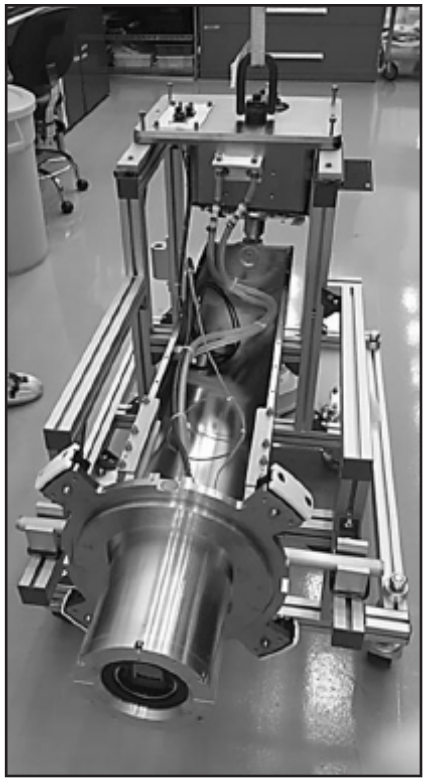
Omega Laser Facility OLUG 2017 Update: Progress on Recommendations and Items of General Interest



S. F. B. Morse
University of Rochester
Laboratory for Laser Energetics

Omega Laser Facility
Users Group Workshop
Rochester, NY
26–28 April 2017

Summary

Omega is an effective and efficient facility and evolves to meet the needs of users

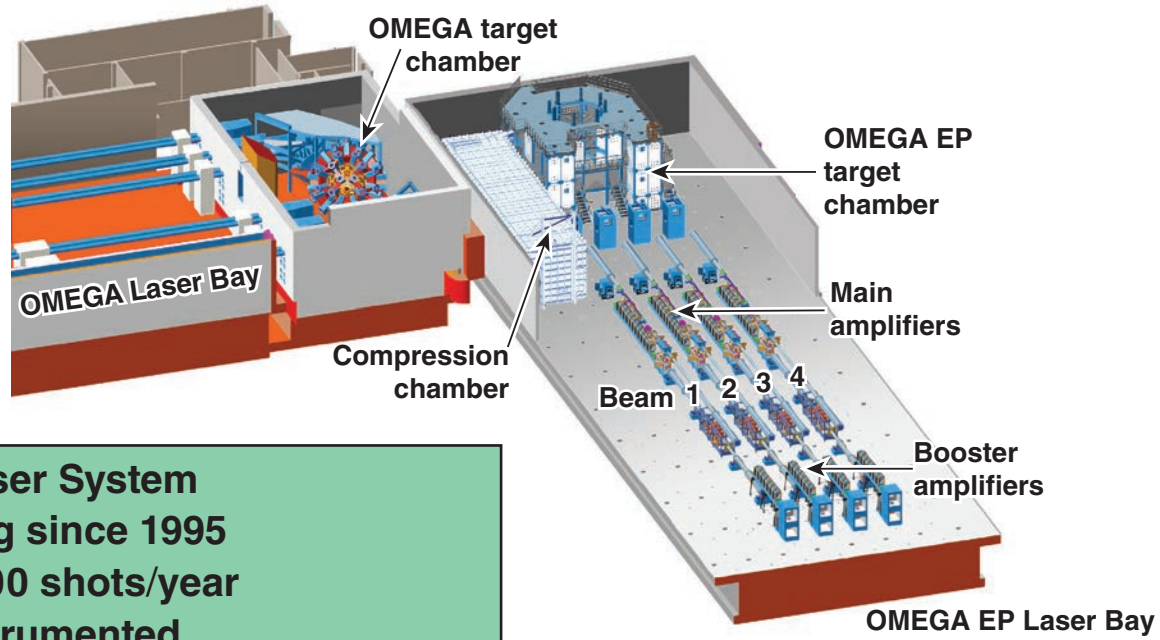
UR LLE

- OMEGA and OMEGA EP are National Nuclear Security Administration (NNSA) workhorse facilities
- Operational statistics show continued high performance
- The facility responds to the Omega Laser User Group (OLUG) recommendations
- The internal focus on 100-Gbar pressures and laser–plasma instabilities (LPI's) are motivating a number of initiatives that have broad benefits
- Omega supports LLE and user-developed diagnostics

OLUG Findings and Recommendations (F&R's) are important input to LLE priorities.

G11258

OMEGA and OMEGA EP continue to be very effective and productive user facilities



OMEGA Laser System

- Operating since 1995
- Up to 1500 shots/year
- Fully instrumented
- 60 beams
- >30-kJ UV on target
- 1% to 2% irradiation nonuniformity
- Flexible pulse shaping
- Short shot cycle (1 h)

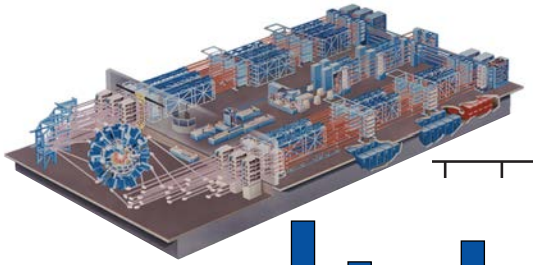
More than half of OMEGA's shots are for external users.

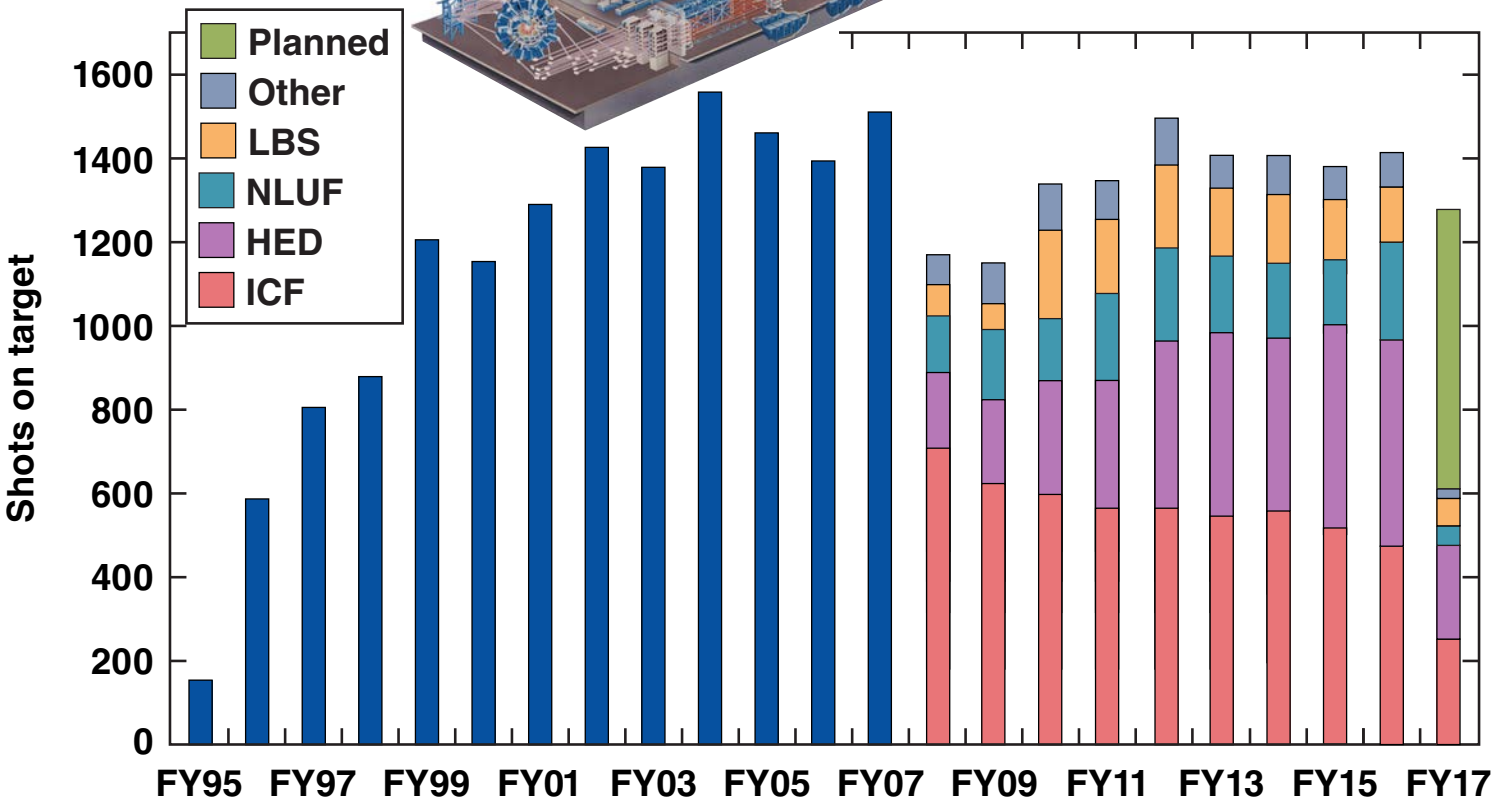
OMEGA EP Laser System

- Operating since 2008
- Adds four National Ignition Facility (NIF)-like beamlines; 6.5-kJ UV (10 ns)
- Two beams can be high-energy petawatt
  - 2.6-kJ IR in 10 ps
  - Can propagate to the OMEGA or OMEGA EP target chamber

G10425a

OMEGA has performed 27,300 shots in the 21 years since the May 1995 commissioning

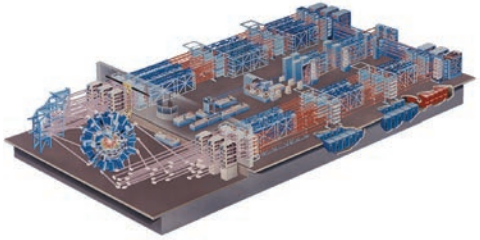




LBS: Laboratory Basic Science
NLUF: National Laser Users' Facility
HED: high-energy density
ICF: inertial confinement fusion

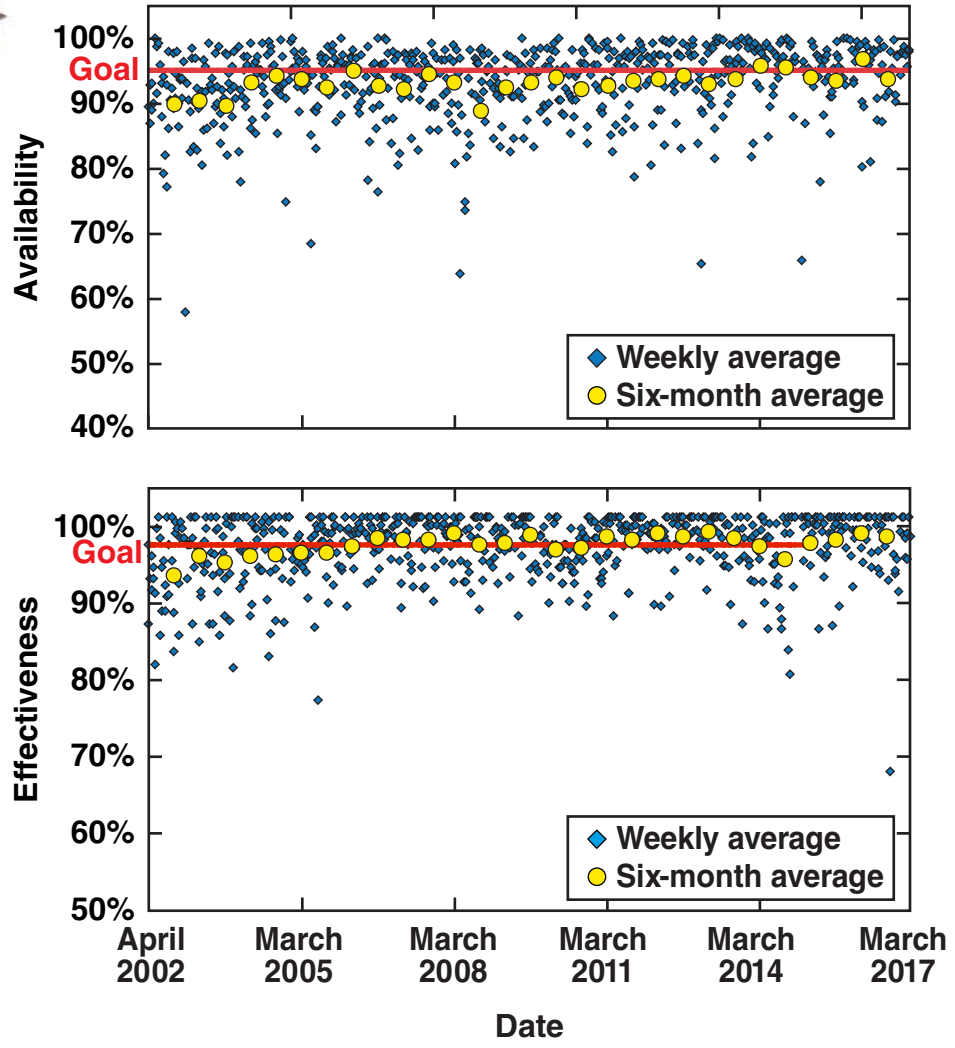
G10046h

OMEGA operational statistics have been recorded since FY00 and remain high



- **Availability:** quantitative schedule performance metric
  - first shot by 0900 hours
  - 60-min shot interval
- **Effectiveness:** initial response of the Principal Investigator (PI) as to whether the shot achieved its goals
  - laser performance
  - target/diagnostic
  - experiment design
- **FY16:**
  - availability = 95.6%
  - effectiveness = 96.6%

OMEGA had 1242 shots since last OLUG.



G10426e

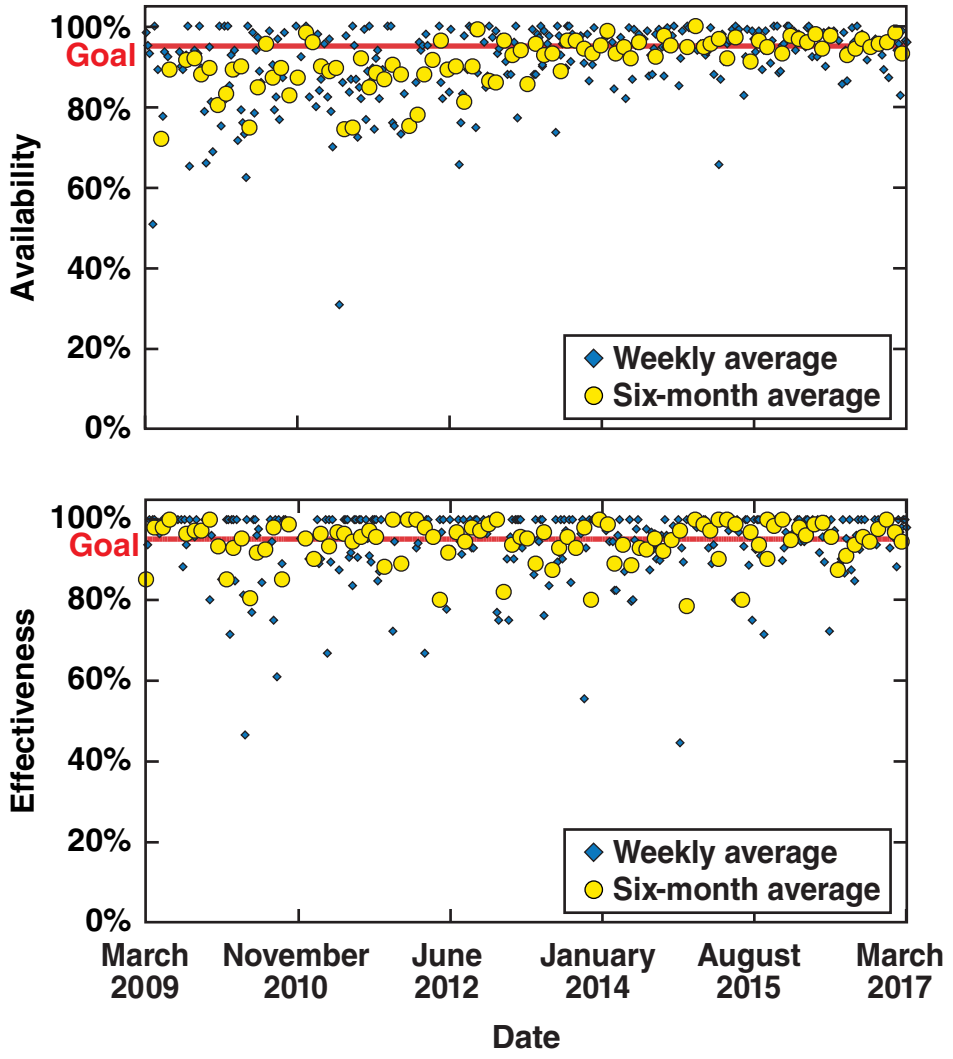
OMEGA EP has performed 5200 shots in the eight years since commissioning in May 2008

G9532k

OMEGA EP operational statistics have been tracked since FY09 and regularly achieve the 95% goal

- Availability: quantitative schedule performance metric
  - first shot goal varies by configuration
  - 105-min shot interval
- Effectiveness: initial response of the PI as to whether the shot achieved experimental goal
- FY16:
  - availability = 96.9%
  - effectiveness = 95.8%

OMEGA EP had 625 shots since last OLUG.



G10427e

LLE is making good progress on many of the April 2016 F&R's

1. Increase magnetic fields to 30 T, 50 T
2. Investigate x-ray streak-camera straight-through noise
3. Improve x-ray streak-camera tube (SSCA)
4. Rochester Optical Streak System (ROSS) for particle x-ray temporal diagnostic (PXTD)
5. Add charge-coupled devices (CCD's) to framing cameras on OMEGA EP
6. Standardize calibration for OMEGA optical Thomson scattering
7. Gate Thomson scattering on OMEGA
8. 2ω capability on one beam of OMEGA EP
9. Add scattered-light diagnostics on OMEGA EP
10. Revise OMEGA EP spherical crystal imager (SCI) to be same as OMEGA instrument
11. Improve information technology (IT) infrastructure in LLE conference room
12. Measure low-energy neutron spectra on OMEGA
13. Enhance the active shock breakout (ASBO)/ streaked optical pyrometer (SOP) diagnostics on OMEGA and OMEGA EP
14. Add a planar cryogenic target capability on OMEGA EP
15. Implement plasma sacrificial mirrors for OMEGA EP
16. Enhance the laser pulse-shaping capabilities on OMEGA
17. Allocate more resources to the CR-39 etch/lab
18. Make gas-jet targets available on OMEGA and OMEGA EP
19. Develop a high-resolution x-ray spectrometer for OMEGA
20. Workshop: Avoid parallel sessions, focus on x-ray imaging techniques for the evening session, retain the national lab session, and add opportunities for career-oriented interaction between young researchers and representatives of the labs
21. Informatics: continue to improve and modernize the PI web-resources

Green = complete
Orange = in process
Red = deferred lack of funding
Black = withdrawn

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F&R 1

LLE contracted with the University of Michigan (Gennady Fiksel, PI) to develop a 10-kJ pulser

UR LLE

- The pulser will be used to evaluate high-field magneto-inertial fusion electrical discharge system (MIFEDS) coil designs
- The goal is to demonstrate coils that can achieve 30 T in 3 cm^3 with sufficient laser beam and diagnostic access
- Preliminary coil test results are anticipated by Fall 2017
- Comsol Multiphysics (COMSOL) is used to model coil and insulator geometry, B-field strength and geometry, coil mechanical, and thermal stresses
- LLE is planning to build a similar pulser, it will be outside the ten-inch manipulator (TIM) and will use the TIM's to deploy the coil

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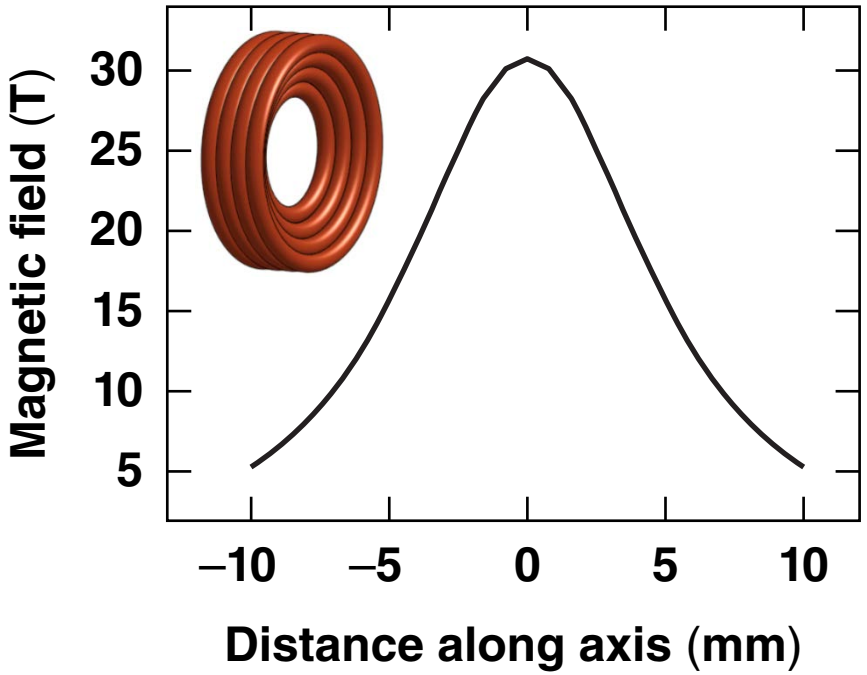
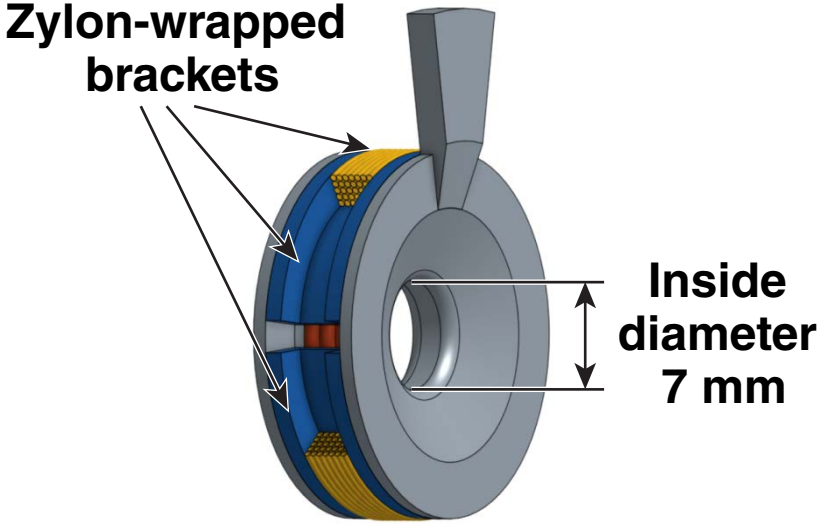
F&R 1

A 30-T field is created by a ten-turn coil wound with Kapton-insulated wire inside a plastic bobbin





- Brackets wrapped with Zylon fiber constrain the electromagnetic forces
- The coil design can accommodate various experimental requirements and laser systems (i.e., OMEGA or OMEGA EP)

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F&R's 2 and 3

Items 2 and 3 are related and are being addressed

UR LLE

2. Investigate the "straight-through" light issue with the SXS-SSCA streaked spectrometer

3. Provide a second x-ray streak camera with capabilities similar to SSCA
   - "straight-through" light is an artifact of the on-axis tube implementation; the new x-ray streak camera will eliminate the leak—completion end of FY18
   - requirements: rotate the photocathode ±90° about the TIM axis, record on CCD's or film, compatible with existing imagers and spectrometers, and provision to run film pack or image plates in front of the photocathode

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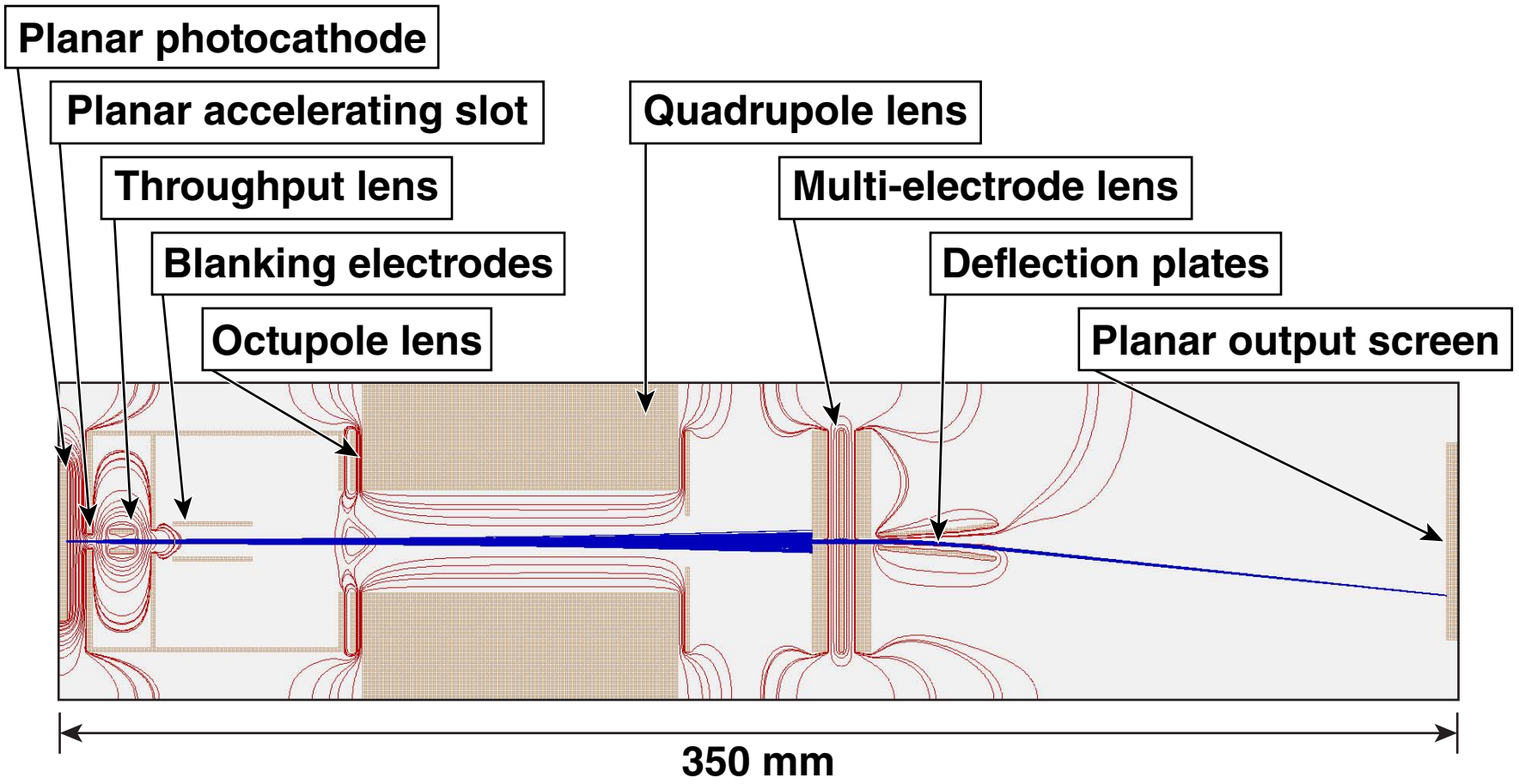
F&R's 2 and 3

An LLE custom-designed picosecond x-ray streak tube modeled using Simion 8.1 is in design



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F&R's 4 and 5

Items 4 and 5 are capital equipment resource limited

4. Implement a ROSS streak camera for the PXTD
   - request withdrawn (MIT)
   - the new PXTD design will accommodate a ROSS when funding for a dedicated camera is secured (no spare ROSS cameras are available)
   - funding will be requested in the FY18 Cooperative Agreement

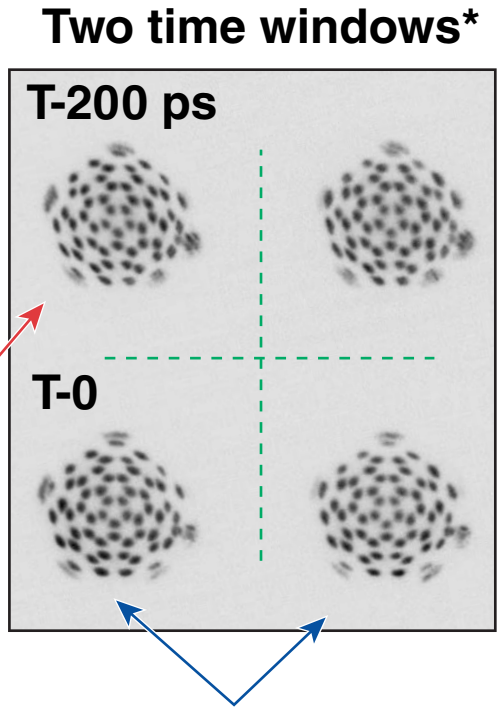
5. Add CCD's to the x-ray framing cameras on OMEGA EP
   - a single CCD camera was made available for use in OMEGA EP earlier this month
   - CCD's will not be used with short-pulse beams
   - C. Sorce is the responsible individual

G11266

F&R's 6 and 7

Optical diagnostics on OMEGA continue to evolve

6. Implement a standard calibration procedure for the OMEGA optical Thomson-scattering diagnostic
   - C. Sorce is working on a standardized procedure to record and distribute the necessary calibration data
   - will consider adding the absolute scattered power to the list of calibration data
7. Implement faster framing cameras for Thomson-scattering measurements on OMEGA
   - a gated optical imager (GOI) was implemented (<150 ps) on the 3ω beamlets diagnostic
   - the system splits the image into *s* and *p* polarizations
   - D. Turnbull is the PI with D. Edgell and J. Katz**
   - the telescope and final-focusing optics were replaced to optimize magnification
   - further resources are needed for Thomson scattering



* D. H. Edgell (16 March 2017).
** J. Katz *et al.*, this conference.

G11267

F&R's 8 and 9

The status 8 and 9 are as follows

UR LLE

8. Enable 2ω operation on one of the long-pulse beams on OMEGA EP
   - when FY17 funding is known it will be considered
   - D. Canning is the responsible individual and will lead a feasibility study prior to the April 2017 OLUG meeting
   - funding will be requested in the FY18 Cooperative Agreement

9. Implement additional scattered-light diagnostics on OMEGA EP
   - implementation of the OMEGA scattered-light calorimeters is straightforward (but not without cost) and will be considered in FY17 (action for C. Sorce)
   - implementation of a near backscatter imager on Beam 4 will not be considered in FY17
   - the capability of the OMEGA EP sub-aperature backscatter station (SABS) is being improved, fibers and streaked spectroscopy are being developed (D. Turnbill is the PI)

G11268

F&R's 10 and 11

Items 10 and 11 status are as follows

10. Reconfigure the SCI diagnostic on OMEGA EP to have the same operational capabilities as the OMEGA instrument
    - the SCI upgrade for OMEGA EP is an approved FY17 project; the PI is C. Stoeckl
    - note: x-ray framing cameras (XRFC) capability is not being ported to OMEGA EP this year
11. Improve the IT capabilities in the Seminar Conference Room

G11269

F&R 12

Item 12 has motivated the LLE project for a second line-of-sight (LOS) and also stimulates a longer-term project

UR LLE

12. Improve the capability to measure low-energy neutron spectra in a DT background on OMEGA
    - a second diagnostic line-of-sight (well shielded for DD/DT ion temperatures and low-energy measurements) is an approved FY17 project (the PI is C. Forrest); the current 15.8-m neutron time-of-flight (nTOF) LOS will be used
    - an evacuated LOS is not being considered (perhaps include in the FY18 Cooperative Agreement renewal); a third LOS has been identified

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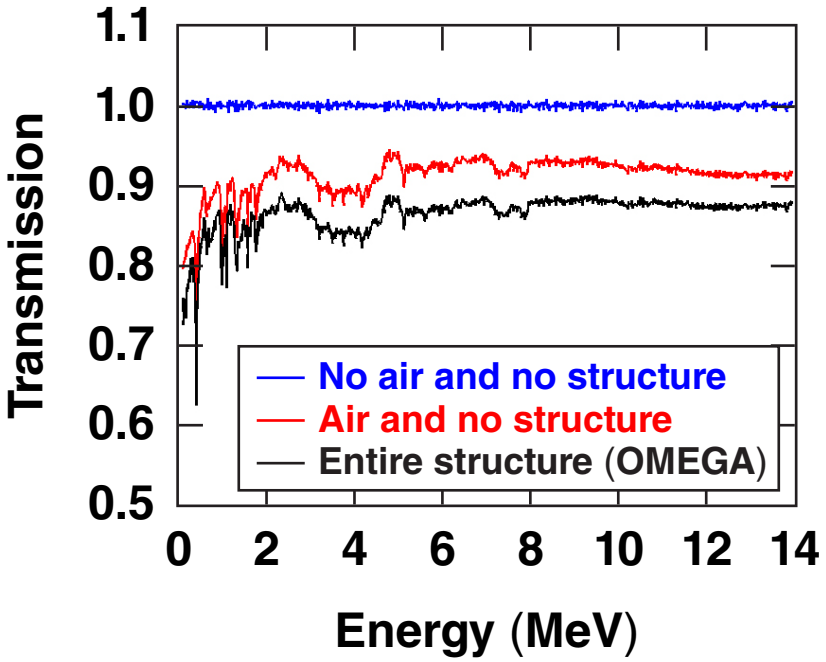
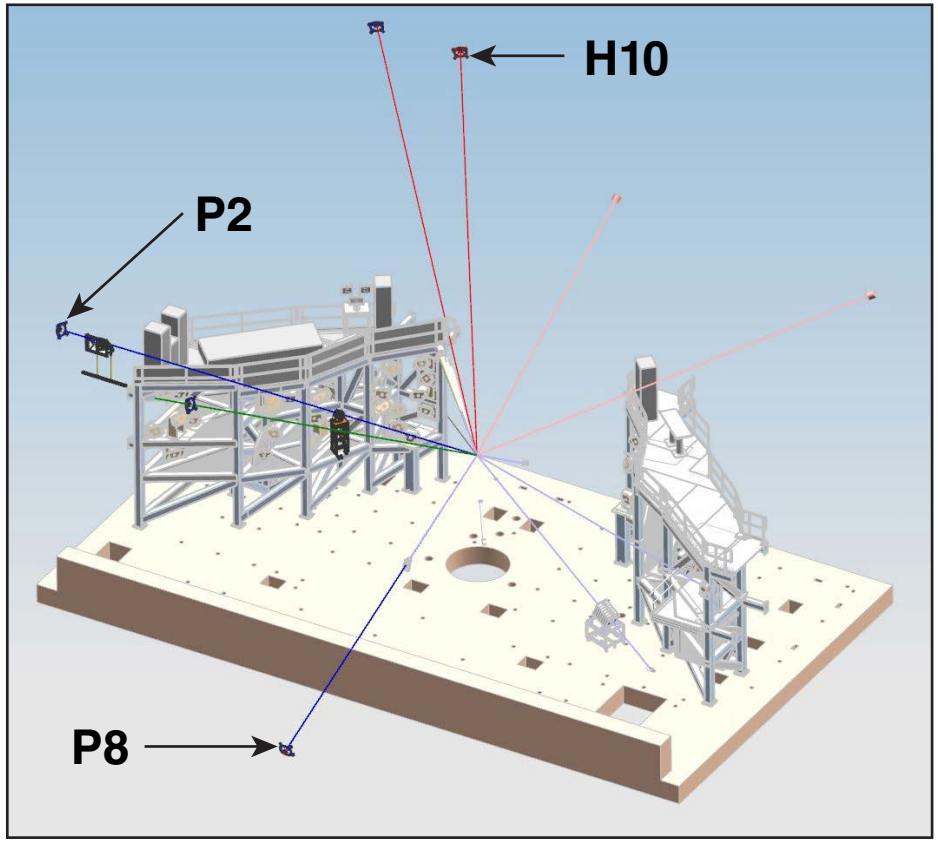
F&R 12

Three new lines of sight are under consideration for low-energy neutron spectroscopy (LENS)



C. Forrest model of 13.4-m neutron transmission



This is a funded project in FY17 (available in FY18).

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F&R's 12 and 13

ASBO/SOP improvements are in process

13. Enhance the ASBO/SOP diagnostics on OMEGA and OMEGA EP
    - an achromatic low-noise telescope on OMEGA EP will enable absolute calibration
    - a retrofit with achromatic optics passed design reviews in March, in acquisition now
    - new comb generators and sweep cards are being developed (R. Boni and W. Bittle are the PI's)
    - T. Boehly and A. Sorce* will coordinate the requested operational improvements

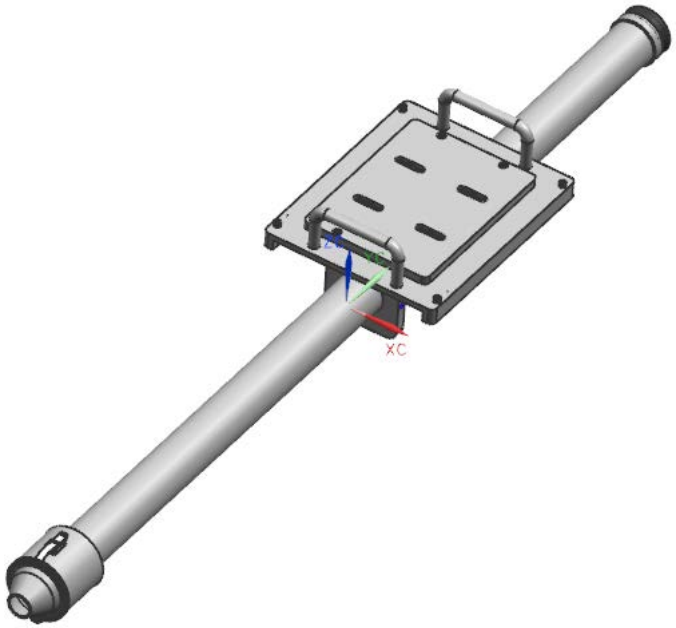
14. Add a planar cryogenic target capability on OMEGA EP
    - this request will be included as a line item in the FY18 Cooperative Agreement renewal
    - note that one of the options being considered for the new 100-Gbar cryogenic fill-tube target capability (2019/20) is a port-based system—such a system could be adapted for planar cryogenic OMEGA EP target payloads

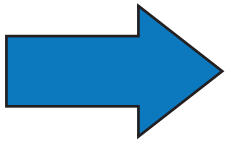
*A. T. Sorce *et al.*, this conference.

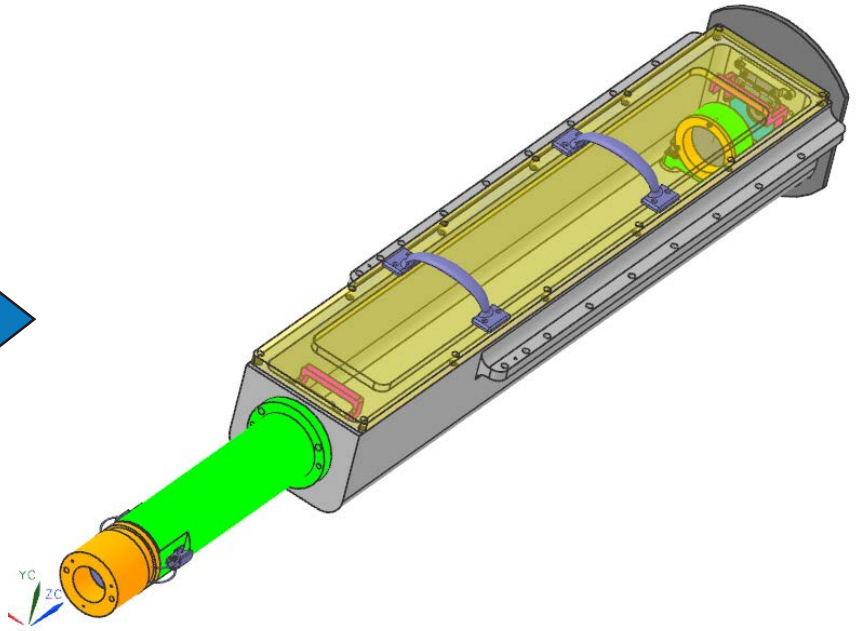
G11272

F&R 13

The SOP on OMEGA EP will be achromatized (590 to 850 nm) for improved spatial resolution







Existing VISAR* telescope

New VISAR telescope

- **Final design in progess, anticipated completion in August 2017**

The changes to the optical transport system will enable improved calibration.

*VISAR: velocity interferometer system for any reflector

G11273

F&R 15

Item 15 is as follows

15. Implementation of plasma sacrificial mirrors for OMEGA EP
    - a demonstration project has been approved (with shots) for Q4; J. L. Shaw is the PI
    - some caution here on the practical use; off-target chamber center (TCC) beam, diagnostic pointing limitations, and focal-spot characterization

G11274

F&R 15

Plasma mirrors are being developed and tested on OMEGA EP

UR LLE

- The goal is to develop plasma mirrors (PM's) for use with OMEGA EP at full energy and best compression
- The design work will optimize efficiency and contrast enhancement while minimizing phase distortion
- During the demonstration and characterization, the following performance metrics will be measured:
  - evolution of the laser spot
  - modification of the temporal duration
  - change in contrast
  - efficiency

Demonstration will begin on OMEGA EP Q4 FY17.

G11275

F&R 16

Item 16 is as follows

16. Enhance the laser pulse shaping capabilities on OMEGA
    - longer pulses on OMEGA require three significant changes:
        - an advanced regenerative amplifier (regen) tracking
        - a new large-aperture ring amplifier (LARA)
        - a new design for 213 vacuum spatial filter pinholes
    - LLE is currently testing advanced regen systems that would support longer pulse durations
    - the LARA upgrade is a straightforward, but significant project
    - the current pinholes are susceptible to closure after ~5 ns and would need to be redesigned [similar to the NIF pinhole design]; this is a very significant effort
    - this capability could be added as part of a longer-term upgraded for wavelength detuning [cross-beam energy transfer (CBET) mitigation]; J. Puth is the point of contact for this activity

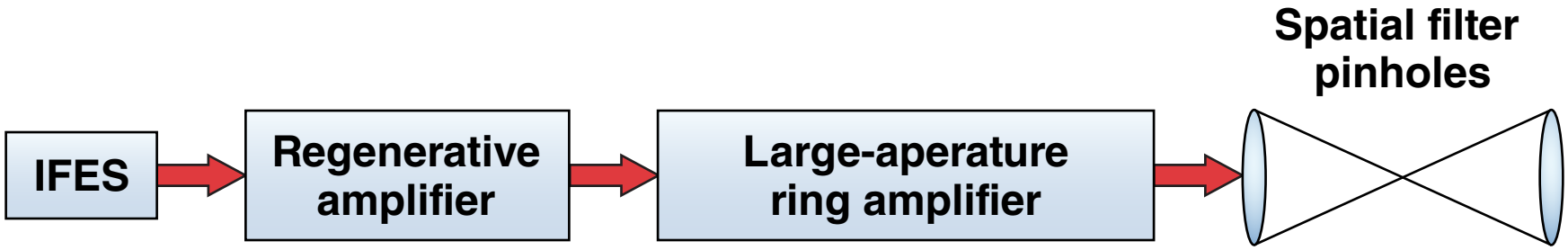
G11313

F&R 16

Longer pulses on OMEGA require changes to four subsystems

UR LLE

- The OMEGA laser is currently limited to 3.9-ns pulse lengths
- Many campaigns have used path-length adjustment system (PLAS) delays to "stitch" together multiple beamline pulses into a longer effective drive pulse
  - susceptibility to timing errors can cause dips or spikes in power
  - energy variations can also change the effective overall shape
- OMEGA has four primary systems that limit pulse-shape duration, from the integrated (fiber) front-end system (IFES) to the final stages of pinholes



G11276

F&R 16

Subsystem upgrades are required to propagate longer pulses

- The IFES system has been upgraded and can support 10-ns pulses
- The regenerative amplifier can potentially support up to 5 ns under investigation in test lab
- Replacement regen designs have succeeded up to 10-ns pulse length
- The LARA may also support slightly longer pulse shapes, but will require significant redesign for substantial increases
- Replacing simple pinholes with tapered pinholes that must be aligned would be required

Direct interest to Rick Kraus (OLUG representative) who will work with Jason Puth on longer pulse shapes on OMEGA-60.

G11277

F&R's 17, 18, and 19

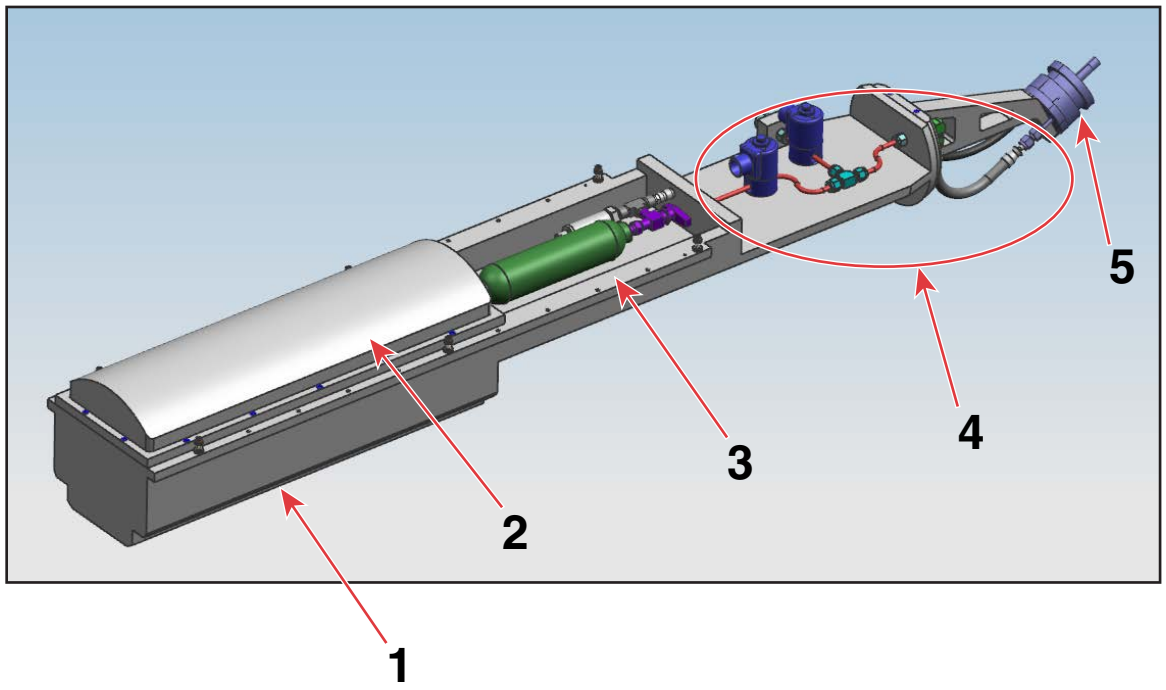
Items 17 to 19 are being addressed as follows

17. Allocate more resources to the CR-39 etch/lab
    - following an internal assessment, LLE has sufficient capacity to etch and scan
    - contact C. Sorce to resolve issues with timely completion (e.g., suggest leaving material at LLE to work into the schedule)
    - note, LLE does not interpret the CR-39 scan data
18. Make gas-jet targets available on OMEGA and OMEGA EP
    - a TIM-based gas-jet target is an approved FY17 project; D. Haberberger is the PI
    - first use is planned in Q4 FY17
19. Consider the development of a high-resolution x-ray spectrometer for OMEGA
    - the time-resolved HiRes Spectrometer on OMEGA EP was qualified for use in Q2 FY17 (P. Nilson is the PI)
    - LLE will assess the design modifications required for implementation of a similar instrument on OMEGA (e.g., less shield if not used with short pulse would reduced the chamber footprint significantly)
    - the instrument is included as a line item in the FY18 Cooperative Agreement renewal
    - will also pursue funding through the National Diagnostics Program

G11278

F&R 18

The OMEGA gas-jet system is in design and is expected to be commissioned in Q4 FY17



1. TIM "chassis"
2. Electronics "bubble" with lid
3. Gas source and pressure sensor
4. Gas delivery system (valves, tubing, flexible gas line)
5. Alameda Applied Sciences Corporation (AASC) gas jet (as modified by LLE) with fixed mounting arm

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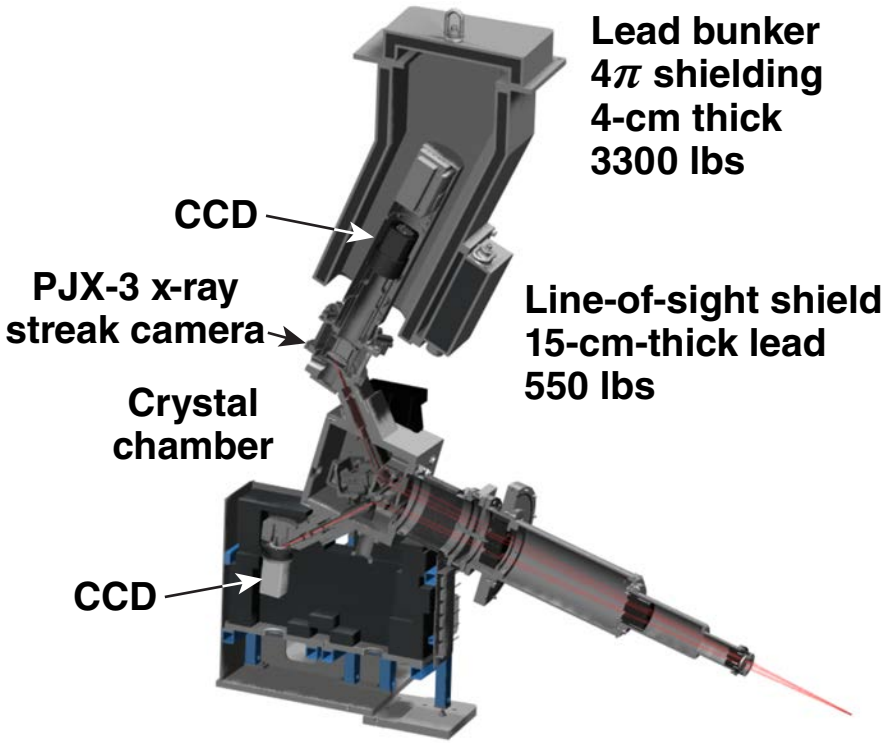
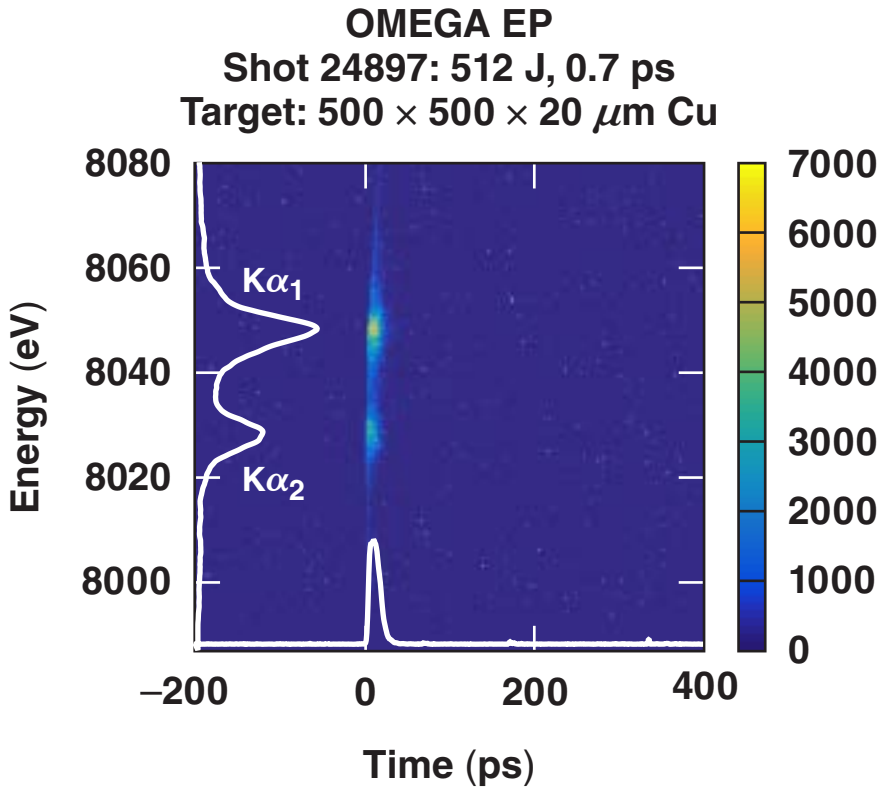
F&R 19

A high-resolution spectrometer (HRS) on OMEGA EP is a new capability and is available to users





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F&R's 20 and 21

The final two OLUG items are items LLE expects to continue into future OLUG meetings

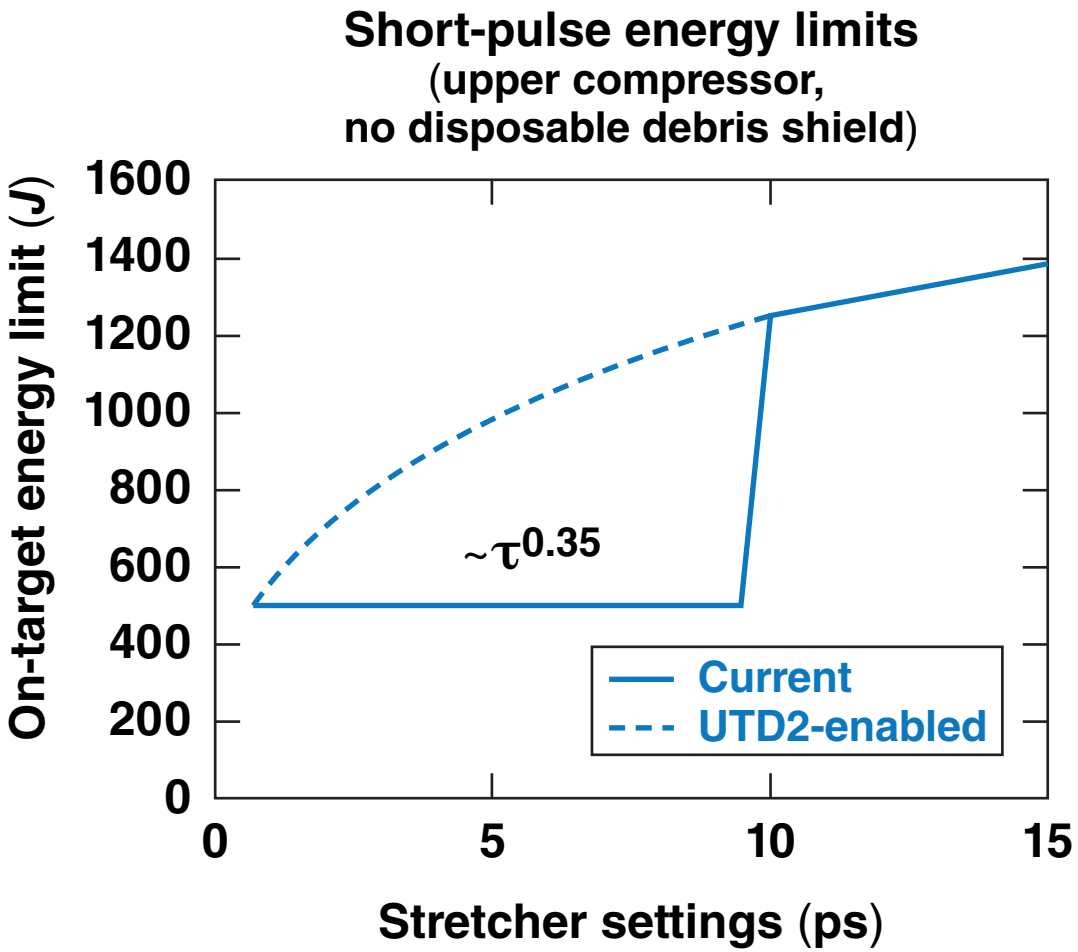
UR LLE

20. Workshop: avoid parallel sessions, focus on x-ray imaging techniques for the evening session, retain the national lab session, and add opportunities for career-oriented interaction between young researchers and representatives of the labs.
    - LLE will support the x-ray imaging evening session and participate in the National Laboratory session
    - LLE will support OLUG executive committee recommendations for additional career-oriented interactions
    - the OLUG executive committee has the action on the meeting organization!
21. Informatics: continue to improve and modernize the PI web resources
    - additional resources have been added to the informatics group
    - exporting the shot request form (SRF) configuration as a "parseable" file will be complete in FY17
    - new access capabilities are being developed to provide characterization and system information (e.g., calibration) for diagnostics
    - suggest a working group be formed to address data access permissions

G11281

General Interest

Ultrafast temporal diagnostic revision 2 (UTD2) will enable increased target energy for pulses between best-compression and 10 ps



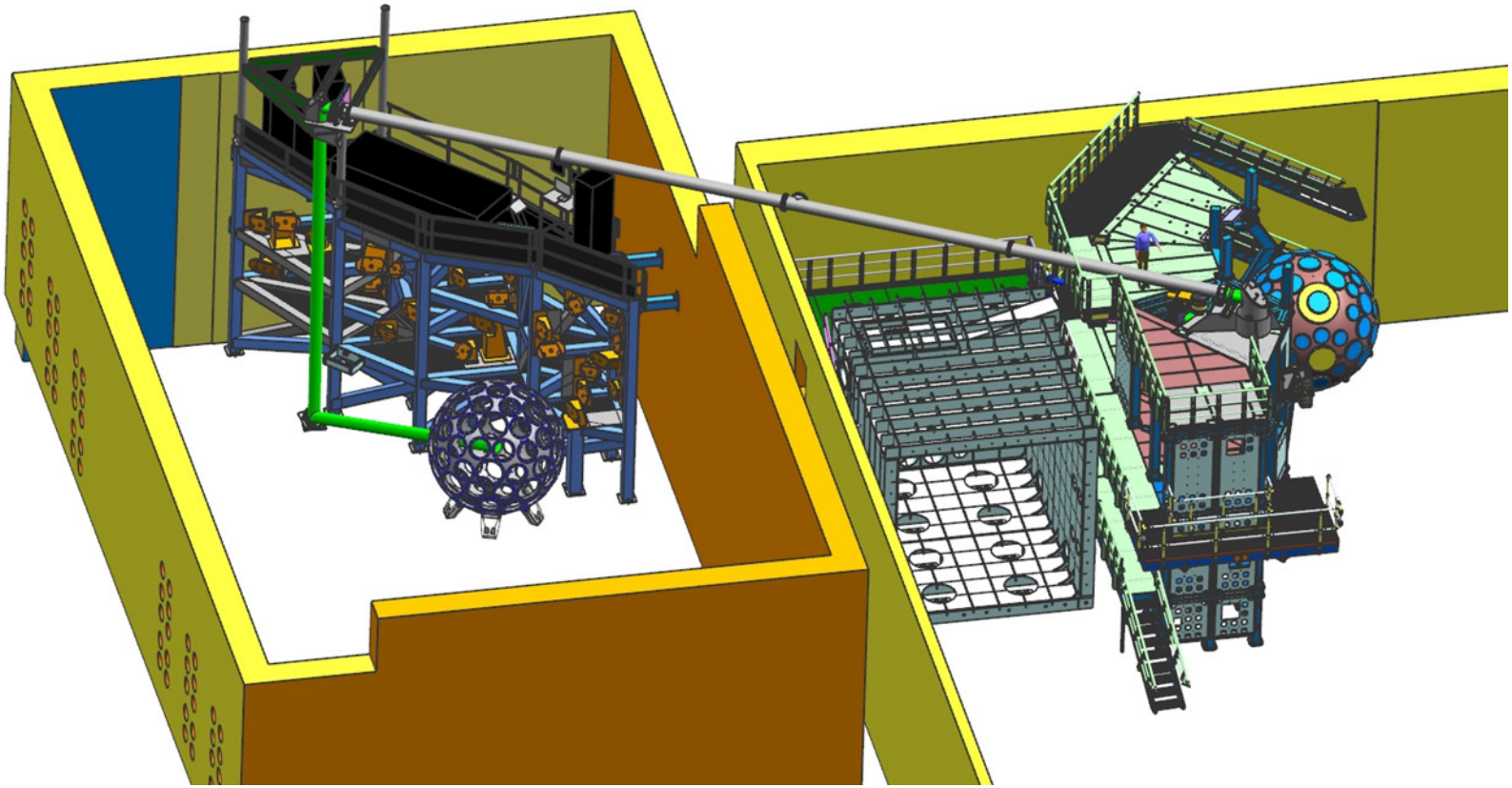
- Current inability to measure pulses <10 ps causes us to impose the best-compression energy limit
- The ability to confirm stretcher setting to the <1-ps level will enable us to deliver higher energies between best-compression and 10 ps without risking damage to optics

G11282

*C. Dorrer *et al.*, this conference.

General Interest

A tunable (~ ±1-nm) UV beam is in development for LPI from OMEGA EP to OMEGA port P9



Planned completion in FY18.

G11283

General Interest

Power balance for 100-Gbar on OMEGA has stimulated improvements to the laser diagnostics

UR LLE

- Realignment of all 60 of the sampling arms for OMEGA's output temporal diagnostic ("P510's") was completed; this resulted in improved utilization of the dynamic range of these instruments
- Stage-F amplifier small-signal gain measurement capability has been developed so that now all OMEGA amplifiers are balanced
- Flash-lamp current waveform digitizers are being implemented on the stage-F amplifiers to help keep the stage-F amplifiers balanced
- The end-of-system UV spectrometer was realigned and recalibrated for measurement of the spectral transmission of individual beamlines
- A dedicated on-shot smoothing by spectral dispersion (SSD) synchronization monitor has been deployed on OMEGA
- Frequency conversion on OMEGA was optimized and variation in frequency-conversion performance from beam to beam was reduced
  - the second tripler crystals were removed from all 60 beams

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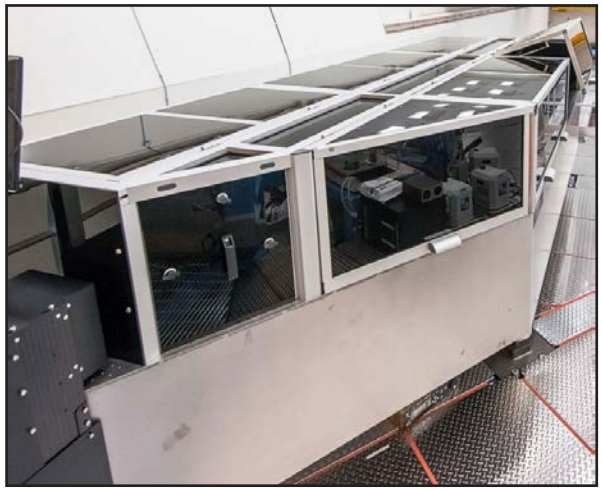
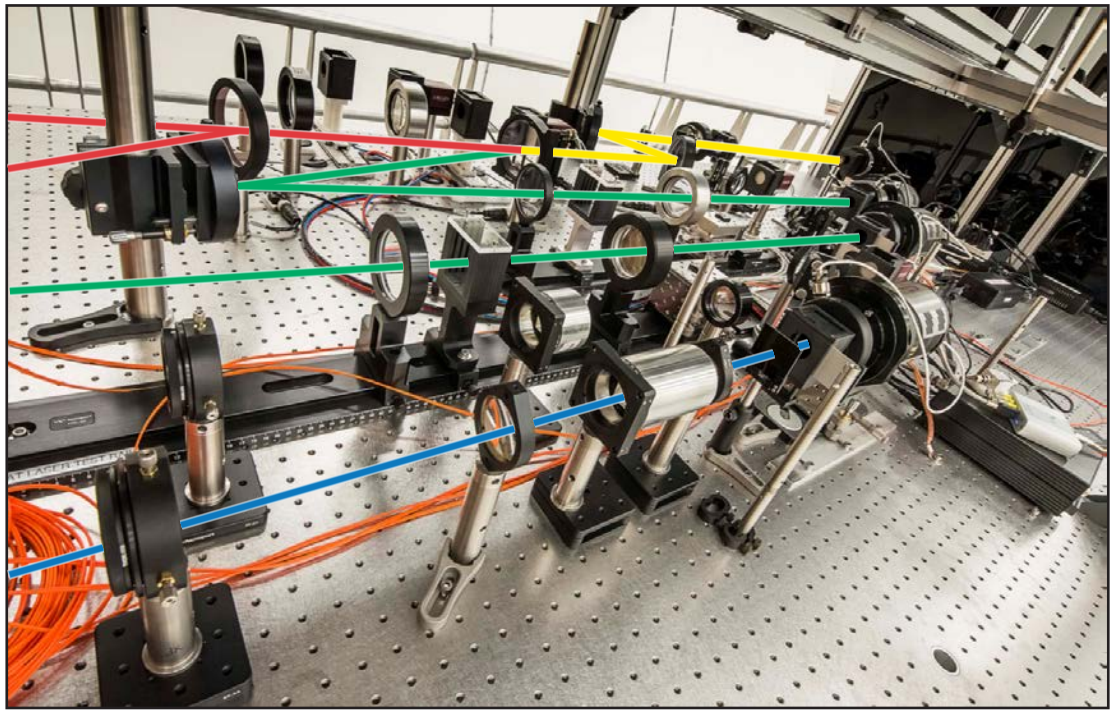
General Interest

A fourth arm was added to the 4ω diagnostic suite on OMEGA EP: interferometry

UR LLE





Shared 4ω beamline

Interferometry

Angular filter refractory (×2)

Polarimetry

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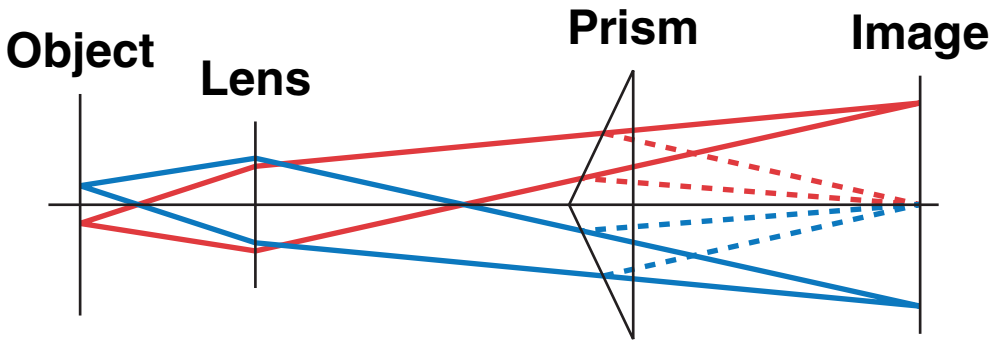
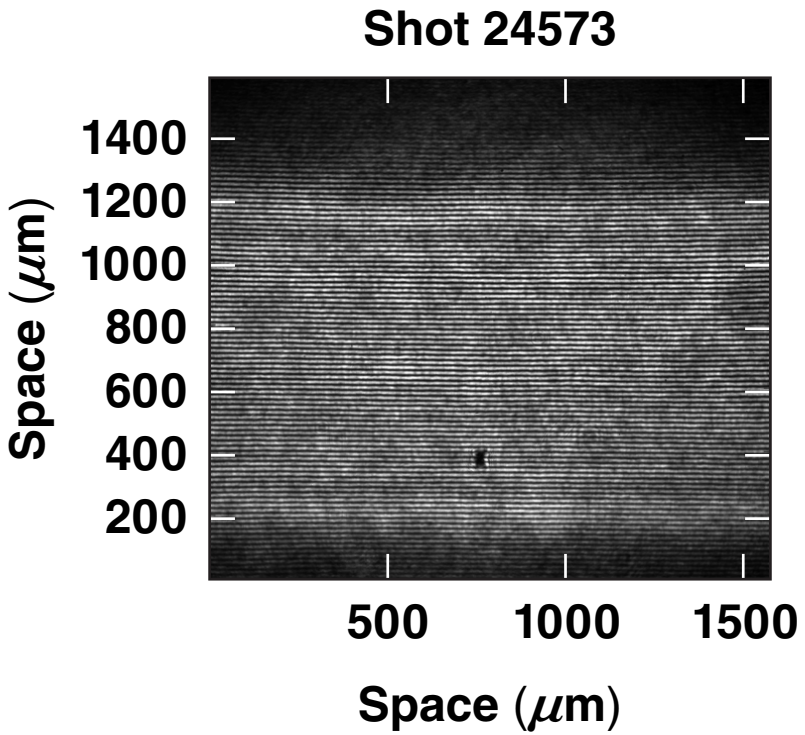
General Interest

A Nomarski-style interferometer was deployed using a Fresnel bi-prism to create the phase and reference beams



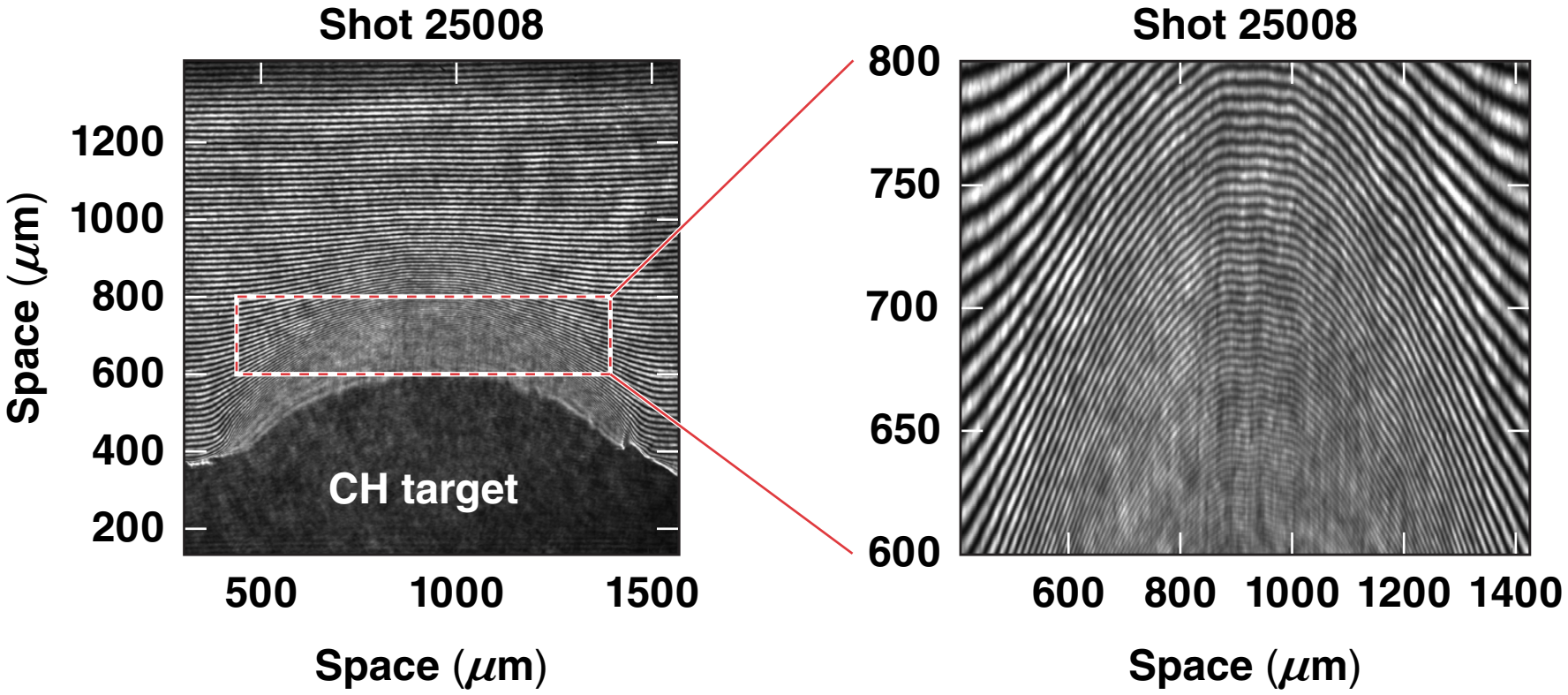


- Magnification = 17.53
- Fringe separation = 15.4 μm
- Optical resolution = 3.9 μm

G11286

General Interest

Images of coronal plasma expansion from a flat CH target were acquired to activate the diagnostic



Development of an analysis package is underway.

G11287

Summary/Conclusions

Omega is an effective and efficient facility and evolves to meet the needs of users

- OMEGA and OMEGA EP are National Nuclear Security Administration (NNSA) workhorse facilities
- Operational statistics show continued high performance
- The facility responds to the Omega Laser User Group (OLUG) recommendations
- The internal focus on 100-Gbar pressures and laser–plasma instabilities (LPI's) are motivating a number of initiatives that have broad benefits
- Omega supports LLE and user-developed diagnostics

OLUG Findings and Recommendations (F&R's) are important input to LLE priorities.

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