Working Group 7 / 1st Part

• **WG7 - High brightness power sources: from Laser Technology to beam drivers**

  Topics addressed:
  Needs for laser driven accelerators (laser-plasma ion source, LWFA, IFEL, dielectric laser, ...)

• State-of-the-art of high peak and average power and perspectives

• Laser beam quality, contrast, stability

• **Co-Leader:** Leo Gizzi
  **Co-Leader:** Barbara Marchetti
  **Co-Leader:** Rajeev Pattathil
**Feedback control of the spatio-temporal properties of high-intensity laser pulses to optimize x-ray and 100 MeV electron generation** 30'
Speaker: Dan Symes (Central Laser Facility, STFC Rutherford Appleton Laboratory, Didcot, UK)
Material: Slides

**Phase-space reconstruction of low-emittance electron beams through betatron radiation in a laser-plasma accelerator at FLAME facility** 20'
Speaker: Alessandro Curcio (LNF)
Material: Slides

**HDR spatio-temporal intensity mapping by single-shot optical probing** 20'
Speaker: Mr. Martin Speicher (LMU Munich)

**Effects of pulse shape and plasma density on laser propagation in laser-driven wakefield accelerators** 20'
Speaker: Dr. Matthew Streeter (The Cockcroft Institute)

“Feedback control of the spatio-temporal properties of high-intensity laser pulses to optimize x-ray and 100 MeV electron generation”
Dan Symes (Central Laser Facility, STFC Rutherford Appleton Laboratory, Didcot, UK)

High rep-rate allows a fine resolution scan of parameter space

- Each row of data is 50-shot average
- Features that may be missed with coarser scan

Showing the great potential of feedback loop with rep-rated laser operation
“Phase-space reconstruction of low-emittance electron beams through betatron radiation in a laser-plasma accelerator at FLAME facility”

Alessandro Curcio (LNF)

A method for “on-line” monitoring of shot-by-shot variations of LWFA performance
“HDR spatio-temporal intensity mapping by single-shot optical probing”
Martin Speicher (LMU Munich)

Summary – HDR spatio-temporal intensity mapping by single shot optical probing

- Optical probing of the laser-generated plasma on a nm-thin foil with a synchronized, chirped probe pulse
- Image multiplexing provides nine images of the dynamic plasma evolution in a single shot with 200 fs temporal and 25 μm spatial resolution
- New concept to acquire a 2D spatio-temporal intensity distribution of a high power laser on target at full shot
- Future: Powerful tool to analyse spatio-temporal laser plasma conditions on target (e.g. with implemented plasma mirror)

Technique to extract details of laser pulse temporal evolution ON TARGET
“Effects of pulse shape and plasma density on laser propagation in laser-driven wakefield accelerators”
Matthew Streeter (The Cockcroft Institute)

Diagnostic of laser properties after driving 0.8 GeV plasma wakefield accelerator provide detailed measurements of pump-depletion and pulse compression in the highly non-linear regime.

This reveals power amplification that precedes self-injection

New model developed to describe laser pulse evolution

Sufficiently redshifted photons, \( \omega < \omega_0 / \sqrt{3} \) drift backwards through the pulse, due to group velocity dispersion.

Redshifted photons contribute to the laser power behind the pulse front.

Pre-injection pulse evolution length (when maximum power is reached) is dependent on initial pulse shape.

For a gaussian laser pulse:

\[
L_{\text{evol}} \approx \sigma_t c \left( \frac{2 \omega_0^2}{3 \omega_p^2} \right) \sqrt{\frac{1}{2} \ln \left( \frac{P_0}{P_c} \right)}
\]

\[
L_{\text{dp}} \approx 2L_{\text{evol}}
\]

Direct detection of role of laser/plasma properties on LWFA
Working Group 7 / 2nd Part

• WG7 - High brightness power sources: from Laser Technology to beam drivers

  Topics addressed:
  Needs for laser driven accelerators (laser-plasma ion source, LWFA, IFEL, dielectric laser, ...)

• State-of-the-art of high peak and average power and perspectives

• Laser beam quality, contrast, stability

• Co-Leader: Leo Gizzi
  Co-Leader: Barbara Marchetti
  Co-Leader: Rajeev Pattathil
18:00  Laser technology for k-BELLA and beyond 30'
Speaker: Dr. Wim Leemans (Lawrence Berkeley National Laboratory)

18:30  The FLAME laser at SPARC_LAB 15'
Speaker: Maria Pia Anania (LNF)
Material: Slides

18:45  Control and propagation effects of the wavefront quality for a high-power laser system 15'
Speaker: Mr. Vincent Leroux (ELI Beamlines)

19:00  Laser beam circulator for high brightness Inverse Compton Scattering Sources 15'
Speakers: Dr. Kevin Cassou (Laboratoire de l'Accélérateur Linéaire), Mr. Cheikh Fall Ndiaye (LAL), Dr. Aurelien Martens (LAL/IN2P3/CNRS)

19:15  Ten Meter Laser Propagation with Resonance Enhanced Ionization of Rubidium for Plasma Generation at AWAKE 15'
Speaker: Dr. Joshua Moody (Max Planck Institute for Physics)
Material: Slides
“Laser technology for k-BELLA and beyond”
Wim Leemans (Lawrence Berkeley National Laboratory)

Summary

k-BELLA can be built and road towards collider relevant power levels seems open
- Ti:sapphire: multi-kW (k-BELLA) straightforward
  - Incoherent fiber pumped
  - Yb:YAG diode laser pumped
  - Cooling geometries developed
  - 10’s – 100’s kW – challenging due to wallplug but one unit would provide injection module
- Tm:YLF: 2 micron system (has implications for collider); very high average power seems possible; existence proof needed on Joule class system
- Fiber based approaches: could ultimately provide highest performance in power and compactness, stability; great progress on tackling challenges; low energy high rep rate systems will be first deliverable
“HIGH EFFICIENCY, DIODE PUMPED PETAWATT LASERS FOR THE NEXT GENERATION PARTICLE ACCELERATORS AND SECONDARY SOURCES”

Constantin Haefner, Craig Siders, Andy Bayramian, David Alessi, Kyle Chestnut, Al Erlandson, Eyal Feigenbaum, Tom Galvin, Paul Leisher, Emily Link, Dan Mason, Bill Molander, Paul Rosso, Margareta Rehak, Kathleen Schaffers, Tom Spinka

- We have developed a conceptual design for a single-aperture, 300 kW Thulium:YLF Petawatt-class laser “BAT” consistent with requirements for laser wakefield accelerators
- The underlying technology is a modest extension of established LLNL gas-cooling and rep rated Petawatt technologies
- BAT makes use of a highly simplified laser architecture, multi-pulse extraction of CW-diode pumped Tm:YLF and thus providing good wall-plug-efficiency
- We have developed a list of system TRLs and challenges that will inform the strategic plan for R&D and RTP efforts

<table>
<thead>
<tr>
<th>System</th>
<th>Type</th>
<th>TRL Estimate</th>
<th>Integration Challenge</th>
<th>delivery horizon</th>
<th>E (J)</th>
<th>t (fs)</th>
<th>$P_{av}$ (kW)</th>
<th>$P_{peak}$ (PW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAPLS</td>
<td>DPSSL+TiS</td>
<td>7</td>
<td>Low</td>
<td>today</td>
<td>30</td>
<td>&lt;30</td>
<td>0.3</td>
<td>1</td>
</tr>
<tr>
<td>SHARC</td>
<td>DP CPA Nd:Glass</td>
<td>6</td>
<td>Low</td>
<td>3yrs</td>
<td>150</td>
<td>150</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Mini-BAT</td>
<td>DP CPA Tm:YLF</td>
<td>3-4</td>
<td>Medium</td>
<td>3-5yrs</td>
<td>3</td>
<td>40 or 100</td>
<td>3</td>
<td>.075</td>
</tr>
<tr>
<td>BAT</td>
<td>DP CPA Tm:YLF</td>
<td>3</td>
<td>Medium</td>
<td>5-7yrs</td>
<td>30</td>
<td>40 or 100</td>
<td>300</td>
<td>.75</td>
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</tbody>
</table>
“The FLAME laser at SPARC_LAB”
Maria Pia Anania (LNF)

Design of the vacuum chamber for the laser transport.
1\textsuperscript{st} chamber is for mirrors and 3 \text{ m} focal length off-axis parabola,
2\textsuperscript{nd} chamber is for interaction and 3\textsuperscript{rd} chamber is for diagnostics.

Movements of the capillary (filled with H2) will be made with hexapod.
Synchronization: needs to be at the fs level.

Unique full range of LINAC/Laser based science cases setting pointing and sync challenges.
“Ten Meter Laser Propagation with Resonance Enhanced Ionization of Rubidium for Plasma Generation at AWAKE”
Joshua Moody (Max Planck Institute for Physics)

- Fiber laser chosen for stability on long runs
- Laser BW is only 15nm with peak spectrum at 780nm
- Several Rb lines within spectrum

Diagnosis (ionizing and self-mod seeding) laser with 4.5 TW fiber technology for stability

<table>
<thead>
<tr>
<th>Laser type</th>
<th>Er: Fiber/Oscillator Ti:Sapphire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse wavelength</td>
<td>$\lambda_p = 780 \text{ nm}$</td>
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<tr>
<td>Pulse length</td>
<td>120 fs FWHM</td>
</tr>
<tr>
<td>Pulse energy (after compressor)</td>
<td>450 mJ</td>
</tr>
<tr>
<td>Laser power</td>
<td>4.5 TW</td>
</tr>
<tr>
<td>Focused laser size</td>
<td>$\sigma_{xy} = 1 \text{ mm}$</td>
</tr>
<tr>
<td>Rayleigh length $Z_R$</td>
<td>$\approx 3.5 \text{ m}$</td>
</tr>
<tr>
<td>Energy stability</td>
<td>$\pm 1.5% \text{ r.m.s.}$</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>10 Hz</td>
</tr>
</tbody>
</table>
“Wavefront and focal spot quality for a high-power laser system: ANGUS”

Vincent Leroux (ELI Beamlines)

CFEL, ELI-Beamlines
vincent.leroux@desy.de
lux.cfel.de
Contributions: M. Schnepp, S. Jolly, A. R. Maier

Great effort in detailed characterization of actual laser specs at interaction point and first investigations of effects of re-rated operation on transport line V
"Laser beam circulator for high brightness Inverse Compton Scattering Sources"

Dr. Kevin Cassou (Laboratoire de l'Accélérateur Linéaire), Mr. Cheikh Fall Ndiaye (LAL), Dr. Aurelien Martens (LAL/IN2P3/CNRS)

Towards successful implementation of self-alignment algorithms for alignment at interaction point
Summary of WG7
High brightness power sources: from Laser Technology to beam drivers

• WG7 was a great opportunity to learn about leading edge science&tech of laser characterization and control and imagine future directions for laser drivers for particle acceleration in plasmas

• Highly recommended WG for future EAAC conferences: will likely grow significantly

• Thanks to all contributors (especially those who uploaded their slides in time 😊)