AE76 High Duty Cycle FEL

Experiment Status Update

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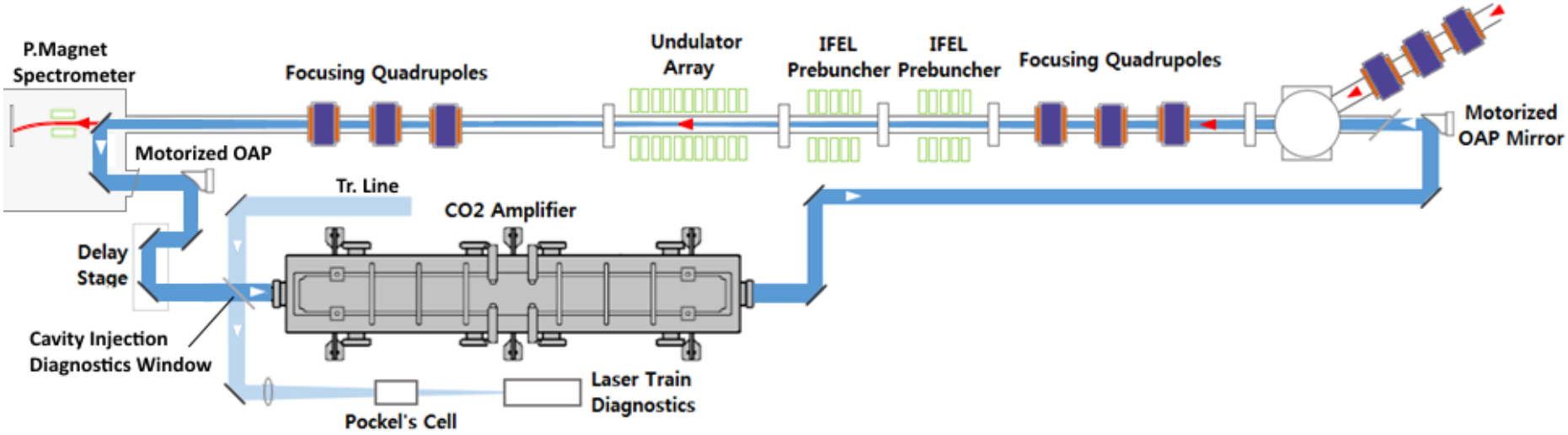
AE76 Schematic Description

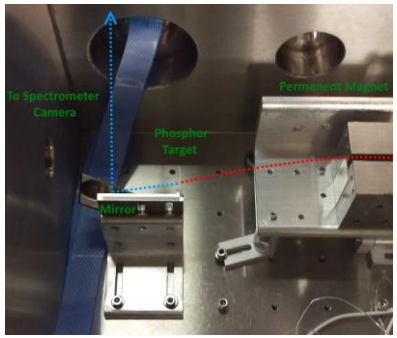
Motivation: IFEL operation in a high rep pulse train regime with the help of an active laser cavity.

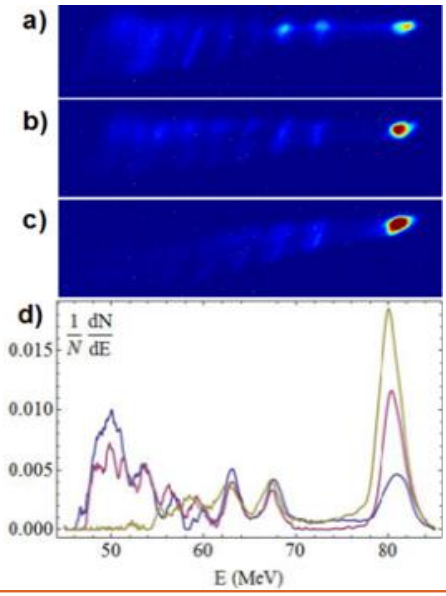


- Joint RBT/UCLA experiment, a combination of Radiabeam's successful intracavity ICS experiment and advanced UCLAs IFEL experience at ATF
- A local laser cavity's rep rate is matched to the RF period with a cavity length of 14.7m (49ns)
- In this scheme IFEL interaction with ATFs standard multi-bunch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

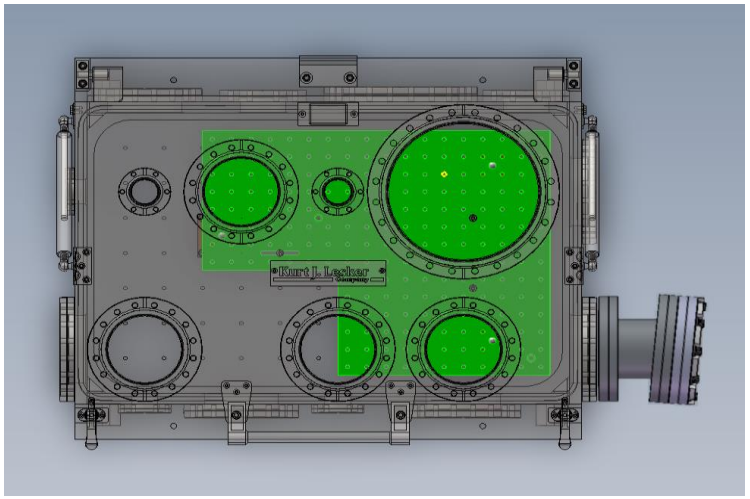
UCLA's Double Buncher Beamline

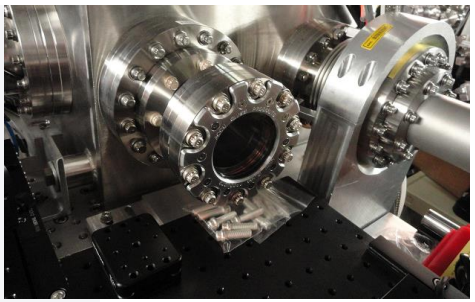
- Improved IFEL capture rate demonstrated by Nick Sudar in UCLA's double buncher experiment this spring
- 2IFL laser cavity was adapted by shifting the undulator downstream and increasing OAP focal length from 2.5 to 3m
- In Nick's experiment undulator was partially tuned for AE76/2IFL parameters, which 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

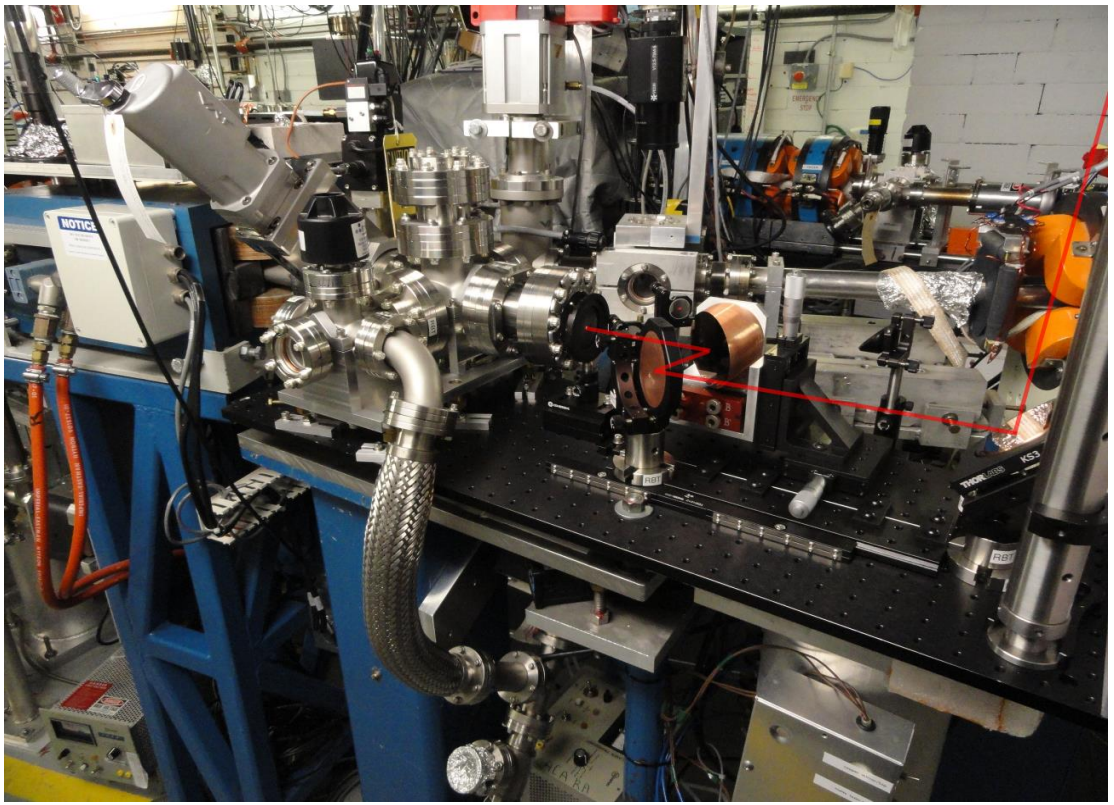


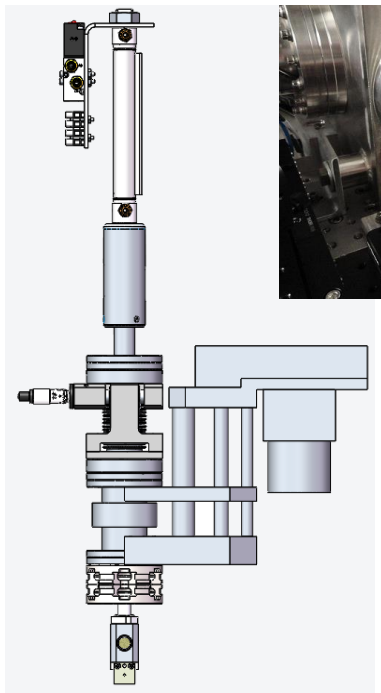


Further Beamline Additions



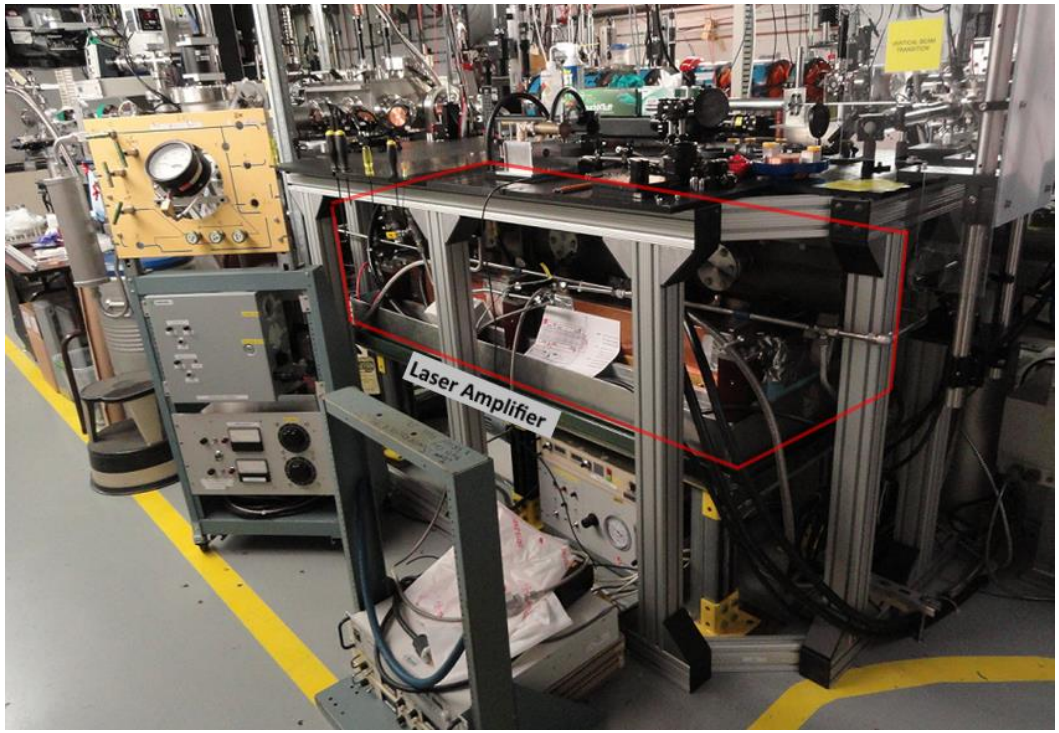


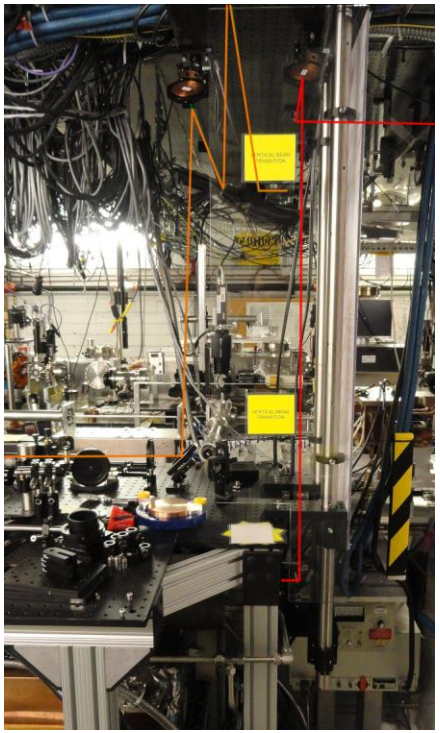


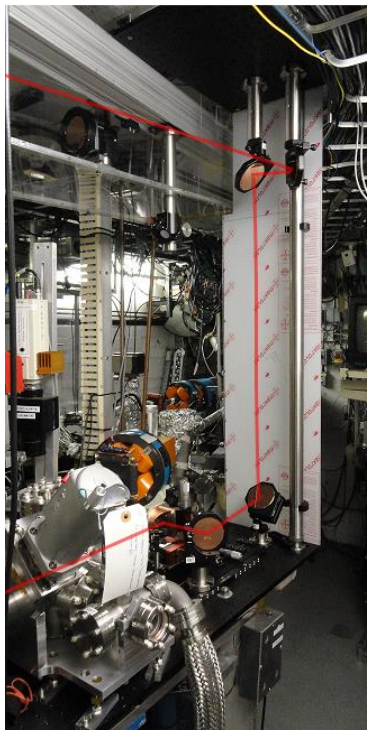


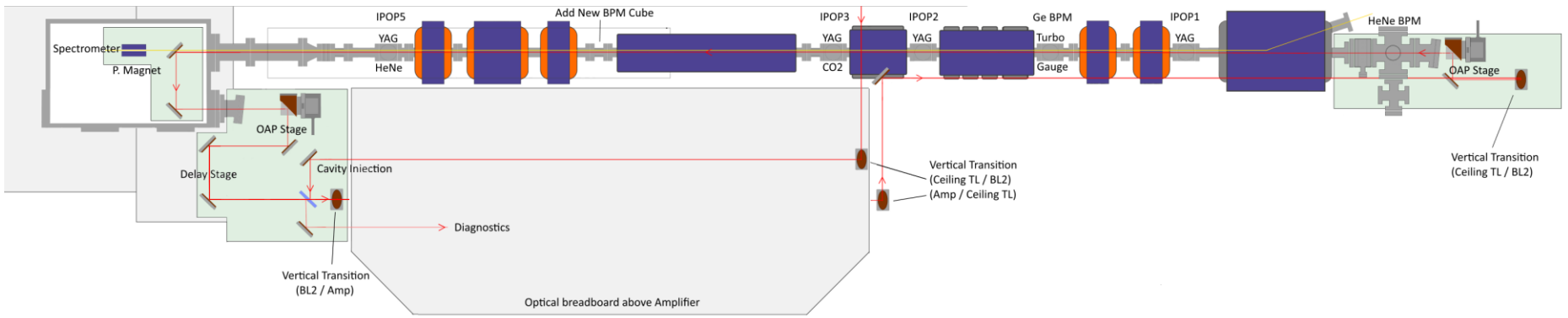
- New kinematic breadboard in the spectrometer chamber
- Rebuild of the laser transport upstream of BL2
- Additional BPMs: dual position Ge/YAG

Amplifier Move to BL2



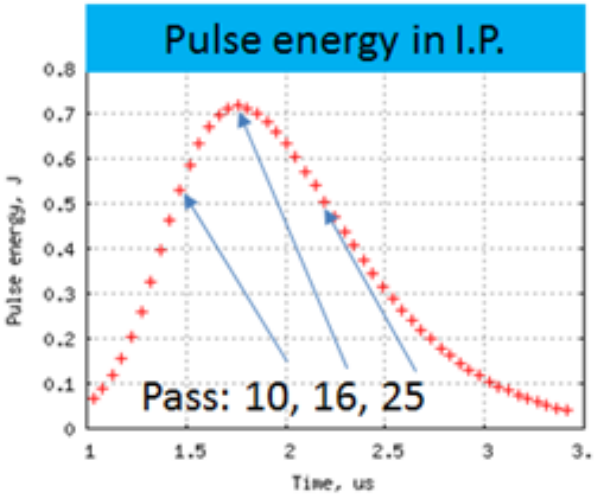


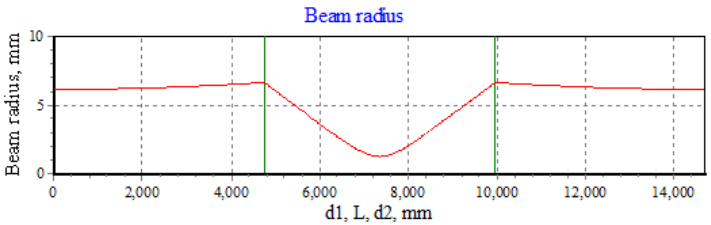


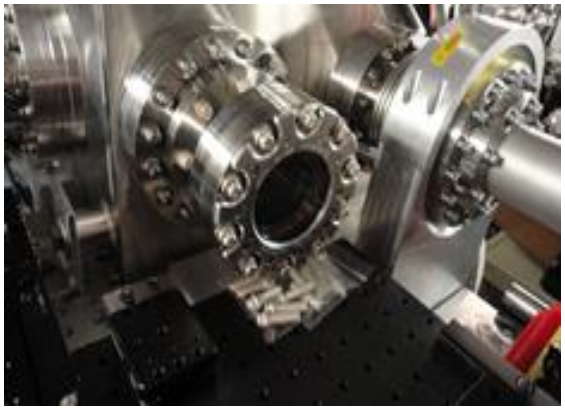


Laser Cavity Overview

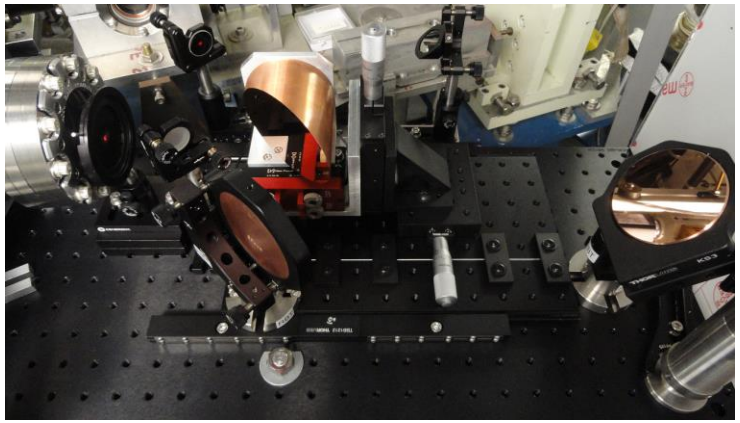
- 14.7m / 49ns long laser cavity
- Circular polarization, 5 degree angled windows on amplifier and beamline
- 3m focusing optics with built in 10cm OAP translation platforms for collimation control
- TW amplifier provides 1J initial energy (limited by amplifier aperture and optical materials)
- 16-pulse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



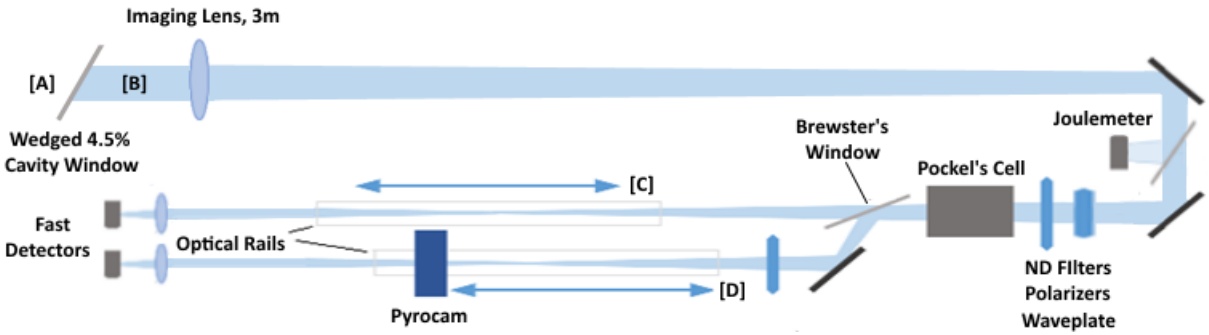




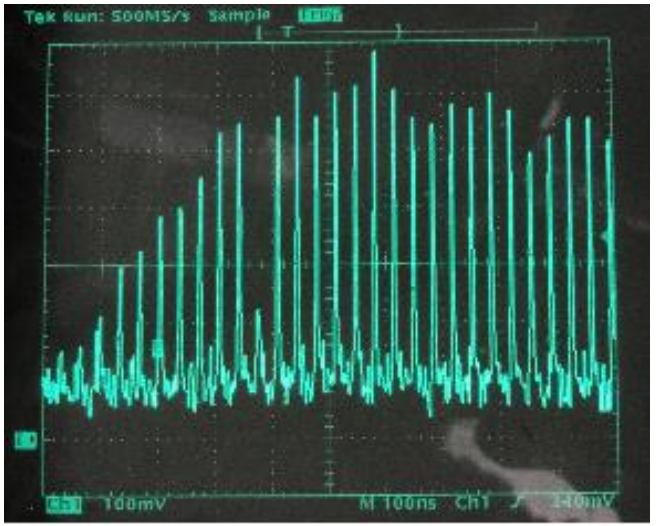
Injection	1J
Laser energy (peak region)	500-700mJ typical
Laser power (peak region)	100-160 GW
Number of pulses	5-15
Spot size, FWHM	1.7 mm
Rayleigh range	0.55 m
Pulse Length	3.5ps



Laser Pulse Train Diagnostics

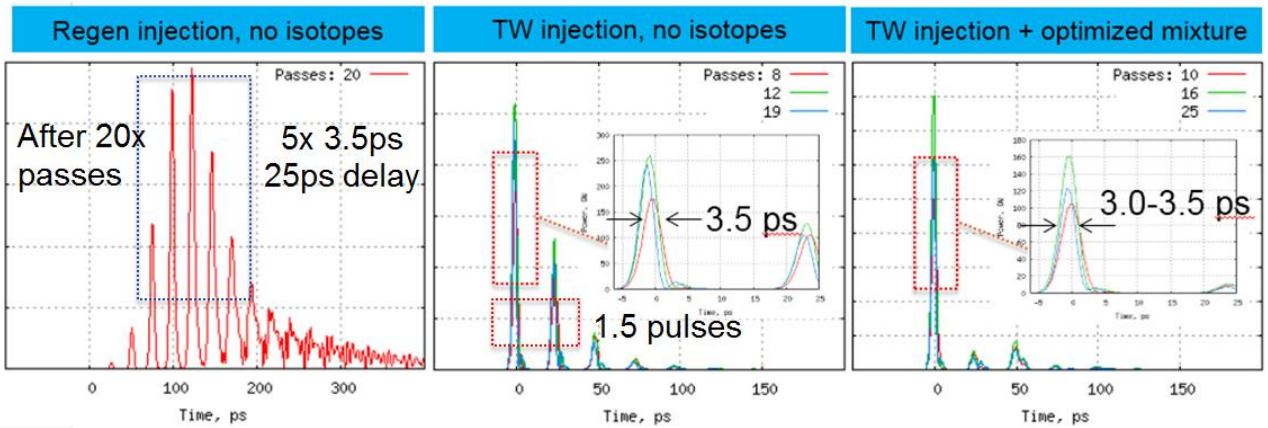


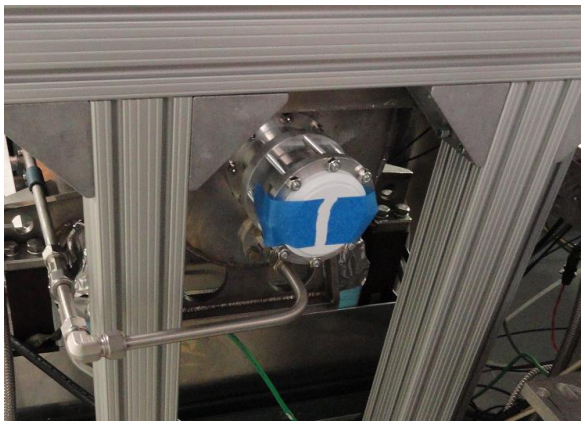
[A] Main Laser Cavity Beam Path
[B] Pulse Train Sample
[C] CO2 Seed Laser Pulse OR Integrated Laser Train
[D] Focus of Single Train Pulse Extracted with Pockel's Cell`



- 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

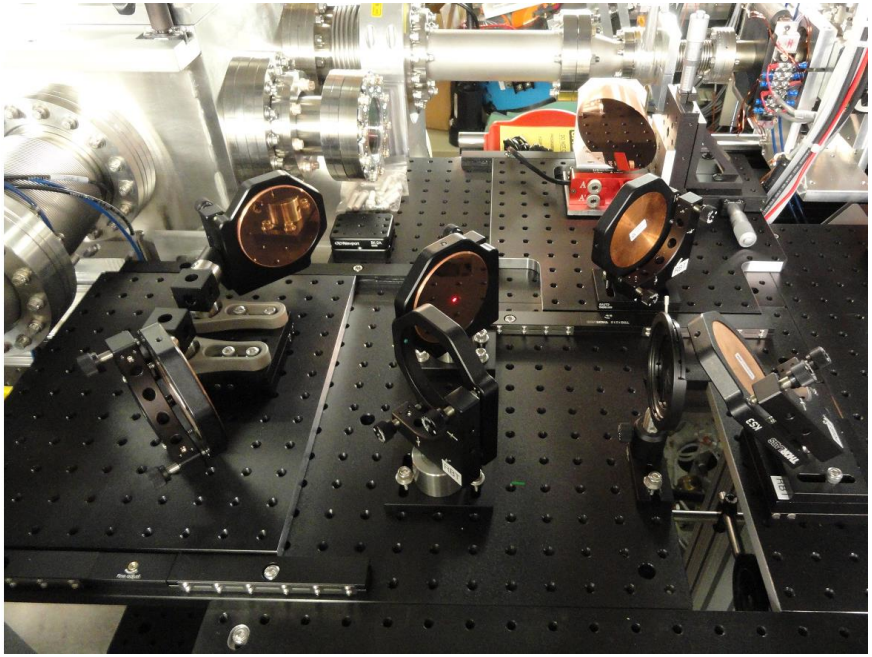
Controlling Pulse Splitting





- 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

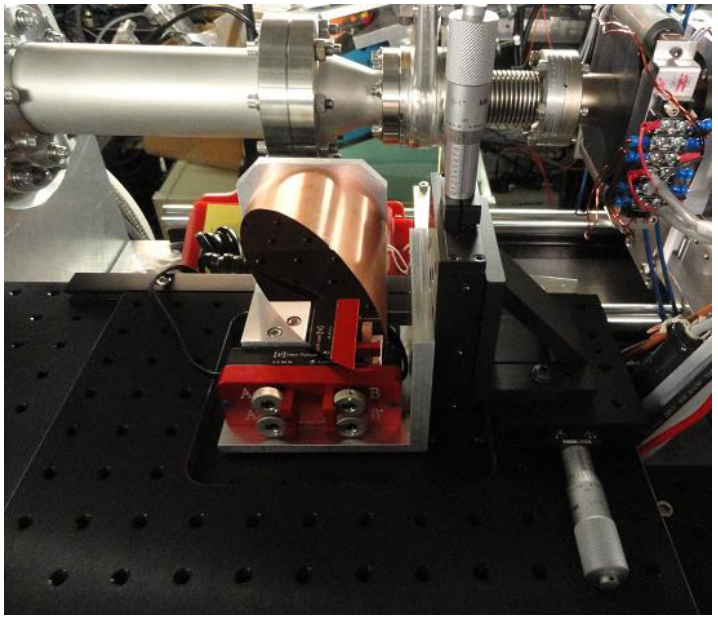
Laser Cavity Status



- 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 2nd 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 2nd 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

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