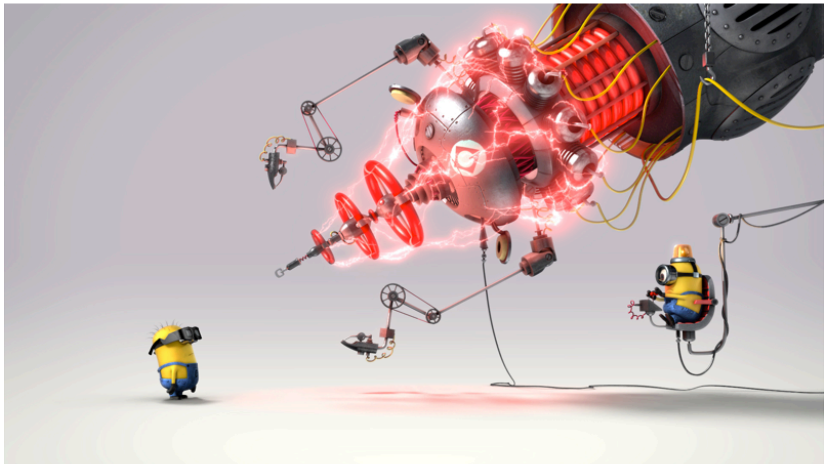
FACET-II

Laser upgrade options: >100TW, transport and quality improvement



FACET-II Science Workshop 2017

Alan Fry

October 20, 2017

Outline

Enhanced capabilities for FACET-II experimental operations

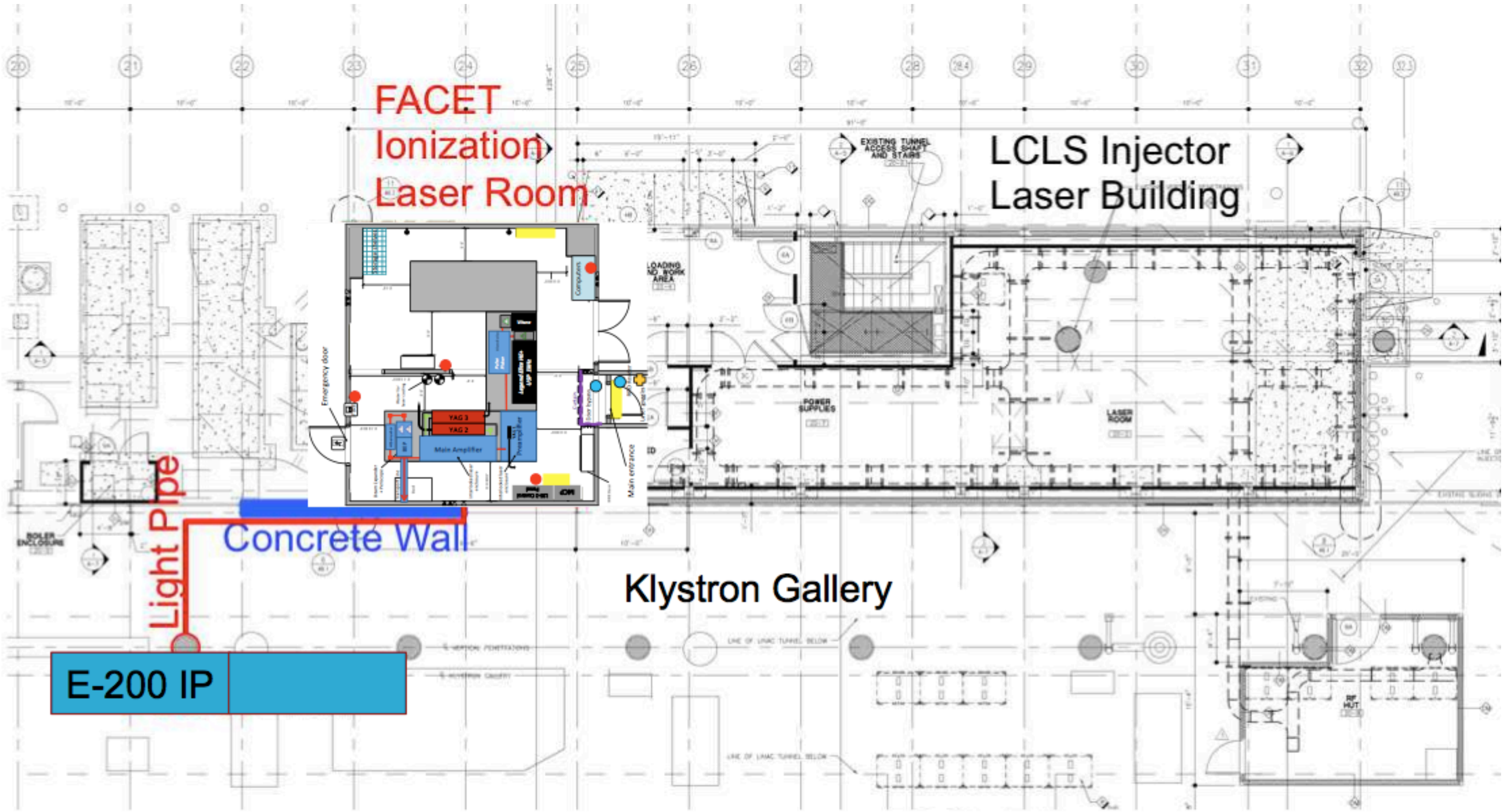
- Shorter pulse duration
- Higher pump laser energy
- Reduced beam transport losses

} Higher peak intensity

- Improved diagnostics

- Major upgrade for high-field QED capabilities
- >100 TW peak power
- Larger beam transport optics
- Larger compressor
- Many additional modifications

FACET Laser in Sector 20



The Laser System: 10-TW Ti:Saphire Laser

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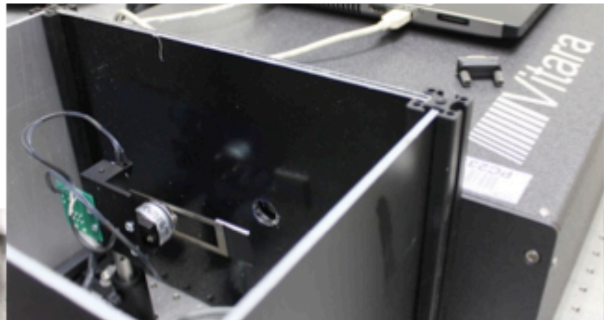
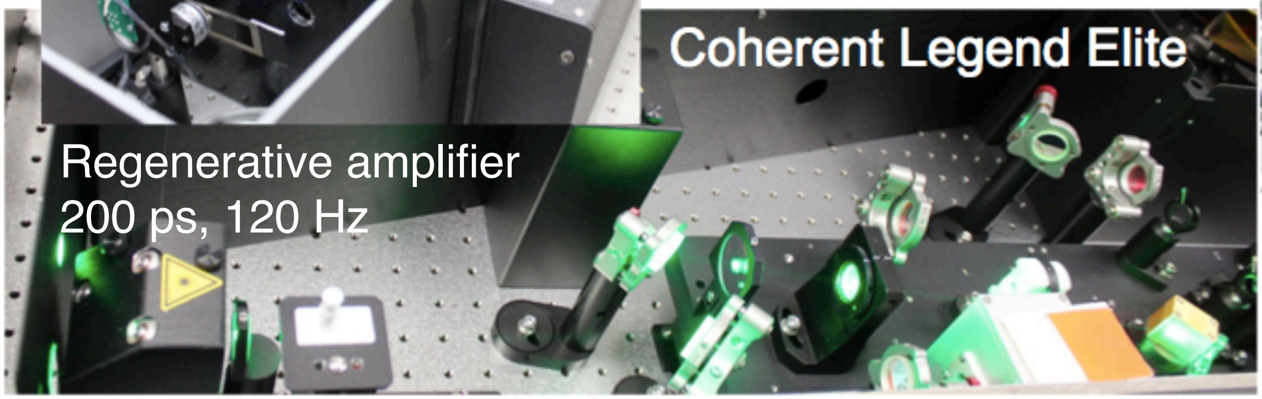
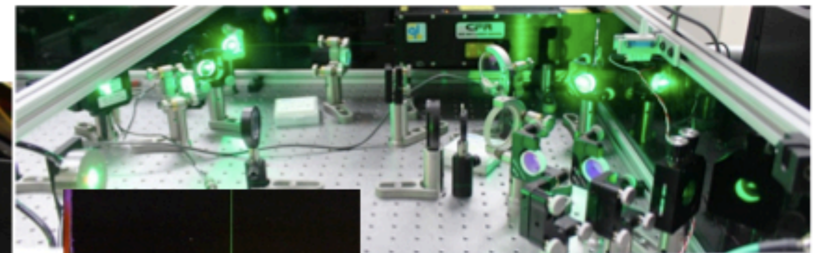
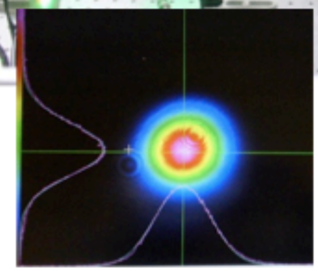


Coherent Vitara oscillator with a Verdi pump laser: 800 nm, 20 fs pulses at 68 MHz

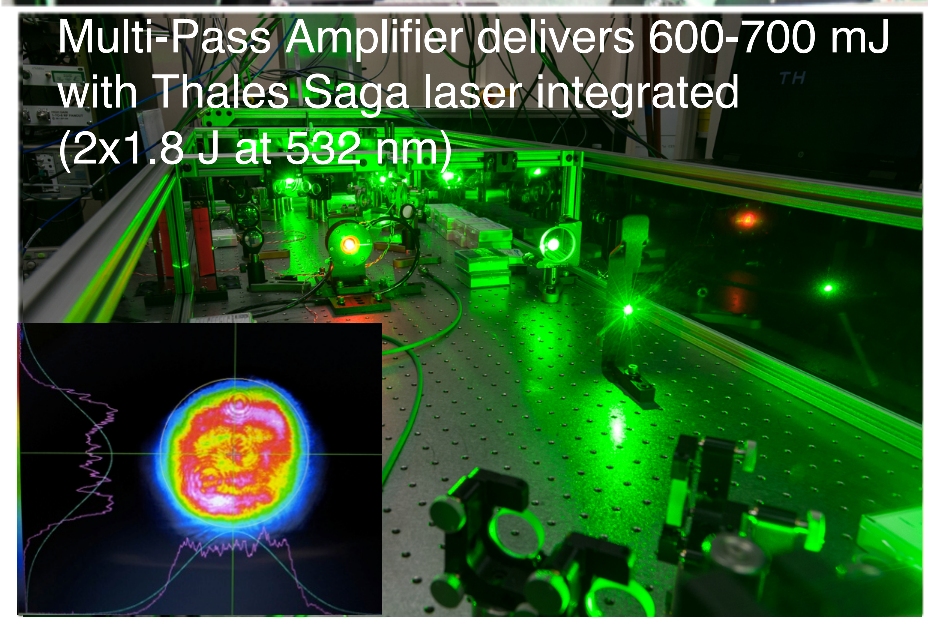


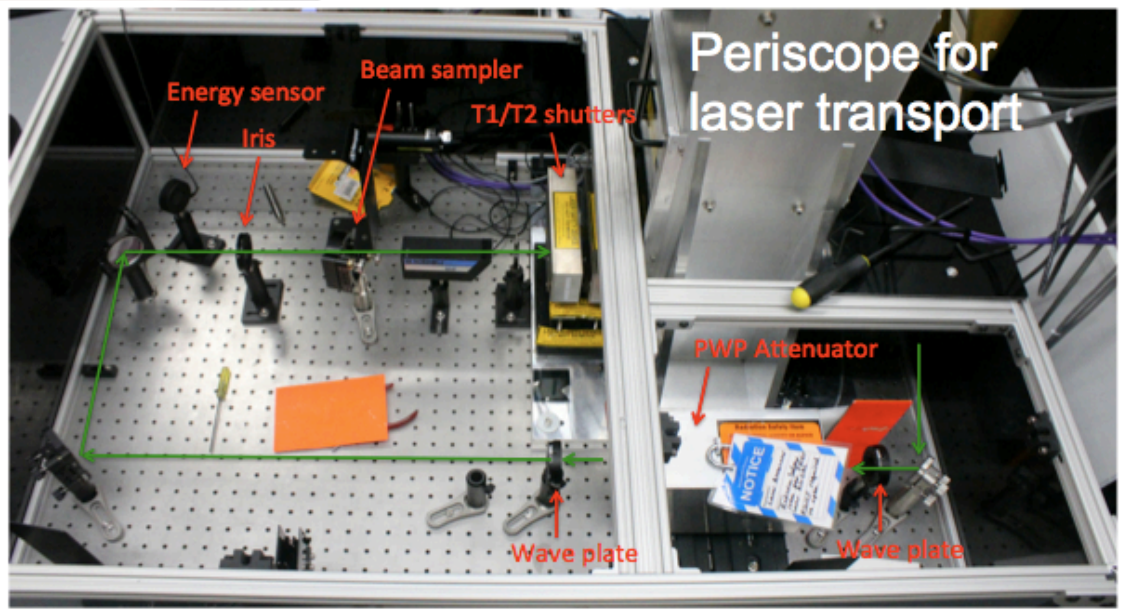
Quantel Nd:YAG flash lamp pump laser: 130 mJ at 532 nm



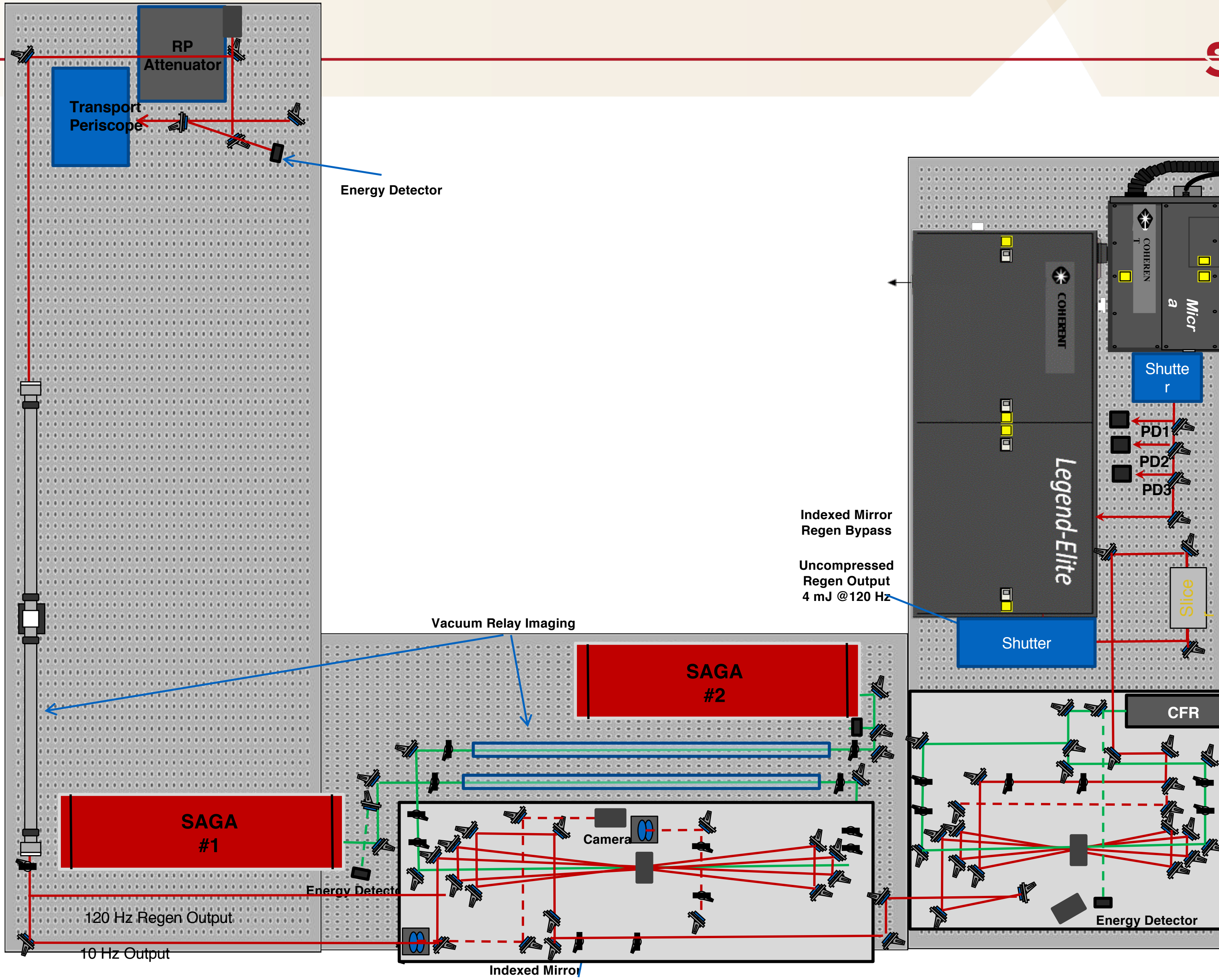


Preamplifier delivers 40 mJ to amplifier





Upgrade-ready FACET laser layout

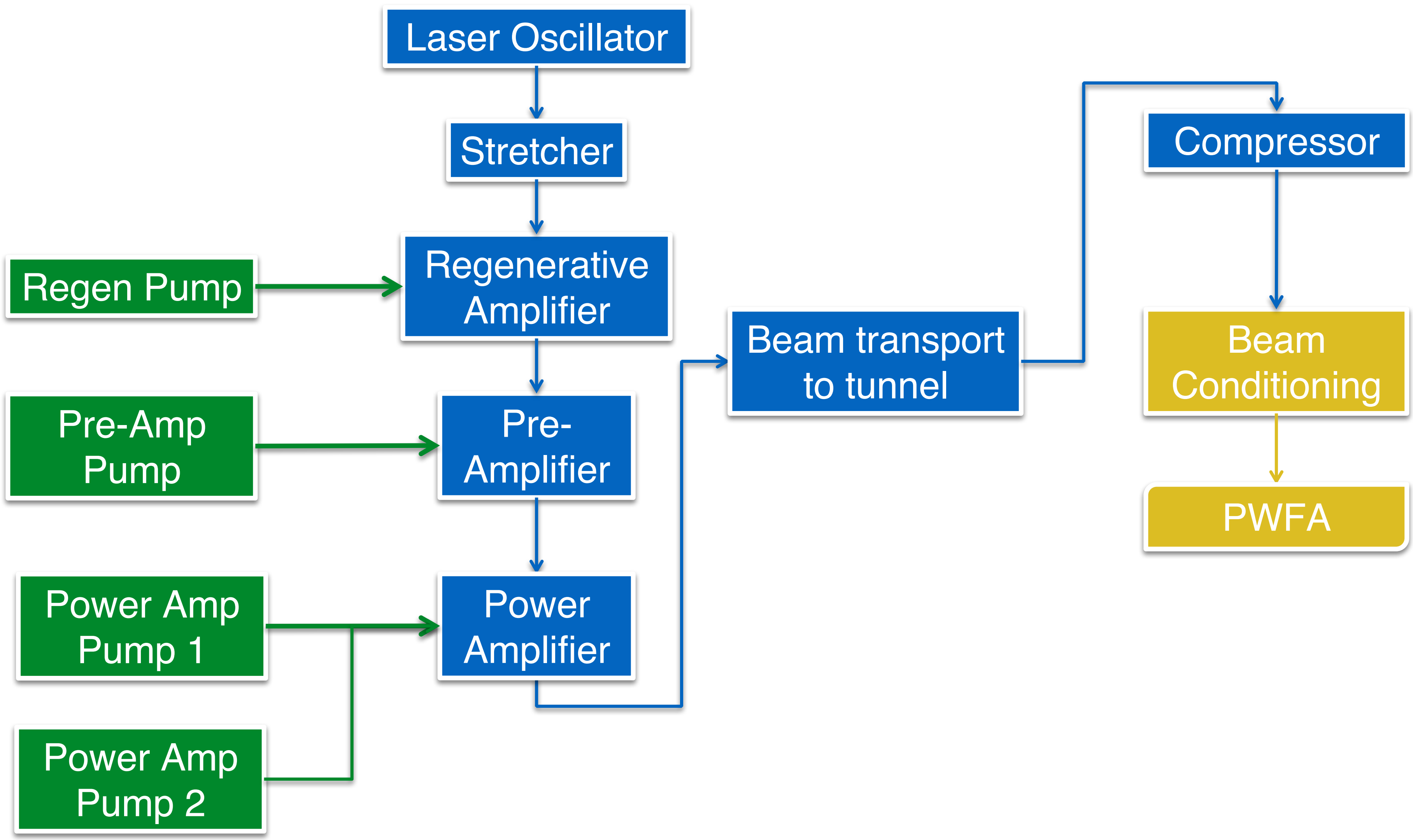


What do we need to upgrade?

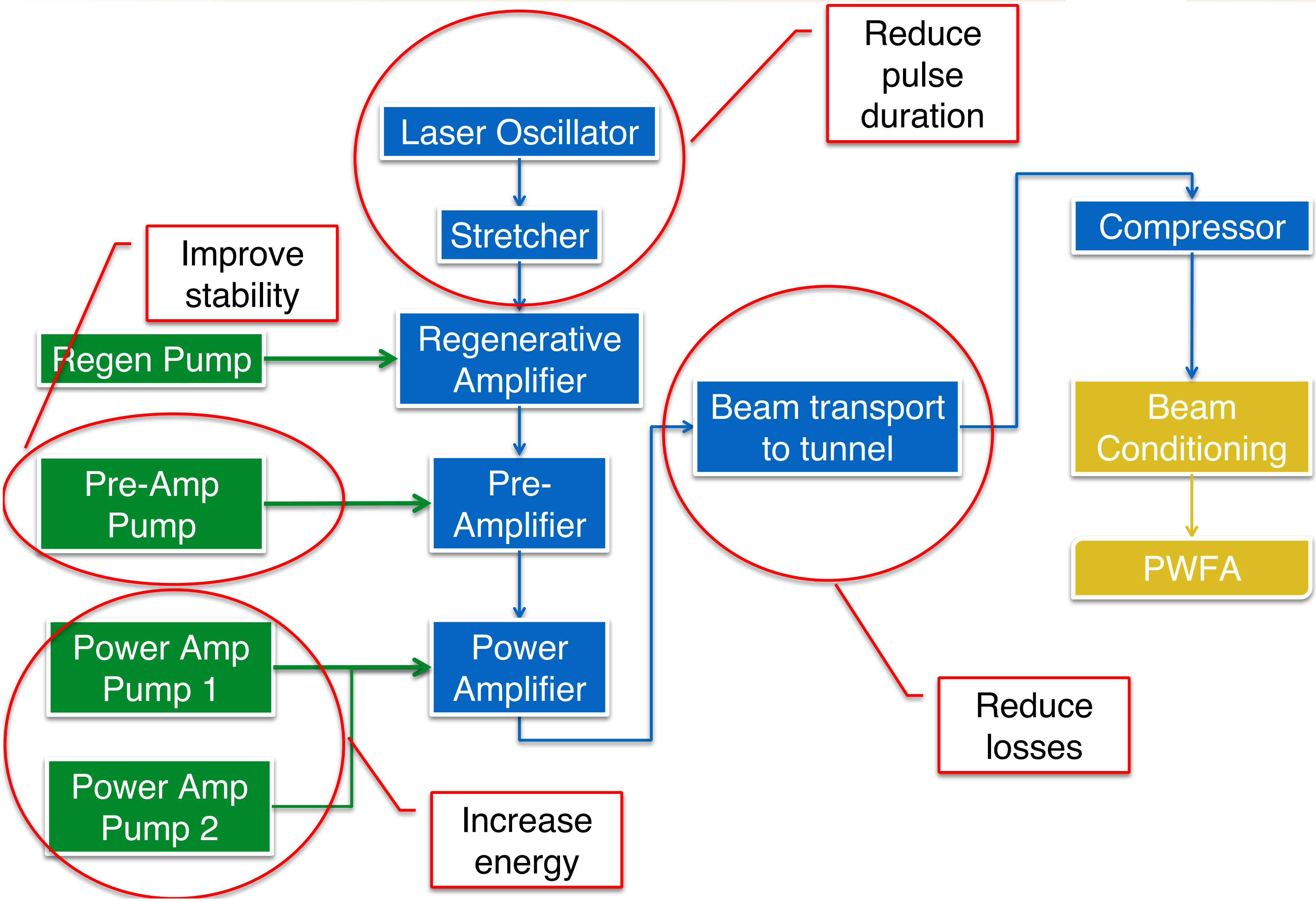
From Mike Litos [traumatized, but no longer on-the-hook]:

- long term (minutes to hours) pointing drift in the transport
- fast pointing jitter through the transport
- increased number and quality of diagnostics from laser room to experiment
- increased automation of laser alignment in laser room and through transport
- improved reliability & stability of intensity profile (Powerlite seemed to help)
- automation of transport lens alignment
- accurate and frequent characterization of pulse compression
- phase monitoring and correction capability (deformable mirror)

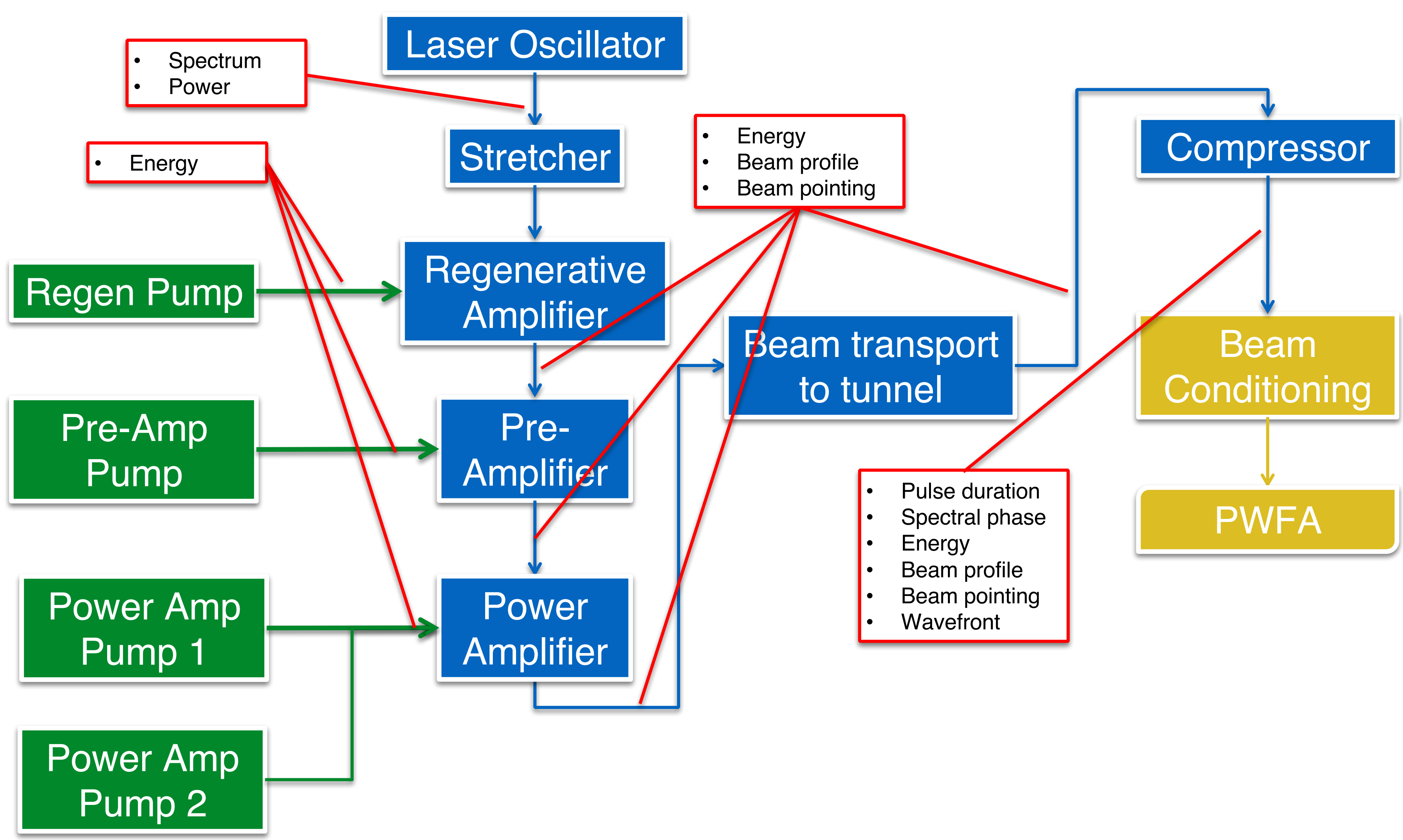
Laser System Block Diagram: current system



Laser System Block Diagram: upgrades



Laser System Block Diagram: diagnostics upgrades



Laser System Performance & Upgrades

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Function	"Spec"	Typical	Upgrade target	Upgrade
Regen Pump	20 mJ	20 mJ	20 mJ	
Regen output			20 mJ	
Pre-amp Pump	120 mJ	120 mJ	100 mJ	DPSS laser for stability
Pre-amp Output	35 mJ	35 mJ	30 mJ	
Power-amp Pump	3.6 J	2.8 J	7 J	Gaia or equivalent
Power-amp output	1.0 J	0.6 J	1.8 J	
Beam transport output	0.8 J (80%)	0.40 J (65%)	1.6 J	Improve optics (to 80%)
Compressor output	0.52 J (65%)	0.25 J (65%)	1.0 J	
Pulse Duration	40 fs	70 fs	35 fs	Spectral phase control
Peak Power	>10 TW	3.5 TW	>25 TW	

Pulse duration upgrade: spectral phase control & monitoring

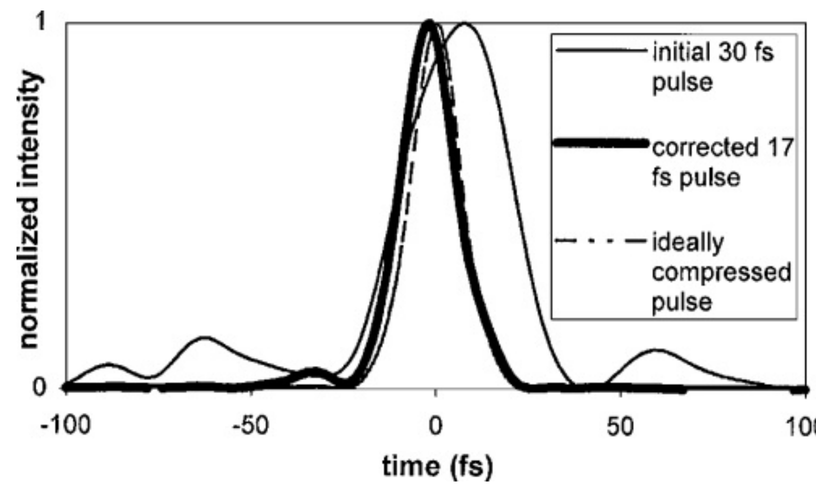
- Uncorrected spectral dispersion can be measured (FROG, SPIDER, D-Scan, etc.) and controlled (Dazzler, SLM, DM, etc.) with commercial devices.
- Anticipate routine operation at 35 fs FWHM

SPIDER

Dazzler


FROG


Wave shaper



Pump laser upgrade: higher energy

Example pump lasers from Thales

(other suppliers have comparable products)

Product Name	Energy @ 532nm [J]	Rep Rate [Hz]	Est. Ti:S compressed energy [J]	Est. peak power [TW]
Gaia-I	7.5	5	1	25

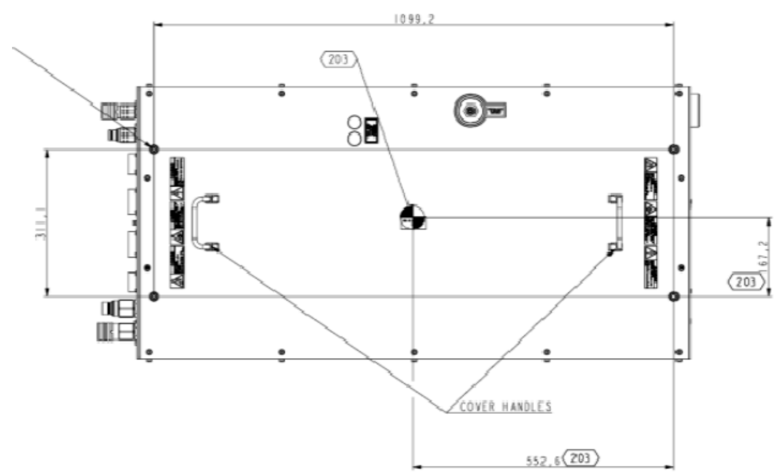
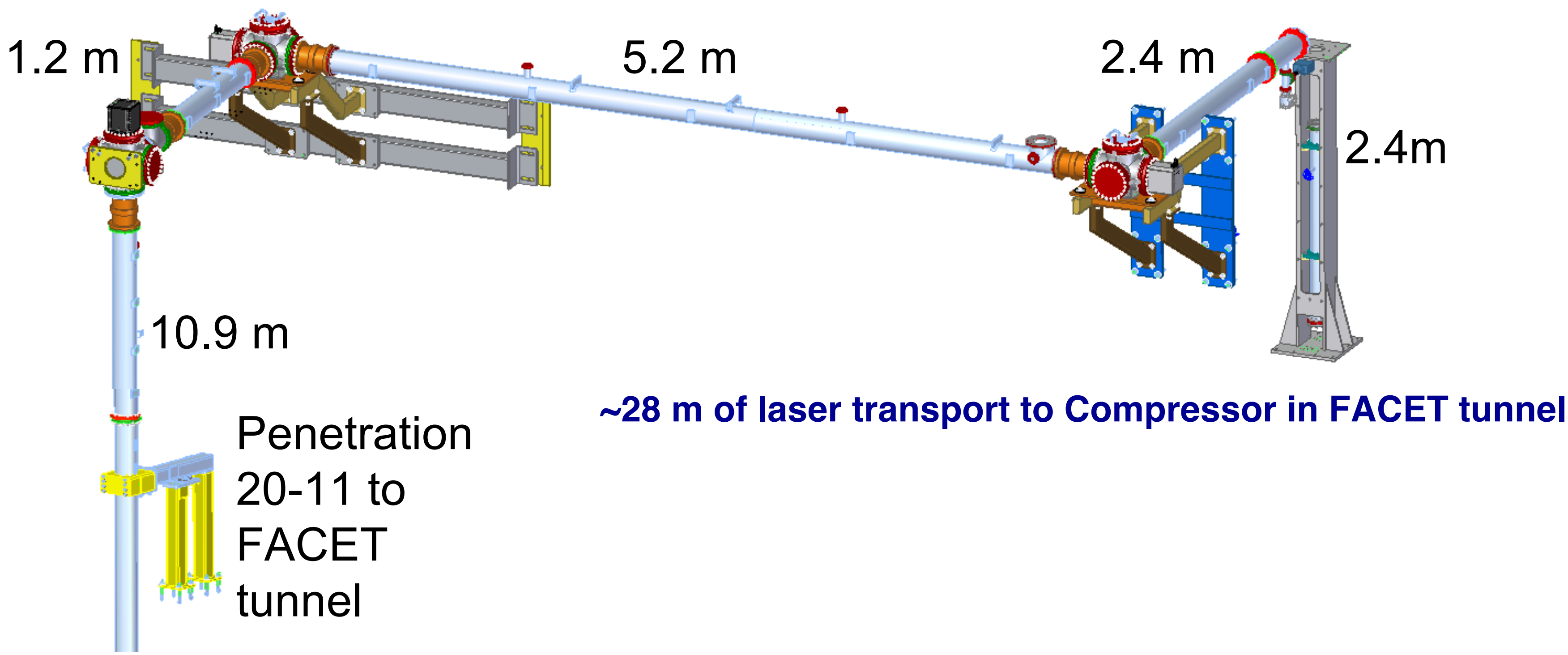


Figure 20 : Laser head - top view

0.6m x 1.1m - fits on existing tables (barely)

Beam transport upgrade: improved optics

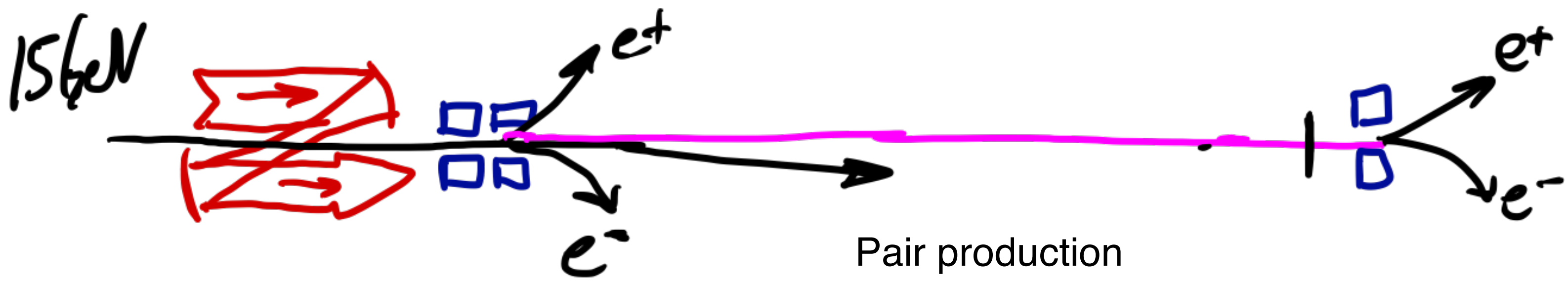
- Beam transport has relatively high losses (35%), uncorrected dispersion, possibly some spectral clipping
- Replacement of optics should increase transmission to 80% and reduce spectral phase and amplitude degradation



FACET-II opportunities

ω =1.55eV, η = 17, Y= 3

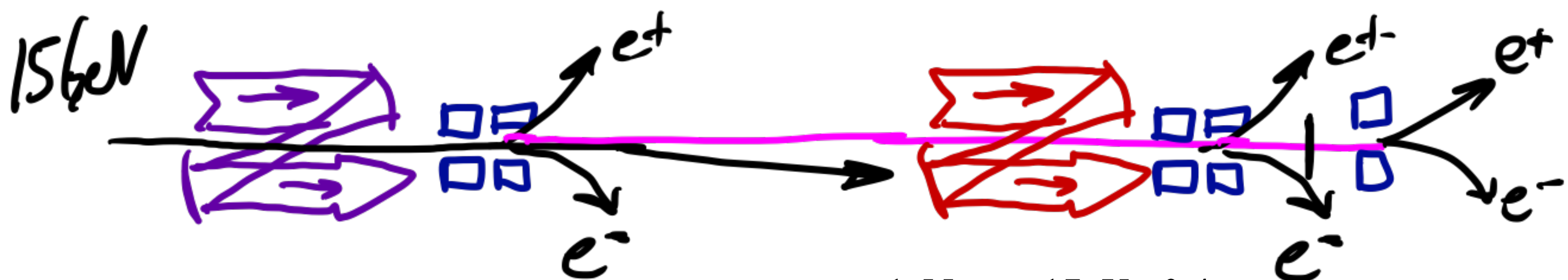
strong-field Compton scattering, rad. reaction



Pair production

ω =4.8eV, η <<1, Ψ = 0

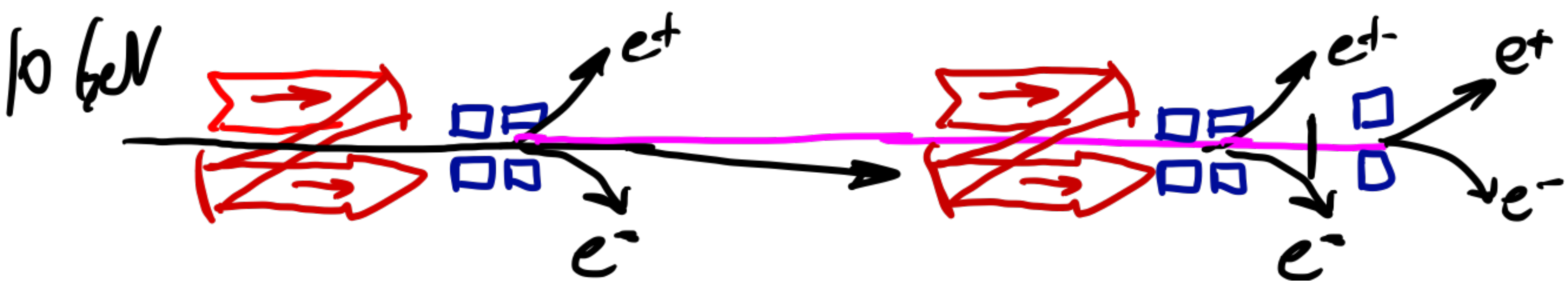
ω =1.55, η = 17, Y= 1.6



ω =1.55, η = 17, Y= 0.4

ω =1.55eV, η <<1, Y = 0, circ pol.

Vacuum birefringence



Courtesy David Reis

100TW upgrade: creative space utilization (and many other upgrades)

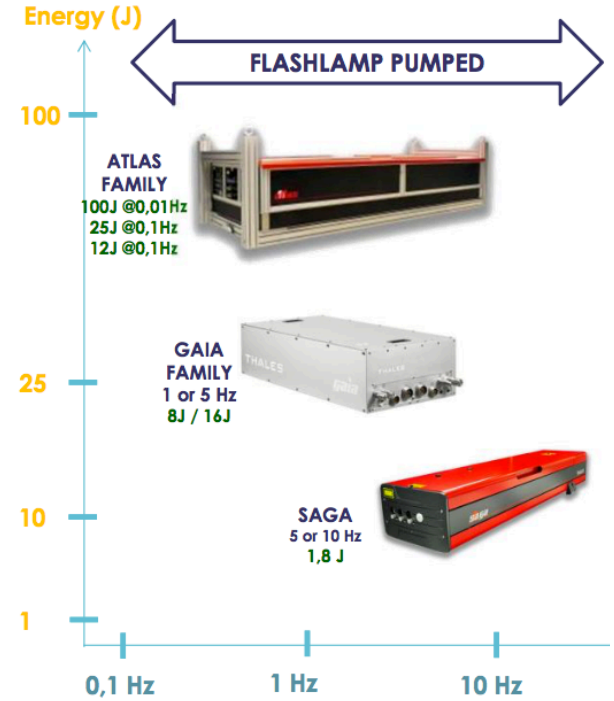
- Higher energy pump laser (possibly at reduced rep-rate)
  - Possibly additional space needed in laser lab
- Larger Ti:sapphire amplifier crystal and beam optics
- Increased stretching to reduce nonlinear effects in amplifier and beam transport
- Increased beam size through beam transport and compressor
- Increased grating size and separation in larger compressor tank
- Possible need to suppress pre-pulses
- High quality parabolic focusing and recollimating optics on hexapod manipulators to achieve highest beam quality
- Deformable mirror and wavefront sensor for high intensity beam at focus
- ….

Pump laser upgrade: toward 100TW

Example pump lasers from Thales

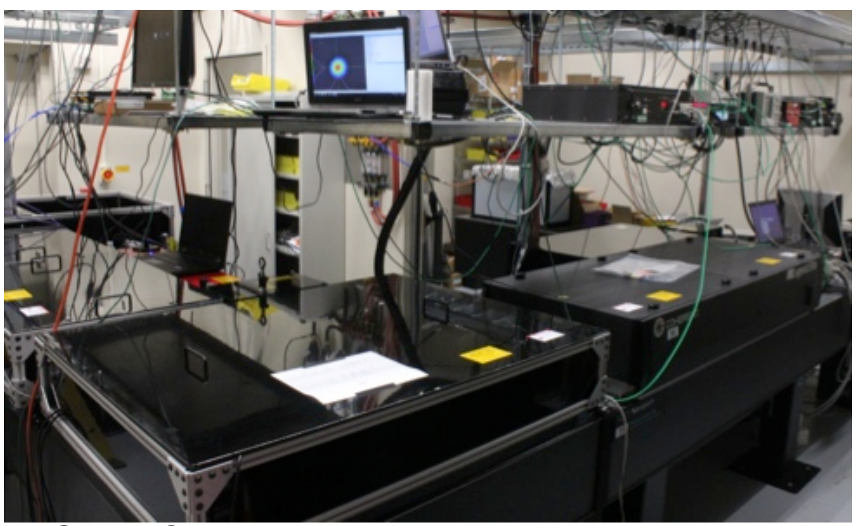
(other suppliers have comparable products)

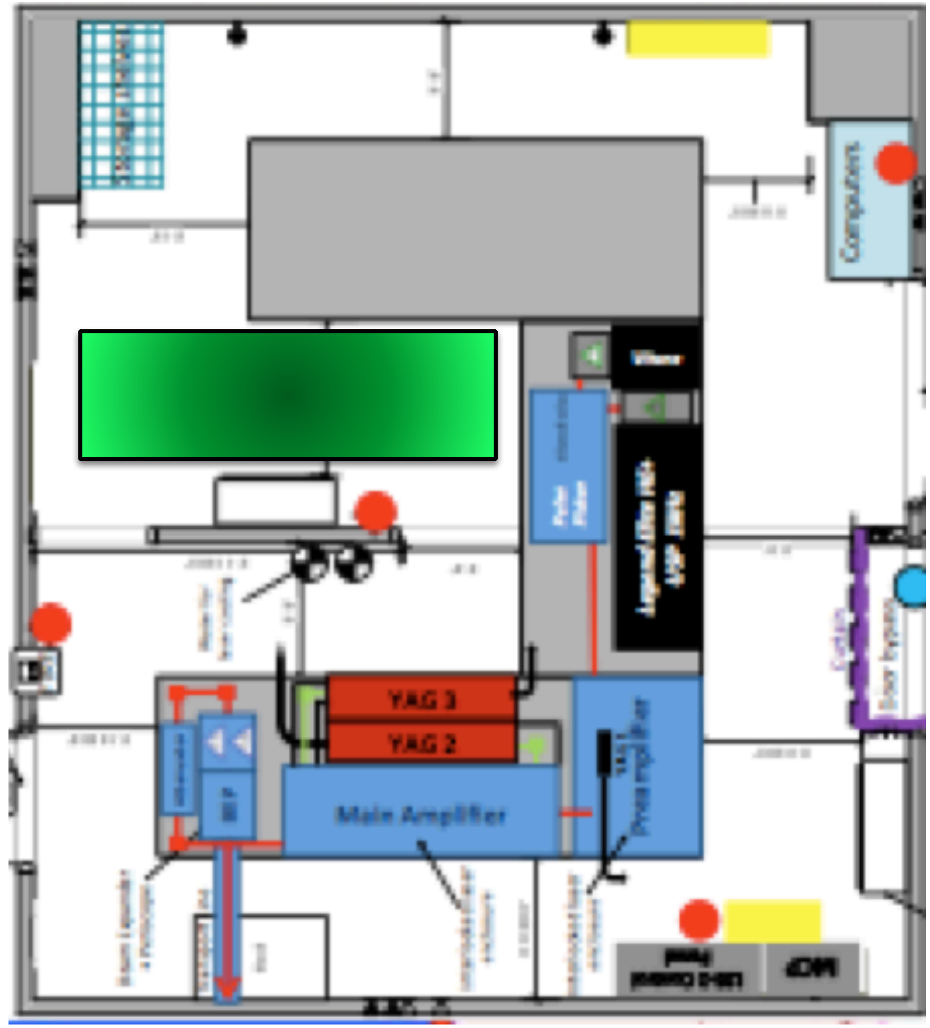
Product Name	Energy @ 532nm [J]	Rep Rate [Hz]	Est. Ti:S compressed energy [J]	Est. peak power [TW]
Gaia-HP	16	5	2	55
Atlas 25	25	0.1	3	85
Atlas 50	50	0.016	6	170



Pump laser upgrade challenge: space

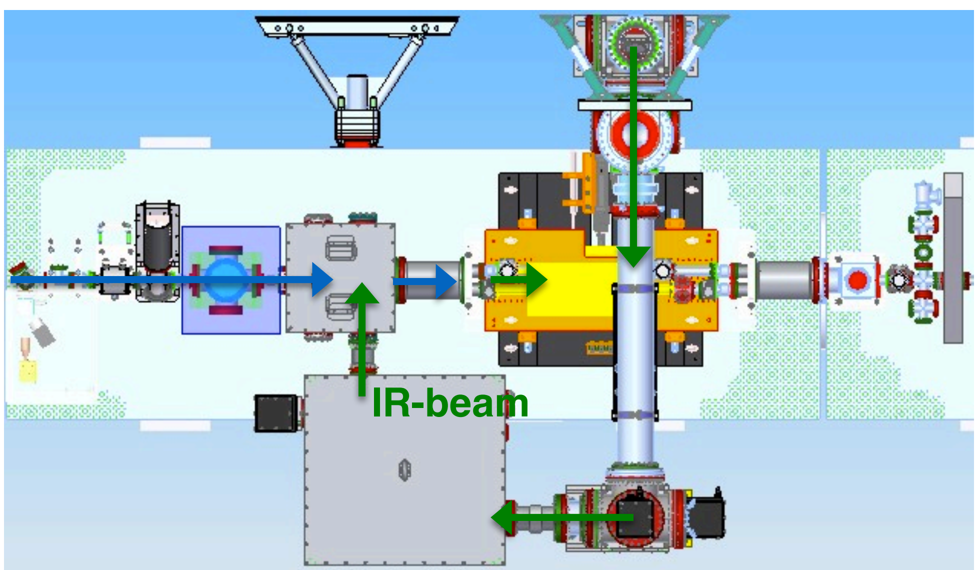
- Gaia-HP laser head is 1m x 2.7m
  - Must be mounted stably, close to power amplifier, with access for maintenance and service
- Power supply and cooling unit are 0.5m x 1.5m together
  - Must be located within ~3m of laser head
- May need to expand room, e.g. into entrance to S20 building

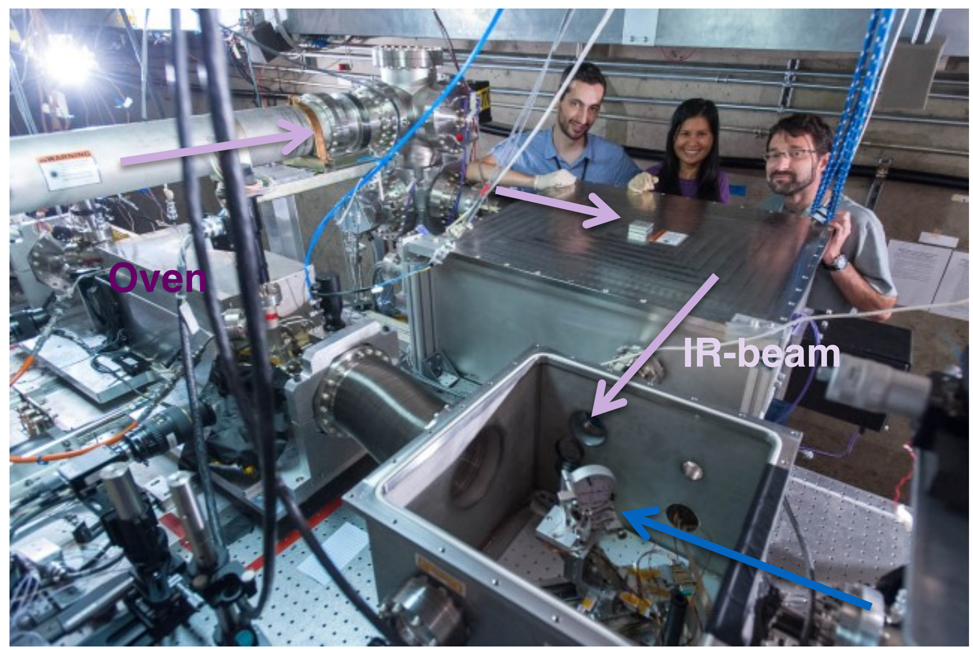




Compressor upgrade: larger optics for 100TW class operation

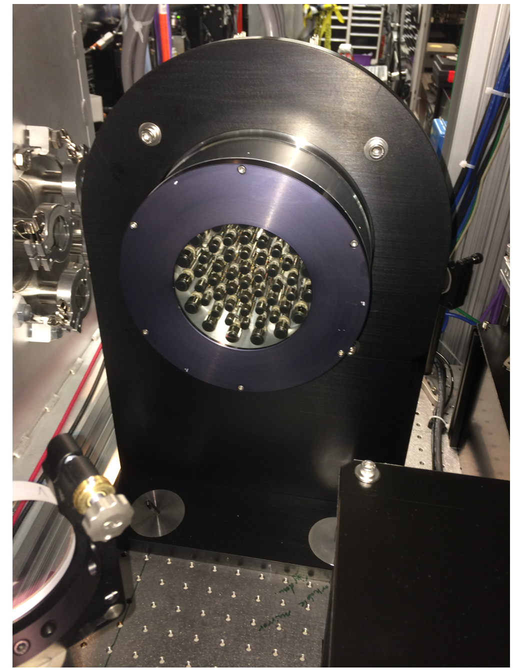
- Increase beam diameter to ~10cm
- Increase grating width to ~30cm
- Increase grating separation by ~2-3x
- Compressor enclosure footprint increases by 3-5x





Beam delivery upgrade: deformable mirror & wavefront sensor

After amplification, a deformable mirror in combination with a wavefront sensor corrects the distortions produced in the laser chain and sent to the compressor. The spot on sample is optimized afterwards using a second feedback loop that corrects the distortion introduced by the compressor and focusing optics in the experimental chamber.



Before correction	After correction
0.576 um RMS distortion	22 nm RMS distortion
2.502 um P-V	100 nm P-V

FACET-II Laser: Conclusions

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- FACET-II ionization laser system can be upgraded at moderate cost to achieve >25TW at 5Hz
  - Spectral phase control
  - Higher energy pump laser
  - Improved beam transport optics
  - Improved diagnostics
- 100TW class upgrade for nonlinear QED is possible at higher cost with multiple upgrades throughout the laser, beam transport, and delivery systems
- Design and operations support provided by experienced LCLS Laser Science & Technology Division

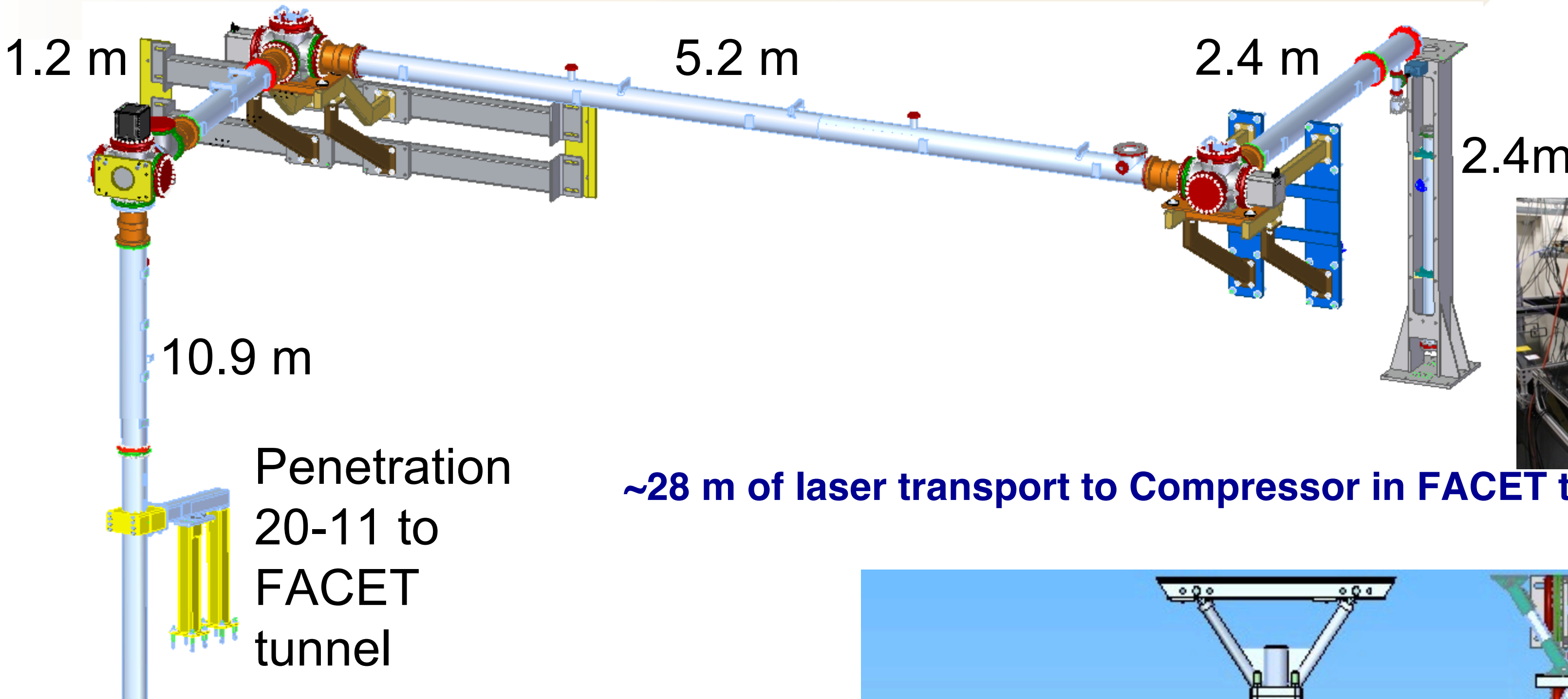
Laser Support Team

LCLS Laser Science and Technology Division (**Alan Fry**, Division Director)

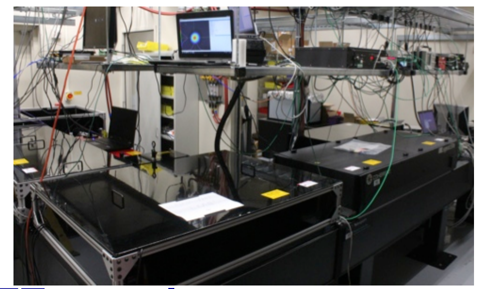
- *Lasers In Accelerators Department* (**Steve Edstrom**, Department Head)
  - **Sasha Gilevich**, Laser Engineer
  - **Philippe Hering**, Laser Physicist
  - **Alan Miahnahri**, Opto-mechanical Engineer
  - **Wayne Polzin**, Laser Engineer
  - **Sharon Vetter**, Laser Engineer
  - **Marc Welch**, Laser Engineer
- *Lasers in LCLS Science Department* (**Joe Robinson**, Department Head)
  - 8 Laser Scientists

Experimental Setup

FACET SLAC



FACET laser room



~28 m of laser transport to Compressor in FACET tunnel