S20 High Power Performance and Possible Upgrades

2023 FACET-II User Meeting

FACET-II
Facility for Advanced Accelerator Experimental Tests

Robert Ariniello / Project Scientist / AARD

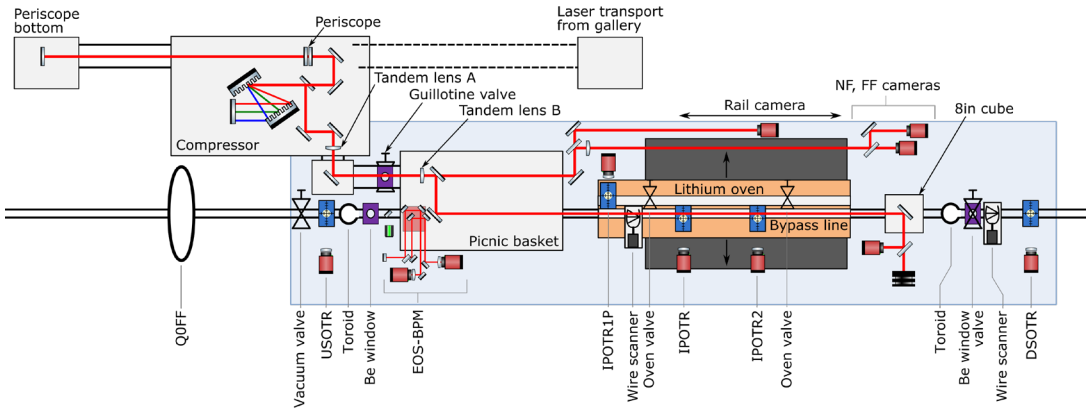
October 17-19, 2023

SLAC NATIONAL ACCELERATOR LABORATORY
Stanford University
U.S. DEPARTMENT OF ENERGY

Outline

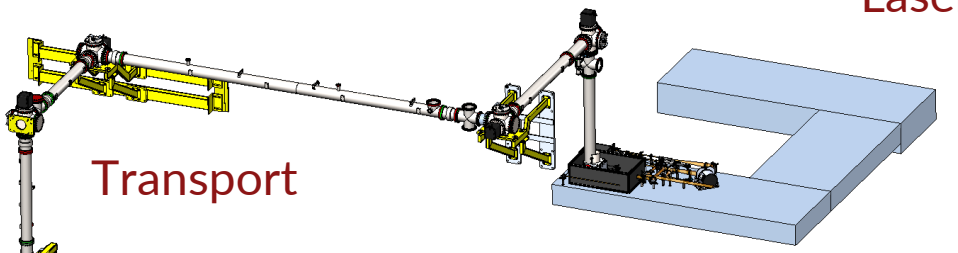
- Overview of the laser
- Current laser performance
- Upgrades over the last year
  - Pulse duration tests
  - Telescope changes in the laser room
  - Wavefront improvement work
  - Main amplifier changes
  - Reinstalled fiber laser
  - Motorized compressor grating
  - New compressor lens mount
  - New Comp NF/FF
  - New PB NF/FF
  - Motorized rail camera
  - New DSHM NF/FF
- Planned upgrades
  - Allow actuation of the valve between the compressor and PB
  - Plasma cleaning in the compressor
  - More automation

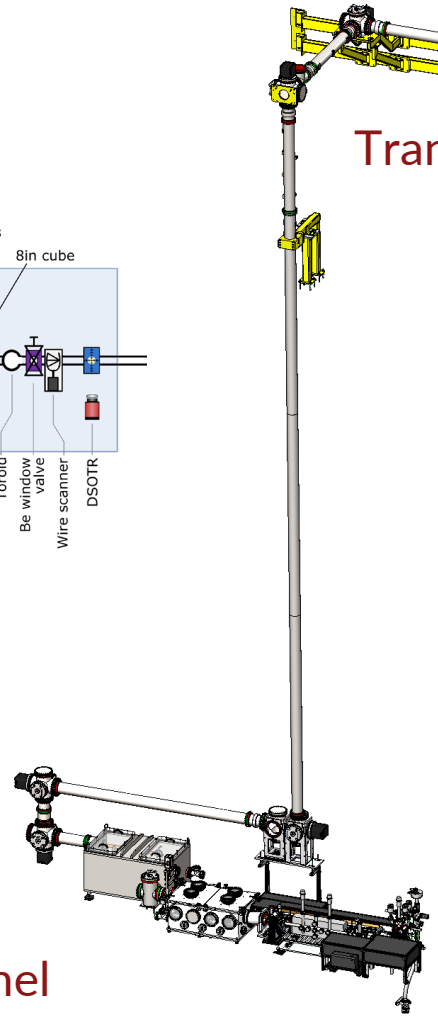
Main laser overview



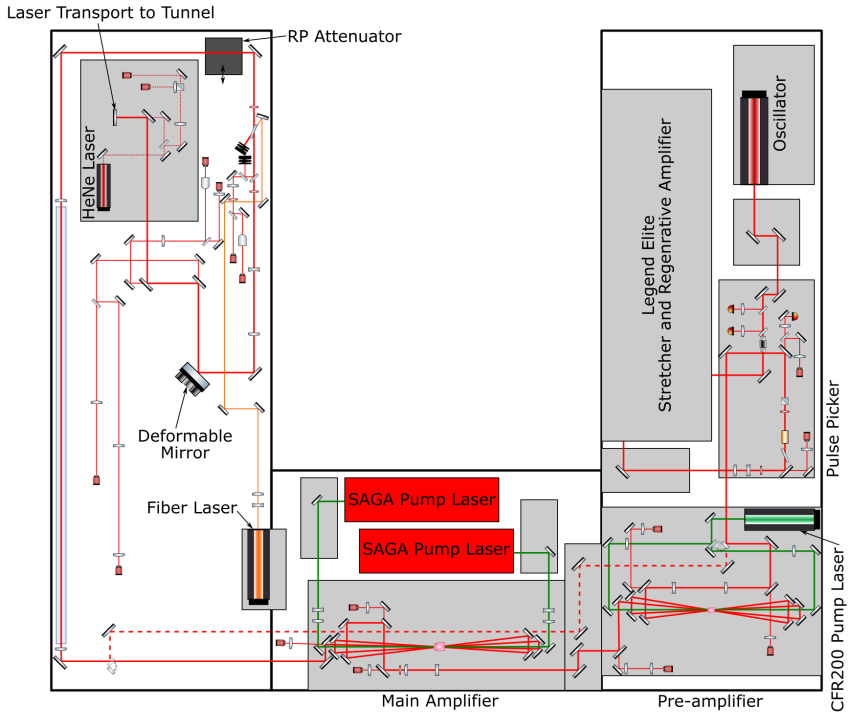
Laser Room

Transport





Tunnel

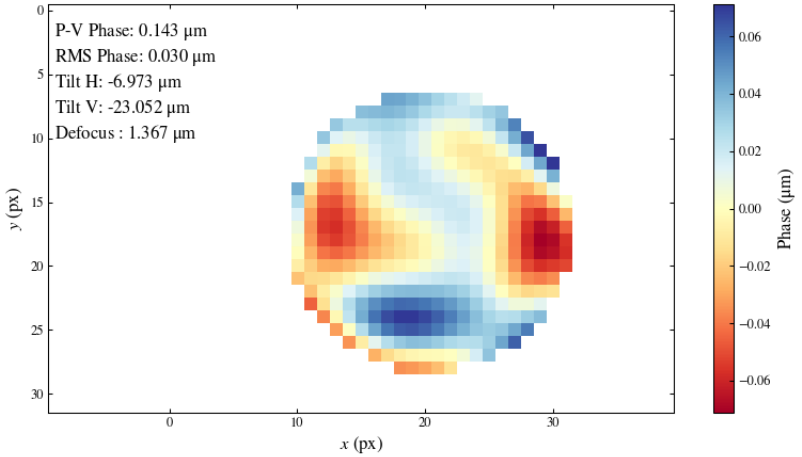


Current S20 laser performance

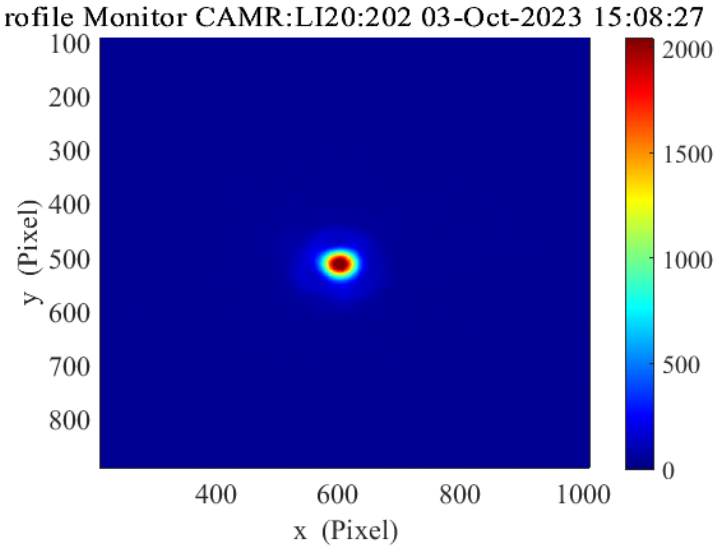
- Actuating the window between the compressor and PB reduces pulse length and wavefront error

Function	*August 2022*	*October 2023*	*Optimal Present*	*Turn things to 11*
Notes			*Actuate Comp+PB window*	*Actuate Comp+PB window + crank the SAGAs* ***a lot of work***
Power-amp Pump [J]	*1.700*	*1.800*	*1.800*	*2.600*
Power-amp Output [J]	***0.510***	***0.612***	***0.612***	*0.884*
Beam Transport Input [J]	*0.434*	*0.520*	*0.520*	*0.751*
Compressor Input [J] (beam transport output)	*0.295*	*0.354*	*0.354*	*0.511*
PB Energy [J]	*0.200*	*0.239*	*0.239*	*0.346*
Pulse Duration after compression (fwhm) [fs]	***200***	***120***	***50***	*50*
Peak Power [TW]	*0.998*	*1.995*	*4.788*	*6.916*
Focus Spot Size FWHM [um]	*6.0*	*6.0*	*2.0*	*2.0*
Energy in Spot [%]	*0.500*	*0.500*	*0.500*	*0.500*
Intensity [10^{18} W/cm^2]	*1.082*	*2.165*	*46.756*	*67.537*
a0	***0.706***	***0.999***	***4.642***	*5.579*

Additional laser performance



λ/6 wavefront in the tunnel, good focus on CompFar



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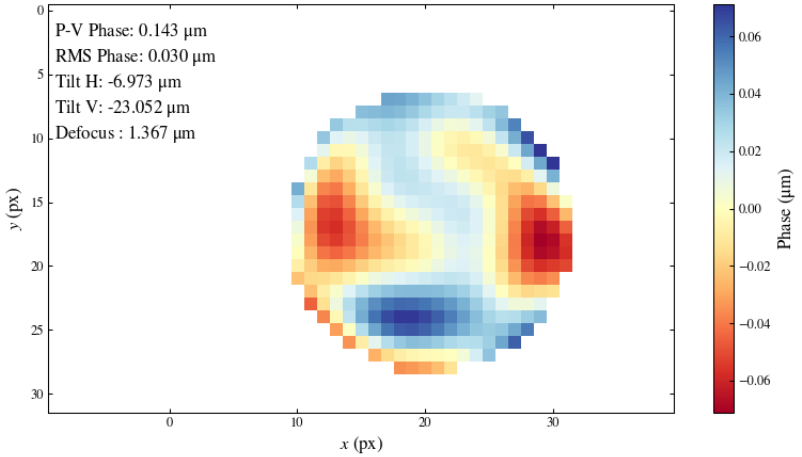

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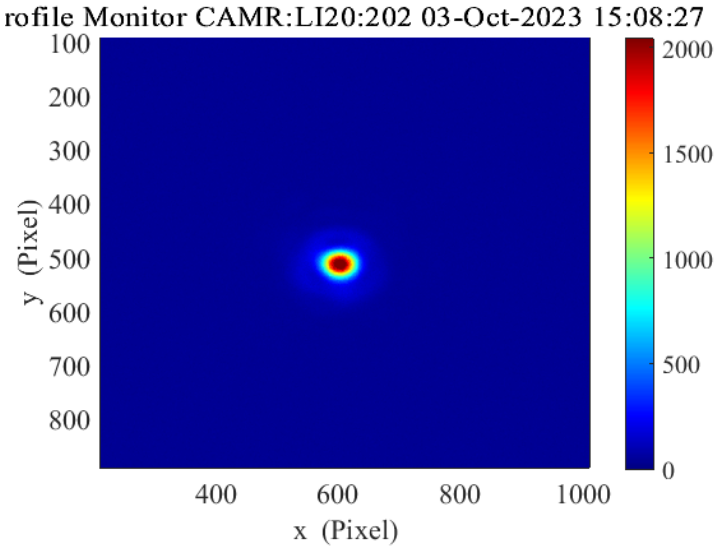
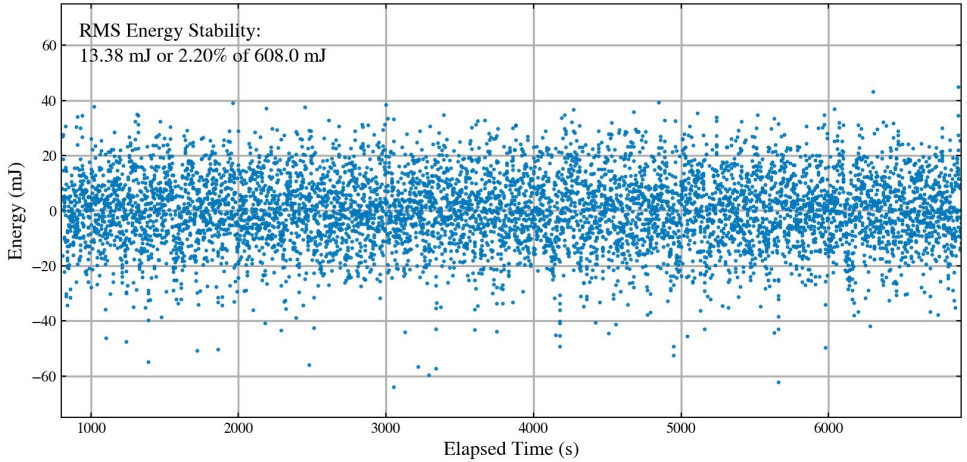
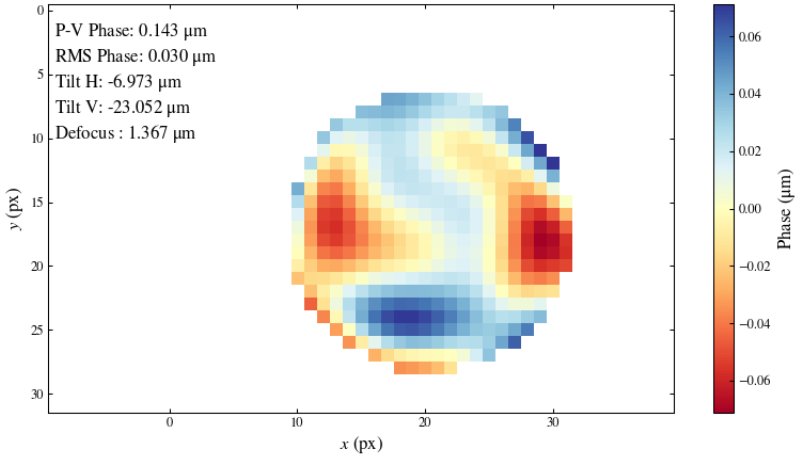




Mainamp energy stability 2.2%

Additional laser performance



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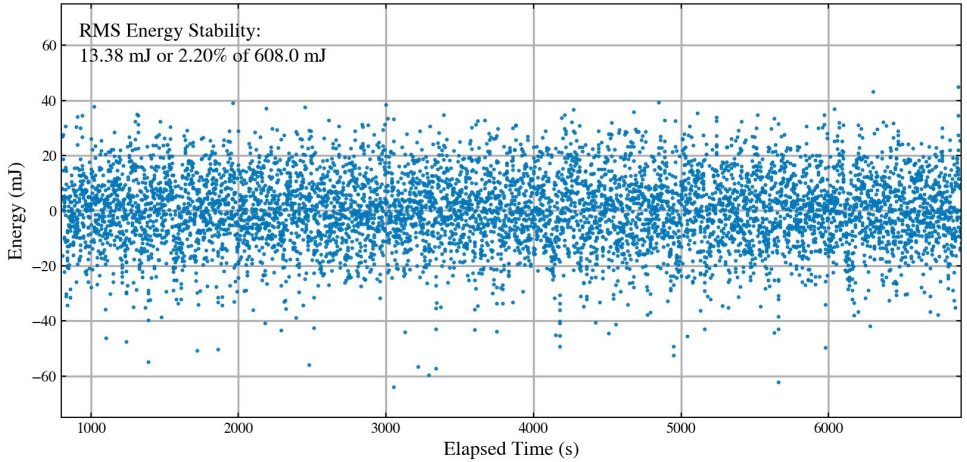

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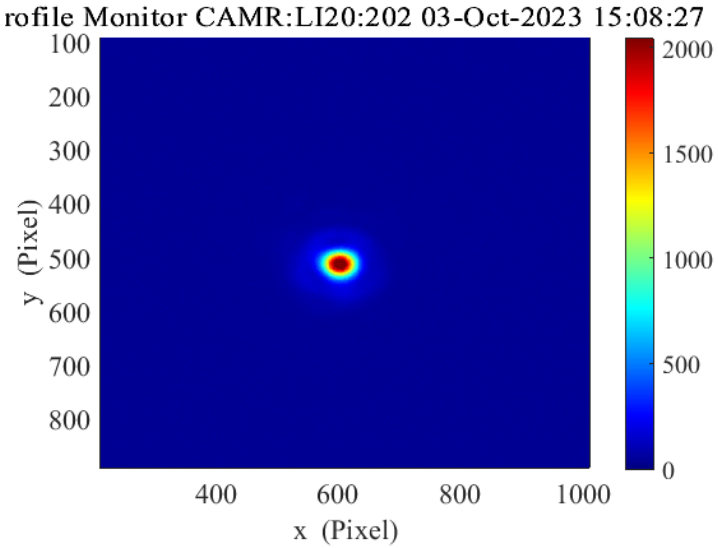
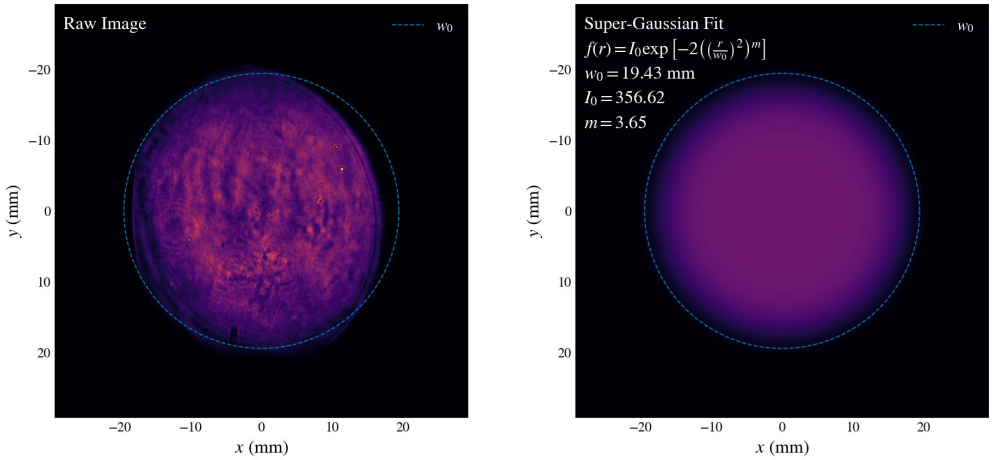
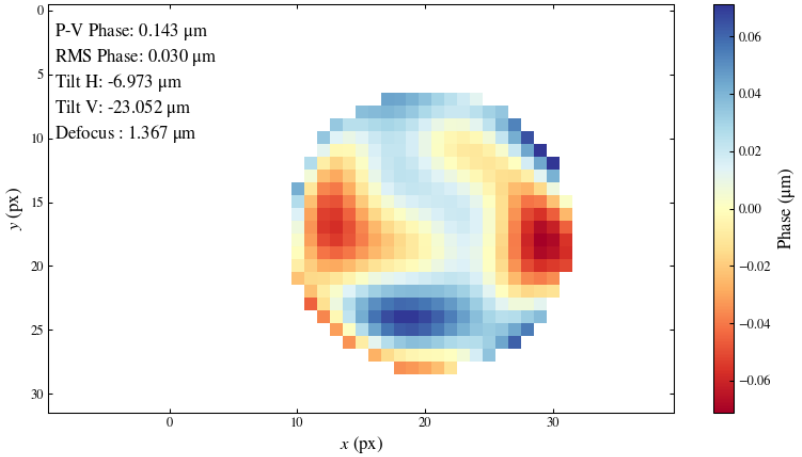


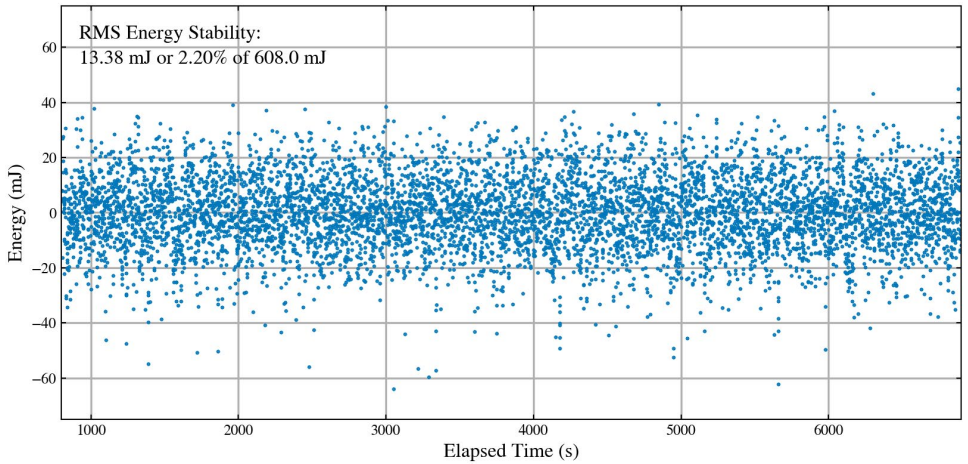


September 2023, $1/e^2$ diameter 38.86mm

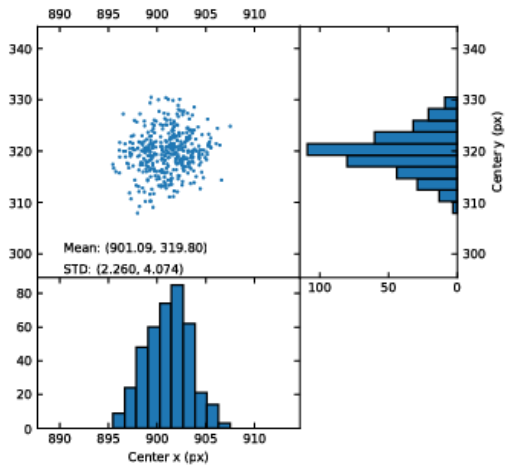
Additional laser performance



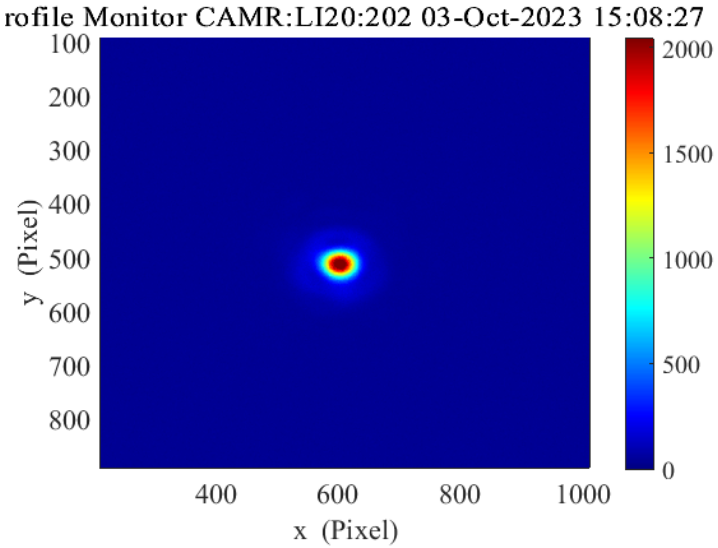
λ/6 wavefront in the tunnel, good focus on CompFar

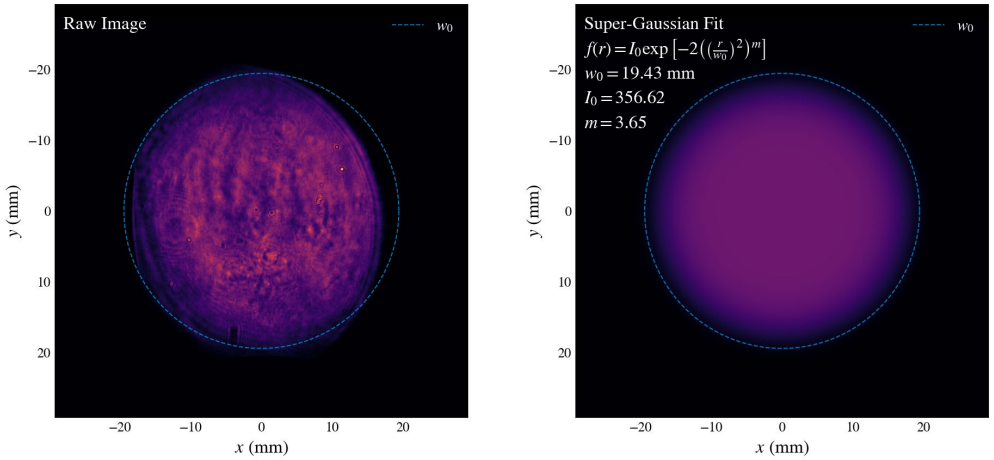


Mainamp energy stability 2.2%

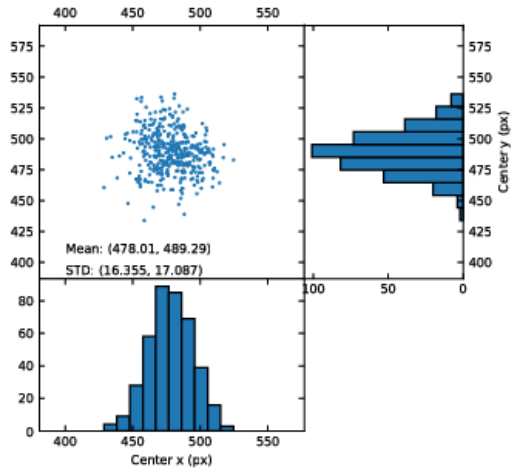


Laser room: (±3.1, ±5.5)urad DMFar





September 2023, $1/e^2$ diameter 38.86mm

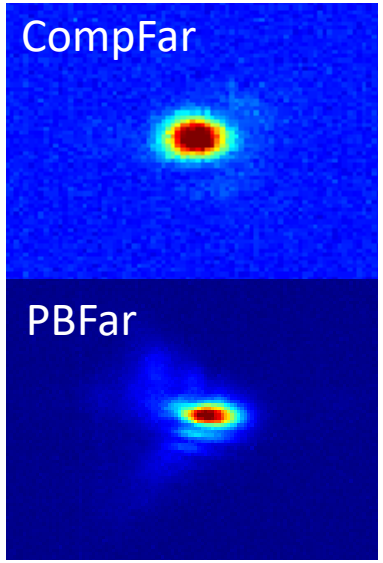


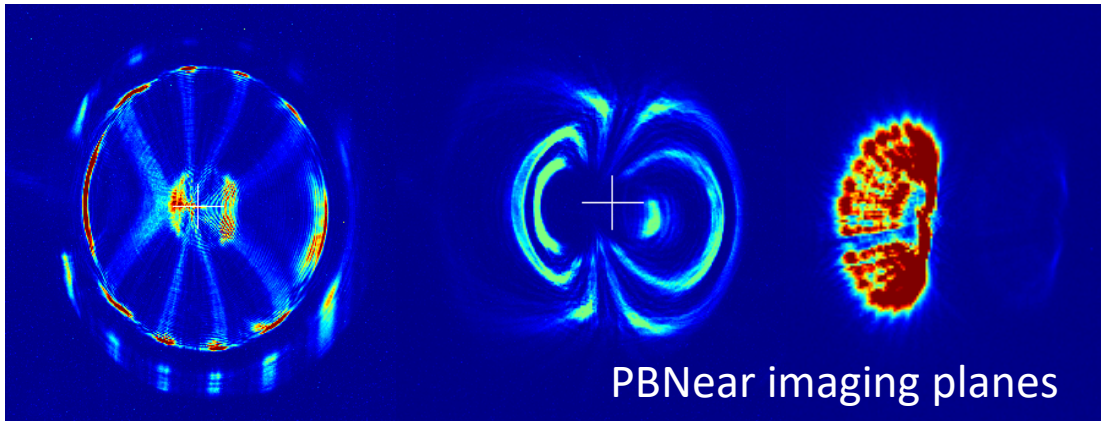
Tunnel: (±9.8, ±10.3)urad CompFar

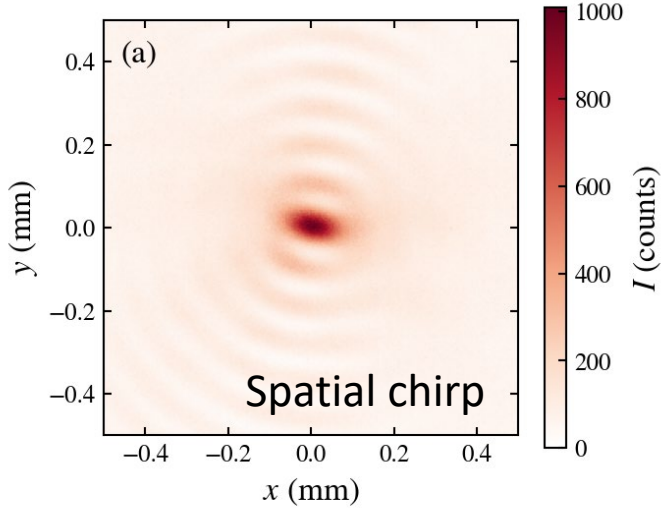
Challenges from 2022

Problems determined in 2022:

- Unreliability
- Spatial chirp
- B-integral in Compressor-PB window
- Time-consuming alignment

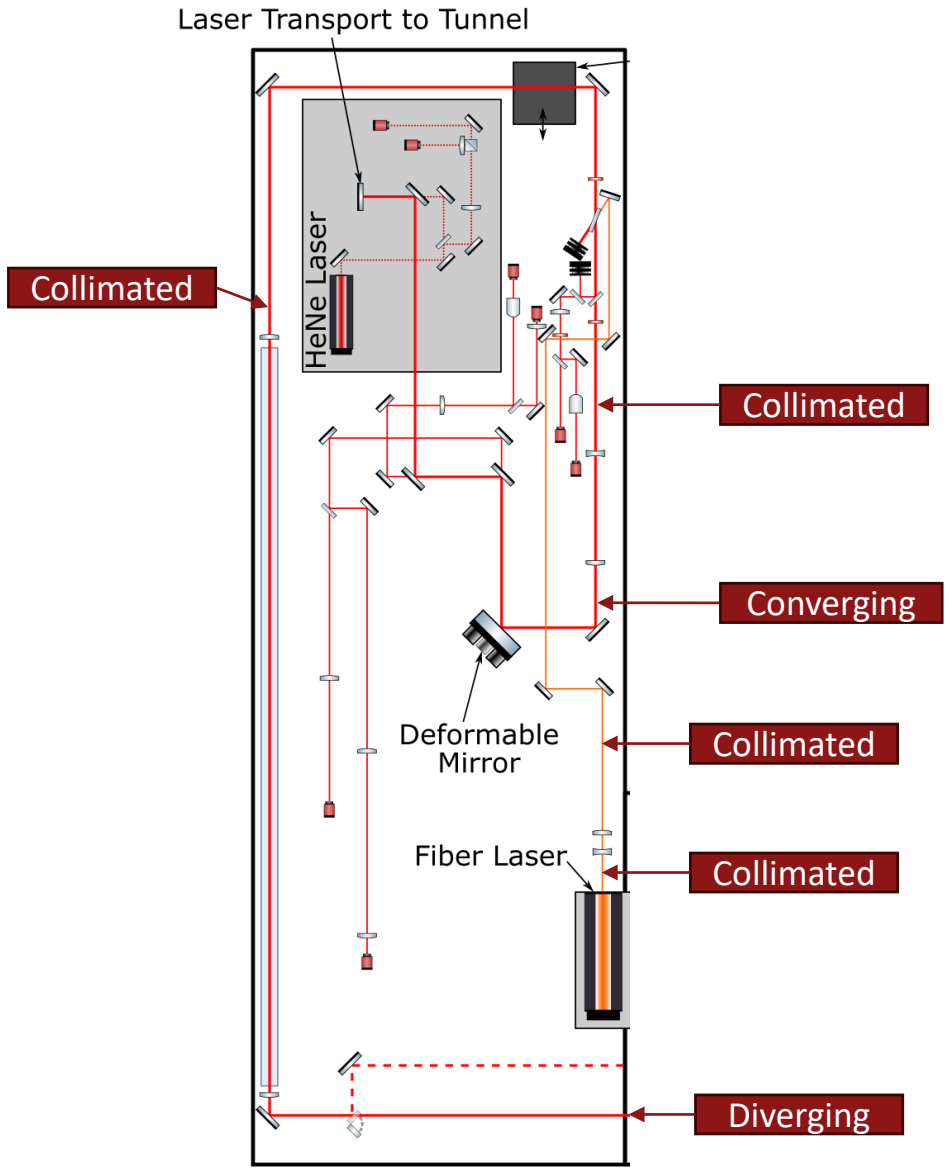


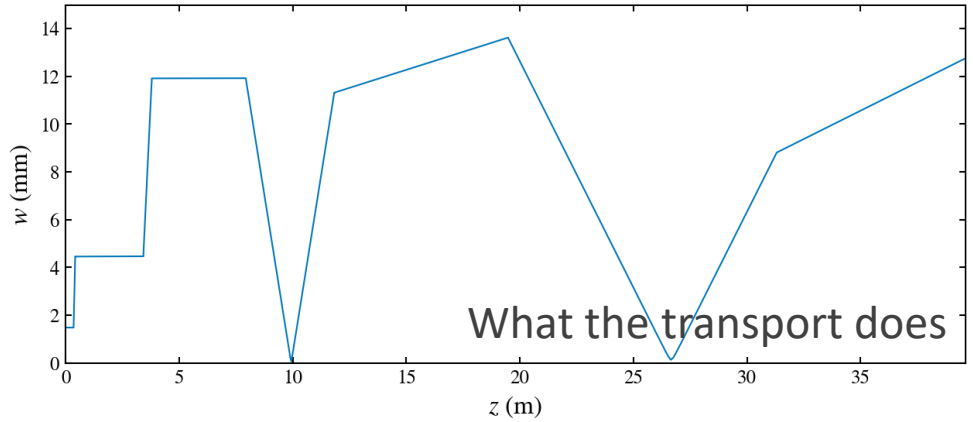


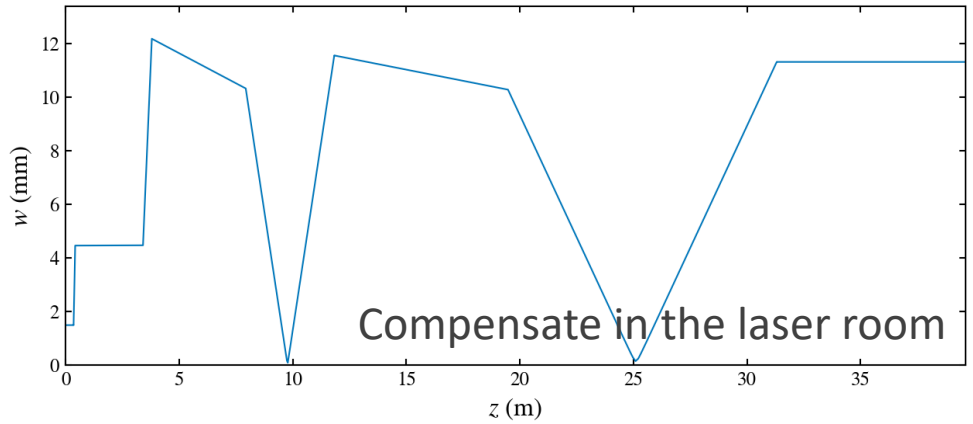


Upgrade goal: consistent, efficient delivery of claimed laser parameters

Collimation changes for sanity





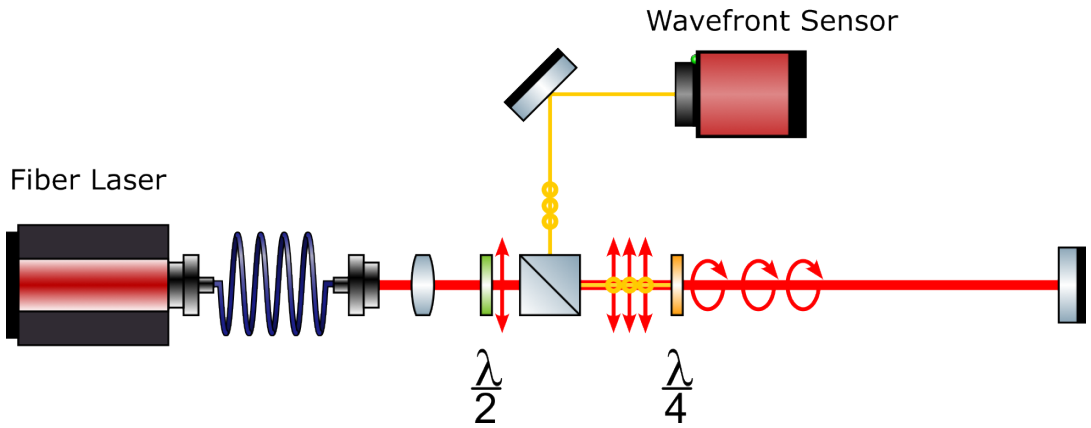


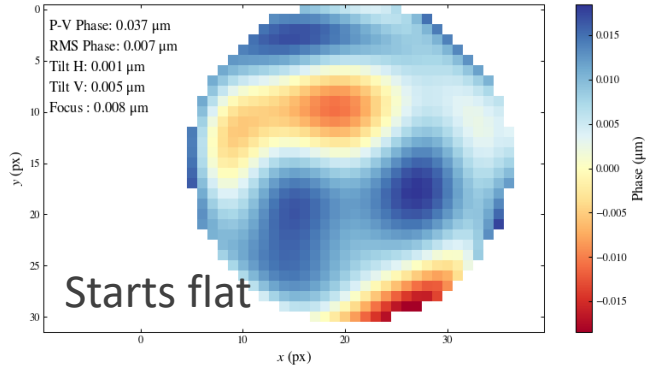
Deliver collimated, 40mm beam to the tunnel.

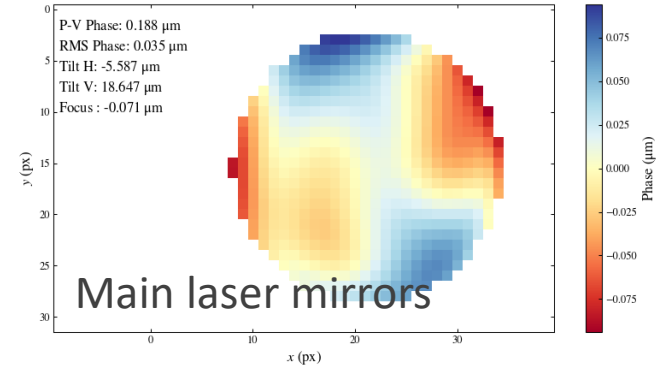
Optic-by-optic wavefront testing in the laser room

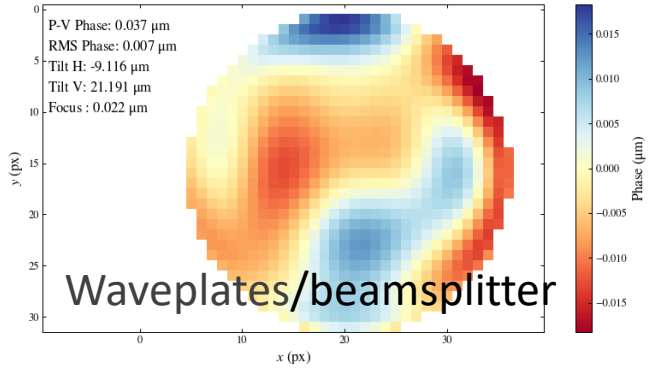
Use fiber laser with flat wavefront

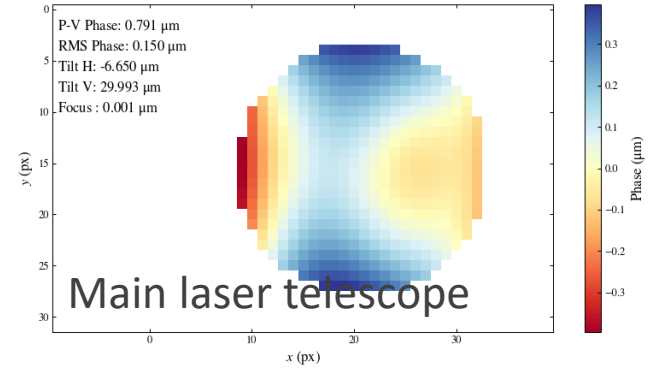
- Avoids questions about the imaging system
- LEO optics often the problem

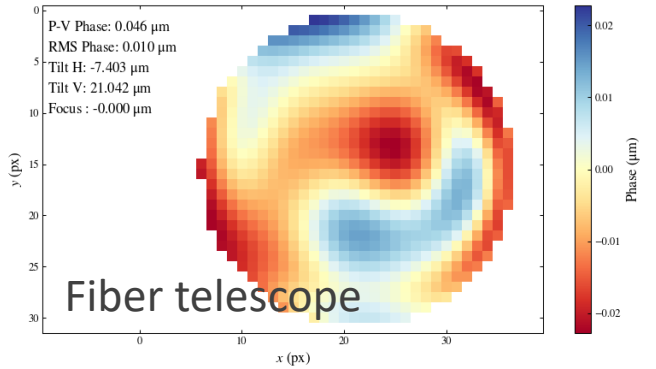


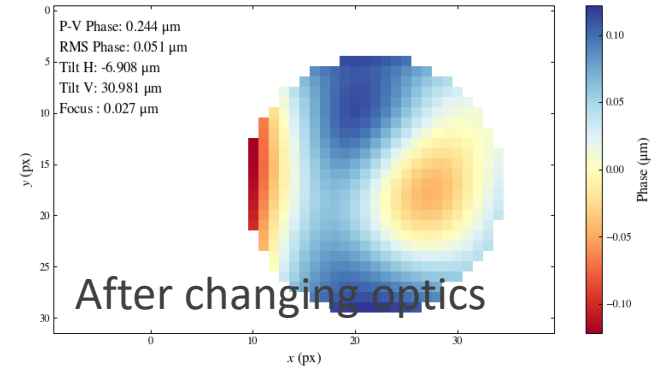






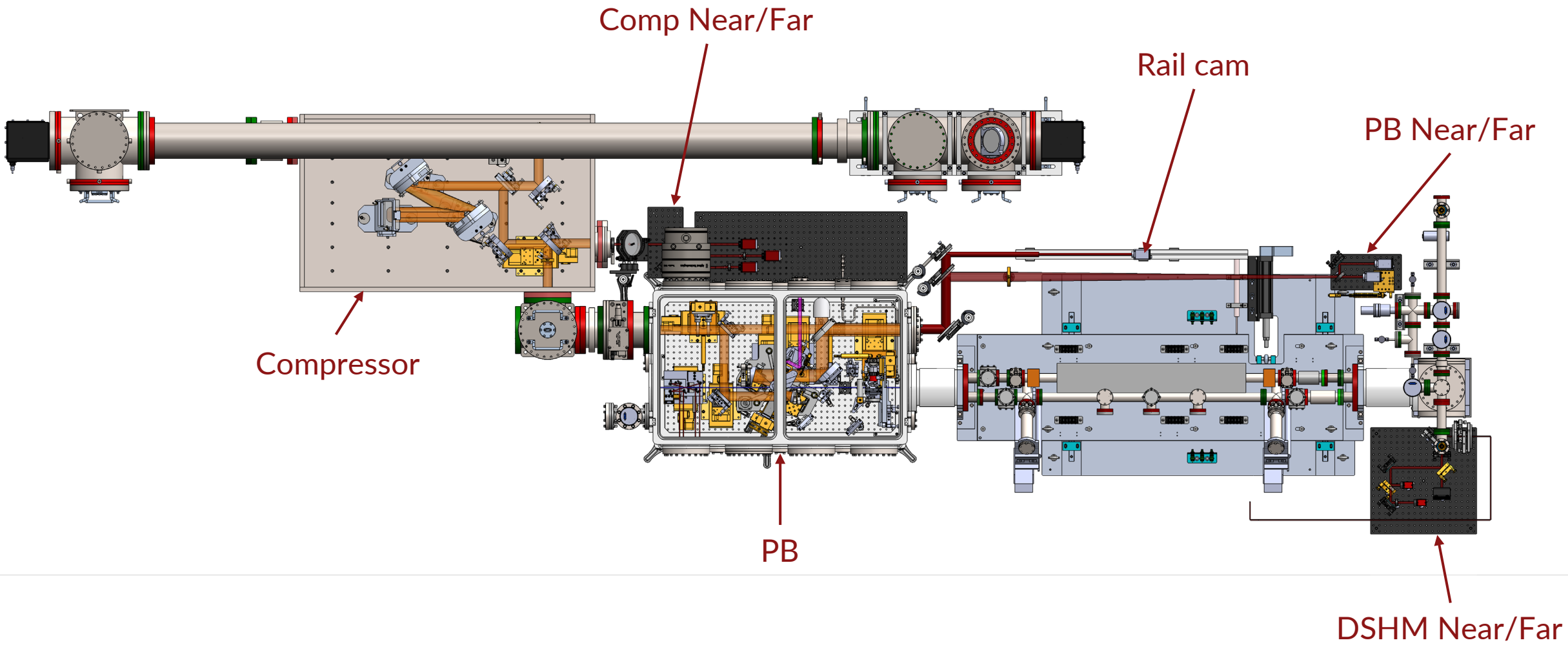




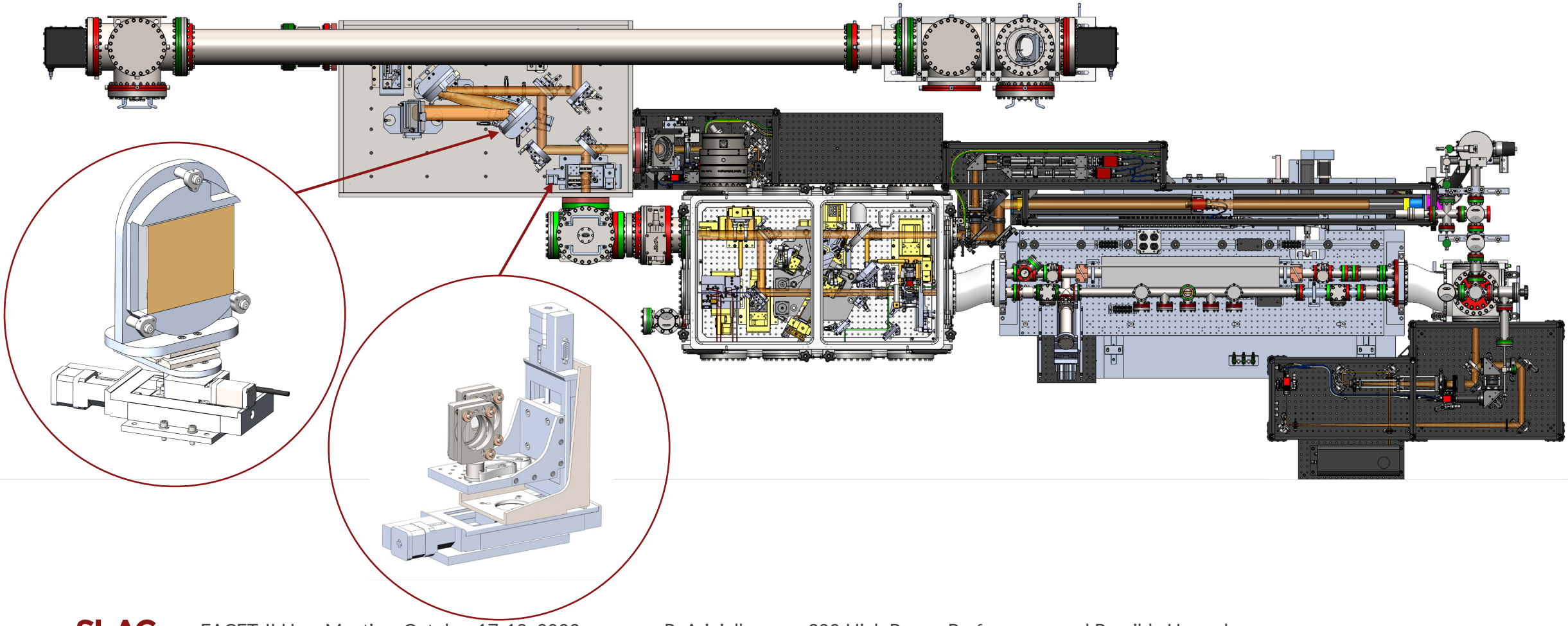


λ/10 in the laser room with pulsed

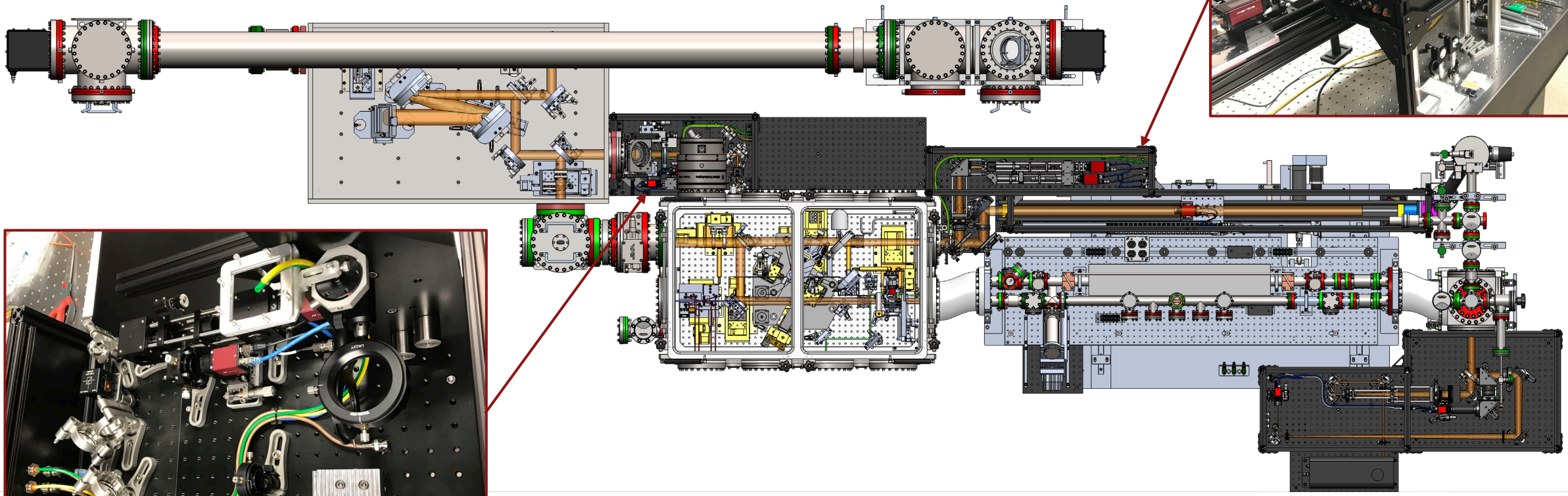
Optical setup in the tunnel before 2023



Optical setup in the tunnel now

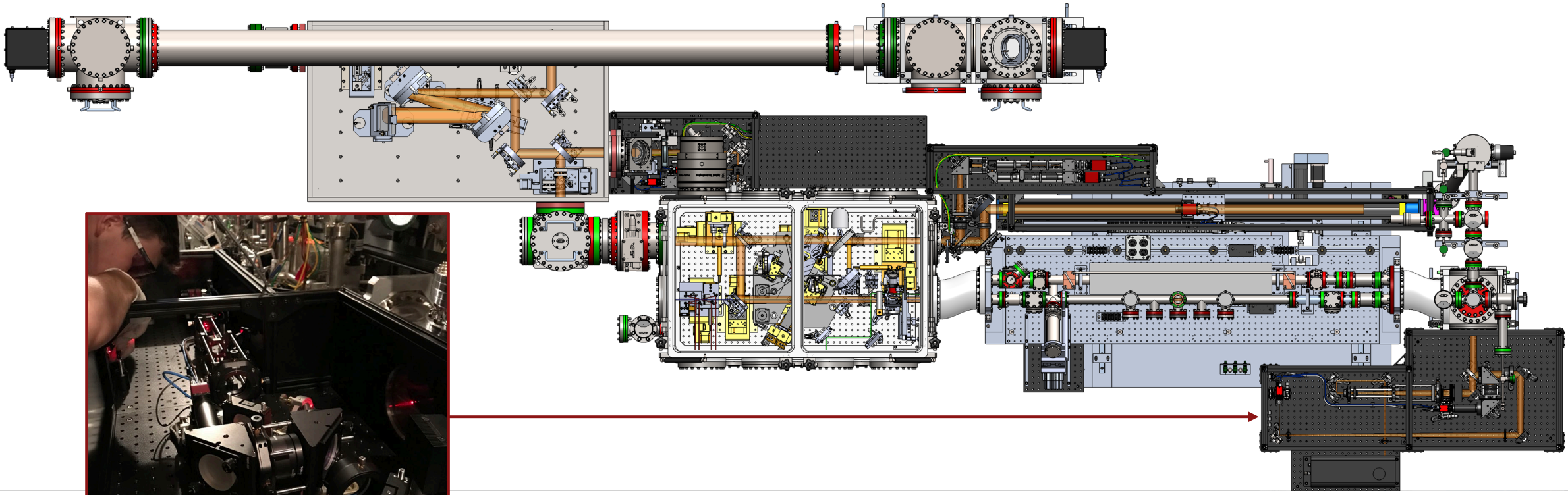


Optical setup in the tunnel now



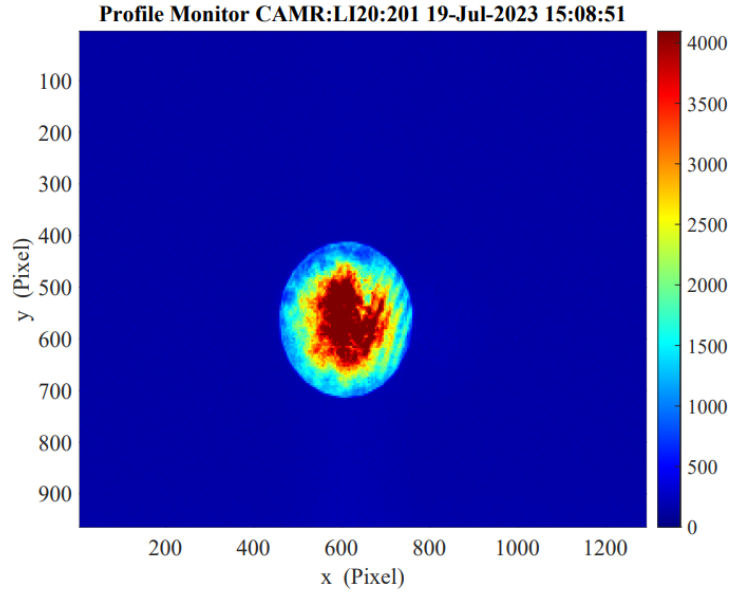
Optical setup in the tunnel now

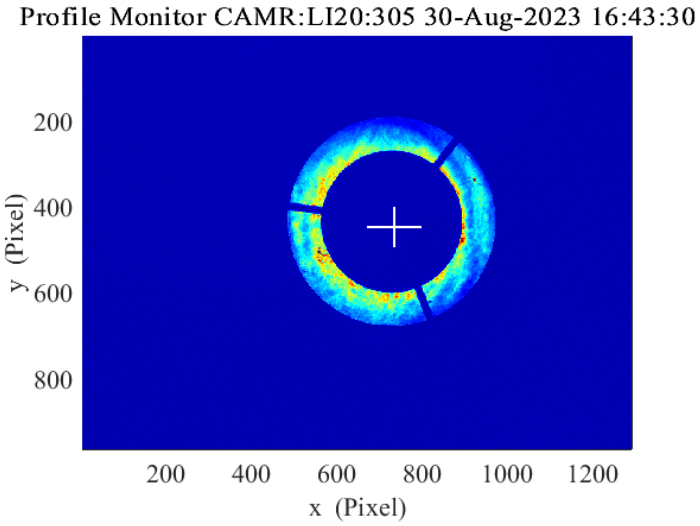
Replaced all the out of vacuum optics



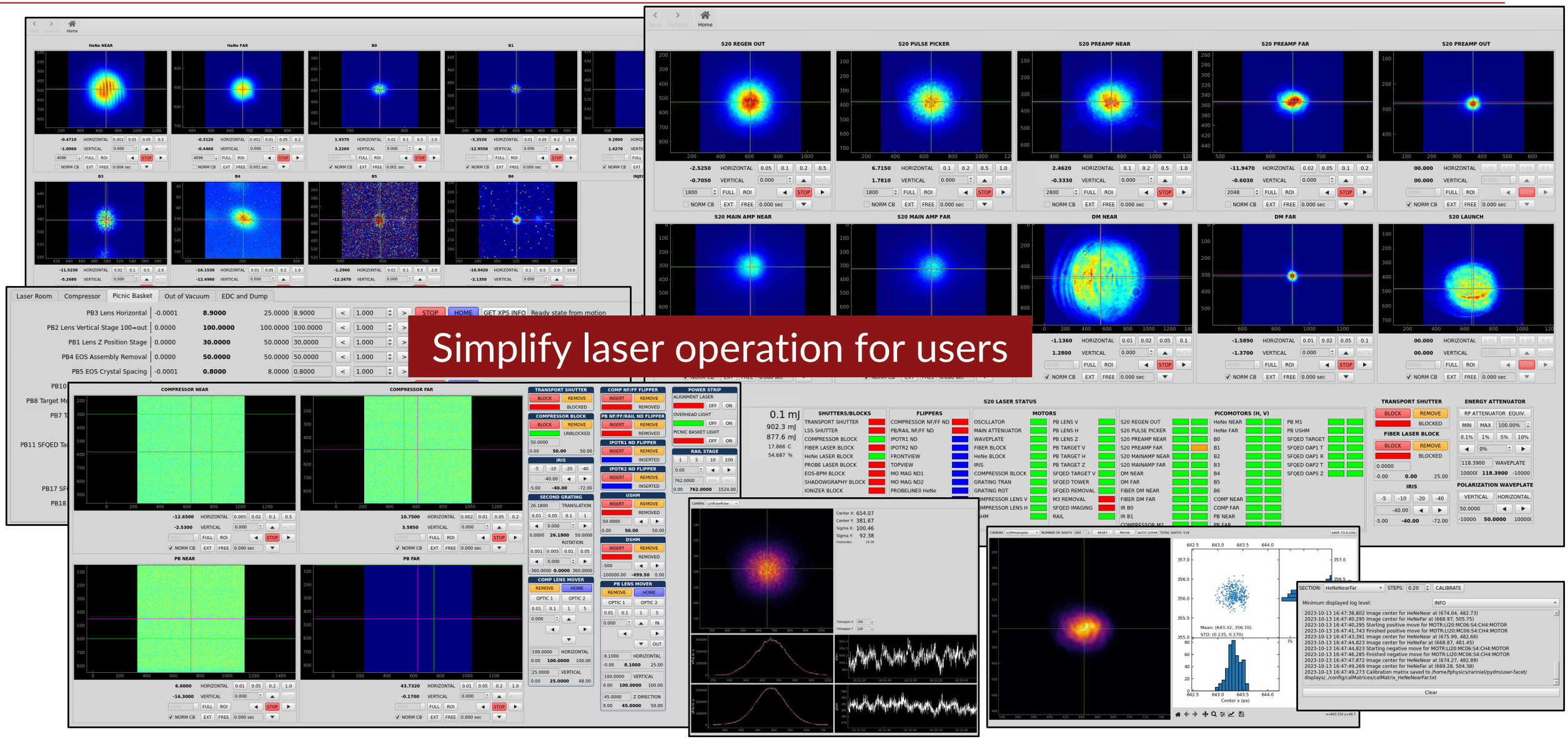
New capabilities and other changes

- Motorized rail camera
  - 1524mm of travel
- Two axis stepper motor stage in the compressor
  - Raster scans with tandem lenses
- Quick to measure pulse duration/wavefront in the tunnel
- SAGA and seed size optimized in the main amp
  - Increased output energy





Improved control systems

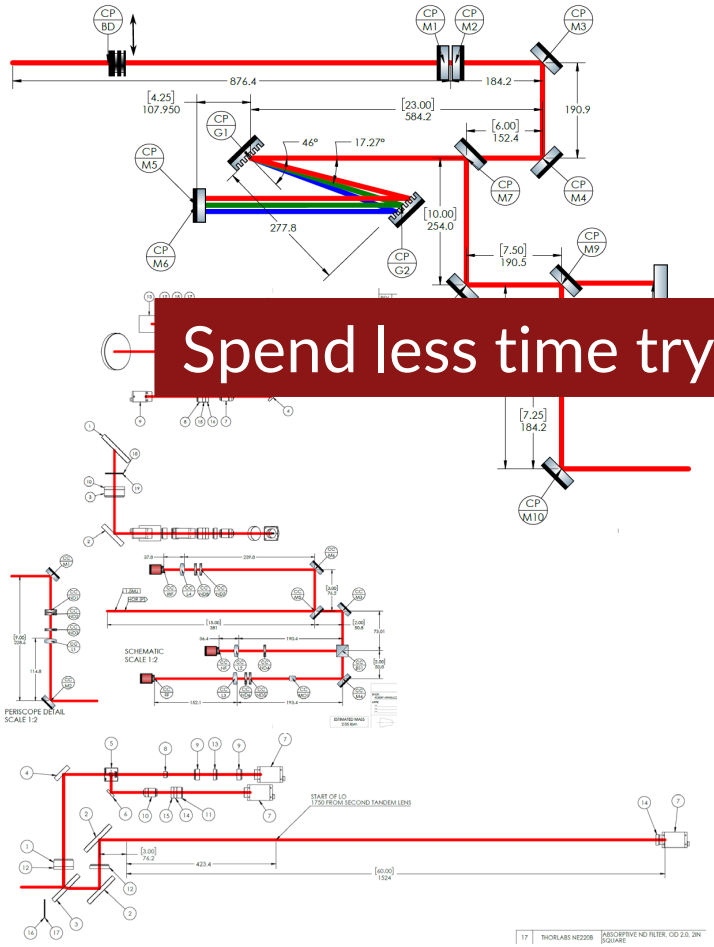


Documentation/organizational improvements

New confluence structure

- FACET S20 Laser
  - Operating Procedures
  - Maintenance Procedures
  - References
  - Measurements
    - Spectrum Measurements
      - Energy Measurements
      - Pulse Duration Measurements
    - Beam Profile/Size Measurements
      - Beam Size After Expanding Telescope
      - Beam Size at the PB Entrance
      - Beam Size Before Expanding Telescope
    - Collimation Measurements
      - Fiber Laser Telescope Collimation
      - Fiber Laser Tunnel Collimation
      - Main Laser Expanding Telescope Collimation
      - Main Laser Vacuum Telescope Collimation
    - Pointing Stability Measurements
      - Compressor Far Pointing Jitter
      - DM Far Pointing Jitter
      - PB Far Pointing Jitter
    - Energy Stability Measurements
      - Main-amp Energy Stability
    - Camera Calibration Measurements
      - DM Near Calibration
      - Inj Near Calibration
      - **PB Near Calibration**
    - Wavefront Measurements
      - Fiber Laser Before Main Expander
      - Fiber Laser Telescope Wavefront
      - Fiber Laser Wavefront Direct
      - Fiber Laser with DM
      - Main Laser in the Tunnel, Flat Downstairs
      - Main Laser in the Tunnel, Flat Upstairs
      - Main Laser Laser Room, Flat Downstairs
      - Main Laser with DM
      - Main Laser without DM
  - System Documentation
  - S20 Laser Archive

Drawings of the optical layout



Spend less time trying to find info

Lots of new and updated confluence procedures

Laser Startup Procedure

Created by Elias Gerstmayr, last modified by Ariniello, Robert on Jan 10, 2023

Procedure to start up and align the IR laser in the laser room.

Assumption is that the oscillator and Regen are running, and that the auto aligner is being used as much as possible.

The auto aligner uses the references recorded here: Camera Alignment References. If those change, the values have to be changed in the code as well.

If an issue appears during the startup procedure, proceed to Procedures to Fix Common Issues.

A) Preparations - in the laser room

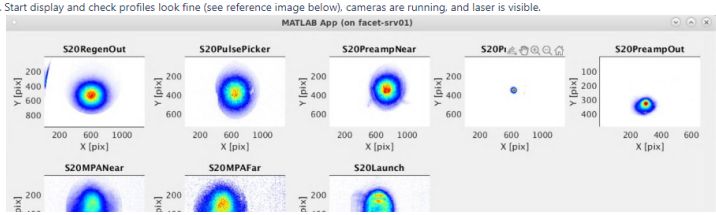
1. Check status of chillers and refill if necessary:
   a. Outside laser room:
      i. Regen: Check for any warning/error lights on chiller.
   b. Inside laser room:
      i. Oscillator: On the floor below the oscillator, check for low water light.
      ii. Main-amp crystal. On the floor near the main amplifier, check for low water light.
   c. Chiller load for SAGAs: Check Chilled Water Load.
2. Oscillator and regen running:
   a. To verify the oscillator is running: The modelocking light should be lit and a spectrum visible on the control computer.
   b. To verify the regen is running: A pulse train should be visible on the scope above the regen.

with the power meter.
laser room.
LSS-2 control panel.
nd High buttons, green means the EPICS shutter is in).

1. Turn on the Pre-amp pump laser by pushing both the Flashlamp and Q-Switch buttons on the remote.
2. Turn on both SAGAs by clicking *Start* on both control computers.

C) PreAmp and MPA alignment

1. Open auto align GUI (FACETHOME→Matlab GUIs→S20 Laser Tools→S20 Laser Auto Alignment), the panel in Figure 3 should open.
2. Press *Stop Alignment* (red button). This will stop any scripts running on other machines.
3. Set camera exposure time for laser room cameras by pressing *Amp cameras* (see Figure 3).
4. Click the *Expert...* button. This opens a new window (see Figure 4).
5. Check the gain settings. No value should be above 0.2000. Higher values tend to overshoot too much and affect pointing.
6. Check maximum tolerances on the same panel:
   a. The top box is the global tolerance. Start with 50 and reduce to 10 after the alignment converges.
   b. The bottom box is the tolerance for the steering into the Main-amp. Start with 150 and reduce to 30 after the alignment converges.
   c. Note: The auto-aligner won't do anything if it measures an offset larger than the tolerance. It will print a warning in the log.
7. Open S20 Laser Room Multi Profile Monitor (FACETHOME→Matlab GUIs→S20 Laser Tools→S20 Laser Room Multi Profile Monitor).
8. Start display and check profiles look fine (see reference image below), cameras are running, and laser is visible.



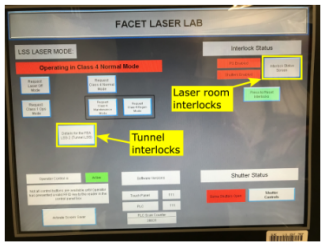


Figure 1: LSS interlock screens.

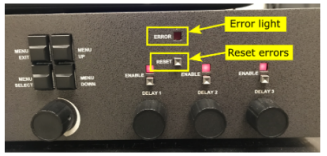
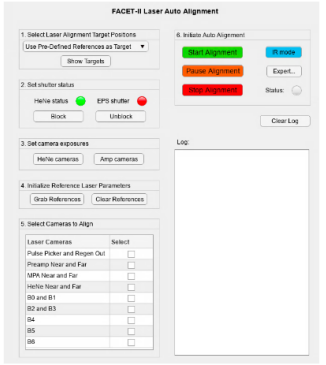


Figure 2: Regen signal display box front panel.



Possible future upgrades

- Actuate window between compressor and PB
  - RGA both chambers to verify vacuum
  - Not compatible with gas in the PB
- Motorize rotation of the first compressor grating
  - Tune to reduce pulse duration to ~40fs
- Improve amplifier auto-aligner cameras
  - Low angular resolution
  - Reduce day-to-day variation
- Laser room enclosures
- EPICS block for the main laser
- Plasma cleaning of the compressor gratings
  - Waiting for input about how well it works

Summary

Laser output tuned up and fully characterized

- >600mJ output (225mJ at PB)
- 50fs FWHM pulse duration
- λ/6 wavefront in the tunnel
- 39mm $1/e^2$ beam diameter
- Collimated

Alex will discuss the probe in his talk

Reliability improvements

- Everything in the tunnel in an enclosure
- Mechanical stiffness improved
- More frequent measurements of laser status

Operational improvements

- Expanded procedures/documentation
- Improved control system

S20 laser almost at the point it can deliver specified parameters every shift

FACET-II | Facility for Advanced Accelerator Experimental Tests

Questions?

2023 FACET-II User Meeting

October 17-19, 2023