AE76 High Duty Cycle FEL
Experiment Status Update

A. Ovodenko, T. Campese, A. Murokh – RadiaBeam Technologies
I. Pogorelsky, M. Polyanskiy – ATF BNL
N. Sudar, P. Musumeci - UCLA
Motivation: IFEL operation in a high rep pulse train regime with the help of an active laser cavity.

- Joint RBT/UCLA experiment, a combination of Radiabeam’s successful intracavity ICS experiment and advanced UCLAs IFEL experience at ATF
- A local laser cavity’s rep rate is matched to the RF period with a cavity length of 14.7m (49ns)
- In this scheme IFEL interaction with ATFs standard multi-bunch e-beam trains is possible for every second bunch
- Beamline layout includes space for two bunchers
UCLA’s Double Buncher Beamline

• Improved IFEL capture rate demonstrated by Nick Sudar in UCLA’s double buncher experiment this spring

• 2IFL laser cavity was adapted by shifting the undulator downstream and increasing OAP focal length from 2.5 to 3m

• In Nick’s experiment undulator was partially tuned for AE76/2IFL parameters, which can be used as a preview of the expected single-bunch performance of 2IFL

• Multi-bunch operation of the spectrometer will require ATFs framegrabber scripts
Further Beamline Additions

- New kinematic breadboard in the spectrometer chamber
- Rebuild of the laser transport upstream of BL2
- Additional BPMs: dual position Ge/YAG
Amplifier Move to BL2

12/6/2017

2017 ATF User Meeting – AE76
Laser Cavity Overview

- 14.7m / 49ns long laser cavity
- Circular polarization, 5 degree angled windows on amplifier and beamline
- 3m focusing optics with built in 10cm OAP translation platforms for collimation control
- TW amplifier provides 1J initial energy (limited by amplifier aperture and optical materials)
- 16-pulse train at 0.5-0.7 J
- Energy could increase up to 1J if injection window can handle higher seed laser energy

<table>
<thead>
<tr>
<th>Injection</th>
<th>1J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser energy (peak region)</td>
<td>500-700mJ typical</td>
</tr>
<tr>
<td>Laser power (peak region)</td>
<td>100-160 GW</td>
</tr>
<tr>
<td>Number of pulses</td>
<td>5-15</td>
</tr>
<tr>
<td>Spot size, FWHM</td>
<td>1.7 mm</td>
</tr>
<tr>
<td>Rayleigh range</td>
<td>0.55 m</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>3.5ps</td>
</tr>
</tbody>
</table>
Laser Pulse Train Diagnostics

- Imaging optics create undulator IP-equivalent laser waist for diagnostics outside of the beamline

- Allows waist scanning of the seed laser pulse, complete laser train developed from it, and any specific IFEL-interacting part of the pulse separated with Pockel’s Cell.

- Waist optimization: OAP focus shape and correction of per pass z-axis focal point

- This system is also able to image IP pinhole (from a custom BPM) which is used for co-alignment of e-beam and laser trains at the upstream end of the undulator
• System needs to minimize pulse splitting
• Amplifier is already operating at peak gas pressure and energy discharge levels
• TW injection leads to a reduction of total amplification of the initial pulse by two orders of magnitude
• Further, by utilizing specific $^{18}$O : $^{16}$O = 0.6 : 0.4 isotopic gas mixture to limit spectral modulation, at a cost of slightly lower per-pulse gain (which is partially offset by the use of increased TW amplifier injection) – pulse splitting is no longer a significant factor
Amplifier installation is complete
System can work with isotopes (50L have been prepared). Isotopic recovery system passed the inspection
This week: working on trigger cables and pulse generator setup
Major laser cavity optics including OAPs are in place
CO2 laser shielding is done, 3B HeNe is in process
Pulse train diagnostics section is being installed this week
December Cavity Commissioning

- Intermediate objectives with CO2 Regen amplifier:
  - Finish transport line telescope
  - Install and calibrate diagnostics
  - OAP alignment
  - Bring the cavity online
  - Detailed waist scans at IP, make corrections to z-axis laser waist drift

- Switching over to TW amplifier injection
  - adjust diagnostics
  - introduce of the O:18 gas mixture into the vessel. If time permits, confirm pulse length with the streak camera
  - Analyze final cavity configuration – total energy, distribution in the laser train and interaction pulse energy, pulse length, waist spot size, etc.
  - Results will determine if undulator needs to be re-tuned from the current state (based on simulated cavity parameters)

- Complete testing by 2\textsuperscript{nd} week of January
- Test out isotopic recovery system at the end of the run
Beam Time Requirements for 2018

- 4 weeks of combined laser/e-beam time + up to one week BL2 installation

- Initial 2-week run - fully functional system with 2+ IFEL interactions. Key goals:
  - Tweaking cavity timing through synchronization to different laser train pulses (probing with single e-beam)
  - Spectrometer calibration and experience with framegrabber scripts
  - Stable single and eventually multi-bunch e-beam tune (0-1 bunchers, 3-7 bunches e-beam)
  - Synchronization to 2+ laser train pulses

- Follow-up run:
  - focus on maximizing efficiency of single IFEL interaction (laser energy in the target region of pulse train + capture rate from addition of 2\textsuperscript{nd} buncher)
  - increasing the length of the e-beam train
  - Improved synchronization for up to 10 IFEL interaction (20-bunch e-beam)
Conclusion

• High duty cycle IFEL project combines two very strong thrusts of ATF program: IFEL program and recirculated ICS

• Key development areas: use of isotopes to limit pulse splitting, effective laser diagnostics tools for 0.5-1ps synchronization of delayed pulse trains, stable IFEL e-beam in multi-bunch mode

• Beamline configuration was jointly developed with UCLA and has had a trial run as part of their single-bunch IFEL experiment in the spring

• Laser cavity development is expected to be completed by mid January

• Overall, the goal of demonstrating a combined high repetition rate IFEL-ICS system during this spring/summer looks to be on track