FACET-II Facility for Advanced Accelerator Experimental Tests

Sector S20 Experimental Laser

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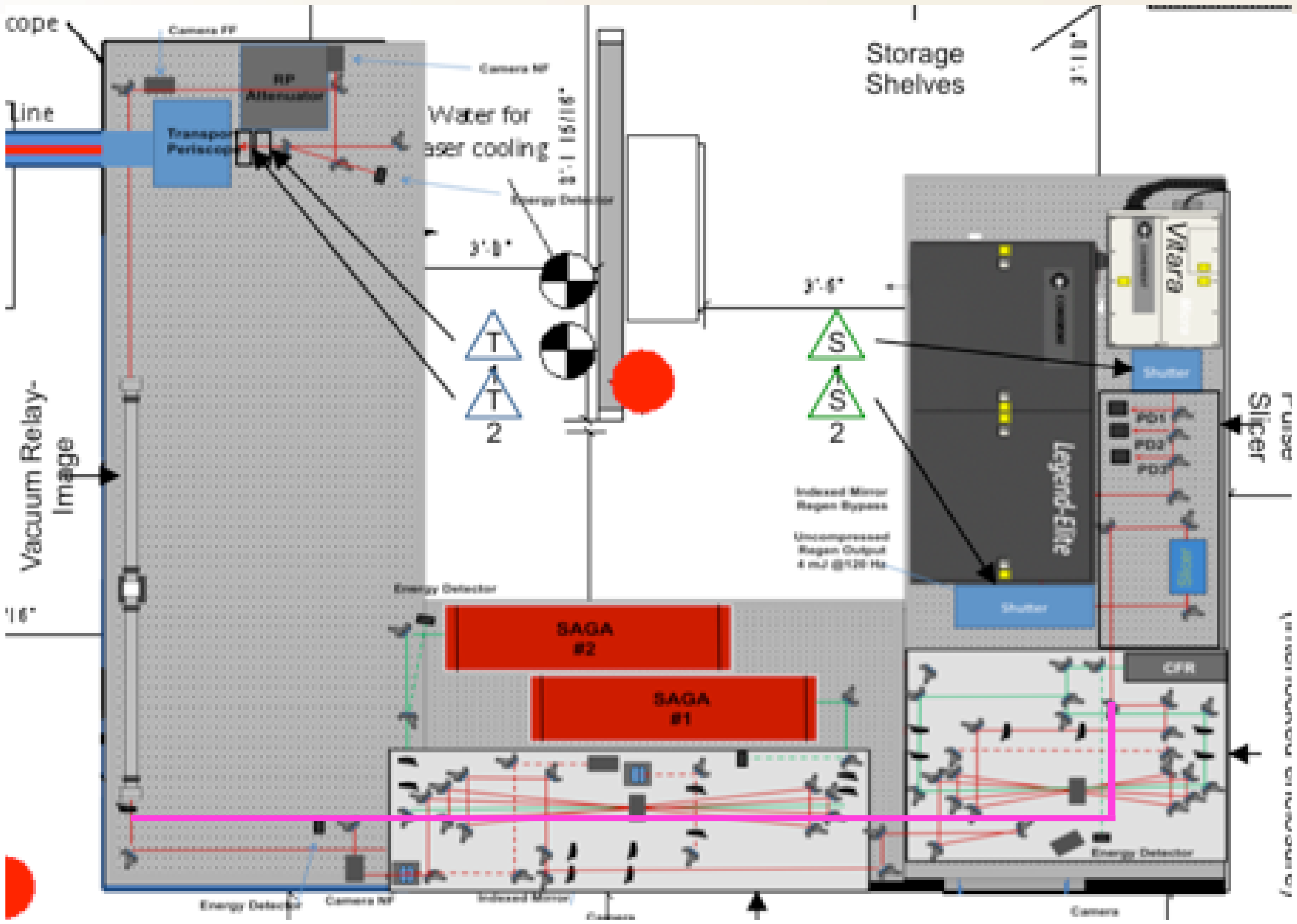
U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

FACET-II Experimental Laser Requirement



Parameter	Range	Units
Energy	30-AHAP	mJ
Duration	40	fs fwhm

- Oscillator -> Regen -> MPA ->MPA
  - First three laser are a common SLAC platform
- 20 m transport from laser room to tunnel
  - Through 3 temperature zones
- Serves 20+ Experiments
  - Laser split in two in tunnel to generate 'probe' beam
  - 'probe' beam then split in 4
- e-beam / laser stability of <100 fs rms
  - e-beam + laser 'collide' simultaneously in 5 locations in IP area

Experimental laser configured to meet diverse scientific needs

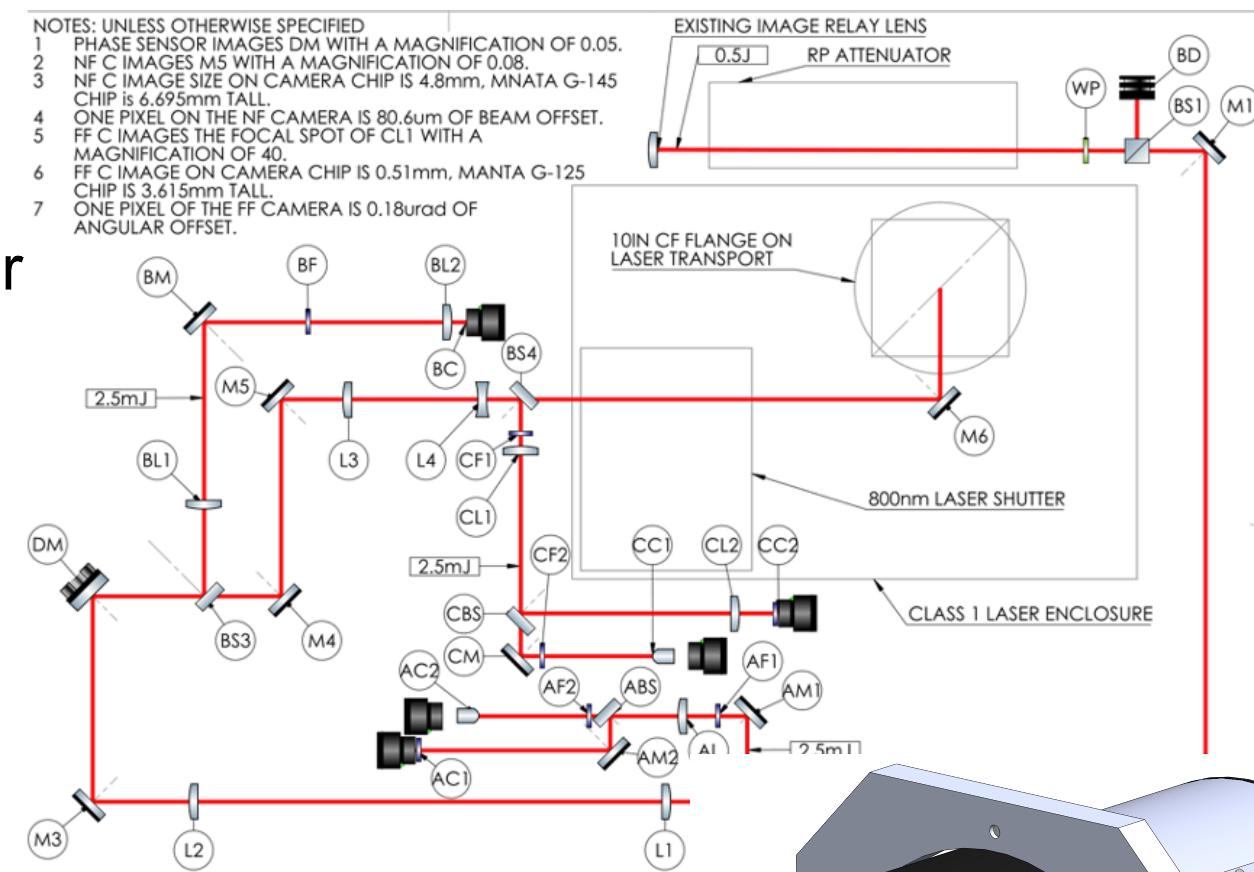
Current and Expected Performance

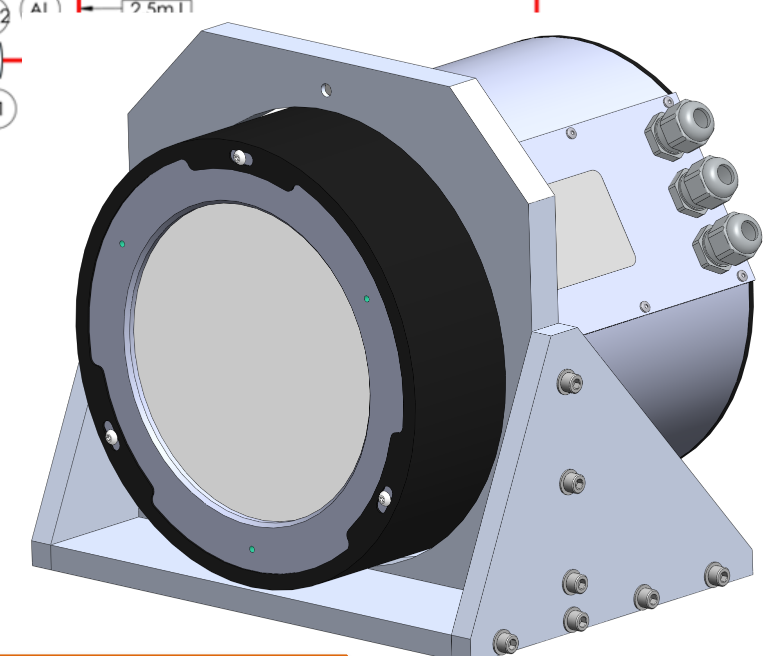
Function	Goal	Limits? Why?
Upgrades	Deformable Mirror Transport	
Power-amp Pump [J]	2.6	
Power-amp Output [J]	0.8	30% from pump to output
Beam Transport Input [J]	0.7	90% Expected due to polarizer
Compressor Input [J](beam transport output)	0.6	65% measured at FACET 90% Expected from transport input to compressor (11 optics @ 99% 21 optics at 99.5%)
Minimum Beam Size @ Compressor [radius, cm]	1.7	Set by gratings damage threshold 1.8 J@ 6 cm max input measured at MEC 8" gratings required for 60 mm beams
Pulse Length Before Compression [ps] [FWHM]	150.0	Set by B Integral in amplifier crystal \DeltaB < ?
Compressor Output [J]	0.44	65% measured at FACET 70% expected
Pulse Duration after compression (fwhm) [fs]	40.0	<40 fs requires spectral shaping Measured after regen
Peak Power [TW]	11.1	
Intensity* [10^{18} W/cm^2]	73.5	3 um focus
a0*	5.8	3 um focus

Well characterized stable operations are quantified and prioritized

Upgrades, Features and Capabilities

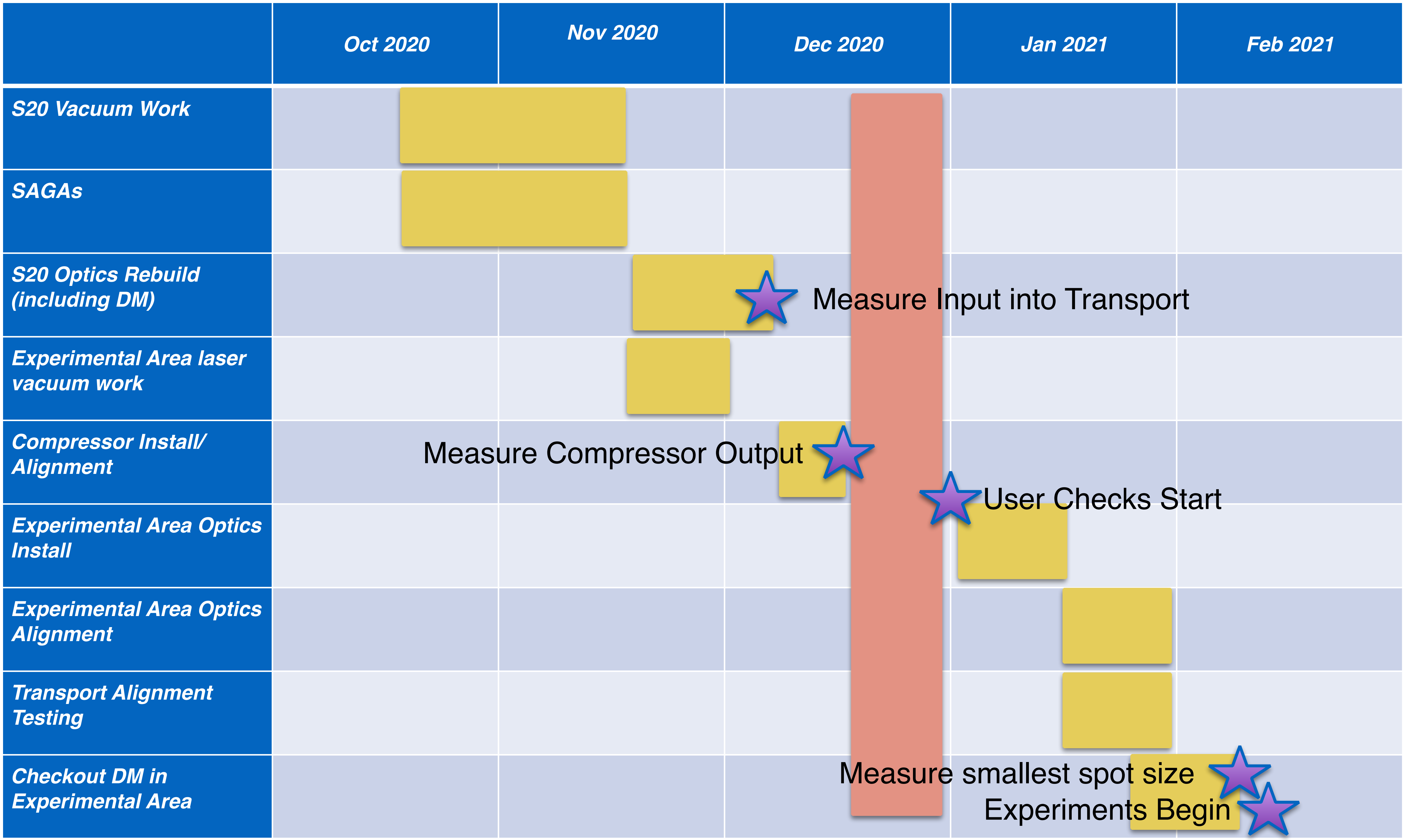
- Only 1 window (FACET had…8?)
  - Source of a lot of aberrations in the beam at FACET
- Closed loop wavefront correction in Laser Room
- Open loop wavefront optimization in tunnel
- Energy Control (Waveplate + polarizer)
- Online laser "health" monitor
- Upgrade HVAC system
- Active monitoring of pointing through gallery transport
  - Source of majority of laser drift at FACET
  - So far have demonstrated 20x reduction in drift





Upgrades following FACET experience will address more demanding needs from the FACET-II User Program

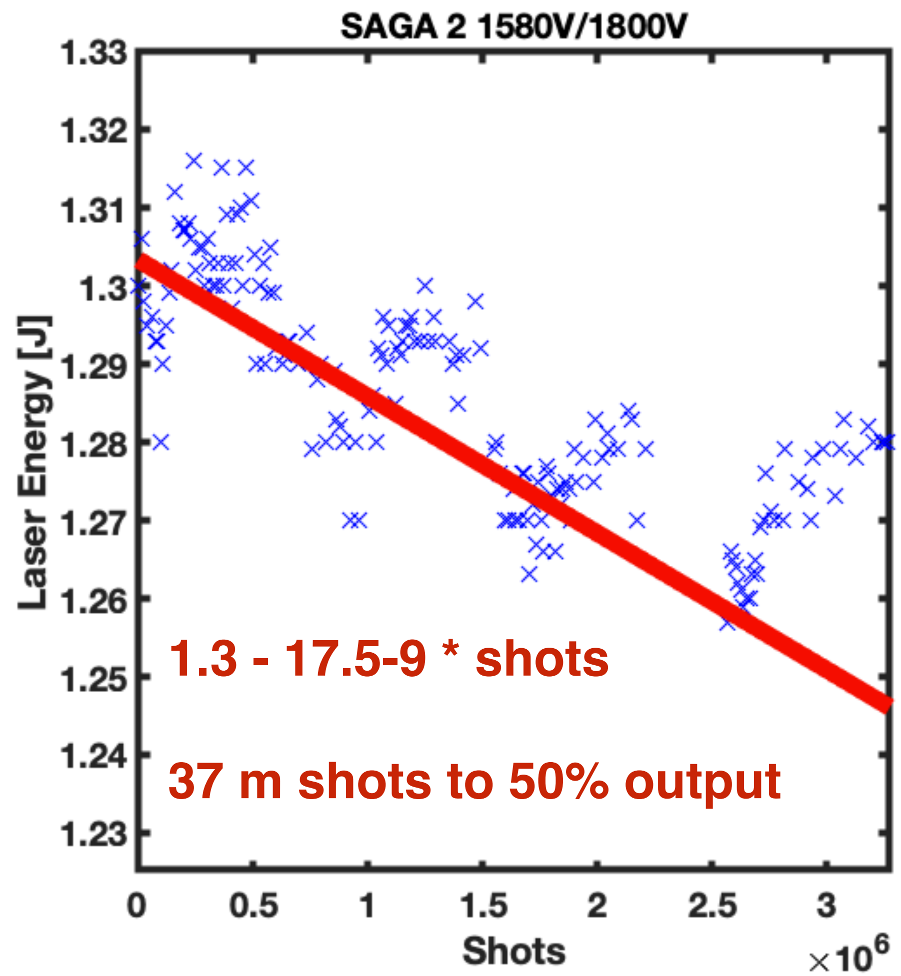
Timeline to develop capabilities



Current Work: SAGAs

SAGA performance in 2016 was unfortunate

- Day-to-day energy stability was not great
- Issue traced to loss of capabilities from vendor

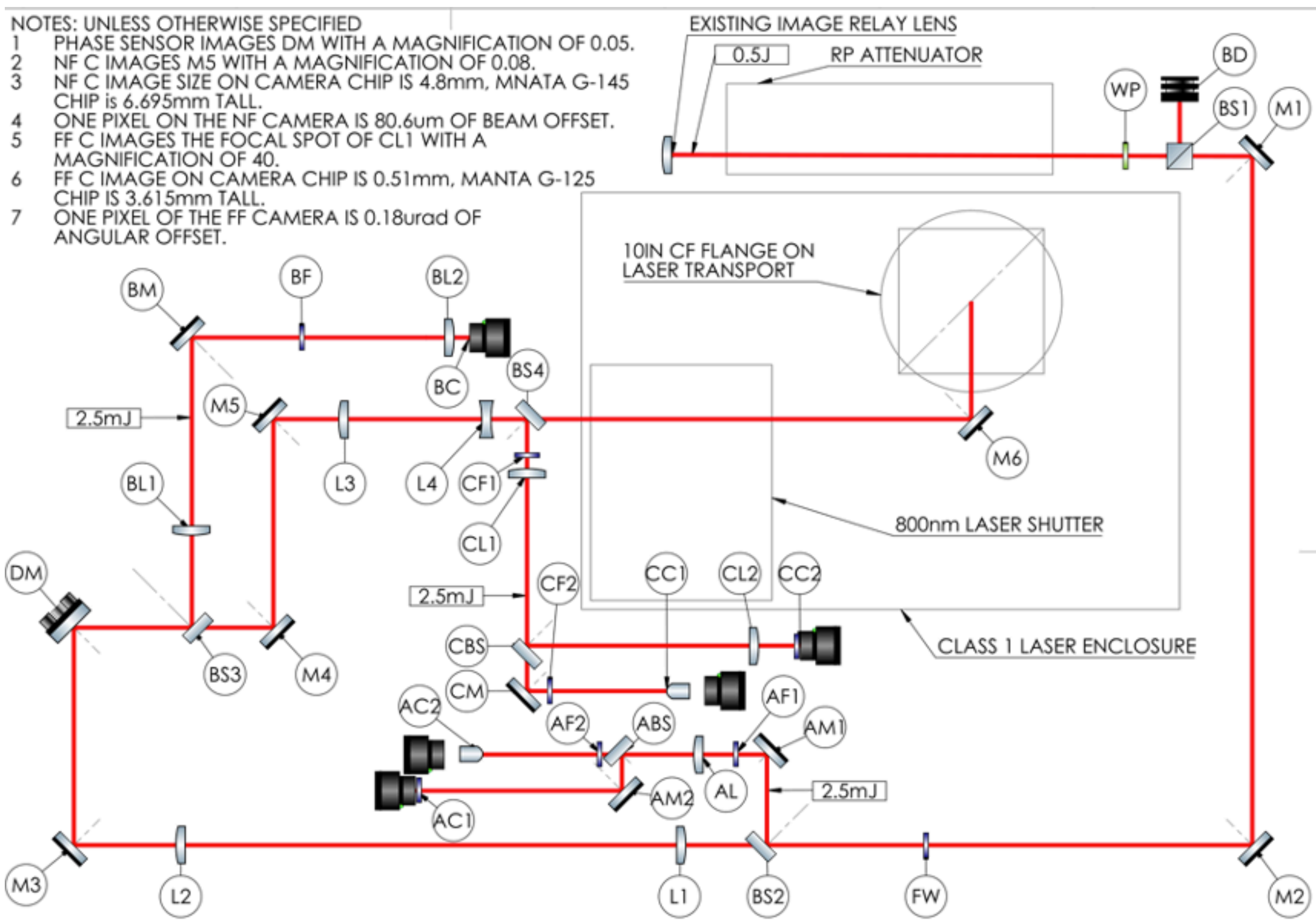


Work to improve stability since 2016:

- Upgraded water system: new filters and added resistivity monitors
- Characterizing energy output inside SAGA (Osc, Amp, Green)
- New sources for components (lamps and laser medium)
- SAGA 2 operational, examining SAGA 1

End the saga of the SAGAs with careful measurement and monitoring

Current Work: Laser room and transport injection modifications



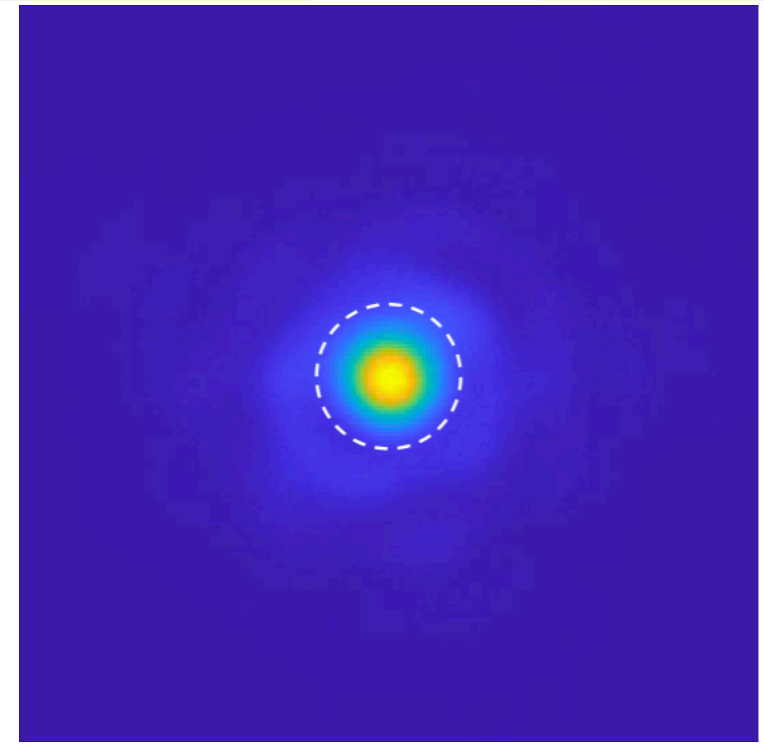
Cutting out windows required reworking laser transport

- New shutters
- New lenses
- Incorporate Deformable Mirror + wavefront sensor
- Cameras to align laser to DM
- Cameras to align laser to transport
- HeNe for ‘always on’ transport monitoring

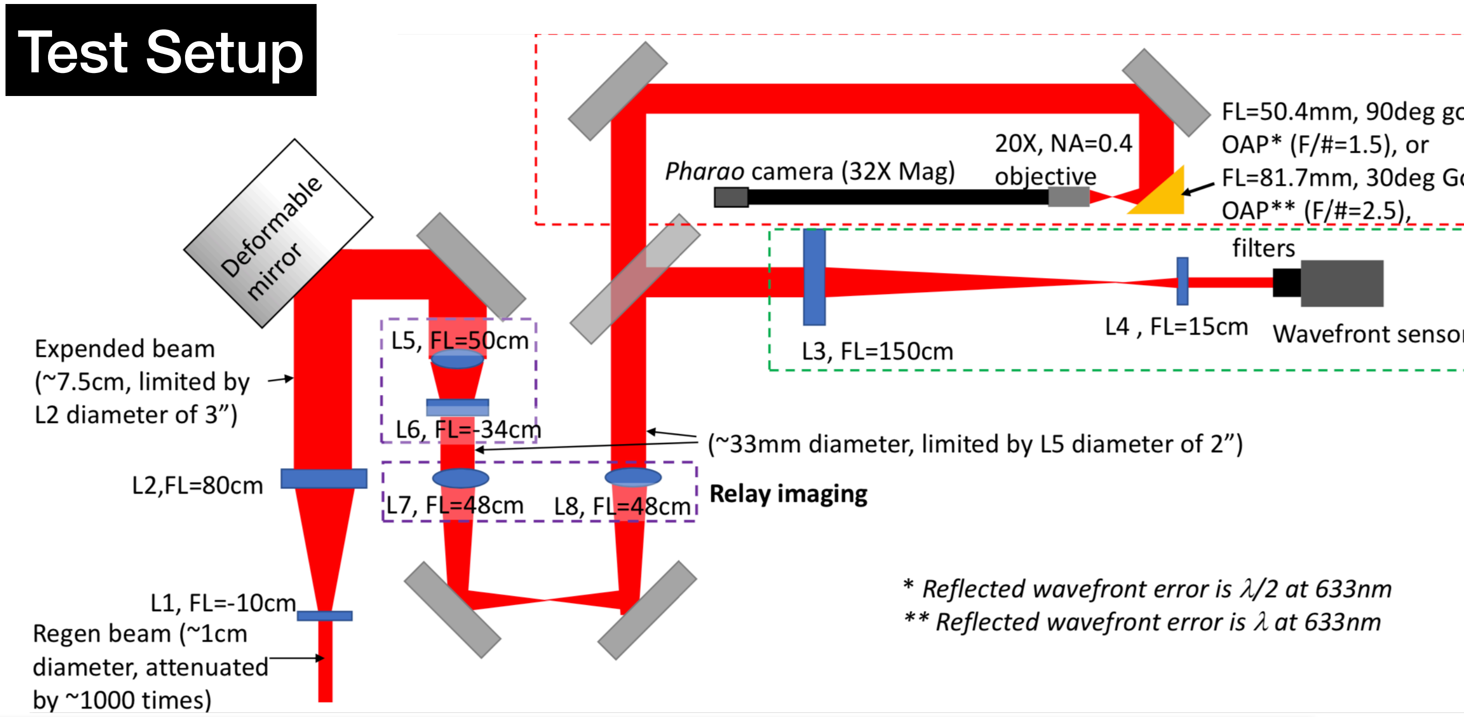
Transport reconfiguration necessary to meet laser quality needs

Current Work: Deformable Mirror

- System uses wavefront sensors and focus optimizer 'pharao' (just a camera)
- Initial tests show 2x intensity from wavefront sensor, 1.3x more with Pharao
- For operations:
  - Wavefront sensor in laser room
  - Pharao camera in tunnel
- DM operation, procedures and simulations quickly reaching maturity



Test Setup



Deformable mirror enables laser to meet highest intensity requirements at FACET-II

Current Work: Laser Monitoring System

rStatusTableGUI@facet-srv01

Laser Status Table

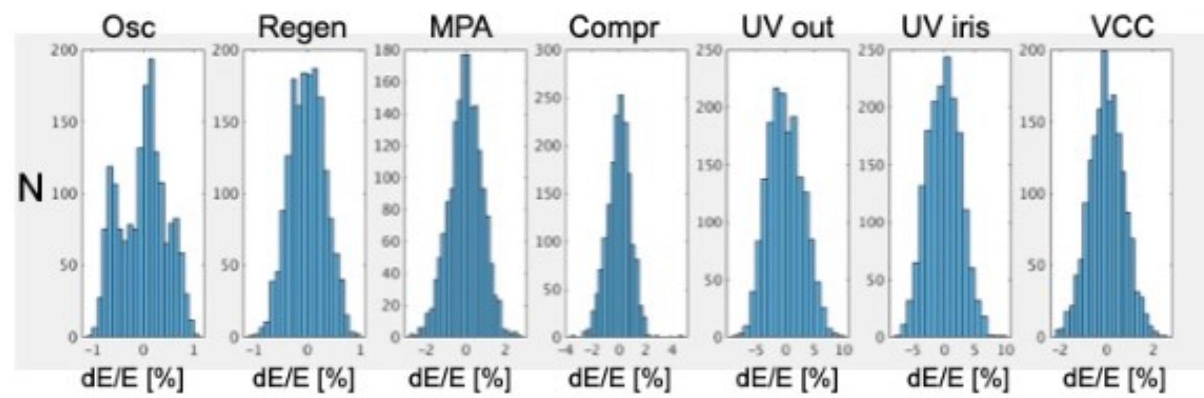
	Laser Property [% of ref]	Current	15 Min. RMS	1 Hr. RMS
1	Oscillator Output			
2	Centroid Offset [mm] (x,y)	2.5,1.9	0.43,0.47	0.51,0.5
3	Spot Size [mm] (x,y)	6.2,6.8	0.39,0.14	0.86,0.21
4	Nonuniformity	3.7	1.3	1.4
5	Energy (mW, RMS [%],Range/RMS)	380	0.26,5	0.45,4.6
6	Regen Output			
7	Centroid Offset [mm] (x,y)	2.2,1.1	0.8,0.11	1.6,0.6
8	Spot Size [mm] (x,y)	0.6,0.69	0.036,0.062	0.065,0.09
9	Nonuniformity	7.3	2.1	2.2
10	Energy (mJ, RMS [%],Range/RMS)	4.4	0.27,6.2	0.33,6.1
11	MPA Output			
12	Centroid Offset [mm] (x,y)	1.9,1.5	0.87,1.2	1.2,1.7
13	Spot Size [mm] (x,y)	0.81,1.1	0.17,0.31	0.19,0.32
14	Nonuniformity	10	2.4	2.4
15	Energy (mJ, RMS [%],Range/RMS)	14	0.65,6.1	0.82,6.4
16	Compressor Output			
17	Centroid Offset [mm] (x,y)	2.3,1.1	0.85,1.1	1.1,1.5
18	Spot Size [mm] (x,y)	2.7,2.8	0.34,0.35	0.34,0.48
19	Nonuniformity	8.7	2	2.1
20	Energy (mJ, RMS [%],Range/RMS)	5	0.68,6.2	0.87,9.5
21	UV Conv. Output			
22	Centroid Offset [mm] (x,y)	1.9,1.2	1.2,1.5	1.6,1.9
23	Spot Size [mm] (x,y)	0.34,0.39	0.16,0.2	0.19,0.22
24	Nonuniformity	7.9	2	2.1
25	Energy (mJ, RMS [%],Range/RMS)	0.18	2.3,6.2	2.9,6.1
26	UV Iris Output			
27	Centroid Offset [mm] (x,y)	2.7,2.4	1.2,1.1	1.5,1.4
28	Spot Size [mm] (x,y)	1.8,2.3	0.19,0.38	0.19,0.48
29	Nonuniformity	17	1.9	1.9
30	Energy (mJ, RMS [%],Range/RMS)	0.043	2.1,6.4	2.7,6
31	VCC			
32	Centroid Offset [mm] (x,y)	3.2,2.5	12,14	21,19
33	Spot Size [mm] (x,y)	0.045,0.049	2,1.9	2.1,2.3
34	Nonuniformity	9.2	6.1	6.8
35	Energy (mJ, RMS [%],Range/RMS)	0.16	0.67,5.9	0.75,6.2
36	Temperature [deg F]	72	0.013	0.029
37	Humidity [%]	51	0.91	1.9

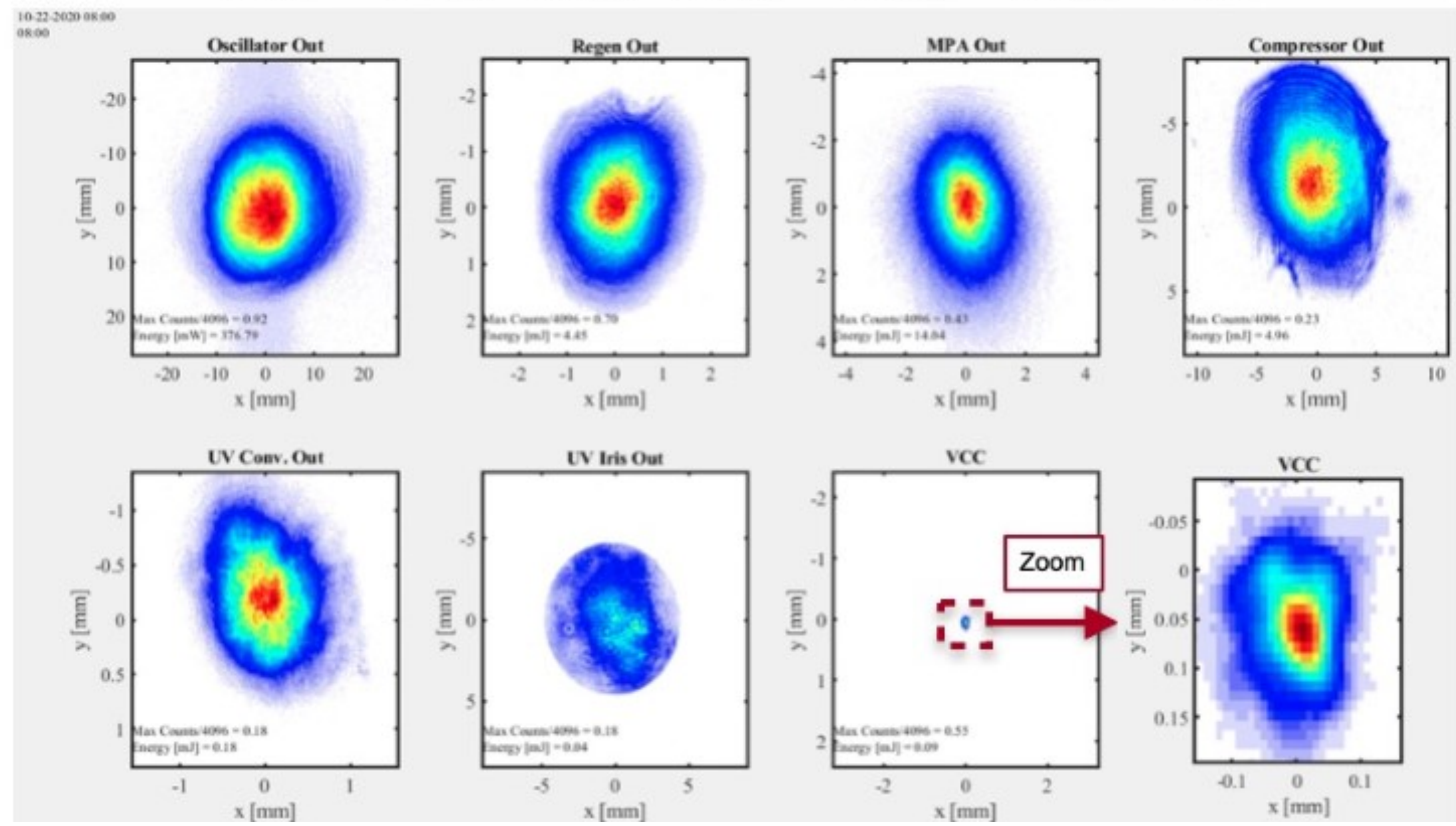
Current data taken at 10-22-2020 08:05

All RMS values given as a percent difference from the mean

Start Live Table

Stop Live Table





Constant vigilance, alert to subtle changes to prevent downtime

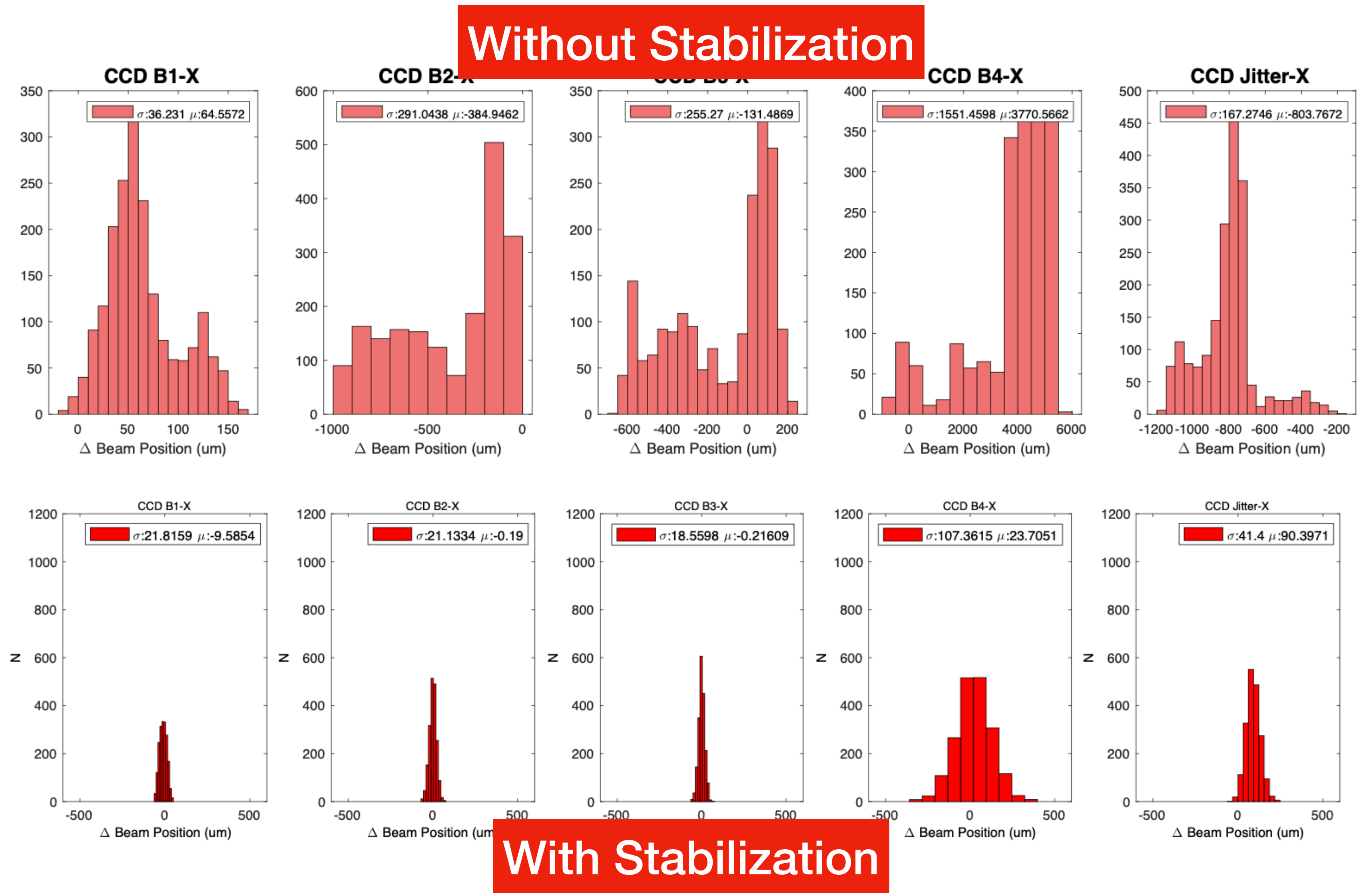
Current Work: Transport Feedback

Pointing from laser room into IP area subject to thermal effects

- Time scale ~10 minutes during sunrise and sunset
- 7 cameras along 16 meters of transport to monitor and correct

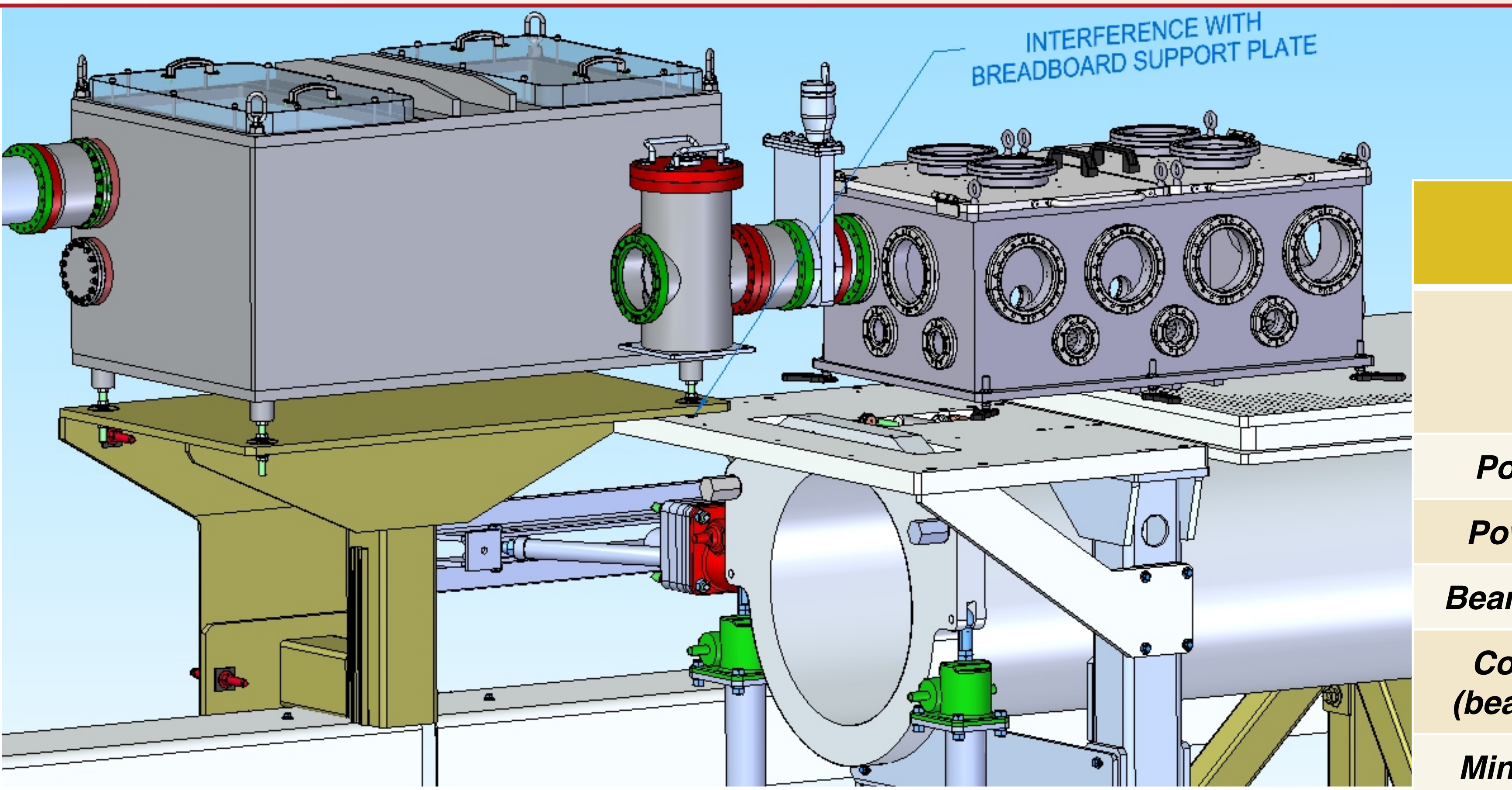
Feedback reduces long time scale drift by 10-15x

- 'hold the beam' while setting up
- Automate transport alignment



Consistent, faster laser alignment compared to FACET

Current Work: Compressor Upgrade



Function	40 TW (Gratings set limit)
Upgrades	Optimal Present + GAIA 8” gratings
Power-amp Pump [J]	7.5
Power-amp Output [J]	2.3
Beam Transport Input [J]	2.0
Compressor Input [J] (beam transport output)	1.8
Minimum Beam Size @ Compressor [radius, cm]	3.0
Pulse Length Before Compression [ps] [FWHM]	150.0
Compressor Output [J]	1.28
Pulse Duration after compression (fwhm) [fs]	35.0
Peak Power [TW]	36.5
Intensity* [10^{18} W/cm^2]	242.4
a0*	10.6

Path to 40 TW with little resistance

- Compressor box easily handles larger gratings - 2x the area of previous box
- Transport mirrors would need to get larger
- SAGA pump lasers replaced by GAIA

Larger Compressor vacuum box accommodates long range upgrades