Summary of Laser Plasma Sessions

Zhengming Sheng

And all contributors of the Laser Plasma Sessions
Program committee for laser plasma

Zhengming Sheng (chair) (China)
Amita Das (co-chair) (India)
Shinsuke Fujioka (co-chair) (Japan)
Chang Hee Nam (co-chair) (Korea)

Yongkun Ding (China)
Cangtao Zhou (China)
G. Ravindra Kumar (India)
Yasuhiko Sentoku (Japan)
Kiminori Kondo (Japan)
Hyyong Suk (Korea)
Kitae Lee (Korea)
Heinrich Hora (Australia)
Donald Umstadter (USA)
Dimitri Batani (France)
A Glimpse of the Program

- 5 Plenary talks
  - Xian-Tu He: The updated advance on inertial confined fusion program in China
  - Jean-Luc Miquel: Laser MegaJoule status and program overview
  - HyungTaek Kim: Overview on the development of laser electron acceleration and radiation sources with PW lasers
  - Tomonao Hosokai: Status of Laser Wakefield Acceleration Research under ImPACT-UPL Program
  - Yutong Li: Bring astrophysics to laboratories

- 27 Invited talks (including 8 talks for the Asian ICUIL)
- 6 Oral talks
- 4 Posters
# A Glimpse of the Program

*(8 sessions)*

### Laser I [14:00-15:45], Place: S6 room in the 2nd Floor of West Building, Chair: Zheng-Ming Sheng

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Speaker</th>
<th>Duration</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-I1</td>
<td>Michel Koenig (25min)</td>
<td>Recent radiative hydrodynamic experiment in Laboratory Astrophysics at LULI.</td>
<td></td>
<td></td>
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<tr>
<td>L-I2</td>
<td>Byoung-ick Cho (25min)</td>
<td>Study of Warm Dense Plasmas with Ultrafast X-rays</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I3</td>
<td>Jiaxiang Wang (25min)</td>
<td>Boron laser fusion by plasma block ignition and avalanche reaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-O1</td>
<td>Toshiya Piku (15min)</td>
<td>New diagnostics developments for pump-probe experiments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-O2</td>
<td>Yang Zhao (15min)</td>
<td>Experimental Study of K-shell Absorption Spectra in Dense Plasma at Shengsiang II Laser Facility</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Laser plasma II [16:20-18:25], Place: S6 room in the 2nd Floor of West Building, Chair: John Pasley

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Speaker</th>
<th>Duration</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-I4</td>
<td>Chi-hao Pu (25min)</td>
<td>Applications of laser-fabricated plasma structures in plasma nonlinear optics, ion acceleration and ultra-intense mid-infrared pulse generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I5</td>
<td>Alessio Monce (25min)</td>
<td>Tailoring beam performance by interfering intense laser beams</td>
<td></td>
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<tr>
<td>L-I6</td>
<td>Hongbin Zhou (25min)</td>
<td>High-order harmonic generation from laser interaction with a plasma pedestal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I7</td>
<td>S. Sengupta (25min)</td>
<td>On Wave Breaking of Relativistically Intense Longitudinal Waves in plasma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I8</td>
<td>Jianfei Huang (25min)</td>
<td>Controllable generation of high quality electron beams with very low absolute energy spread in a laser wakefield accelerator (LWFA) and the demonstration of wakefield snapshots using LWFA electron beams</td>
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</tr>
</tbody>
</table>

### Laser III [14:00-16:05], Asian ICUL session, Place: S6 room in the 2nd Floor of West Building, Chair: Chang-Ming/Sheng

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Speaker</th>
<th>Duration</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-I9</td>
<td>Ruxuan Li (25min)</td>
<td>Progress of the SULF 10PW Laser Project</td>
<td></td>
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</tr>
<tr>
<td>L-I10</td>
<td>Hiromitsu Kiyama (25min)</td>
<td>10TW/cm², 0.1 Hz, High-Contrast J-KAREN-II Laser Facility at QST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I12</td>
<td>Suman Bagby (25min)</td>
<td>Laser Plasma based Micrometer Size Mono-energetic Heavy Ion Accelerator</td>
<td></td>
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<tr>
<td>L-I13</td>
<td>Xiong Yuan (15min)</td>
<td>Efficient and stable ion acceleration from nanometer targets</td>
<td></td>
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### Laser IV [16:30-18:10], Asian ICUL session, Place: S6 room in the 2nd Floor of West Building, Chair: Hiromitsu Kiyama

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
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<tbody>
<tr>
<td>L-I14</td>
<td>Chang Hee Nam (25min)</td>
<td>Investigation of Superintense Laser-Matter Interactions with a 4 PW Laser</td>
<td></td>
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<tr>
<td>L-I15</td>
<td>Jitse Lee (25min)</td>
<td>Quasi-monenergetic proton beams from a layered target irradiated by an ultra-intense laser pulse</td>
<td></td>
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<tr>
<td>L-I16</td>
<td>Yuqi Gu (25min)</td>
<td>Status of fast ignition researches in LPER</td>
<td></td>
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<tr>
<td>L-I17</td>
<td>Akifumi Yogo (25min)</td>
<td>Ion acceleration mechanism driven by multi-picosecond PW laser pulses</td>
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<td></td>
</tr>
</tbody>
</table>

### Laser V [14:00-15:45], Place: S6 room in the 2nd Floor of West Building, Chair: M. Murakami

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Speaker</th>
<th>Duration</th>
<th>Summary</th>
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</thead>
<tbody>
<tr>
<td>L-I18</td>
<td>Min Chen (25min)</td>
<td>Laser wakefield based particle accelerator and radiation sources at SIFU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I19</td>
<td>Min Suop Hur (25min)</td>
<td>Realization of hypothetical plasma dipole oscillation leading to burst of coherent radiation</td>
<td></td>
<td></td>
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<tr>
<td>L-I20</td>
<td>Xiaomei Zhang (25min)</td>
<td>Particle-In-Cell Simulation of X-ray Wakefield Acceleration and Beptron Radiation in Nanotubes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I21</td>
<td>Seong G. Lee (15min)</td>
<td>Double Plasma Mirror System for the 4 PW Ti:Sapphire Laser at CoReLS</td>
<td></td>
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<tr>
<td>L-I22</td>
<td>Kai Huang (15min)</td>
<td>Electron Energy Spectrum Evolution during Magnetic Reconnection in Laser-Produced Plasma</td>
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</table>

### Laser VI [16:20-18:25], Place: S6 room in the 2nd Floor of West Building, Chair: D. Batani

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
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<th>Duration</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-I23</td>
<td>João Jorge Santos (25min)</td>
<td>Strong quasi-static and transient fields driven by laser and the enhancement of the energy-density flux of charged particle beams</td>
<td></td>
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<tr>
<td>L-I24</td>
<td>Ke Lan (25min)</td>
<td>Progress in Octahedral Spherical Holden Study</td>
<td></td>
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<tr>
<td>L-I25</td>
<td>Kazuhide Schemperi (25min)</td>
<td>Diamond ablator for direct drive inertial confinement fusion targets</td>
<td></td>
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</tr>
<tr>
<td>L-I26</td>
<td>Dong Yang (25min)</td>
<td>Investigating the hohlraum radiation properties through the angular distribution of the radiation temperature on Shengsiang-III prototype</td>
<td></td>
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<tr>
<td>L-I27</td>
<td>Weimin Wang (15min)</td>
<td>Magnetically assisted fast ignition scheme for inertial confinement fusion</td>
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</table>

### Laser VII [14:00-15:45], Place: S6 room in the 2nd Floor of West Building, Chair: Ke Lan

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Speaker</th>
<th>Duration</th>
<th>Summary</th>
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</thead>
<tbody>
<tr>
<td>L-I28</td>
<td>Masakazu Murakami (25min)</td>
<td>Quasimonenergetic Proton Generation for Compact Neutron Sources</td>
<td></td>
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<tr>
<td>L-I29</td>
<td>Mancheki Kizumonamu (25min)</td>
<td>Acceleration of neutral atoms in laser produced plasmas</td>
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<tr>
<td>L-I30</td>
<td>John Pasley (25min)</td>
<td>Hydrodynamics Driven by Intense short-pulse lasers</td>
<td></td>
<td></td>
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<tr>
<td>L-I31</td>
<td>Busong Xie (15min)</td>
<td>Accelerating and guiding carbon ions in laser plasma by mechanism of breakout afterburner with a tapered channel</td>
<td></td>
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<tr>
<td>L-I32</td>
<td>Dimitri Batisti (15min)</td>
<td>Generation of high-pressure in aluminum by femtosecond low-energy laser irradiation</td>
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</tr>
</tbody>
</table>

### Laser VIII [16:20-18:25], Place: S6 room in the 2nd Floor of West Building, Chair: Hongbing Zhuo

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Speaker</th>
<th>Duration</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-I33</td>
<td>Qiangyu Hu (25min)</td>
<td>Laser plasma evolution in external 10T magnetic field</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I34</td>
<td>Bin Qiao (25min)</td>
<td>Brilliant gamma-ray emission from near-critical plasma interaction with ultraintense laser pulses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I35</td>
<td>Liangming Li (25min)</td>
<td>Near QED-regime of laser-plasma interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I36</td>
<td>Kataryaka Jakubovskaya (25min)</td>
<td>Refraction Index of Shock Compressed Water in the Megabar Pressure Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-I37</td>
<td>Yongsheng Huang (25min)</td>
<td>Laser Particle Acceleration, Radiation and Laser Nuclear Physics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Topics covered in the talks

- Inertial confined fusion physics and technologies, new concepts
- Laboratory astrophysics and high energy density physics
- Ultra-high power laser system development
- Laser plasma based particle acceleration (electrons, ions) and radiation
- Fundamental laser plasma physics (physics related with fs laser-driven shock waves, strong magnetic fields, nonlinear plasma waves, etc.)
High energy laser topics

High energy density physics & fast ignition

Inertial Confined Fusion

Laboratory Astrophysics

High power laser technologies and diagnostic technologies

Fundamental laser-plasma

Short intense laser topics

Laser-driven particle acceleration

Laser-driven radiation

Laser-driven QED plasma physics
Inertial confined fusion physics and technologies, new concepts
(new facilities, new schemes and concepts)
Hybrid drive (HD) approach for ICF combined the advantage of indirect drive (ID) and direct drive (DD) and discarded their shortcoming, and is performs in two phases:

- Spherical hohlraum (SH) with six laser entrance holes (LEHs) and a layered capsule inside SH
- Typical driving source for ID T (black) and DD laser power (red)
- Cutting capsule
For the first phase: radiation temperature of T~200eV lower than that in traditional ID is generated by long pulse (~10 ns) ID lasers which irradiate to inner wall of SH through six LEHs, and ablates the surface of a layered capsule with fuel to drive a pre-compression via implosion dynamics, meanwhile, a long scale ID corona plasma is formed.

For the second phase. DD laser beams incident upon critical surface formed by ID corona plasma during last 2 ns of ID long pulse and are absorbed there. A supersonic-e-thermal wave is formed near critical surface and propagates in the ID corona toward radiation ablation front (RAF).
Such high plasma pressure drives a maximal implosion velocity $V_{im} > 400\text{km/s}$ and stops the ID shock reflection, which rebounded from off-center of hotspot, at the hotspot interface. As a result, the HD shock suppresses hotspot deformation and hydrodynamic instabilities caused by the ID shock reflection at hotspot interface. The HD shock enters hotspot that is further heated and the non-stagnation and high-gain ignition occurs when the HD shock rebounded near hotspot center first reflects there.
Laser Megajoule Status and Program Overview

LMJ status

- LMJ is part of the Simulation Program which combines physics models, numerical simulation and experimental validation
- 6 experimental configurations have been defined during the ramp-up of LMJ
- LMJ is now working in the 2\textsuperscript{nd} configuration (2 bundles = 16 beams, 60 kJ, 4 diagnostics) since end 2016, and it provides good overall performances
- 3 other bundles are mounted and will be activated next year (3\textsuperscript{rd} configuration, 150 kJ, 10 diagnostics)
- Three activities are performed at the same time:
  - Mounting of new bundles
  - Commissioning of the previous assembled bundles
  - Physics experiments
- The 1\textsuperscript{st} step of nuclear commissioning is in progress (October 2017)

Program overview

- CEA is developing a thematic approach on LMJ, and has defined 8 experimental topics for the Simulation Program
- Several physics campaigns have been performed since 2014 and have addressed 3 of these topics.
- The obtained experimental results are in good agreement with the simulations
- About 10 experiments are planned till 2019 and will addressed 6 different topics
- The first implosions with D\textsubscript{2}+Ar capsules are planned in 2019
PETAL status academic access to LMJ-PETAL

- PETAL, a multi-PW beam coupled to LMJ, will offer the opportunity to study a wider field of physics
- A record of 1.2 PW (840 J – 700 fs) has been obtained in 2015.
- Pulse duration has been improved (570 fs) and should bring the power to 1.8 PW

Academic access to LMJ-PETAL

- 2 call of proposals for 2017-2020 have received a great success (25 proposals)
- 6 experiments have been selected by the international scientific advisory committee
- LMJ-PETAL is ready for the first international academic experiments in December 2017
Proposal of two-system PIC for the whole FI heating study

Laser

Conventional PIC system (maximum of ne = 200 nc)

Hybrid PIC system (real density profile ne up to 54000 nc = 300 g/cm$^3$ for tritium target)

Injection point of fast electrons of $E > 0.1$ MeV and $p_x > 0.45mc$ (50 keV)

Fast electron current ($J_{fx}$) in the hybrid system

Magnetically assisted (MA) scheme with cone-free target

MA scheme can bring much higher laser-to-core coupling than the cone.

Two-system PIC simulations show: via MA, two counter-propagating lasers of 28kJ and 5 ps can heat the target core >5keV, reaching an ignition temperature.

W.-M. Wang et al., arXiv:1606.02437
The neutral plasma block acceleration by intense picosecond \((10^{16} \text{W/cm}^2)\) has been demonstrated by PIC simulation for the first time.
Boron laser fusion by plasma block ignition

-Jiaxiang Wang and Heinrich Hora-

The neutral plasma block acceleration by intense picosecond ($10^{16}$W/cm$^2$) been demonstrated by PIC simulation for the first time.
Laboratory astrophysics and high energy density physics

(radiative shocks, hydrodynamic instabilities, warm dense matters, strong magnetic field effects, and diagnostic, etc.)
Astronomical observation is passive, far-distanced, and uncontrollable.

Experimentally studying astrophysics with the intense laser-driven extreme conditions in lab.

Space and time scaling
Typical results of laboratory astrophysics we have obtained

- Strong B fields in universe
  - APL 107, 261903
  - MRE 1, 187

- Magnetic reconnection in solar-earth space
  - Nat. Phys. 6, 984
  - PRL 108, 215001
  - AJPS 225, 30

- Collisionless shocks in supernova remnants
  - New J. Phys. 13, 093001
  - Sci. Rep. 7, 42915
  - Sci. Rep. 6, 27363

Highlighted by Nature China
Highlighted by Nature Photonics

P30: Yutong Li
Summary

- Strong B fields \( \sim \text{hundreds T} - \text{kiloT} \) can be obtained with intense lasers.
- Laser-driven magnetic reconnection has been constructed.
- We have studied the collisionless shocks generated in the interactions of two counter-streaming flows. Filaments probably due to Weibel-type instability are observed.
Time-resolved XANES (x-ray absorption near edge structure) for warm dense matters

Warm dense Cu:
- $L_{2,3}$ – XANES measurement with 2ps resolution
- Temporal evolution of WDCu has been determined by comparing MD-DFT calculations with XANES measurement
- Enhanced electron-phonon couplings of noble metal in WD condition have been experimentally determined
Warm dense SiO$_2$
- Electronic states associated with broken Si-O bonding during the insulator-metal transition are examined.
- $T_e$ and $T_I$ effects on O K-edge XANES spectrum has been investigated.
Strong quasi-static and transient fields driven by laser and the enhancement of the energy-density flux of charged particle beams

João Jorge Santos (joao.santos@u-bordeaux.fr)

- Magnetostatic-field on the excess of 0.5 kT from ns laser-driven diode

- Driving laser: 500 J, 1 ns, $10^{17}$ W/cm²

- Reproducible B-field peak and rise-time
- Few ns duration
- Magnetized volume of 1 mm³ (for $a = 250 \mu$m)
- Compact, open geometry, suitable for laser-plasma experiments

At the coil center:

$$B_0 \approx \frac{\mu_0 I}{2a} \approx 600 \text{ T}$$

coil radius = 250 µm

RCF data

Simulation pour $B_0 = 95 \text{ T}$

J.J. Santos et al., New J. Phys. 2015

Strong quasi-static and transient fields driven by laser and the enhancement of the energy-density flux of charged particle beams

João Jorge Santos (joao.santos@u-bordeaux.fr)

- Magnetic guiding of 10 MA current of MeV-electron beams in solid targets

M. Bailly-Grandvaux et al., submitted to Nat. Comm.

- 10^{10} V/m transient discharges driven by intense ps lasers

Space-time scales captured by proton-deflectometry

- Lens effect on up to 12 MeV protons lasts < 30 ps

⇒ possible energy selection by tuning the lasers delay
Interest about H$_2$O justified by planetological research: origin of the magnetic fields of Uranus and Neptune.
Experimental results on refraction index of compressed water and comparison with ab-initio calculations

Quantum molecular dynamic calculations performed with the ABINIT-ATOMPAW code, a common project of the Université Catholique de Louvain, Corning Incorporated, Commissariat à l’Energie Atomique, Université de Liège, Mitsubishi Chemical Corp (www.abinit.org)

Interpolations of simulation results with an extended Lorentz-Drude model can provide information on underlying physics (gap closure, ionization, ...)

\[ E_g (\rho, T) = E_{g0} \left[ \frac{\rho_c - \rho}{\rho_c - \rho_0} - B \frac{T}{T_0} \right] \]
Colliding-shock compression @ ShenGuang

- Hohlraum Design

“Dog bone” gold hohlraum

J. Y. Zhang et al., POP 19, 113302 (2012)
Y. Zhao et al., PRL 111, 155003 (2013)

- near-Planck x-ray radiation.
- symmetrical inward shocks.
- two shocks simultaneously propagated into the layer and collided at the center.

The central target was invisible to the laser-hitting point, and therefore, it stopped the M-band x rays from preheating and scattered laser lights ablating the sample.
Absorption Edge of Warm Dense Matter

**Experiment**

- Heating laser: 8×260J, 1ns
- Backlighter (Bi): 130J, 130ps
- CHCl filter
- Diffraction crystal
- X-ray film
- Backlighter, KCl

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**Multi-1D code**

- 38μm CH
- 5μm KCl

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**Hydrodynamic process**

**K-edge at three delays**

The shifts and broadenings of the K-shell absorption edge for the compressed WDM are studied.
Electron Energy Spectrum in Magnetic Reconnection in Laser-Produced Plasma

L-O4: Kai Huang

- **squeezing stage** ($\Omega_t = 0 - 0.6$)
  - Electron get accelerated when reflected by the plasma bubbles
  - Acceleration dominated by convective electric field
  - Fermi acceleration

- **reconnection stage** ($\Omega_t = 0.6 - 0.79$)
  - Electron gets accelerated in diffusion region
  - Acceleration dominated by non-ideal electric field
  - Reconnection electric field acceleration
Simulation results

- Energy distribution of non-thermal electrons produced during squeezing stage at initial time ($\Omega_i t = 0$)
  - Energy threshold

- Energy distribution of non-thermal electrons produced during reconnection stage at initial time ($\Omega_i t = 0.6$)
  - No obvious multistep acceleration
Ultra-high power laser system development
(multi-PW lasers, intensity contrast control)
IBS Center for Relativistic Laser Science

L-I14: Chang Hee Nam

• PW Ti:S Laser
  (1) Beam line I: 20 fs, 1.0 PW @ 0.1 Hz
  (2) Beam line II: 20 fs, 4.2 PW @ 0.1 Hz
• 150-TW Ti:S Laser: 25 fs @ 5 Hz
Laser Compton $\gamma$-ray production via the interaction of GeV e-beam with $10^{18} - 10^{22}$ W/cm$^2$ laser field

- **Compton backscattering:** $e^- + \omega_0 \rightarrow e^- + \gamma$
  MeV-Gamma beams useful for photo-nuclear physics

- **Nonlinear Compton Scattering:**
  $e^- + n\omega_0 \rightarrow e^- + \gamma$

- **Measuring radiation reaction** effects
  Energy loss and radiation damping (cooling) of electron beam

- **Breit-Wheeler pair creation:**
  $\gamma + n\omega_0 \rightarrow e^- + e^+$

- **Assessing strong field QED theories**
SULF (Shanghai Superintense Ultrafast Laser Facility): 200J/20fs

implement the 10PW laser in a new lab. (2015-)

L-I9: Ruxin Li
Current view of the J-KAREN-P laser system

L-I10: Hiromitsu Kiriyama

Focal spot has been evaluated using an OAP with f/1.3 – approaching diffraction limit –

✓ Focal spot

✓ Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2016-11-08 Ti:S BA1</th>
<th>Diffr. Limit</th>
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</thead>
<tbody>
<tr>
<td>FWHM x, μm</td>
<td>1.32±0.05 (4%)</td>
<td>1.07</td>
</tr>
<tr>
<td>FWHM y, μm</td>
<td>1.37±0.03 (2%)</td>
<td>1.23</td>
</tr>
<tr>
<td>FW1/e² x, μm</td>
<td>2.19±0.15 (7%)</td>
<td>1.72</td>
</tr>
<tr>
<td>FW1/e² y, μm</td>
<td>2.30±0.17 (8%)</td>
<td>2.04</td>
</tr>
<tr>
<td>Energy above 1/2, %</td>
<td>32±4 (11%)</td>
<td>50</td>
</tr>
<tr>
<td>Energy above 1/e², %</td>
<td>56±2 (4%)</td>
<td>82</td>
</tr>
<tr>
<td>I₀ at 300 TW, W/cm² (f/1.25)</td>
<td>(0.93±0.12)×10²²</td>
<td>2.0×10²²</td>
</tr>
<tr>
<td>Strehl ratio</td>
<td>0.46±0.06</td>
<td>1</td>
</tr>
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</table>

10²² W/cm² at 0.1 Hz is achieved at 0.3 PW power level

Recently, advanced type of double plasma mirror system was established in CoReLS, Korea.

For 4 PW laser system, Reflectivity of the double plasma mirror is measured \(~70\%\) which shows better performance compare to the reflectivity measured with 1 PW laser system by \(~40\%\).

When plasma mirror transform from transmissive surface to reflective surface within 5ps, it has higher reflectivity than the case after 5ps.
Laser plasma based particle acceleration and radiation

(electron acceleration: higher energy, higher quality, higher acceleration gradients)
4 PW Laser & LWFA setup at CoReLS

4 PW + 1 PW Laser

Electron acceleration chamber

Focusing mirror 1 (f=6m)

Deformable mirror chamber (D=30 cm, 129 channel)

Target chamber

Dipole magnet

Gas cell

1-m long magnet
Preliminary results using multi PW laser pulses

Laser parameters: 52 J on target, focal spot ≈ 50 μm (FWHM), + 30 fs (GDD +350 fs⁻²), \( I \approx 4 \times 10^{19} \text{ W/cm}^2 \), \( a_0 \approx 4.5 \)

Gas medium: He mixed with 1-% Ne, 7-cm gas cell, plasma density \( \approx 1.5 \times 10^{18} \text{ elec./cc} \)

- **LANEX 1 (profile)**
- **LANEX 2 (spectrum at the end of magnet)**
  - Electron energy at peak: \( \approx 4.5 \text{ GeV} \)
- **LANEX 3 (spectrum at 53 cm from magnet)**
- **LANEX 4 (spectrum at 146 cm from magnet)**

Deeply saturated
Divergence < 2 mrad
Total Charge >> 1 nC
High quality electron acceleration in LWFA based on controlled ionization injection

1. Self-truncated ionization injection

2. STII demonstration at SJTU

3. Two color ionization injection
   low energy spread

4. Two color ionization injection
   low transverse emittance

Vacuum → Gas → Ionization → Ionization

Wake → 1st Injection → Acceleration → 2nd Injection

Charge Density ($\times \ pC/MeV$)

Electron Energy (GeV)
1. Plasma channel based undulator radiation

2. Nonlinear Thomson scattering

References:
A high quality laser wakefield injector with sub-half MeV absolute energy spread at Tsinghua Univ.

Very low absolute energy spread (AES) and relative energy spread (RES) observed using 5TW 60fs laser system:

On many shots, AES below 0.5MeV (rms), with the lowest 0.18MeV

On many shots, RES around 1-2% (rms), with the lowest 0.8%

Small divergence of a few mrad, with the smallest 1.2mrad

Booster in second accelerator:
Energy gain: 1.9GeV;
ABS: 0.365MeV rms; RES: 0.0192% rms
Femtosecond Relativistic Electron Probe

**Benefits:**
- Direct measurement of field;
- Work at Low density plasma.
- $E_z$ field: Sin form
- $E_r$ field: $r \times \exp(-r^2/\sigma^2)$
- Peak $E_z$ is $\sim 1$ GeV/m
- Linear $E_r$ field (+/-8µm)

Observation of the Plasma Wake Reversal
Guided versus unguided

For 1 nm drivers, energy gain is 2TeV/cm

Energy gain gradient is 2TeV/cm instead of 2GeV/cm in the optical laser case.

X ray laser can be well guided by nanotube
(a) The space distribution \((x, y)\) and (b) the transverse phase space \((y, p_y/p_x)\) of the top 80% highest energy electrons in the case of X-ray laser.

Electron transverse motion is drastically reduced but momenta is the same, so emittance is expected to be reduced.

Top 80% energetic particles
Laser plasma based particle acceleration and radiation

(Ion acceleration: new facility, new target designs for better control, multiple beam effects, neutron atom acceleration)
1. Compact Laser Plasma Accelerator is running @PKU

1) Small emittance \&
Proton energy stability <3%

2) Quadrupole focusing

3) Before Analyzing

4) Position 4:
After BM

5) Position 5:
Radiation Platform

Original picture on the EMCCD

L-I13: X. Yan
2. 0.6 GeV Carbon acceleration in cascaded acceleration RPA+TNSA

Carbon Nano-Tube + DLC foil

W.J.Ma, Kim...X.Q.Yan, C.H.Nam, submitted 2017

~4 times enhancement, compared to one stage RPA acceleration

Experiments were performed using CoReLS PW Laser in Korea (Prof. C. H. Nam), cooperation between GIST and PKU
Layered Target
• For the generation of an energetic proton beam with narrow energy spread
• By utilizing a Bulk electrostatic field in the plasma

Target ion layer

Metal Foil | Metal Foil

Ion Layer-Embedded Foil target

1D Fluid Simulation

2D PIC Simulation (XOOPIC)

L-I15: Kitae Lee
Compact and efficient laser-neutron source

3D MD simulation shows that very high conversion efficiency ~ 30% can be obtained by hollow nanosphere

Hollow cluster targets

Energy spectrum (arb. unit)

Kinetic energy per nucleon (MeV)

Target 3

- Carbon
- Protons

C+H

30.1 %

L-I26: M. Murakami
Neutron energies produced by $p + Li \rightarrow n + Be$ are dramatically reduced due to the endothermic reaction $-1.64$ MeV.

Expected moderator thickness for low temperature neutrons is of the order of a few cm or even less.

$Ep = 1.9$ MeV

$Ep = 2.3$ MeV

$Ep = 2.7$ MeV

L-I26: M. Murakami
Accelerated atoms in laser produced plasmas

85% of ions become neutrals!

\[ w = 115 \, \mu m \]
\[ \eta = 85\% \]

Neutral Cu atoms up to 1 MeV are generated

Ions passing through colder preplasma are efficiently neutralised

Focal waist size crucially controls the extent of neutralisation
Proposition:
Co-propogation of electrons with protons??

Reduced velocity in the proton frame can contribute to electron ion recombination.

Gated Thomson spectrometer show H0 and H- emission from solid targets even at $10^{18}$ W cm$^{-2}$ high contrast pulses.

Neutral H atom emission @ $10^{18}$ W cm$^{-2}$
Laser plasma based particle acceleration and radiation

(Radiation: Compton scattering sources, gamma-rays near QED regime, mid-infrared radiation, etc.)
Compton scattering $\gamma$-rays based on high quality e beams

Previous works: Ta Phuoc et al., Nat. Photonics 6, 308 (2012)
Tsai et al., Physics of Plasmas 22, 023106 (2015)
This work: C. Yu et al., Scientific Reports, 6, 29518 (2016)

L-19: Ruxin Li
Self-matching resonant acceleration by CP laser is much more advantageous over direct laser acceleration by LP laser.

Electron acceleration:

- Trapping can be enhanced by $B_{sz}$
- Self-matching process leads to that much more electrons can be preaccelerated to achieve resonant condition
- $B_{sz}$ contributes to the betatron frequency, help to reach the resonance condition

Synchrotron radiation:

- Synchrotron radiation can be much enhanced due to helical motion trajectory (always locate at the “turning” point)
- $\gamma$-ray photon radiation has vortex structure
A new resonance acceleration scheme for generating ultradense relativistic electron bunches and emitting brilliant vortical γ-ray pulses in the QED regime by CP lasers.

With QED

Without QED

Vortex γ-ray photons

- Femtosecond duration (40 fs);
- Relatively small polar angle (0.2 rad);
- The photon energy can extend to 1.2 GeV;
- The radiation power (6.7PW);
- The brightness at 15 MeV

$3.5 \times 10^{25} \text{photons/s/mm}^2/\text{mrad}^2/0.1\%BW$
Radiation Reaction trapping effect is discovered in the near-QED regime when the expelling Lorentz force is balanced by the RR force.

\[ F_{L,y} \sim F_{rr,y} \]

\[ a_{thr} \sim (2 k_p \omega_0 r_e / 3 c)^{-1/3} \sim (r_0 / r_e)^{1/3} \]

- RRT significantly change the LPI in the near-QED regime.
- Leads to efficient emission of Gamma-photons

\[
\frac{dp}{dt} = F_L + F_{rr}
\]

\[
F_{rr} \approx -(2e^4 / 3m_e^3c^5)\gamma^2 v \left[ (E + v \times B / c)^2 - (E \cdot v)^2 / c^2 \right]
\]

\[
F_L = -e(E + v \times B / c)
\]

Laser-electron collider within a micro-channel

Laser:
\[ 2 \times 10^{22} \text{W/cm}^2, 35 \text{fs}, \sigma_0 = 4 \text{ um} \] (5 PW, 170 J)

A laser-electron collider is proposed by coupling one-single multi-PW laser system with micro-channel structure.

First proof-of-principle experiment with 200 TW laser verifies the advanced electron source from micro-channel structure.

Proof-of-principle experiment using a 200TW laser

L-I 31: Liangliang Ji
Laser-compton scattering gamma-ray source based on BEPCII

- X-ray/γ-ray calibration
- Photon-nuclear physics
- Nuclear astrophysics
- γ-γ collider
- Basic QED/QCD phenomenal exp. Check

0.16-111MeV γ-ray Energy-tunable, polarized

L-I33: Y. Huang
Ultra-intense laser+relativistic plasma -> to check QED effect in Plasmas

- QED effect cancels with the plasma effect:

\[ \Delta n_{\pm} \approx \mp \hat{\omega}_p^2 \pm \frac{3}{2} (1 \mp \beta_0)^2 \xi, \]

To estimate the thickness of the magnetosphere of a millisecond pulsar:

\[ L_{B,ms} = C_{L,\psi} \frac{\lambda}{(1 \pm \beta_0)^2 B_0^2} \psi_{\max,\lambda}, \]

To estimate the plasma density of a pulsar:

\[ n_0 \approx C_{n,B} (1 \pm \beta_0)^2 \frac{B_0^2}{\lambda_{c,l}^2} = C_{\omega,B} \omega_{c,l}^2 (1 \pm \beta_0)^2 B_0^2, \]

Yongsheng Huang, Scientific Reports, 2015,5:15866
Photon deceleration in the bubble regime

- The laser pulse undergoes strong self-phase modulation due to the longitudinal gradient of the refractive index in the plasma bubble. If the laser pulse completely resides in the first half of the plasma wave, its frequency can be completely down-shifted (photon deceleration).

- With a plasma structure, this photon deceleration process can be largely enhanced.
Photon deceleration in the bubble regime can be largely enhanced with a tailored plasma structure.

With plasma structures, under the optimal conditions, the energy of the generated mid-IR pulse in 2-8 μm wavelength range reaches 15.5mJ, corresponding to conversion efficiency as high as 5.2%.

L-I5: Chi-hao Pai

- 30fs, 300mJ, 800nm, 10Hz Ti:sapphire laser
Fundamental laser plasma physics
(fs-laser driven shocks, external magnetic control of plasma dynamics, nonlinear plasma waves)
Hydrodynamics Driven by Intense short-pulse lasers,

J. Pasley et al

York Plasma Institute, University of York

(Please see next slide for bibliography/major institutional collaborators)

Ring-like XUV signature of shock propagation from central hotspot

Non-ablative RT growth driven by radiative cooling

Shock formation

Hydro-instability producing high frequency soundwaves
Hydrodynamics Driven by Intense short-pulse lasers

J. Pasley
York Plasma Institute, University of York

Generation of high-pressures in aluminium by femtosecond low-energy laser irradiation


CELIA (Bordeaux), LOA (Palaiseau), IPPLM (Warsaw)

Formation of a blast wave

1D hydro simulations performed with the code CHIC
Highlights of the experiment:

✓ Very strong pressures using a short-pulse high-intensity laser \((\text{initially} \geq 100 \text{ Mbar})\);

✓ The shock has a BLAST WAVE structure and the pressure rapidly decreases to \(\leq 1 \text{ Mbar} \) at shock breakout

✓ There is a complex shock dynamics dominated by the effects of target expansion. The shock has constant velocity;

✓ Due to target decompression the blast wave is lost along the axis but the blast wave structure is maintained out of axis;

✓ We measured the color temperature at shock breakout which resulted in good agreement with CHIC simulation.

✓ HED states can be created and probed with short-pulse high-intensity lasers

✓ It will be possible to perform studies on blast waves with implications for astrophysics
B field can replace gas filled in hohlraum to confine plasma expansion

- 15% of the absorbed laser energy converts into B field energy
- Effective in 0.3-1000J laser energy
Hall effect caused asymmetric bubble
B field enhances ablation

L-I29: Guangyue Hu
Wave breaking of Relativistically intense longitudinal waves in plasma - I (cold plasma)

L-I7: Sudip Sengupta (IPR, India)

Akhiezer-Polovin wave propagating through a cold plasma

Perturbed Akhiezer-Polovin wave exhibiting wave breaking

- A longitudinal Akhiezer-Polovin wave breaks via phase mixing at an amplitude well below its wave breaking limit, when it is longitudinally perturbed.
- Therefore all those experiments which depend on Akhiezer-Polovin wave breaking limit for their interpretation will require revisiting.

Wave breaking of Relativistically intense longitudinal waves in plasma - II (Warm plasma)

- Longitudinal waves in a warm plasma also break via the process of phase mixing.
- Therefore there is no real wave breaking limit for a longitudinal wave in a warm plasma.
Summary

- New fusion concepts remain an important topic.
- Laboratory astrophysics and high energy density physics are emerging frontiers.
- Short pulse laser-plasma interaction and their applications are pursued widely in Asian countries.
- New technologies related with ultra-high power lasers, diagnostics, and magnetic field push the laser-plasma interaction to new regimes.
Many thanks to laser-plasma program speakers!

Thank you for your attention!