy machine called "Quantum Scalpel"[1]. In this system, the main accelerator is a synchrotron based on the super conducting magnet technology. Then the most important requirement to the laser driven heavy ion injector is the production of enough number of several MeV/u-class carbon beams continuously

In this study, the development of Quantum Scalpel will be introduced, and a present condition of the development of the laser driven carbon beam injector will be also shown.

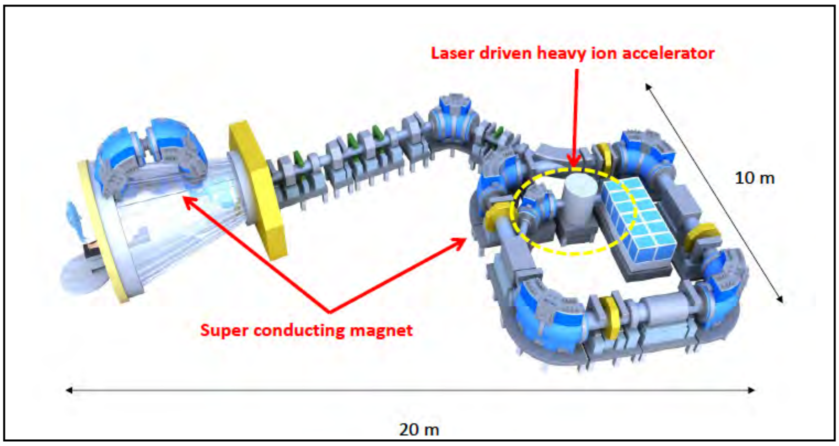

Fig.1 Schematic drawing of Quantum Scalpel. The injector for the main synchrotron accelerator could be based on the laser driven ion acceleration phenomena.

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The BELLA PW laser proton beamline: a new platform for ultra-high dose rate radiobiological research

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Keywords: Laser driven ion acceleration, proton therapy, radiation therapy

Radiotherapy is the current standard of care for more than 50% of all cancer patients. Recently, the beneficial differential effects on tumor versus normal tissues using the delivery of single, high radiation doses of >10 Gy at ultra-high dose rates (UHDR), has received increasing attention and is called the FLASH radiotherapy (FLASH RT) effect. However, extensive radiobiological research with UHDR electrons, X-rays, protons or carbon ions has not yet completely identified the underlying mechanisms of action for FLASH RT. Accelerator capabilities at the BELLA LasernetUS node at LBNL were extended by adding a magnetic proton transport system to the newly commissioned iP2 beamline. This allowed us to deliver petawatt laser-driven (LD) proton pulses of 10 MeV energy to irradiate radiobiological samples *in vivo* at ultra-high instantaneous dose rate (UHIDR). We investigated the differential sparing of LD protons on healthy tissues *in vivo* by measuring acute skin damage and late radiation-induced fibrosis in murine ears after high dose radiation exposure. In a first experiment at iP2, we demonstrated the irradiation of 7 mm diameter patches of mice ear *in vivo* with proton doses up to 39 Gy at an IDR of 10^8 Gy/s. Results were compared to conventional dose rate exposures, and the analysis of the biological data is pending. To further investigate the mechanism of the FLASH effect, we tested X-ray effects on peptide oxidation with the CONVDR X-rays (300 kVp) and at the Advanced Light Source synchrotron at LBNL, using UHDR 8-20 keV photons. These experiments will be repeated at the BELLA iP2 beamline. Current work is focused on determining the mechanism of the FLASH effect using UHDR LD protons and expanding our studies to investigate the efficacy of UHDR LD protons in eradicating tumor cells using mouse xenograft models. We will summarize our results to date.

Funding Acknowledgements

Work supported by U.S. Department of Energy Office of Science, Offices of Fusion Energy Sciences and High Energy Physics, Contract No. DE-AC02-05CH11231 and LaserNetUS (https://www.lasernetus.org/) and LBNL Laboratory Directed Research and Development Grant, PI A. M. Snijders

Proton beamlines and applications at the BELLA PW facility

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Keywords: Laser-driven ion acceleration, Proton therapy, Defect engineering.

The BELLA Center has been pursuing laser-plasma acceleration (LPA) of electrons since its inception [1]. Laser-driven ion acceleration has also been explored at the BELLA PW facility with a relatively large f-number (~65) focus, providing protons up to 8 MeV with 35 J laser energy on target [2]. In 2022, a second interaction point (iP2) with a small f-number (~2.5) focus has been developed [3], enabling an on-target laser intensity beyond 10^{21} W/cm^2 and therefore higher energy ion beam generation. The iP2 has been commissioned with up to 17 J laser energy on target, providing a proton energy cut-off of 40 MeV. This presentation introduces our laser-driven proton beamlines at both large and small f-number interaction points as well as applications of laser-driven ion beams, such as ultra-high dose rate radiobiology and defect engineering [4,5].

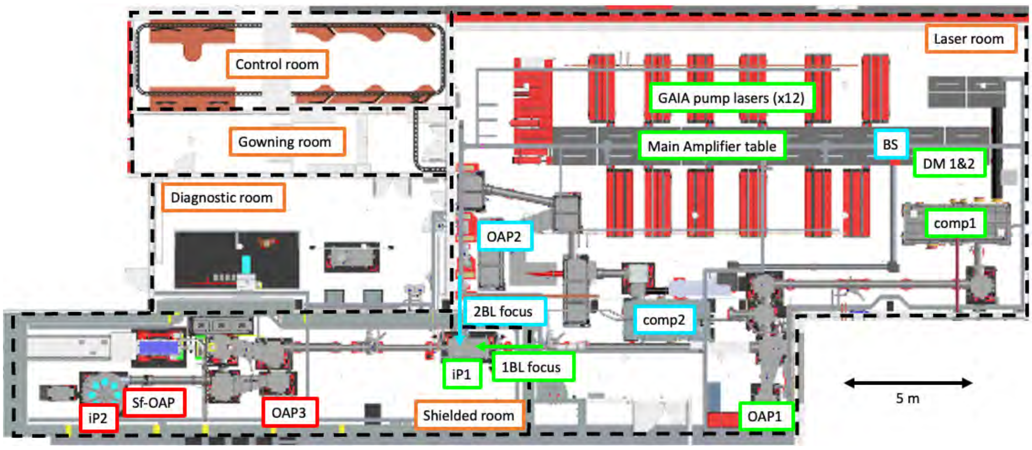

Figure 1: Schematics of the BELLA PW facility [1] including the new iP2 area on the bottom left.

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Funding note: Work supported by U.S. Department of Energy Office of Science, Offices of Fusion Energy Sciences and High Energy Physics, under Contract No. DE-AC02-05CH11231, LaserNetUS (www.lasernetus.org).

Terahertz radiation to amyloid fibrils

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Keywords: Terahertz, Free electron laser, amyloid fibrils, Gyrotron, Sub-millimeter wave

Physical engineering techniques using terahertz beams have been attracted in chemical, biological, and material research fields. Also, the high-power radiation from the infrared light source can give the remarkable effects to biological materials distinct from a simple thermal treatment. Amyloid fibrils work as multi-functional players in medical and biomaterials fields. A common feature in the structure of amyloid fibrils is a fibrous conformation that is rigid and insoluble in water, and it is often difficult to regulate the stacking formation unless using high temperature and denaturants. We discovered that amyloid fibrils can be conformationally controlled by using high-power terahertz beams from a free-electron laser and gyrotron (Fig. 1). In this talk, we would like to show our studies on the effects of terahertz radiation on the amyloid fibrils and discuss about the potential use of the far-infrared radiation to regulate the biomolecular self-assembly [1-3].

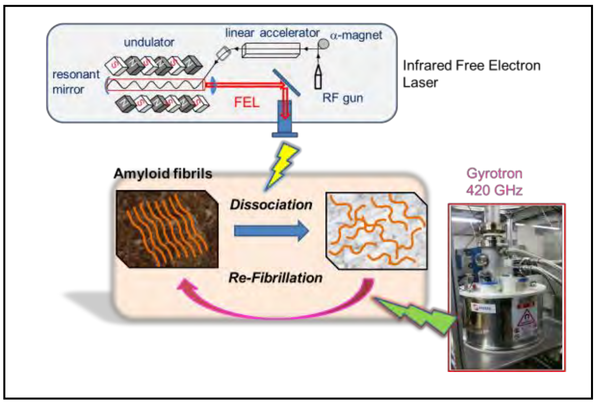

Fig.1 Dissociation and re-association of amyloid fibrils by terahertz beams

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25P-04

Single-shot ultrafast imaging for observation of non-repetitive laser-induced plasma and shockwaves

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Keywords: Ultra-short pulse laser, Ultrafast imaging, Bioimaging, Material processing

Laser-induced plasmas and shockwaves have unique properties and the potential to produce new technology or improve the performance of existing techniques in not only basic studies but also the medical field[1] and industry[2]. To capture these ultrafast phenomena, time-resolved pump-probe imaging is utilized. In this method, the images of target phenomena are obtained one by one by changing the delay time (time difference between the pump pulse and probe pulse). Although this method achieves a high time resolution in the imaging, the technique cannot be applied to non-repetitive events. Recently, we developed an ultrafast single-shot imaging method called Sequentially timed all-optical mapping photography (STAMP) that allows us to capture poorly reproducible ultrafast phenomena[3,4]. STAMP is an all-optical imaging method based on optical 'mapping': the projection of the target's spatial profile from the time domain to the spatial domain. The STAMP system consists of an ultrafast laser source, temporal mapping device (TMD; to produce a chirped-pulse or pulse train depending on the imaging timescales), spatial mapping device (SMD; to perform spectral imaging), image sensor, and computer. With the recent improvements in TMD and SMD, we achieved visualization of the detailed behaviors of plasma dynamics and acoustic dynamics induced by ultrashort laser pulses.

In this talk, I will introduce the biomedical applications we developed based on laser-induced phenomena first, then present the recent development of our single-shot imaging technology to visualize and analyze the non-repetitive laser-induced plasma and shockwaves.

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25P-05

Use of quantum beams in improving the properties of glowing pants

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Keywords: Gamma-radiation, electron beam, mutagenesis, bioluminescence, FRET

There are many bioluminescent organisms in nature, such as fireflies, bacteria and mushrooms, and the luminescent proteins from these organisms have been used for countless biological studies. Bioluminescence is produced upon catalysis of the oxidation reaction of the substrate (luciferin) by the luminescent enzyme (luciferase). The genes that produce luciferin and luciferase has been elucidated from the glowing mushroom species [1], and we cloned and introduced these genes into the plant genome to create autoluminescent plants that can be used for various applications including bioimaging. However, the current luminescence intensity is insufficient for observing intercellular or intracellular phenomena. As an approach to increase the luminescence intensity, we will irradiate the seeds of the autoluminescent plant with gamma- or electron beam to induce random mutations in the genome to create a population of various mutants. We aim to find a mutant with enhanced mutation that can be used to further analyze and identify the mutated gene/s that lead to luminescence enhancement. In combination with a technique to enhance luminescence intensity by the fusion of a fluorescent protein (Nano-lantern technology), we aim to produce a bright and multicoloured autoluminescent plant that can be used not only for various biological studies, but also as an electricity-free light source to help build a sustainable society.

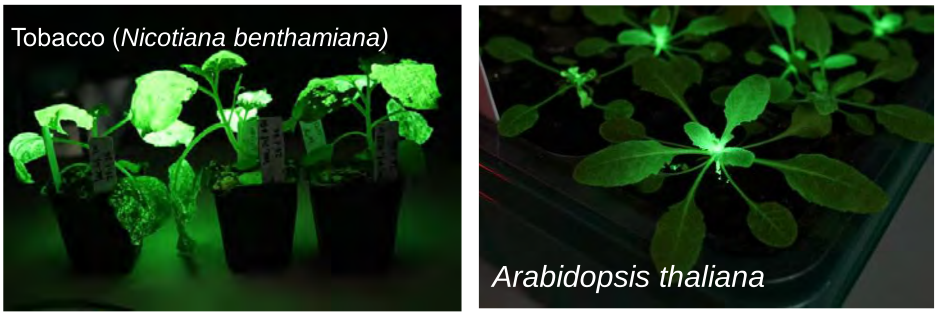

Fig.1 Autoluminescent plants generated using the luminescent genes from mushroom.

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25P-06

Drug discovery with high-energy electron beams

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Keywords: Laser wakefield acceleration (LWFA), Electron beams, Prodrugs, Chemotherapy

Laser wakefield acceleration (LWFA) is expected to be a next-generation accelerator capable of accelerating electron beams with energies above the GeV class on the scale of a small table-top device. Under the JST-MIRAI project, our research team has been conducting research and development of the LWFA with the aim of amplification in XUV wavelength range of the free-electron laser (FEL). Since the quality of the LWFA electron beam has been dramatically improved by the progress of this FEL research, we decided to explore applications of LWFA that can be implemented in society at an early stage in parallel with the FEL research, and started research on drug discovery using high-energy electron beams and prodrugs with our teams in beam physics, organic chemistry, radiation chemistry and radiation oncology.

A prodrug is a drug whose chemical structure is converted to an inactive form so that the drug does not work after it enters the body and before it reaches the site of disease in chemotherapy. After administration, an external or internal stimulus (trigger) at the disease site (affected area) converts the chemical structure back to the active form and causes the drug to function, so that the drug is potent only at the target site and is expected to reduce systemic side effects. When the human body is irradiated, free radicals and reactive oxygen species are generated in body tissues through the ionization or excitation of water molecules. The use of chemical reactions based on the indirect action of these reactive molecular species for prodrug activation has been investigated, and recently there have been reports of prodrug activation using x-ray irradiation as an external trigger [1]. However, when targeting localized lesions deep in the trunk, an external trigger of beams with high enough energy to penetrate and reach deep into the trunk, and with sharp directivity that does not spread in the body, is required.

In order to investigate the potential of high energy electron beams of tens to hundreds of MeV as external triggers, we first started to study prodrug activation using ~30 MeV electron beams of the L-band LINAC at SANKEN. The target is irradiated with the electron beams at clinically acceptable doses of 5 Gy or less; in vitro experiments prodrug activation and growth inhibition of human cervical tumor HeLa cells and in vivo experiments inhibition of tumor growth in xenograft mouse models are investigated.

In this presentation, beam drug discovery research will be presented as a realistic application of compact high energy electron accelerators, including laser accelerators.

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25P-07

Chemotherapy triggered by electron beams

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Keywords: prodrugs, quantum beams, pulse radiolysis, chemotherapy

Chemotherapy is one of the pillars of cancer treatment, along with surgery and radiation therapy. It suppresses the growth of cancer cells using anticancer agents. However, even approved drugs have limitations such as their high toxicity and serious side effects on normal cells or tissues, due to their low selectivity for tumor cells. To eliminate these undesirable properties and improve efficacy, the prodrug strategy is often used. Prodrugs are intrinsically inactive forms that are converted to active forms by exogenous or endogenous stimulation, and they are expected to control drug activity in tumor cells or tissues. In general, prodrugs are designed by masking the functional group of a bioactive compound essential to its drug activity (Fig. 1). In recent years, some reports have been shown that prodrugs can be physically activated by X-rays, with spatio-temporally control [1]. However, their tissue permeability is insufficient for clinical applications targeting deep lesions. Therefore, we thought that radiation that can reach at deeper tissues is available as a complementary method to X-rays. In this context, we focused on high-energy electron beams, which have superior properties in terms of tissue penetration. So far, we have achieved the activation of prodrugs by electron beams in vitro, and we have tested the electron beam-prodrug activation in cell-based assays and mouse experiments. In this presentation, our detailed studies on the activation of prodrug by electron beams, including its pharmacological effects and the reaction process will be introduced.

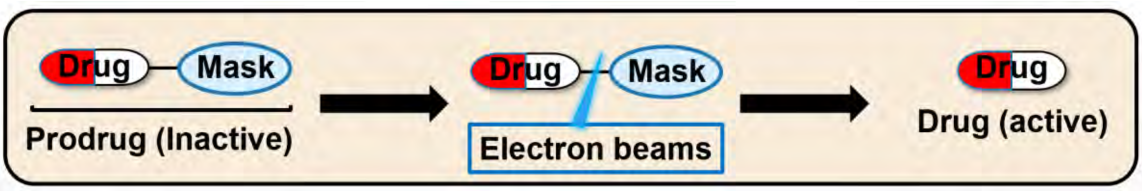

Fig.1 Prodrug activation by electron beams

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Introductory talk

Mitsuhiro Yoshisda

Grand challenges of future colliders

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Keywords: Higgs factory, energy frontier

During the recent US high energy physics strategy process, aka Snowmass, the enthusiasm towards beyond-the-LHC energy frontier has been evident. Several new proposals for next high energy colliders including Higgs factories such as Cool Copper Collider were presented and evaluated together with well-known proposed ILC, CLIC, FCC-ee, CEPC by the Implementation Task Force. This talk will provide a brief overview of the evaluation. Design study on demonstrating the Cool Copper Collider technology as well as grand challenges for reaching ultimate colliders will also be presented.

Laser-Plasma Accelerator Research at the BELLA Center

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Keywords: Laser-plasma accelerators, electron acceleration.

This talk will summarize the current activities of the BELLA Center on laser-plasma accelerator (LPA) research and applications. This will include a description of the newly commissioned extensions to the BELLA PW laser, namely the second beamline (2BL) and the interaction point two (IP2) beamline and target chamber [1]. 2BL provides a second beamline to the interaction point one chamber, along with the first beamline, where experiments are done on LPAs. The primary objectives are experiments on laser-generated plasma channels to yield electron energies near 10 GeV, and the high efficiency staging of LPA modules at the multi-GeV level. IP2 provides a new short focal length capability to provide ultrahigh laser intensity for experiments on ion acceleration and high energy density science. The BELLA Center also houses two independent 100 TW lasers that are used for a wide variety of studies, including x-ray generation by Thomson scattering and LPA-driven free electron laser research. Also discussed will be the development of fiber lasers that use coherent combining in both space and time to enable high average power at kHz repetition rates and beyond.

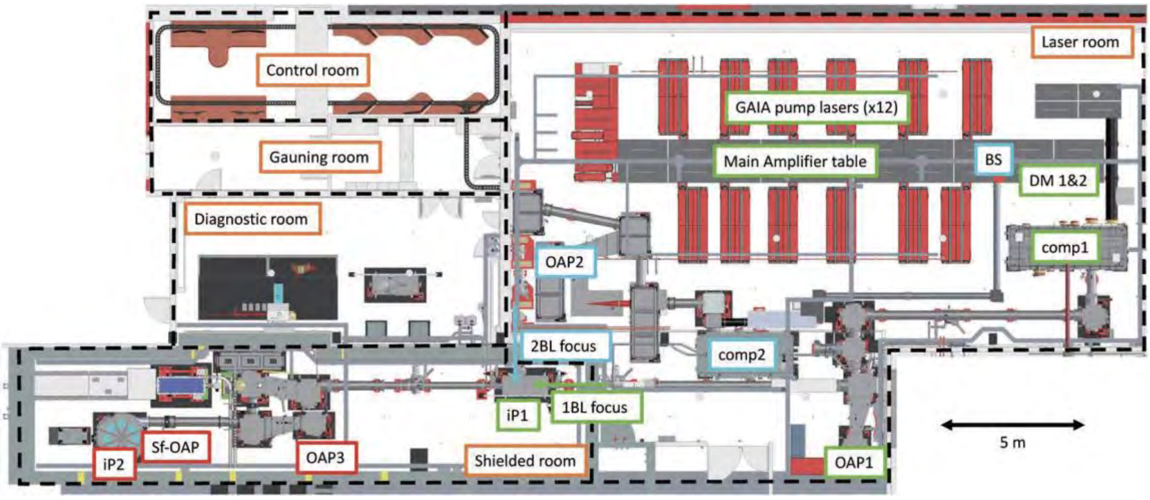

Figure 1: Schematics of the BELLA PW facility [1] showing new 2BL and iP2 beamlines.

References

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Funding note: Work supported by U.S. Department of Energy Office of Science, Offices of High Energy Physics and Fusion Energy Sciences, under Contract No. DE-AC02-05CH11231, and LaserNetUS (www.lasernetus.org).

Title: Particle Acceleration Using Laser-Driven Photonic Structures

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Keywords: Laser, acceleration, on-chip, photonic, nanofabrication

Acceleration of particles in photonic nanostructures fabricated using semiconductor manufacturing techniques and driven by ultrafast solid-state lasers is a new and promising approach to developing future generations of compact particle accelerators. Substantial progress has been made in this area in recent years, fueled by a growing international collaboration of universities, national laboratories, and companies. Performance of these micro-accelerator devices is ultimately limited by laser-induced material breakdown limits, which can be substantially higher for optically driven dielectrics than for radio-frequency metallic cavities traditionally used in modern particle accelerators, allowing for 1 to 2 orders of magnitude increase in achievable accelerating fields. The lasers required for this approach are commercially available with moderate (micro-Joule class) pulse energies and repetition rates in the MHz regime. We summarize progress to date and outline potential near-term applications and offshoot technologies.

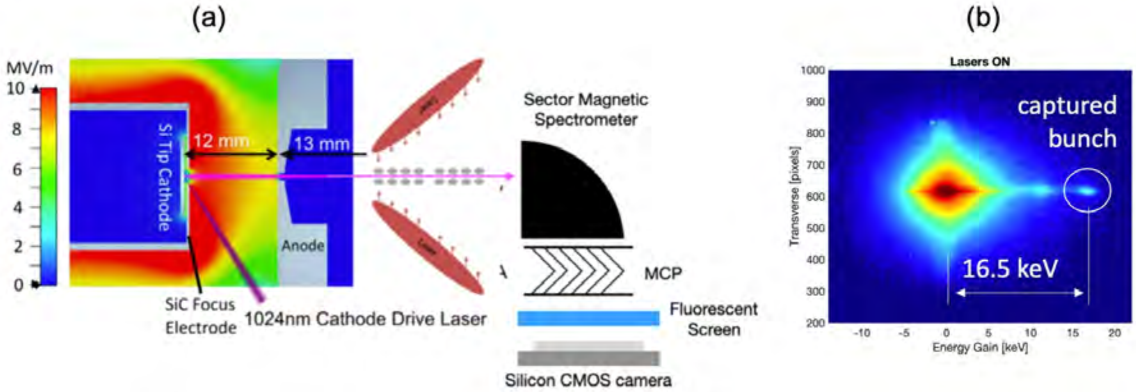

Fig.1 Experimental setup (a) and measured energy spectrum (b) for recent experimental results to accelerate a captured electron bunch from a tip emission source by 16.5 keV over 480μm interaction length in a dielectric laser accelerator.

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26P-05

Current status of the MIRAI free-electron laser project using laser-accelerated electron beams in Japan

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Keywords: laser acceleration, free-electron laser, laser wakefield acceleration

We aim to realize a compact, X-ray free-electron laser (FEL) based on laser wakefield acceleration (LWFA) through the JST MIRAI program (Creating new values that meet social and industrial needs by science and technology) [1]. As a milestone goal, we pursue to demonstrate lasing in self-amplified spontaneous emission (SASE) regime in the extreme ultraviolet wavelength. Here, we show our recent electron beam parameters achieved in our laser electron platform LAPLACIAN in RIKEN SPring-8 Center [2]. The platform equips with a dedicated Ti: sapphire laser system with three beamlines. Currently, we use a single beam to generate electron beams using a conical gas-jet target with a razor blade that employs localized density-ramp injection. Manipulating laser profile [3] produces high-quality electron beams with a charge of >10 pC, an energy of 200-400 MeV, and a relative energy spread smaller than 1% (root-mean-square). We show our achieved beam parameters allow lasing at the XUV (extreme ultraviolet) regime with a 2-m-length undulator of the undulator strength K=1.4 and the period of 10 mm.

In the talk, we discuss the LWFA electron beam parameters and the calculation of SASE FEL, the current beamline preparation status, and the plan for the FEL experiment.

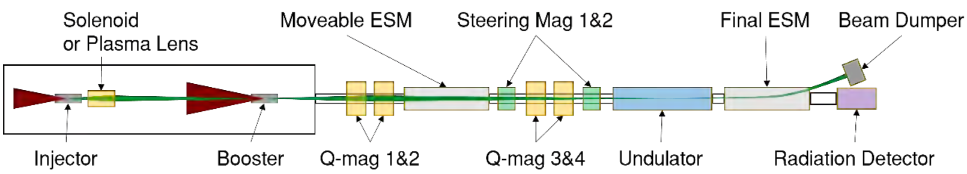

Fig.1 An experimental setup at the LAPLACIAN facility in SPring-8 Center.

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The COXINEL seeded Free Electron Laser driven by the HZDR Laser Plasma Accelerator

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Keywords: Q-BASIS, Ultra-short pulse laser, Free Electron Laser

Laser Plasma Accelerators (LPAs), reaching gigavolt-per-centimeter accelerating fields, can generate high peak current, low emittance and GeV class electron beams that can be qualified by a Free Electron Laser (FEL) application. Electron beam transport [1] along the COXINEL line has been mastered and undulator radiation has been controlled [2] with the line installed at Laboratoire d'Optique Appliquée. We first describe the commissioning of the COXINEL beamline driven by the HZDR plasma accelerator, including electron beam transport, undulator spontaneous emission and tuning for FEL. We report on experimental demonstration of FEL lasing at 270 nm in a seeded configuration [3]. Control over the radiation wavelength is achieved with an improved bandwidth stability. Furthermore, the appearance of interference fringes, resulting from the interaction between the phase-locked emitted radiation and the seed, confirms longitudinal coherence, representing an essential feature of seeded FELs. These results are in good agreement with by ELEGANT (beam transport) and GENESIS (FEL) simulations.

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KAIO-BEAMLINE, à modular high repetition rate laser electron accelerator for broad range of applications

François SYLLA

Lightwave control of relativistic laser-matter interactions

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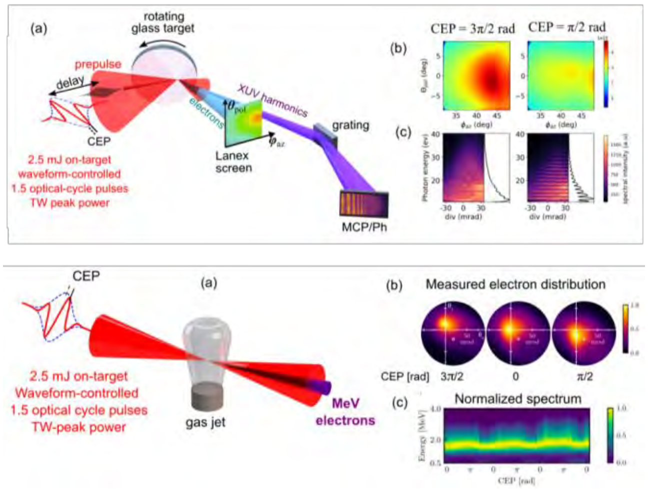
Keywords: Ultra-short pulse laser, relativistic interactions, high harmonic generation, electron acceleration, carrier-envelope phase, coherent control.

Lightwave control of collective electron dynamics during relativistic laser-plasma interactions is challenging as it requires few-cycle driver laser pulses with relativistic intensity (> 10^{18} W/cm^2) and controlled carrier-envelope phase (CEP), combined together with a target system (gas, liquid or solid) featuring extremely well-controlled interaction conditions from shot to shot. The Salle Noire 2.0 laser system developed at the Laboratoire d'Optique Appliquée delivers CEP-stable, TW peak power, 1.5 cycle NIR transients (3.5 fs at 780 nm) with high-temporal contrast (> 10^{10}) at 1 kHz repetition rate with a 300 mrad shot-to-shot CEP stability [1]. This unique laser system has opened the door to studying relativistic laser-plasma interactions with unprecedented precision: we show how we can control the spatio-spectral properties of both high-harmonic and electron beams simultaneously emitted by plasma mirrors formed on solid density targets [2] and relativistic electron beams produced by laser-wakefield acceleration in sub-critical gas jets [3].



Top: Schematic representation of the relativistic plasma mirror set-up (a), measured electron distribution (b) and high-harmonic spectra (c) for two CEP values offset by π. **Bottom:** Schematic representation of the laser-wakefield electron accelerator in a gas jet (a) and measured CEP-dependent electron beam pointing (b) and energy spectrum (c).

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26P-02

Ultra-high charge electron acceleration for nuclear applications

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Keywords: Laser wakefield acceleration, electron beam charge, Isomeric state, unclear excitation

Laser plasma acceleration is not only suitable for advance accelerator, but also possess great potential for plasma exciter or collider. At present, main research topics in this field focus on the quality improvement of accelerated electron beam. On the other hand, the laser plasma accelerator also has extremely high electron density which will produce high brightness gamma ray source and intense neutron source, resulting in powerful tool for nuclear physics research.

Recently, our team has carried out systematic studies on electron acceleration with large charge. For example, we used a solid target to realize relativistic electron acceleration of 100 nC [1] with very small divergence angle; And achieved stable acceleration of ~ 20 nC and electron energy of tens MeV in high-density gas targets, through a novel efficient injection that the atom inner shell electrons are ionized and continuously injected into multiple plasma bubbles [2].

Based on new experimental results of electron acceleration obtained, we have carried out the research of "laser-plasma exciter". Firstly, a high brightness neutron source [3] is obtained by driving a solid target with an electron beam. Then, using the nonlinear resonance of Kr clusters excited by intense laser, the 83Kr isomeric state is achieved experimentally with peak efficiency 2x10^15 p/s [4]. And also, with optimized high charge electron beam driven (γ ,n) reaction, the peak flux of neutron source reaches to 10^21 n/cm^2/s, which is comparable to Supernova [5].

In order to carry out the experimental verification of laser "plasma exciter" and extremely strong field QED, we are constructing the "laboratory astrophysics research platform" (LAP) in TsungDao Lee Institute, for the nuclear astrophysics research in relativistic.

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Recent progresses of laser plasma based electron acceleration and radiation at Shanghai Jiao Tong university

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Keywords: laser plasma, wakefield acceleration, plasma channel, high harmonics generation

Laser plasma based electron acceleration and radiation have many applications. Aiming to the high energy electron acceleration and intense harmonics generation, we have performed both theoretical and experimental studies. A curved plasma channel has been proposed to guide intense lasers for multistage laser wakefield acceleration [1,2]. In our recent experiment we found that when the channel curvature radius is gradually increased and the laser incidence offset is optimized, the stable laser guiding is possible and wakefields can be excited in the curved channel. Electrons with maximum energy of 0.7GeV have been observed. Our results show that such a channel exhibits good potential for seamless multi-stage laser wakefield acceleration. For high harmonics generation in laser solid interaction, we also experimentally demonstrate that efficient harmonics can be achieved directly by compressing large-scale surface plasma via the radiation pressure of a circularly polarized normally incident prepulse. The harmonic generation efficiency obtained by this method is comparable to that obtained with optimized plasma scale length by high-contrast lasers. Our scheme does not rely on high-contrast lasers and is robust and easy to implement. Thus, it may pave a way for the development of intense extreme ultraviolet sources and future applications with high repetition rates [3,4]. A 200+300TW two-laser system platform will be installed in SJTU. The research plans, such as staged wakefield acceleration, Thomson scattering and plasma optics studies on this platform, will be introduced.

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Poster presentation

(April, 26, 12:20 - 15:30, SANKEN, CReA)

Efficient high-order harmonic generation via surface plasma compression with lasers

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Keywords: High-order harmonic generation, Laser contrast, Normally incident prepulse, Surface plasma compression

The efficiency of high-order harmonic generation from a relativistic laser interacting with solid targets depends greatly on surface plasma distribution. The usual method of enhancing efficiency involves tuning the plasma scale length carefully by improving the laser contrast [1]. Here, we experimentally demonstrate that efficient harmonics can be achieved directly by compressing large-scale surface plasma via the radiation pressure of a circularly polarized normally incident prepulse. The harmonic generation efficiency obtained by this method is comparable to that obtained with optimized plasma scale length by high-contrast lasers, and the harmonic spectrum plateaus at high orders. Our scheme does not rely on high-contrast lasers and is robust and easy to implement. Thus, it may pave a way for the development of intense extreme ultraviolet sources and future applications with high repetition rates. Moreover, our studies also reveal that the preplasma can be actively tailored into a curved surface using the radiation pressure of a normally incident prepulse. This may also be an efficient way to focus relativistic harmonics [2] or to produce high-order vortex harmonics [3].

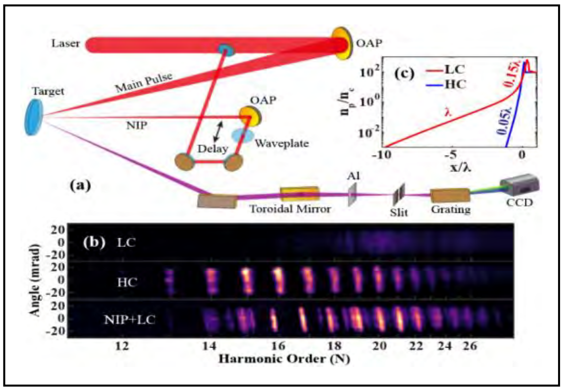

Fig.1 Experimental setup

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Challenges to make LPA viable for industrial XFEL sources

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Keywords: LWFA, Laser wavefront, Halo, Electron control

Since its inception by Tajima and Dawson [1] Laser plasma acceleration (LPA) has gained traction as an alternative to classic RF accelerators.

LPA offers high acceleration gradients (up to 10s of GeV/m) making possible the generation of GeV electrons in tens of cm [2]. Multiple uses for LPA systems are already being seriously considered including their use as electron beam sources for Free Electron Laser. The generation of LPA based FEL has been recently demonstrated [3,4]. However, achieving proper electron beam parameters for such use in a consistent manner and a reliable coupling with the undulator is non-trivial and still under research.

Being able to provide a reliable and clean laser source for LPA is a key part to go towards industrial applications. One important issue lies with instabilities induced by imperfect beam tainted with aberrations. It has already been shown that real laser beams, with poor focus quality, can be detrimental for electron generations [5,6].

The presented work introduces the LAPLACIAN (Laser Acceleration Platform as a Coordinated Innovation Anchor, Fig.1) experimental facility inside the MIRAI project framework. The LAPLACIAN facility, situated in the SPRING-8 site, aims for the generation of X-ray FEL with relativistic electrons (GeV) from an LPA source in a beamline of under 10 m (from electron source to radiation diagnostics). In LAPLACIAN, multiple gas targets and LPA schemes are being studied and also the combined use of magneto-optics and plasma-based optics for coupling the source with the undulator.

This work will present an overview of the facility, its capabilities, and the raised challenges. Current investigations to improve LPA, both from the laser part and electron generation and transportation, will be shown. First results regarding electron generation as function of a controlled aberrated laser are presented.

Fig.1 Laser system at LAPLACIAN facility.

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Fold-rotational Symmetric Radiation Vortex stem from Nonlinear Thomson Scattering of Intense Laser with Circular Polarization Topology

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The radiation carries the angular momentum has been extensively applied in particle manipulation, nuclear excitation, and state diagnostics. New conceptions of the high energy radiation vortex would extremely extend the field of application. Herein, we discovered the interesting structured radiation vortex in the nonlinear Thomson scattering between the relativistic electron slice and ultra-intense circularly polarized Laguerre-Gaussian laser. In the nonlinear scattering process, the radiation near field could be redistributed into structured patterns that imprinted by the so-called `fold-rotational symmetry' of the laser field, which is characterized by the quantum numbers of the spin (σ) and orbit (l) angular momentum. These processes were illustrated by both theoretical analysis and numerical calculations. With the specific (σ, l) combination, the radiation pattern will turn into the dynamic radiation focusing, and form an extremely small gamma-ray focus with an unprecedented intensity $I_p = 3 \times 10^{19} W/cm^2$, which is highly beneficial for the researches on the nuclear physics and quantum electrodynamics.

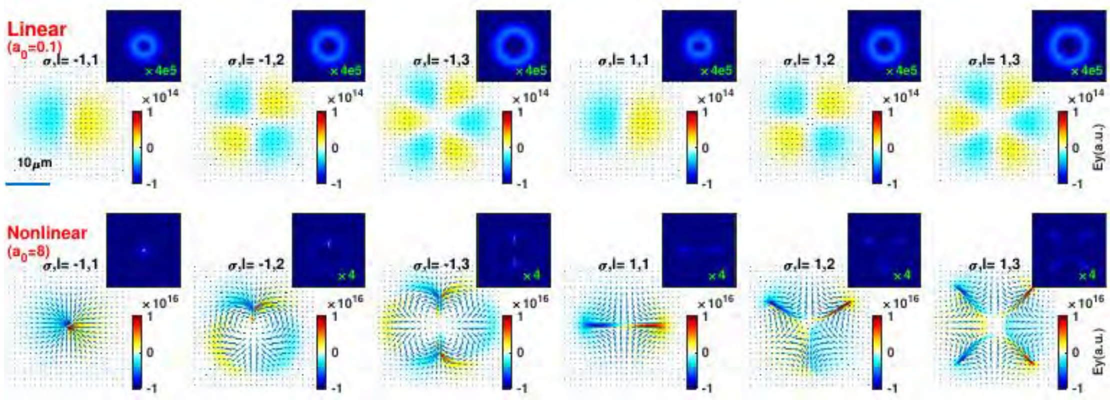

Figure. The radiation field strength and corresponding radiation intensity distributions on the detective plane.

Development of a compact electron source using self-modulated laser wakefield acceleration driven by a Sub-TW class laser

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Keywords: Plasma, Laser wakefield acceleration, Particle-in-cell simulation, Electron beam

Since, Tajima and Dawson reported the concept of laser wakefield acceleration (LWFA), many experimental and theoretical work have been reported [1]. LWFA has a large acceleration gradient due to the use of high-density plasma. Moreover, the acceleration distance exceeds the Rayleigh length, resulting in a large energy gain. A. J. Gonsalves et al. reported the feasibility of petawatt laser guidance and electron beam acceleration up to 8 GeV in capillary discharge waveguide [2]. LWFA experiment using a Sub-TW class laser that can be operated in a small-scale laboratory has been also performed, and generation of a MeV class electron beam by a self-modulated laser wakefield acceleration method has been reported [3].

We simulate a laser pulse interacting with a plasma density of 10^{20} cm^{-3} by using a two-dimensional particle-in-cell code. The laser energy is 120 mJ with 120 fs of pulse duration (full width at half maximum). The laser intensity is 2.0×10^{18} W/cm^2 (normalized vector potential $a_0 = 1$). As shown in Figure 1 the laser pulse produces wakefiled in which the envelope of the laser electric field is modulated, achieving a large electric field. We also preparing the experiment to confirm the simulation result. Figure 2 shows the diagram of the experimental setup. We plan to conduct LWFA experiment using a 1 TW Ti:Sapphire laser system which produce 120 mJ of energy with 120 fs of pulse duration (FWHM). In our poster presentation, we plan to discuss using simulation results etc.

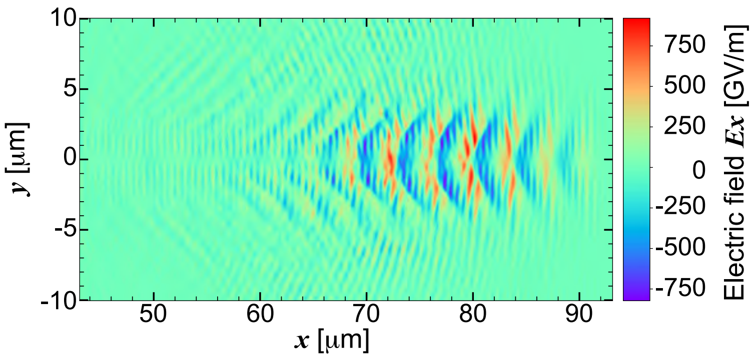

Fig. 1 Electric field in *x* direction of laser axis propagation from two-dimensional particle-in-cell code simulation result.

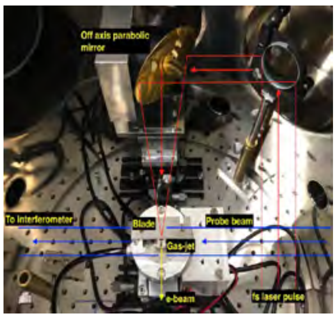

Fig. 2 Experimental setup.

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Induction heating for desorption of surface contamination for high-repetition laser-driven heavy-ion acceleration

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Keywords: Laser-driven particle acceleration, Radiation cancer therapy, heavy-ion

We report on a first demonstration of surface contamination cleaning from high repetitive supplying thin tape target for laser-driven heavy-ion acceleration. Contaminants (mainly water vapor and hydrocarbons), including protons, are adsorbed on the surface of materials exposed to low vacuum (>10–3 Pa), suppressing heavy-ion acceleration. The newly developed contamination cleaner heats a 5 □m thick nickel tape to over 400°C in 100 ms by induction heating, and it can scale to laser-driven heavy-ion acceleration at rates over 10 Hz in the future. Furthermore, the Langmuir adsorption model adequately explained the temperature dependence of desorption and readsorption of adsorbed molecules on a heated target surface, and the temperature required for proton-free heavy-ion acceleration can be estimated. This type of contamination cleaner is the basis for laser-driven compact heavy-ion accelerators, which will reduce the facility size and construction cost of heavy-ion cancer therapy devices and enable their widespread use.

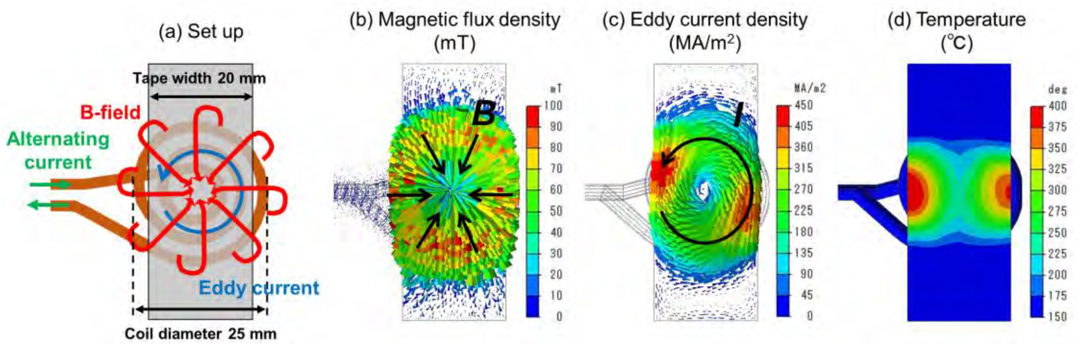

Figure. 1. The finite element analysis code (Femtet ver. 2021) was used to analyze the heating process.
(a) Schematic view of setup. (b) Magnetic flux flow inside the nickel foil. (c) Eddy current flow inside the nickel foil.
(d) Temperature distribution of the heated nickel tape.

Numerical simulation of laser ion injector for quantum scalpel project

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Keywords: Laser ion injector, Carbon ion acceleration, Particle-In-Cell simulation

The National Institutes for Quantum Science and Technology (QST) is currently conducting the quantum scalpel project, which aims to improve the performance and miniaturization of heavy ion cancer therapy devices, which are highly effective in treatment [1,2]. The "Quantum scalpel" means cancer therapy using a quantum beam without a real scalpel in a body. It's a treatment method with minimal side effects, making it possible for patients to go to the hospital (day surgery) and be treated for cancer while working. The fifth generation of heavy ion cancer therapy devices, namely the Quantum Scalpel consists of the laser ion injector, super-conducting synchrotron, and super-conducting rotating gantry. It is required to miniaturize the ion injector and synchrotron to develop compact heavy ion cancer therapy devices. In the quantum scalpel project, the synchrotron and injector will be miniaturized by introducing super-conducting technology and replacing the conventional linear accelerator with the laser ion injector, respectively. Laser ion acceleration has a large acceleration gradient and its technique is expected to develop a compact ion injector [3].

The requirement for the injector of the quantum scalpel is the 10 Hz generation of more than 10^8 of 4 MeV/u C^{6+} ions with 1% energy bandwidth. However, at the point of the laser acceleration, the 10% energy bandwidth of these ions is allowable. The 10% energy bandwidth of these carbon ions is compressed to 1% using the phase rotation technique after the laser acceleration and then they are transported to the synchrotron.

We have conducted quasi-1D and 2D PIC simulations to verify the condition of C^{6+} generation. These simulation results agree with the simple model that roughly predicts the maximum sheath strength and achievable ionization degree. We have also discussed simulation results in the cases of Carbon coated Ni targets.

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LPA-Driven Electron Radiography at OMEGA EP

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Keywords: Ultra-short pulse laser, Imaging, Electron radiography, LPA-drive

Recently, a sub-picosecond, laser-plasma accelerator (LPA)-driven flash electron radiography source has been demonstrated at the OMEGA extended performance (EP) laser system at the Laboratory for Laser Energetics (LLE) in Rochester, NY.[1] This enables the visualization of ultra-fast, ultra-thin dynamic processes and associated electromagnetic fields, with potential application as an inertial confinement fusion diagnostic. Using this *ultra-fast*, *high-flux* LPA-driven electron source, high quality radiography has been demonstrated with an areal density sensitivity from 7 mg cm^{-2} of aluminum up to 3 g cm^{-2} of tungsten, and a spatial resolution of 75 µm.[2] Work is underway to implement a magnetic lens system at OMEGA EP that could increase spatial resolution to 10 µm or better, and allow for better quantification of magnetic field imaging,[3] as shown in Fig. 1.

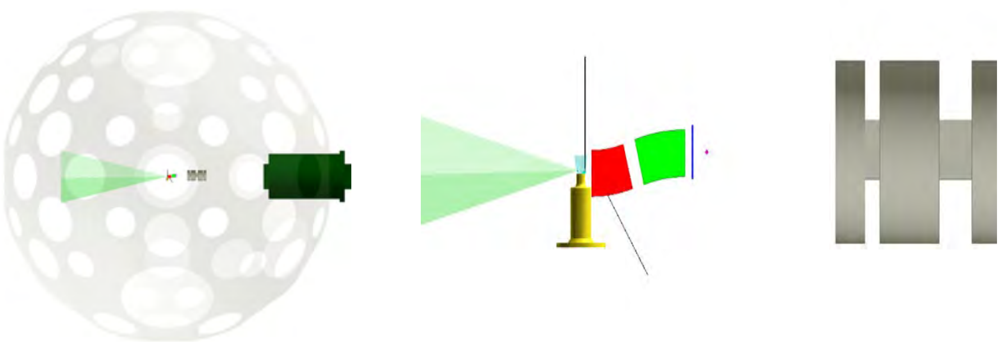

Fig.1: Conceptual visualization of magnetic-lensing implemented with LPA-driven eRad at OMEGA EP (at left), and a close up of the sidelighter beam in green, generating an electron source to enter a magnetic lens system (at right).

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Ultrafast electron microscopy with relativistic femtosecond electron pulses

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Keywords: Ultrafast electron microscopy, Femtosecond-pulsed electron beam, Imaging, Structural dynamics

Femtosecond atomic-scale imaging is a most challenging subject in materials science and has long been a cherished dream tool for scientists wishing to study ultrafast structural dynamics in various materials. In this research, we aim to develop an innovative relativistic femtosecond-pulsed electron microscope by combining a radio-frequency electron acceleration technology into high-voltage electron microscope. In this paper, we reported the concept and construction of the relativistic femtosecond-pulsed electron microscope. Some demonstrations of electron diffraction and imaging with 3-MeV-energy femtosecond electron pulses were presented. The single-shot imaging of micro-crystals with femtosecond electron pulse was reported. Recently, we have succeeded to observe the TEM images of 40-nm-diamter gold nanoparticles with femtosecond electron pulses in our UEM. The potential of ultrafast relativistic electron microscope was discussed.

This work was supported by a Basic Research (A) (No. 21H04654, No. 22246127, No. 26246026, and No. 17H01060) of Grant-in-Aid for Scientific Research from MEXT, Japan.

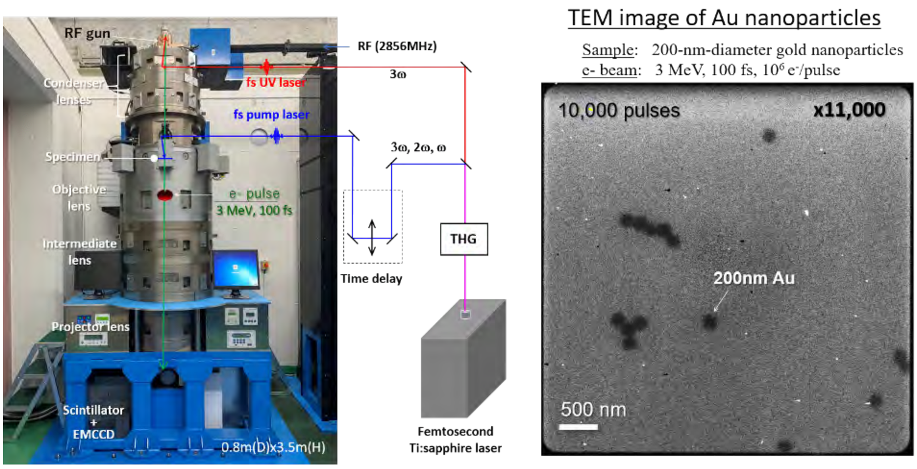

Fig 1. Ultrafast electron microscopy using RF electron gun and TEM image of gold nanoparticles using relativistic femtosecond electron pulses.

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Supercontinuum-seeded 4-micron KTA optical parametric amplifier for seeding TW-class Fe:ZnSe multipass amplifiers

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Keywords: Ultra-short pulse laser, Mid-IR, Optical parametric amplifier

Driven by the λ^2 energy scaling law of strong field phenomena [1], high-power optical parametric amplifiers (OPAs) in the 3–10 μm [2-4] bands attract much attention as the next generation sources for attosecond science and its related areas. While such mid-IR OPAs have almost all of the required features for attosecond physic such as stabilized carrier-envelope phase, wavelength tunability, power-scaling, etc., excellent pulse energy scaling of 4-micron Fe:ZnSe(S)-based laser [5] can surpass that of the mid-IR OPAs. By carefully combining the Fe:ZnSe(S) as a booster of KTA OPA, we are constructing a novel all-in-one hybrid laser system for attosecond physics, plasma physics, and related area [Fig. 1(a)]. In this work, we report our recent development of a three-stage 4-micron KTA OPA driven by a homemade Yb:CaF_2 CPA [Fig. 1(b,c)], which will play crucial roles as a seed laser of the hybrid system.

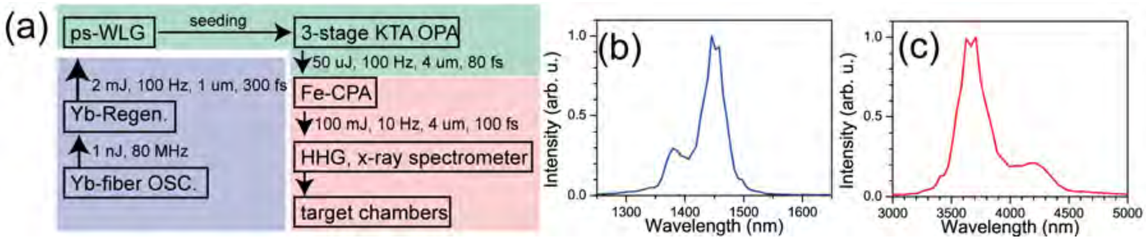

Fig.1 (a) The OPA/CPA hybrid system and setup for attosecond physics. (b,c) Observed spectra of the signal waves (b) and the idler waves (c) from the developed KTA OPA.

T.K. acknowledges financial support by SPIRITS 2022 of Kyoto University, THE AMADA OUNDATION, MATSUO FOUNDATION, and Japan Society for the Promotion of Science (JSPS, 23H01877, 21H04474). S.T. is financially supported by JSPS (21H01845) and the New Energy and Industrial Technology Development Organization (NEDO, JPNP20004).

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Simulation of self-focusing ultrashort femtosecond lasers in air for the detection of viruses and VOCs

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Keywords: Ultra-short pulse laser, Simulation, Self-focusing, Laser Induced Breakdown

The COVID-19 pandemic brought to the forefront the need to be able to quickly detect whether viruses are present or not in the air. We have proposed using laser-induced breakdown spectroscopy (LIBS) using ultrashort femtosecond lasers to detect them directly or indirectly via the presence of volatile organic compounds (VOCs). Ultrashort laser pulse propagation simulations, which solve the nonlinear Schrödinger equation [1], are being performed for air. Since the laser pulse has sufficiently high power to self-focus, it generates a plasma filament [2]. We will show the temperature and density of the plasma which are generated. The strength of the initial focusing of the laser pulse influences the plasma density and propagation characteristics [3]. So, we will also briefly discuss this in relation to the possibility of detection.

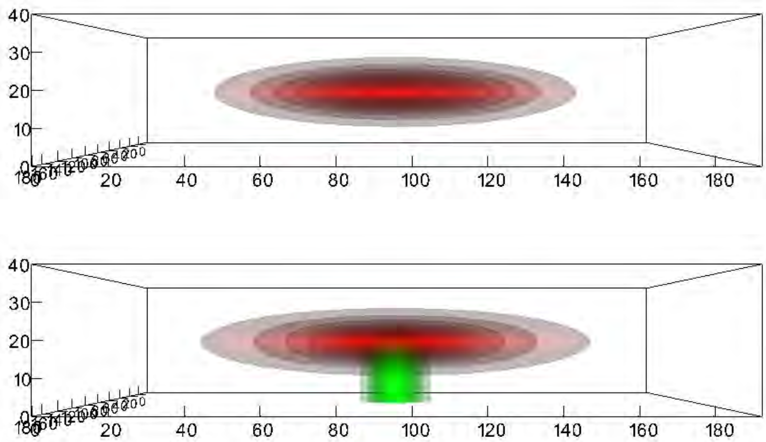

Fig.1 Simulation of laser pulse (red) and plasma density (green): initial (top) and after propagating 1.4 cm in air (bottom).

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Acknowledgements

This research was supported by the crowdfunding project, 'Can lasers detect viruses in air?', using the academic crowdfunding platform 'academist'. The computations were performed with the supercomputer HPE SGI8600 at JAEA Tokai.

Laser Cavitation Peening Using a Nd:YAG Laser with and without Q-switch

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Keywords: Cavitation, Laser peening, Normal oscillation, Pulse width, 3D-metal, Fatigue strength

Additive manufactured three dimensional metals (3D-metal) attractive materials for medical implants. However, fatigue strength of 3D-metal is nearly half of bulk metals, and then the improvement of fatigue strength of 3D-metal is big issue.

At submerged laser peening, a bubble which behave cavitation bubble, i.e., “laser cavitation”, is generated after laser ablation, and the impact induced by laser cavitation was bigger than that of laser ablation [1-2]. The peening using laser cavitation is named as “laser cavitation peening”. At conventional laser cavitation peening, a Nd:YAG laser with Q-switch was used. If a Nd:YAG laser without Q-switch, i.e., normal oscilation, can be used for laser cavitation peening, the reputation frequency can be improved to about 1000 times that of conventional systems, as the other laser such as a fiber laser can be used.

Figure 1 shows the aspect of laser cavitation produced by a Nd:YAG laser at normal oscillation. Figure 2 reveals the typical case of pressure detected by a hydrophone. As shown in Fig. 1, laser cavitation was generated by the laser pulse with 200 μs. At the laser cavitation collapse, the pressure was detected as shown in Fig. 2. Namely, a Nd:YAG laser at normal oscillation can be utilized for laser cavitation peening.

This research was partly supported by JSPS KAKENHI grant numbers 23H01292 and 22KK0050.

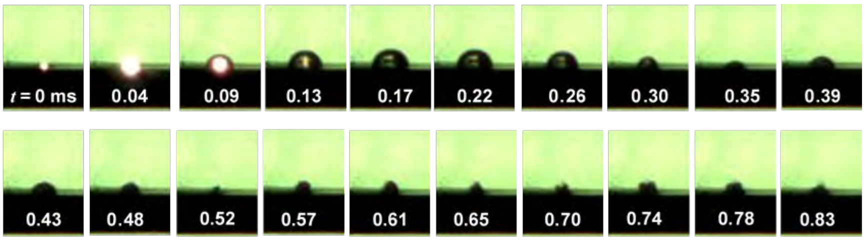

Fig. 1 Aspect of laser cavitation produced by Nd:YAG laser without Q-switch

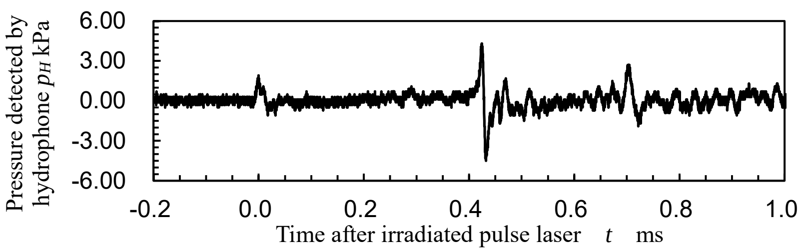

Fig. 2 Pressures of laser ablation and laser cavitation collapse produced by Nd:YAG laser without Q-switch

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Development of a 6-mJ, 100-Hz, femtosecond Yb:CaF_2 regenerative amplifier for driving 4-micron KTA parametric amplifiers

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Keywords: Ultra-short pulse laser, Mid-IR, Optical parametric amplifier

The laser diode (LD) pumped Yb-doped lasers attract much attention from their robustness, compact size, and low cost, and frequently adopted as ideal drivers for mid-IR optical parametric amplifiers (OPAs) [1,2]. Among the Yb-doped host materials, Yb:CaF_2 has advantages in high energy and ultrashort pulse operation [3] because of its broad gain bandwidth over 20 nm and long fluorescence lifetime of 2.4 ms. In this work, by adopting Yb:CaF_2 as the laser medium and a Yb-fiber oscillator mode-locked via nonlinear polarization evolution scheme [4], we develop a compact and robust 6-mJ, 100-Hz, femtosecond regenerative amplifier for driving 4-micron KTA OPA, which will be used for studies of attosecond/zeptosecond physics. The schematic diagram of our laser system is depicted in Fig. 1(a) and the achieved maximum power and highest pulse energy are 600 mW and 6 mJ, respectively [Fig. 1(b,c)].

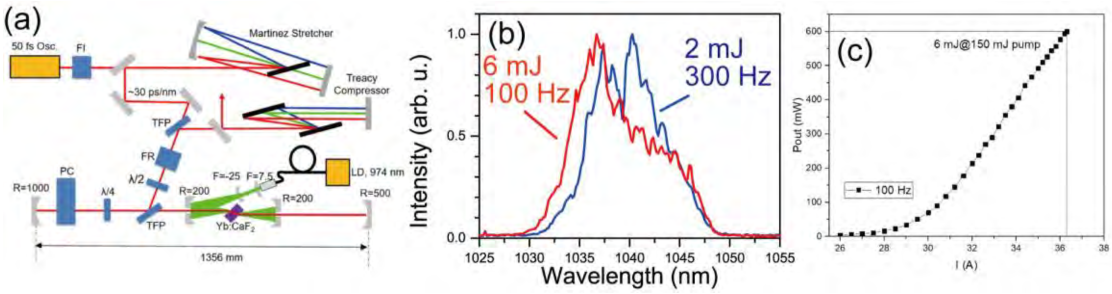

Fig.1. (a) The experimental setup. (b) Typical spectra for the 6-mJ, 100-Hz setting (red curve) and the 2-mJ, 300-Hz setting (blue curve). (c) Typical output power as a function of the LD current.

T.K. acknowledges financial support by SPIRITS 2022 of Kyoto University, THE AMADA OUNDATION, MATSUO FOUNDATION, and Japan Society for the Promotion of Science (JSPS, 23H01877, 21H04474). S.T. is financially supported by JSPS (21H01845) and the New Energy and Industrial Technology Development Organization (NEDO, JPNP20004).

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Temperature-driven, Sub-100-fs Mode-locked Fiber Oscillators Based on the Symmetry-Broken Nonlinear Polarization Evolution Method

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Keywords: Ultra-short pulse laser, fiber laser, nonlinear polarization evolution

All fiber polarization maintaining (PM) mode-locked oscillators attract much attention from its simplicity, robustness, and low manufacturing cost. Passive mode locking in all-PM ytterbium (Yb) fiber oscillators has been demonstrated by means of material saturable absorbers (SAs) [1,2] and virtual SAs based on nonlinear polarization rotation (NPE) [3,4] and nonlinear amplifying loop mirror (NALM) [5]. Recently, J. Szczepanek *et al.*, demonstrated a novel NPE-based virtual SA with zero group velocity mismatching (GVM) between the two orthogonally polarized SA-inducing paths [3]. The proposed NPE-SA is composed of symmetrically-spliced three PM fiber segments and the length inaccuracy of the segments must be within a small fraction of the beat length of the PM fibers. Furthermore, the use of the both polarization components in the NPE SA part makes the mode-locking sensitive to the mechanical stress. In this work, we propose a mildly symmetry-broken NPE SA as a mode-locker and demonstrate an environmentally-stable, sub-100-fs mode-locked fiber oscillators. The proposed NPE SA enables ones to control the GVM into small desirable regions for self-starting region of the mode-locking via controlling the temperature of the NPE SA part. A Peltier device is adopted for the precise temperature controlling and by robustly gluing the NPE SA part onto the device with thermally conductive resin, the influence of mechanical stress-induced birefringence is also disentangled. The achieved power and pulse duration after compression were 33.7 mW (18.31 MHz, 1030 nm) and 96 fs, respectively, and the stable mode-locking started automatically in a few seconds after starting the temperature control.

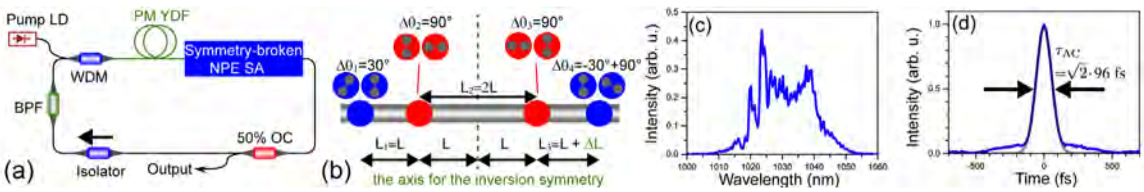

Fig.1 (a) The experimental setup. BPF: bandpass filter, YDF, ytterbium-doped fiber, WDM: wavelength division multiplexer, and OC: output coupler. (b) Detailed illustration of the symmetry-broken NPE SA. (c) Measured output spectrum. (d) Intensity autocorrelation trace, which supports the pulse duration 96 fs of the compressed output pulses.

T.K. acknowledges financial support by SPIRITS 2022 of Kyoto University, THE AMADA OUNDATION, MATSUO FOUNDATION, and Japan Society for the Promotion of Science (JSPS, 23H01877, 21H04474). S.T. is financially supported by JSPS (21H01845) and the New Energy and Industrial Technology Development Organization (NEDO, JPNP20004).

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In-line Detection of Internal Defects in Fillet Welded Sheet of Lap Joint by Laser Ultrasonic and Its Robotic Application Using Microchip Laser

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Keywords: Laser ultrasonics, Galvanized steel sheet, Blowholes, Non-contact, Small size laser

A blowhole is a problem in lap joint welding of galvanized steel sheets, often used in automobile manufacturing. This study developed a defect detection method using laser ultrasonic for blowholes. The laser ultrasonic measurement is a non-contact method for generating and detecting the ultrasonic waves, has high spatial resolution due to the point-to-point operation, and can be applied to non-planar surfaces. In a lap joint welding with a thickness of 2.3 mm and 1.6 mm, the attenuation of the reflected signal from the back surface of the lower plate of the ultrasonics excited on the weld bead was effectively captured in the targeted cross-section. Resultantly, the presence or absence of blow holes was determined. The automatic defect judgment algorithm was derived and applied to moving measurements at high speed. Furthermore, in-line measurement was realized by a robot system equipped with a microchip laser.

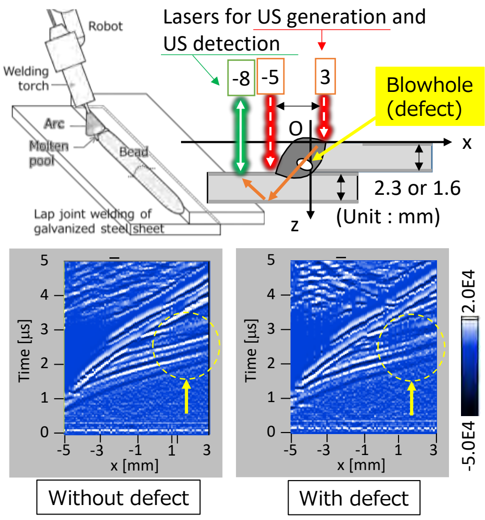

Fig. 1 Blowhole detection

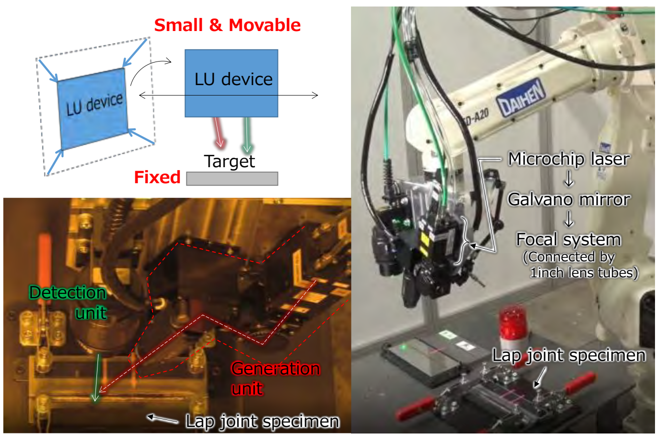

Fig. 2 Robotic system using microchip laser

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Title: Development of a Start-to-End simulation code for the laser-driven ion injector

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Keywords: Q-BASIS, TNSA acceleration, Plasma simulation, Particle-in-Cell（PIC） simulation

We plan to develop a laser-driven ion injector as an application of laser-driven ion acceleration [1]. For this development, it is necessary to design a beam transport method for the efficient use of the laser-driven ion accelerator beam through appropriate simulation. This simulation code needs to manage the entire process, from the laser part to the end of the injector (start-to-end). In other words, a "versatile simulation code" must be developed that can freely calculate the time evolution of the electromagnetic field over a wide range of time scales, from the femtosecond regime for lasers (on the order of a few micrometers) to the nanosecond regime for ion beams (on the order of several meters).

Therefore, we develop a new code for this purpose, based on the basic PIC code developed at QST Kansai. In this presentation the progress and plans of the development will be shown.

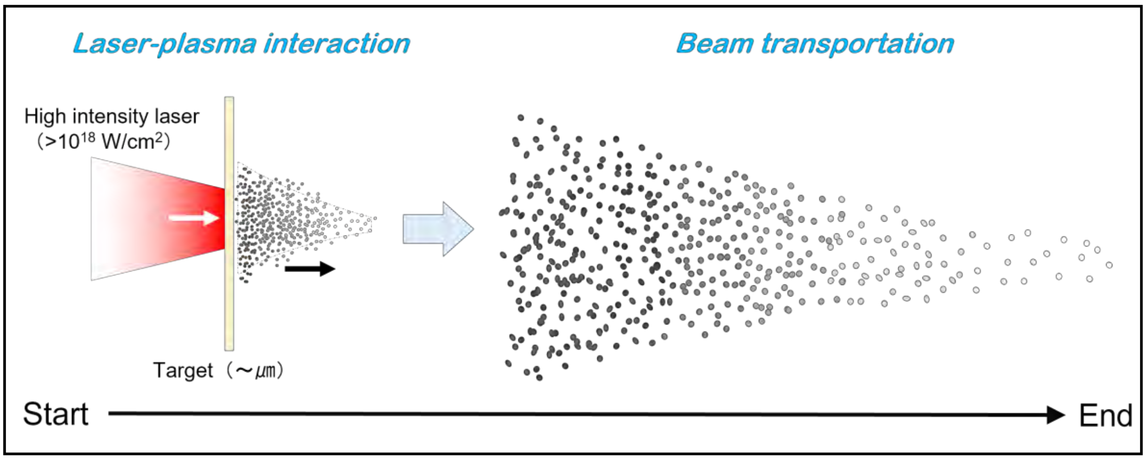

Fig.1 Image of Start-to-End Simulation

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Title: Optimization of laser irradiation conditions for high-brightness beam generation in laser-driven ion beams

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Keywords: Laser-driven ion acceleration, TNSA, Ion beams, Emittance, PIC simulation

In Target Normal Sheath Acceleration (TNSA), one of the best-known laser-plasma ion acceleration mechanisms, an ultra-intense laser is focused onto a thin foil target, accelerating electrons to relativistic levels and generating a charge separation field gradient of ~TV/m on the rear side of the target. This field accelerates ions on the rear side of the target at multi-MeV kinetic energies [1]. The ion beams produced in TNSA have high quality with small transverse emittance and short bunch widths. According to Cowan et al., the transverse emittance of the proton beam at 10 MeV is 0.004 mm-mrad (normalized RMS value) [2]. From these characteristics, this acceleration mechanism is suitable for various applications such as the miniaturization of particle accelerators, FLASH therapy [3], and physical property experiments including PIXE [4]. In the development of this novel laser accelerator, one of the most important works is to generate a high-brightness beam, but the laser irradiation conditions have not been sufficiently optimized.

In this study, the correlation between the beam quality and the laser irradiation conditions is observed to control the ion beam for the realization of a laser accelerator. A two-dimensional particle-in-cell simulation: EPOCH 2D was performed to optimize the ion beam quality with the target thickness and laser spot diameter as parameters. The beam brightness determined from the emittance and current is evaluated to optimize these parameters.

This work was supported by JST-MIRAI R&D Program No. JPMJMI17A1 and JSPS KAKENHI Grant Number JP21J22132.

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Temporal measurement of laser wakefield electrons via electro-optic sampling

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Keywords: Ultra-short pulse laser, electron acceleration, beam diagnostics, EO

Temporal diagnostics on electron bunches from laser wakefield acceleration [1] via single-shot electro-optic spatial decoding. We established electro-optic (EO) [2] sampling techniques adequate for the diagnostics of electron temporal information in laser wakefield acceleration (LWFA). For the investigation of electron timing jitter and injection process, EO spatial decoding on the electron Coulomb field was performed. The spherical wavefront of the Coulomb field [3,4] and plasma-density-dependent electron emission timing were discovered. For the determination of electron bunch durations, EO spatial decoding on the coherent transition radiation (CTR) produced when electrons passing through a metal foil was conducted. Electron beam timing fluctuation of 7 fs [5] and bunch durations of few tens of femtoseconds had been demonstrated.

This research not only showed the capability of EO sampling serving as a real-time electron temporal diagnostic for laser-driven sources but also demonstrated the ultra-fast and high-brightness nature of laser-driven electron sources for various applications.

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This work was funded by the JST-Mirai Program Grant No. JPMJMI17A1, Japan, the Grant-in-Aid for Early-Career Scientists (No. JP21K17998, No. 23K17152) from JSPS KAKENHI, Japan and the QST President's Strategic Grant (Exploratory Research), Japan.

Development of a high-power terahertz source baced on laser-produced plasma for electron acceleration

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Keywords: Plasma, Terahertz

Acceleration gradient of conventional accelerator is limited by the breakdown threshold of acceleration tube, and it has been experimentally confirmed that use of the electromagnetic wave (EM wave) with higher frequency and shorter pulse length can solve the problem of breakdown threshold. Terahertz (THz) is a candidate of the future radio-frequency acceleration. E. A. Nanni et al. demonstrated that THz-driven linear electron accelerator with a radially polarized THz pulse produced via optical rectification of a laser pulse [1]. In practical use, it is necessary to make high-power THz source like conventional radio-frequency sources, such as klystron. N. Yugami et al. reported that laser generated plasma emits radially polarized THz wave [2], furthermore, when applied a static electric field along the laser propagation axis, the THz intensity is enhanced proportionately to square of the applied electric field [3]. This is expected as a high-power THz source, but the mechanism of radiation source is still unclear.

To develop high-power THz source, we plan to carry out experiment with Ti:Sapphire laser system which deliver 800 nm, 120 mJ and 120 fs (full width at half maximum) pulse at 10 Hz repetition rate. Electric field applied to the plasma is approximately 30 kV/cm. Figure 1 shows the diagram of the experimental setup. We plan to measure the THz using single-shot time-domain spectroscopy. And we will measure spectra of light from plasma to study the state of plasma. In our presentation, we plan to discuss about a model of radiation and experimental plan.

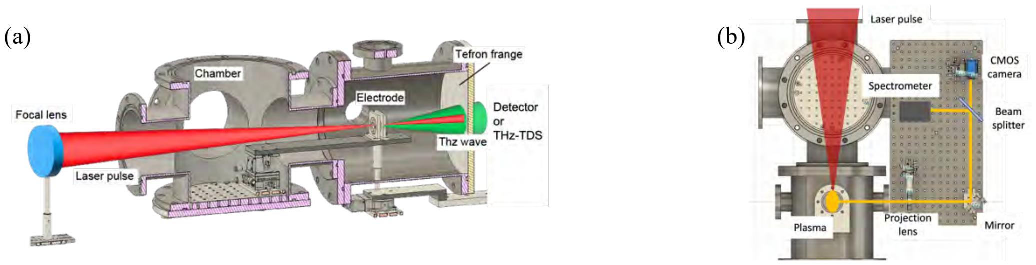

Fig.1 Experimental setup. (a) Setup of THz measurement. (b) Top view of the setup. Emitted light from plasma is observed by using a CMOS camera and spectrometer.

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Laser peening with microchip laser mounted on a controlled robotic arm

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Keywords: *Microchip laser, Material processing, Laser peening, residual stress, fatigue properties*

Laser peening (LP) or laser shock peening (LSP) introduces compressive residual stresses on the surface of metallic components covered with water by irradiating them with successive high-intensity laser pulses.[1-3] The advantage of LP is the possibility of fine execution management and the capability to introduce deep compressive residual stresses on the material surfaces. It is well known to be highly effective in inhibiting stress corrosion cracking and fatigue cracking on material surfaces. In addition, LP has an excellent effect on improving the fatigue strength of welds, which compensates for the disadvantage of high strength steels when welded. LP has a high potential for enhancing material surface, but the high-power laser used requires clean room facilities, large equipment and severe operating conditions. Therefore, the application of the LP has been limited to high cycle fatigue of jet engine fan blades and stress corrosion cracking of nuclear reactor structures. If microchip lasers, which are small and easy to handle, could be used as a light source for LP, it would be possible to apply them not only to production processes in factories but also to existing steel structures such as bridges, to which conventional lasers have been difficult to apply for the above reasons. In this presentation, we report the results of the LP treatment of A7075 (aluminum alloy) and HT780 (high strength steel) with the laser pulse energy of less than 10 mJ. Even at such a low pulse energy, compressive residual stress was imparted (Fig.1) and fatigue properties were improved.

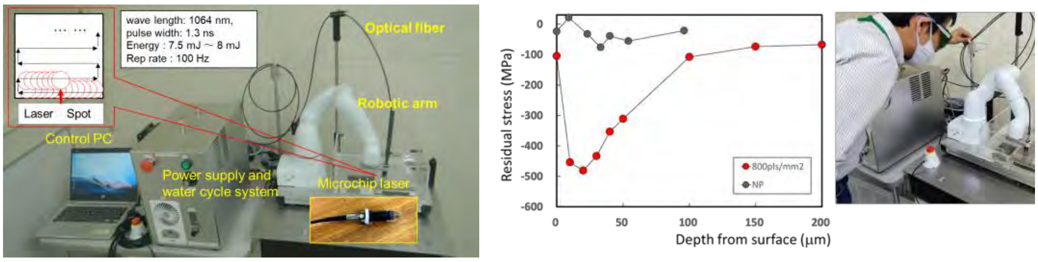

Fig.1 Experimental setup and surface residual stress of HT780(High strength steel) after laser peening

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Undulator light source with a compact, slender and lightweight frame based on a magnet technology developed for very-short-period undulators

Presenting Author's photo

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Keywords: Undulator, Short period lengths, Synchrotron light source, FEL

We have been exploring a novel method to fabricate undulator magnets having a very short period length of a few mm. Plate monolithic magnets (PMM) made of Nd-Fe-B, 100mm long with 4-mm period length have been successfully fabricated[1-3]. The 4-mm period length allows us to obtain 12-keV radiation with the first harmonic of this undulator in the 2.5-GeV light source accelerator. A connection method of these magnet plates has also been successfully developed to fabricate longer undulator magnets[4-5].

As a next step of the development, we are developing a magnetic cancellation method of an attractive force produced by the undulator main magnets by using repulsion magnets. The attractive force is effectively cancelled out by them placed outward in the magnet gap. We found that the repulsion magnets made of PMM were easily optimized in the present system where the main magnets were also made of PMM in contrast to the previous work[6].

We are also developing a compact undulator frame, in which magnetic attractive force between the main undulator magnets is effectively cancelled out by the above cancellation method using repulsion magnets. This undulator is designed as a light source for an XUV-FEL development which has been undertaken in the experimental plat-form at SP-8 for the JST-MIRAI project. Target parameters of the undulator for this experiment are: period length, λu=25mm, field strength K=1.4 at the gap=5mm or larger, and number of period=80. The magnet array is divided into two segments 1m long each, gap of which can be controlled independently.

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Current status and prospect of RLQBS in SANKEN

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Keywords: electron linac, cobalt-60, pulse radiolysis

The Research Laboratory for Quantum Beam Science (RLQBS) was established in 2009 as a successor of Radiation Laboratory [1]. The representative facilities are L-band electron linac, 150 MeV S-band linac, photocathode RF-gun equipped S-band electron linac and Co-60 γ-ray irradiation facility as shown in Fig.1. These machines are available not only for the users in Osaka University, but also for the collaborators in the world. Relating with the electron linacs, the unique studies about such as time-evolved chemical reaction triggered by energetic electron beam using pulse radiolysis system and pursuing the achievement of ultimate short-pulsed-electron-beam have been carried out in addition to the many radiation-related studies. Furthermore, so far the developments and applications of THz FEL and slow positron beam have been promoted. However, these linacs have been aged and maintenance becomes difficult despite the replacement of partial equipment with new one, especially 150 MeV S-band linac was stopped working and will be removed soon. Thus, a new project to promote linacs and quantum beam science are desired. Recently, a C-band electron linac is due to shift to our laboratory, after discarding the old 150 MeV linac. This accelerator is compact and has good enough beam-quality. We are also planning to develop a laser-driven electron accelerator, meanwhile, the C-band linac is thought to turn to be a useful alternative electron source for developing not only a new FEL source but also a new pharmaceutical approach, which is also presented in this conference. To exploit new themes, it is necessary to prepare the spaces for researchers to work creatively with each other. Thus, the second floor of linac building is scheduled to be out of restriction area for radiation hazard, so that the new spaces will be located in there.
The recent results of our laboratory and the future plans are presented.

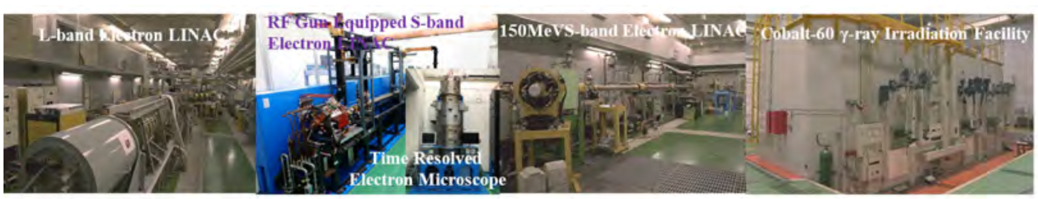

Fig.1 Facilities in RLQBS

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Development of a compact 50 TW laser for energetic quantum beam generation toward practical applications

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Keywords: Ultra-short pulse laser, High power laser, Laser ion acceleration, Quantum beams,

Recently several petawatt-class lasers have been constructed worldwide, thanks to the invention of chirped-pulse amplification (CPA) together with titanium-doped sapphire (Ti:sapphire) media. Such laser facilities provide opportunities for experimental investigation of the behavior of matter in ultra-high electromagnetic fields. Apart from that, there has been a keen demand of reliable TWs laser system for practical applications. Here, the laser development for energetic quantum beam generation ongoing at QST will be reported. The schematic setup of our laser system is shown in Fig. 1. We combine a double CPA with cross-polarized wave generation (XPW) technique to improve the temporal contrast. Figure 2 shows typical beam properties after the XPW pulse cleaner. A nearly diffraction-limited beam quality (Fig. 2(a)) and a highly stable operation (Fig. 2(b)) was achieved. At such condition, the laser contrast after 2nd CPA was better than 10^{10} at 100 ps before main pulse.

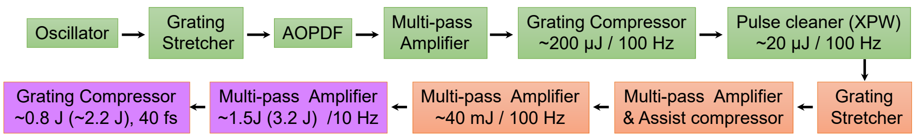

Fig.1 Schematic of the laser system.

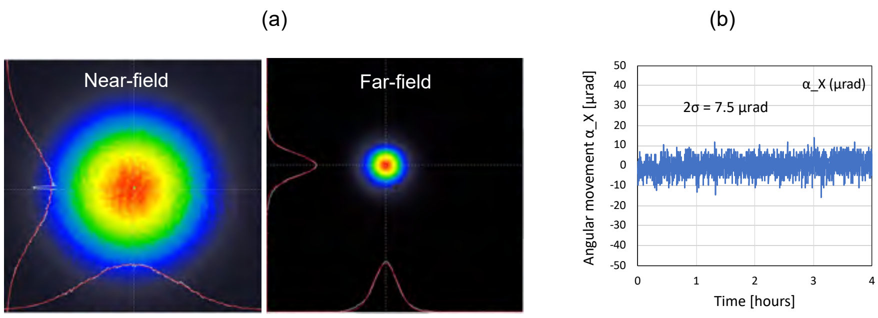

Fig.2 Typical beam profile (a) and pointing stability (b) at the output of pulse cleaner.

Acknowledgements

This work is supported by JST-MIRAI R & D Program #JPMJ17A1. The authors (T.-H.D., N.H., M.I., M.N.) acknowledges support from Japan Society for the Promotion of Science (JP21H03750)

Plasma Effects on Electron Beam Bunching in External Periodic Fields

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Abstract

Low density plasma focusing and modulation of high energy electron beams can result in essential increasing of beam brightness and, therefore, the free electron laser (*FEL*) gain in undulators. However, strong coupling between the transverse beam focusing and modulation by plasma and longitudinal electron bunching in the undulator field can affect the radiation both positively and negatively. Here, the interaction of electron beams with plasma and an external periodic magnetic field is studied by particle-in-cell simulations in a booster reference frame with the resolution allowing direct evaluation of beam bunching and *FEL* radiation. To obtain characteristics of forward radiation, the booster reference frame is chosen with a large relativistic factor γ_R to achieve a necessary resolution for radiation, with the wavelength $\lambda_x=\lambda_u\gamma_R/\gamma_B^2$, of electrons with the energy $mc^2\gamma_B$ in an undulator with the period λ_u. The non-resonance plasma cases with rather long plasma wavelengths $\lambda_p>\lambda_x\gamma_R^{1/2}$ are considered.

Focusing and reduction of correlated energy spread of chirped electron beams in passive plasma lens.

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Keywords: LWFA, Plasma lens, PIC

For the next generation of the particle accelerators, including laser wakefield acceleration (LWFA), application of plasma based focusing of electron beams is an area of active research. This approach will pave a path for the miniaturization of the beam transportation line in particle accelerators. In the context of LWFA scheme, this approach will open the opportunity to realize an extremely small setups of multi-GeV and bright source of electron beams. We will present numerical results of passive plasma lens of an electron beam via self-consistent and relativistic particle-in-cell (PIC) simulations. The focusing of an electron beam by a passive plasma lens is a non-linear and dynamic process, which strongly depends on the space charge induced evacuation of the plasma electrons in the vicinity of the propagating electron beam. An initially negative energy chirp is essential in suppressing the unwanted growth in the relative energy spread of the electron beam during the passive lensing. A passive plasma element is useful for both a single as well as multi-stage laser wakefield acceleration configuration.

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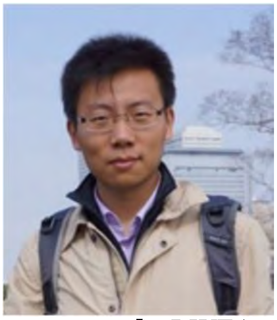
Study of gas jet stability for LWFA in the context of shock injection



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Keywords: LWFA, shock injection, supersonic nozzle, CFD, PIC

Shock-front injection becomes a promising and controllable electron injection mechanism in laser-wakefield-acceleration (LWFA). Supersonic gas jets are widely employed to produce shock waves via the interaction with a blade. The stabilization of the gas flow is critical to control the injection process and the electron beam quality. In this work, we focused on the role of the Converging-Diverging nozzle to improve the stability of the gas jets. By the Computational Fluid Dynamics (CFD) simulations and the Mach-Zehnder interferometric measurements, the instabilities originated from the nonlinear eddies and the mechanism to suppress them are discussed. Both the numerical and experimental results prove that a nozzle with a stilling chamber can reduce perturbation by more than 10%.

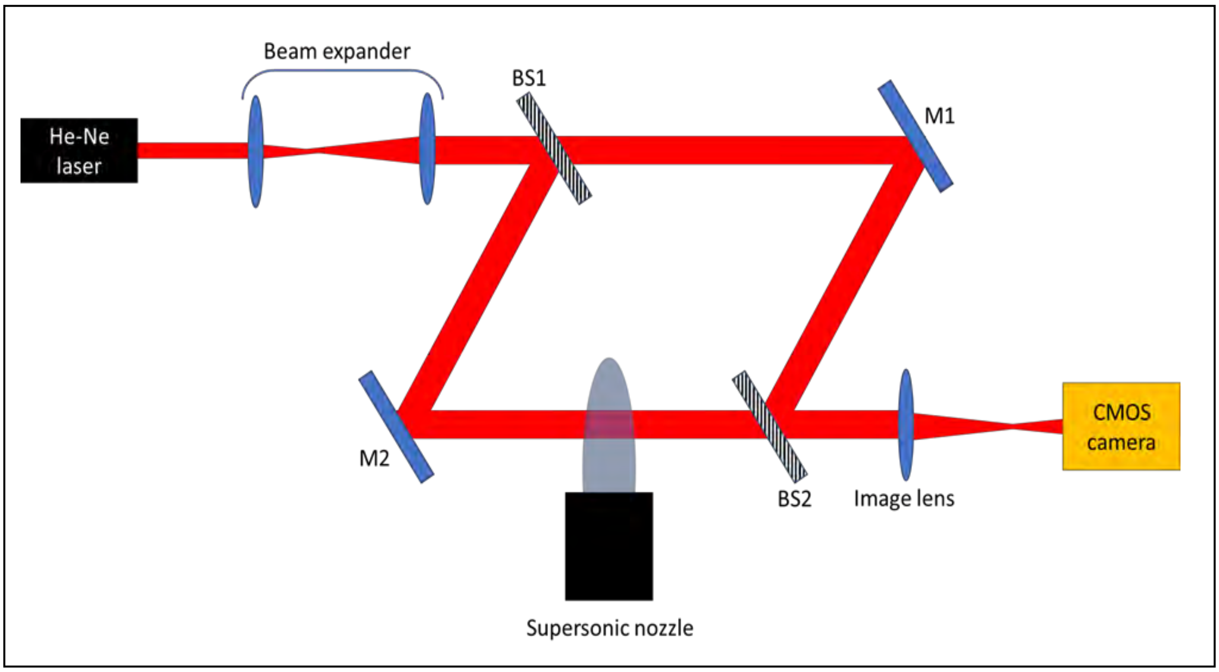

Fig.1 Experimental setup

An Overview of Laser Wakefield Acceleration Platform in Spring-8

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Keywords: Laser wakefield accleration

Laser-wakefield acceleration (LWFA), providing potentially jitter-free sources of radiation and electrons, is one of the rapidly developed scientific fields [1]. Staging LWFA is considered to be a necessary technique for developing full-optical high energy electron accelerators. Splitting of the acceleration length into several technical parts and with independent laser drivers allows not only the generation of stable, reproducible acceleration fields but also overcoming the dephasing length while maintaining an overall high acceleration gradient and a compact footprint [2, 3].

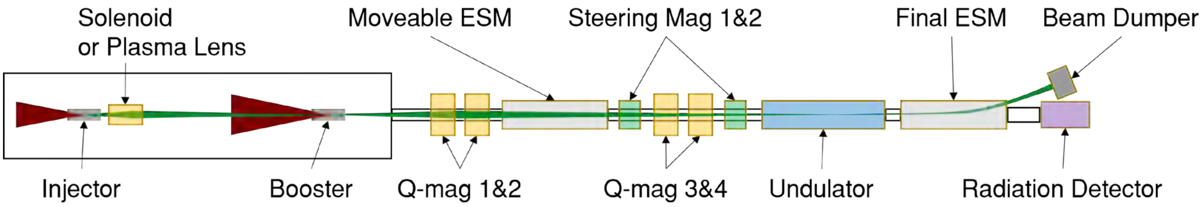

Figure 1 Experimental setup of staging LWFA and electron beam transportation.

The Laser Acceleration Platform is a unique experimental platform specially designed for laser wake-field acceleration research, which is located in the RIKEN SPring-8 center, Harima, Hyogo Prefecture, next to the 8 GeV storage ring and SACLA linear accelerator and XFEL. In this presentation, we will give an overview of our recent progress in this platform.

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Title: Characterization of Plasma Targets for Electron Beam Generation in Laser Wakefield Acceleration Systems

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Keywords: shock injection, schlieren image, supersonic gas jet, Mach-Zehnder interferometry

Plasma targets play a crucial role in electron beam generation within Laser Wakefield Acceleration (LWFA) systems, particularly for non-external injection schemes where the plasma target properties significantly impact electron injection and acceleration. In our current experiment, we employ the sharp density down ramp injection (shock injection) for electron beam generation, where the precise control of position and intensity of the shock are essential for achieving high-quality electrons. To characterize the shock, we investigate the use of a Schlieren imaging system at Osaka University.

The post-shock plasma profile greatly influences the electron beam acceleration. For our experiment, we aim to achieve a relatively flat density distribution in the plasma following the shock. We have implemented a Mach-Zehnder interferometer in our system at the Harima facility to measure the plasma density in the corresponding region. Additionally, we utilize another Mach-Zehnder interferometer setup at Osaka University to investigate the overall profile of our supersonic gas jet.

Here we discuss our experimental setup and the characterization techniques for plasma targets in LWFA systems to improve the electron beam generation and beam quality.

The electron beam diagnostics system for MeV range high repetition rate LWFA sources

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Keywords: LPA, LWFA, Electron beam diagnostic, Ultra-short electron beam, Ultra-high dose rate

Electron accelerators are widely used as a source of relativistic electrons for medical applications (FLASH and very high electron energy therapy), material science, secondary photons sources [1,2] and as a laboratory analogue of space radiation environment for radiation effects to electronics (R2E) [3] research. Conventional particle acceleration technologies (e.g. linear accelerators, LINAC) are limited by a maximal acceleration gradient of about 100 MeV/m due to the breakdown [4]. Laser-plasma acceleration (LPA) devices [5] overcome this value with the potentially achievable 100 MeV/mm range [6]. The use of the high laser repetition rate allows achieving a average dose rates reasonable for irradiation experiments. One of such device, a recently constructed by the ELI-Beamlines electron accelerator group Allegra Laser For Acceleration (ALFA) [7,8] electron beam accelerator is developed to prove a concept of using Laser Wakefield Acceleration (LWFA) devices for irradiation experiments and real-life application. Electron beam diagnostics for compact LWFA device with short focal distance optics, high repetition rate and minimal required laser intensity is a technical challenge due to probability of the interaction of the laser and electron beams with components of the device. It may result in damage of the optical system, reducing of the vacuum quality and affect the electron beam properties. The proposed electron beam diagnostic system (EBDS) includes energy, beam profile and delivered dose measurement. The calibrated phosphor screen charge density [9] and orthogonal magnetic field energy [10] measurement techniques has been used for the beam diagnostics. A relatively small dipole magnet with a distance between poles higher than width and length of magnets has been used to optimize the dimensions of the device and increase the electron beam acceptance angle. Proposed geometry of the beam diagnostic setup is efficient for the optimization of broad electron

beams with variable pointing and also it minimizes risks of damage to the system by a high-power laser. A numerical electron trajectories simulation and Monte Carlo models were developed to improve accuracy of the spectrometer, which is strongly dependent on the definition of the magnetic field geometry. This technique is designed for ultra-short, unstable, diverged electron pulses with the 1 kHz repetition rate.
Theoretical results have been verified by the experiment in the range of 6 – 20 MeV. The accuracy of energy measurement is better than 10%. The beam imaging system is cross-calibrated to measure electron charge density and available dose. The experiment confirms linearity and average accuracy of the measurement better than 2% for electron radiation dose available for the water target and beam charge density in the measurement range of mGy/pulse and pC/cm2/pulse respectively. The electron energy spectrometer is also proposed to be used as a high-pass energy filter and for beam pointing manipulation for irradiation experiments.

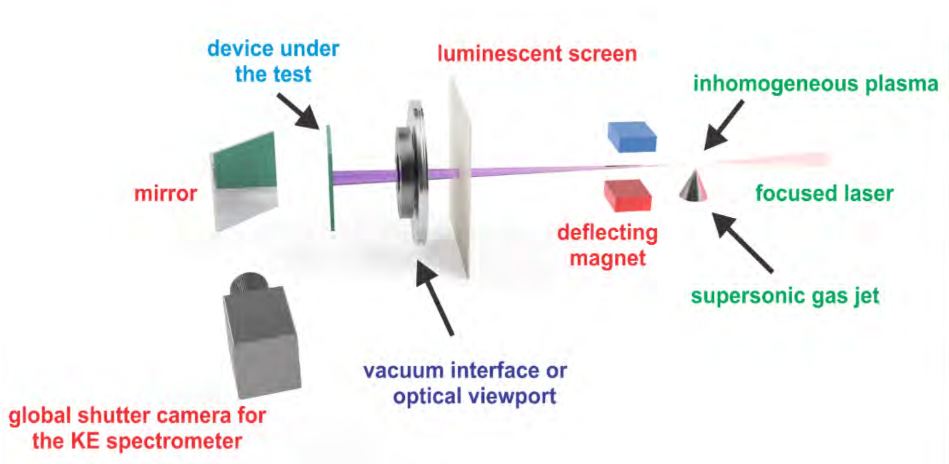

Fig.1 Scheme of the experimental setup

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The electronic structure of the solvated electron investigated by pulse radiolysis

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Keywords: Electron beam, Radiation chemistry, solvated electron, Radiation induced reaction

We are trying to understand radiation induced reaction in condensed phase using pulse radiolysis technique with pulsed el ectron beam. In this study, we focus on solvated electrons (e_{sol}) in alcohol, especially on the electronic structure of solvated electrons. Because the e_{sol} is an important active reaction intermediate which is the starting material for ionizing radiation induce chemical reactions in polar fluid solution. It is also known that the pre-solvated electron (e_{pre}) as precursor of e_{sol}. Both transients has been well known, though there are still two open questions, "Whether is e_{pre} an excited state of e_{sol}, or not?" and "How to understand the absorption spectra of e_{sol}?" In this study, the electronic structure of the solvated electron in 1-pentanol was studied by ns-pulse radiolysis and the electron-photon double-excitation pulse radiolysis.

The e_{sol} photo-excitation experiments showed the bleach of the e_{sol} absorption due to the photo-excitation. And the bleach was not recovered at all. The e_{pre} formation due to the photo-excitation was not observed. The photo-excitation of e_{sol} formed by electron beam irradiation results in the charge recombination via the conduction band, which is distorted by the Coulomb potential of the parent radical cation. This observation was quite different from the similar experimental result conducted on e_{sol} formed by photo-ionization by Silva *et. al* [1] which has been good evidence supporting "e_{pre} is the excited states of e_{sol}" story.

The absorption bands due to the e_{sol} were observed for the binary mixture of 1-pentanol and THF with the concentration range of 0 to 100 vol.% with every 10 vol.% separation. The absorption maxima were gradually shifted from ~640 nm to ~1200 nm according to the 1-pentanol concentration decreased. Thus, the absorption band can be assigned to the electronic transition to the conduction band, because this observation can be understood by the conduction band energy level perturbation due to mixing of solvents.

Two series of experiments suggests the absorption band of the e_{sol} can be assigned to the electronic transition to the conduction band described in Fig. 1.

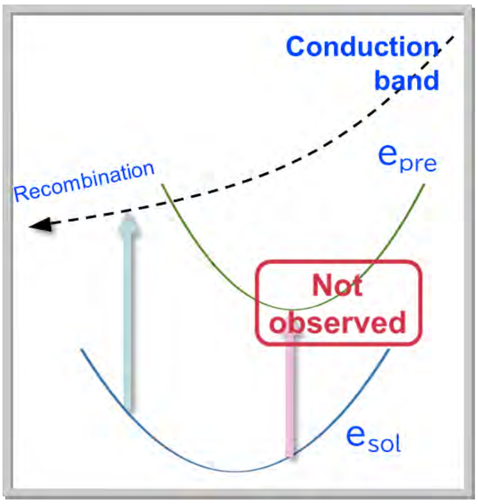

Fig.1 Experimental setup

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Beam pointing control of laser wakefield accelerator by shaping near field profile of laser pulse

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Keywords: Laser wakefield accelerator, Beam manipulation, Ultra-short pulse laser

A laser wakefield accelerator (LWFA) with an acceleration gradient three orders of magnitude higher than conventional accelerators is expected to be a next-generation compact accelerator. For the practical uses of the LWFA such as a free electron laser (FEL)[1,2], the stability and directional control of the electron beams is crucially important. If the pointing of the beams is unstable, the electron beam cannot be transported in a beamline and emit. The stability of the LWFA beams has been improved by the stabilization of the laser system and the choice of injection methods. However, still typical pointing fluctuations of the electron beams observed in experiments are three times larger than those of the driving laser pulses. The cause of the instability of the LWFA electron beams needs to be clarified.

We have stabilized the electron beams by putting an aperture in the laser transport line before an off-axis parabolic mirror. Shaping of near field profile of the laser pulse with the aperture removes the outer part of the laser pulse with unstable wavefront and intensity. That improves the quality and stability of the focusing laser pulse, so the electron beam generated by this laser pulse also becomes stable. Moreover, the direction of the beam can be controlled by just moving this aperture perpendicularly to the laser pulse propagation [3]. This simple method could expect to be one of the key techniques to realize an ultra-compact accelerator with LWFA in the future.

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Picosecond pump-probe study on radiation-induced primary reaction processes of solutions at extreme conditions

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Keywords: Picosecond pump-probe, Radiation-induced reaction kinetics, High temperature high pressure solution, supercritical solution

To understand fundamental processes of beam-material interactions is basically of great importance for advanced application fields of ionizing radiation. In nuclear engineering field, radiolysis of water (from room temperature up to subcritical regime) has been paid much attention as it seriously affects on sustainability of nuclear structural materials in nuclear power plants.

In order to study the radiolysis process experimentally, novel techniques have been developed and practically applied, such as steady-state beta/gamma radiolysis (non time-resolved), picosecond- and nanosecond- pulse radiolysis (time-resolved) etc. Among them, to investigate reaction mechanisms, highly time-resolved techniques will be the most powerful because transient behaviors of short-lived intermediates can be directly traced. For room temperature solutions, the techniques have been successfully adopted and have revealed various radiation-induced physical, physicochemical, and chemical phenomena. However, it has been difficult for high temperature / high pressure solutions (HTHP).

In this work, aiming to characterize the radiation-induced fast process in solutions at HTHP conditions, picosecond electron pulse radiolysis technique for HTHP study will be introduced. Moreover, some experimental results by using the system, such as shallowing potential well of solvated electron, electron solvation process, and inhomogeneous reaction scheme at elevated temperatures will also be presented.

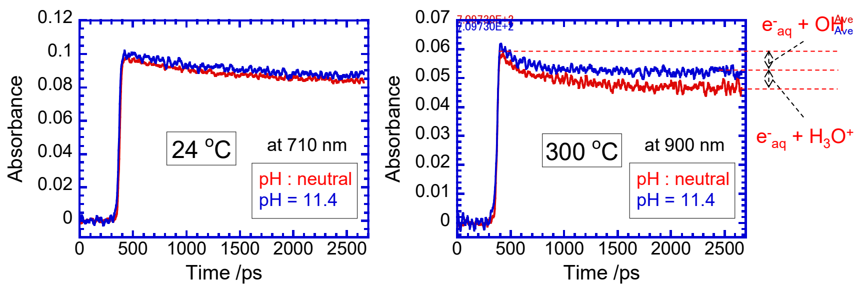

Figure 6. Direct observation of radiation-induced primary reactions of solvated electron in water at different pH and temperature.

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