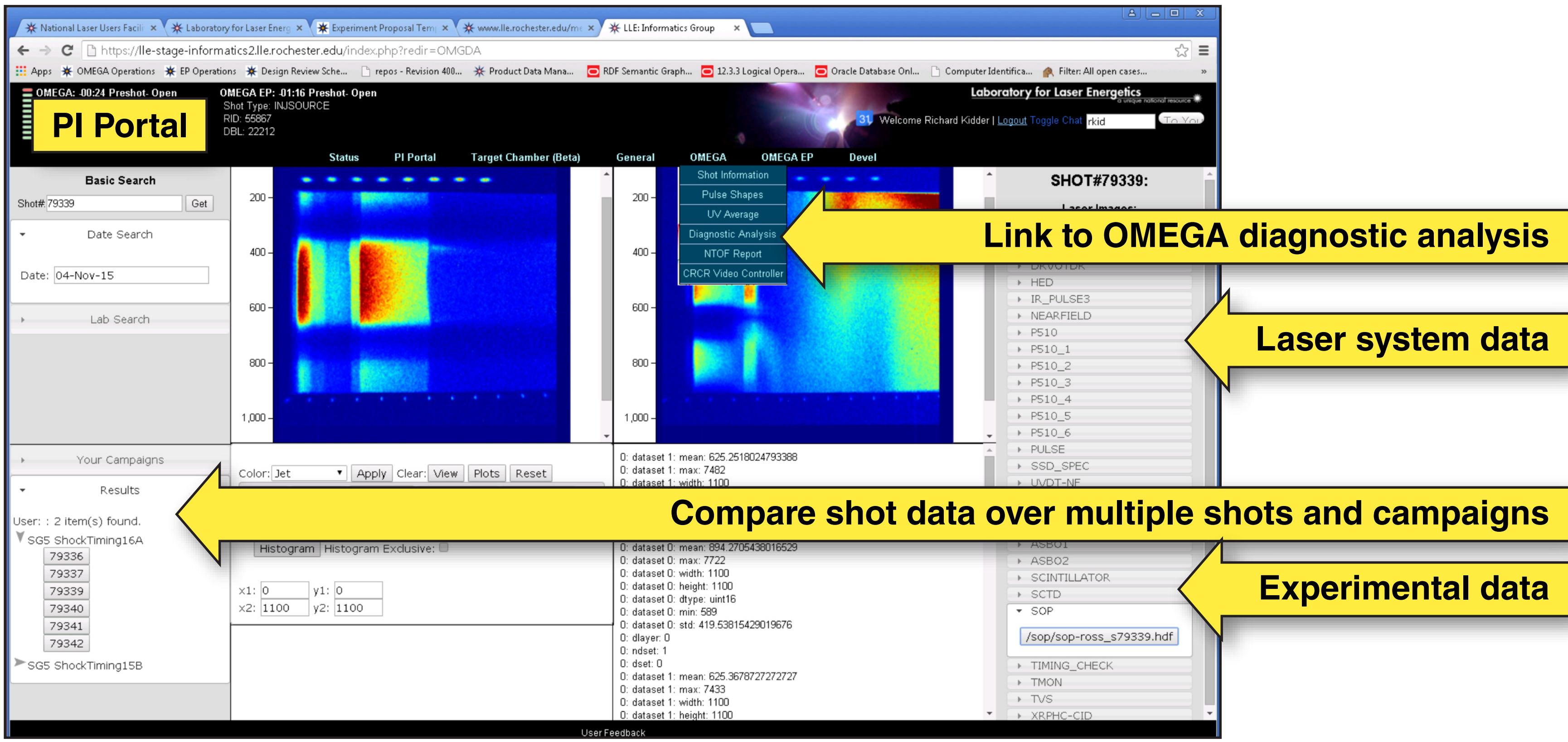
# Omega Facility 2016 OLUG Update:
# Progress on Recommendations and Items of General Interest




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

**Omega Laser Facility**
**Users Group Workshop**
**Rochester, NY**
**27–29 April 2016**

Summary

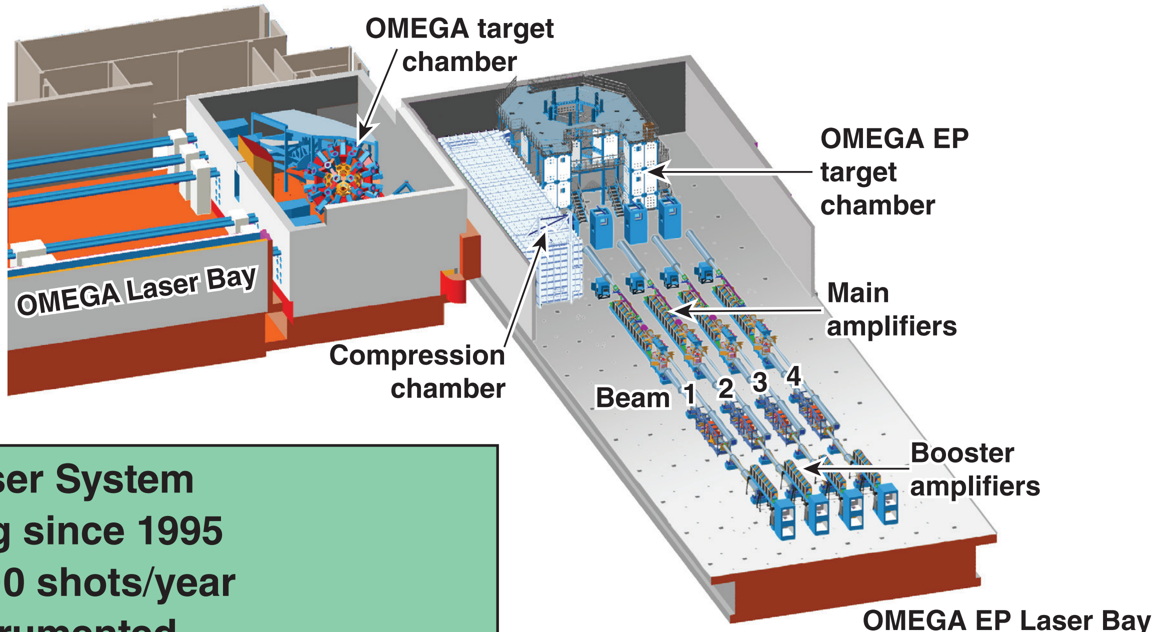
# Omega is an effective and efficient facility and continues to evolve to meet user requirements

- OMEGA, at 21 years old, is a National Nuclear Security Administration (NNSA) workhorse
- Operational statistics show continued high performance
- Progress has been made on a number of Omega Laser User Group (OLUG) recommendations
- A focus on achieving 100-GBar pressures in symmetric direct-drive implosions is driving a number of initiatives that benefit all users
- OMEGA EP operational envelope continues to expand
- Omega supports the Laboratory for Laser Energetics (LLE) and user-developed diagnostics

**LLE provides 80% of shots for the National Inertial Confinement Fusion (ICF) and Stockpile Stewardship Programs.**

G10773

# 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**

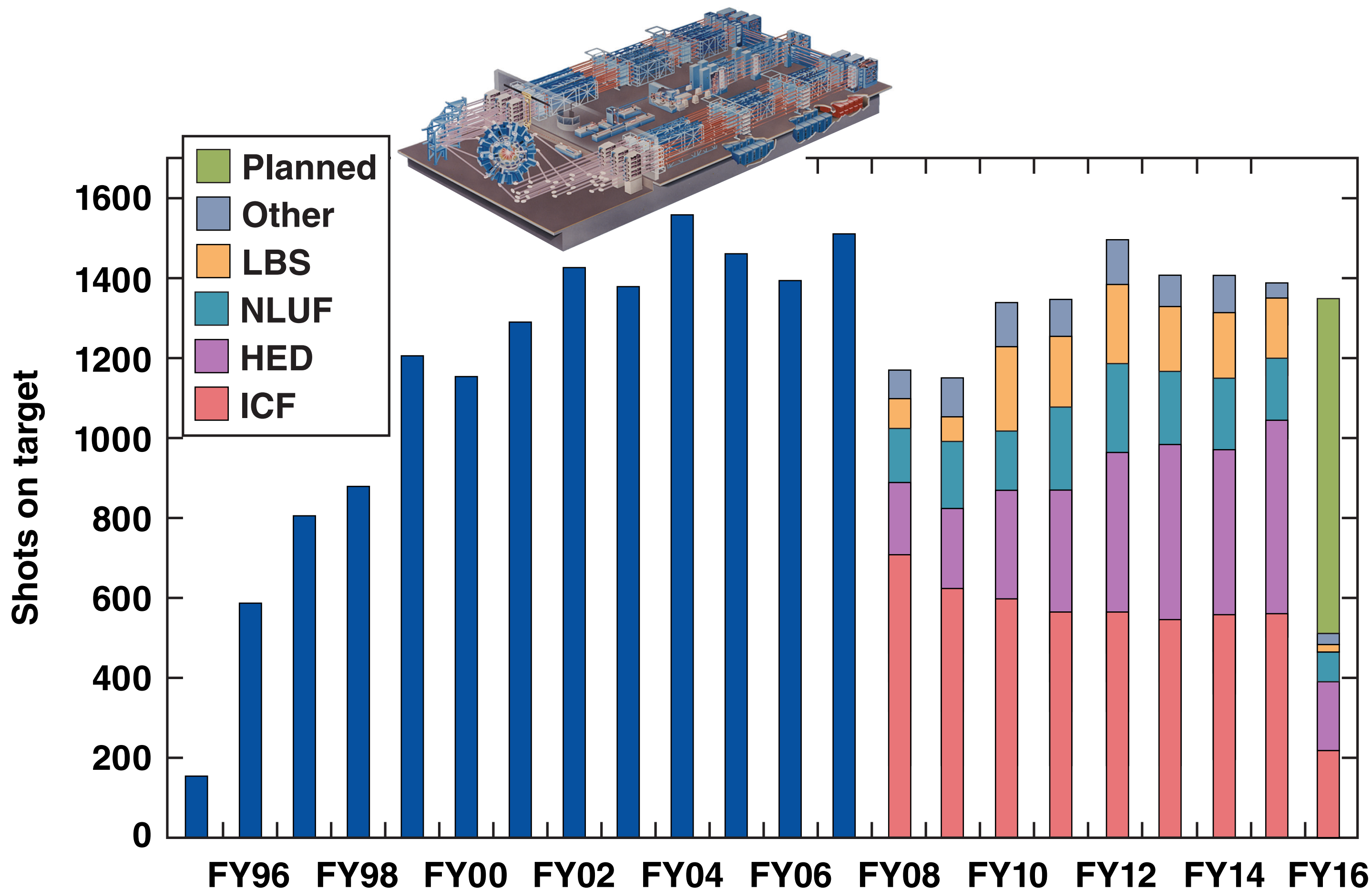
- Operating since 2008
- Adds four NIF*-like beamlines; 6.5-kJ UV (10 ns)
- Two beams can be high-energy petawatt
  - 2.6-kJ IR in 10 ps
  - Can propagate to the OMEGA or OMEGA EP target chamber

G10425a

*NIF: National Ignition Facility

# OMEGA has performed 26,100 shots in the 21 years since the May 1995 commissioning

UR LLE

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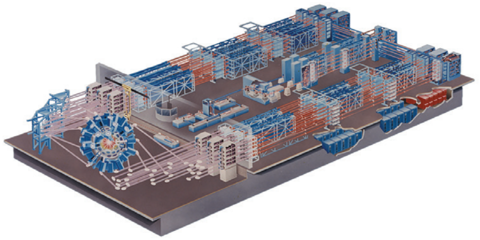
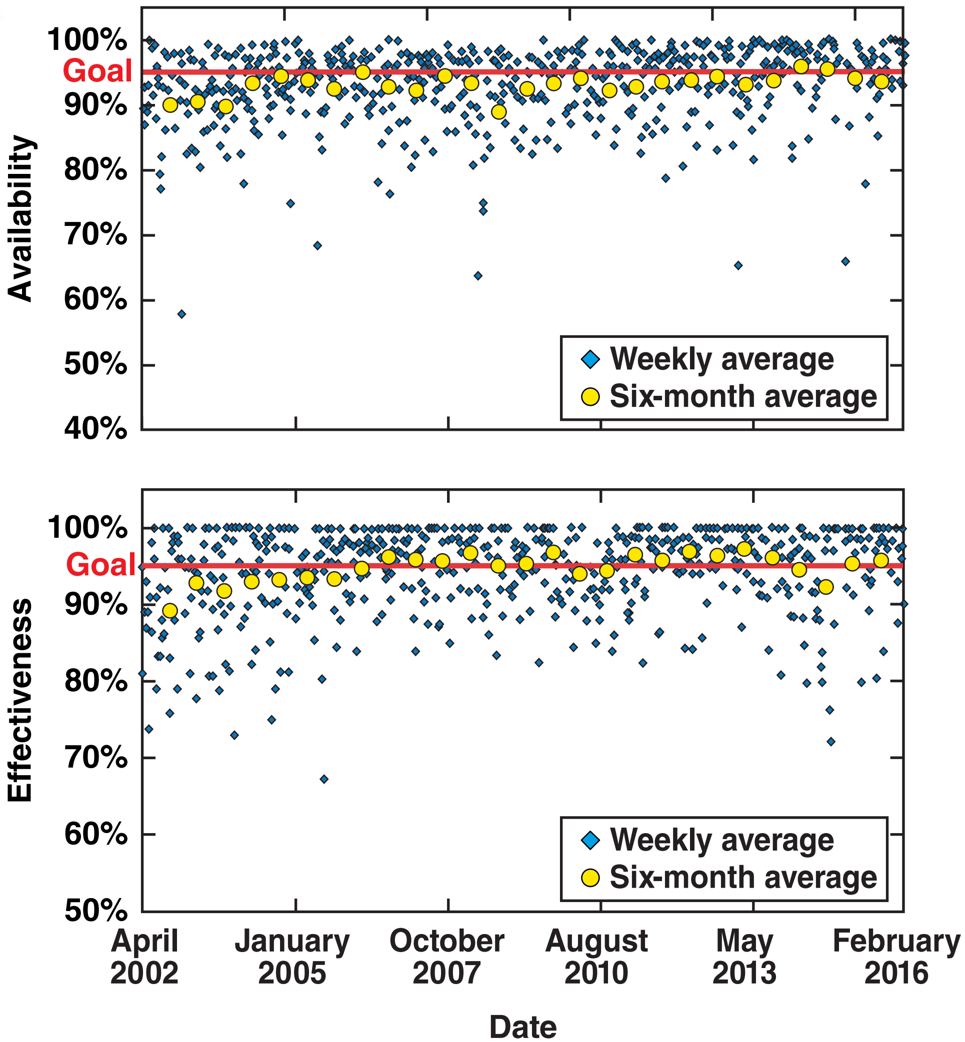
LBS: Laboratory Basic Science; NLUF: National Laser Users' Facility; HED: high-energy density

# 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 produced good data
  - laser performance
  - target/diagnostic
  - experiment design
- **FY15:**
  - availability = 95.7%
  - effectiveness = 93.9%

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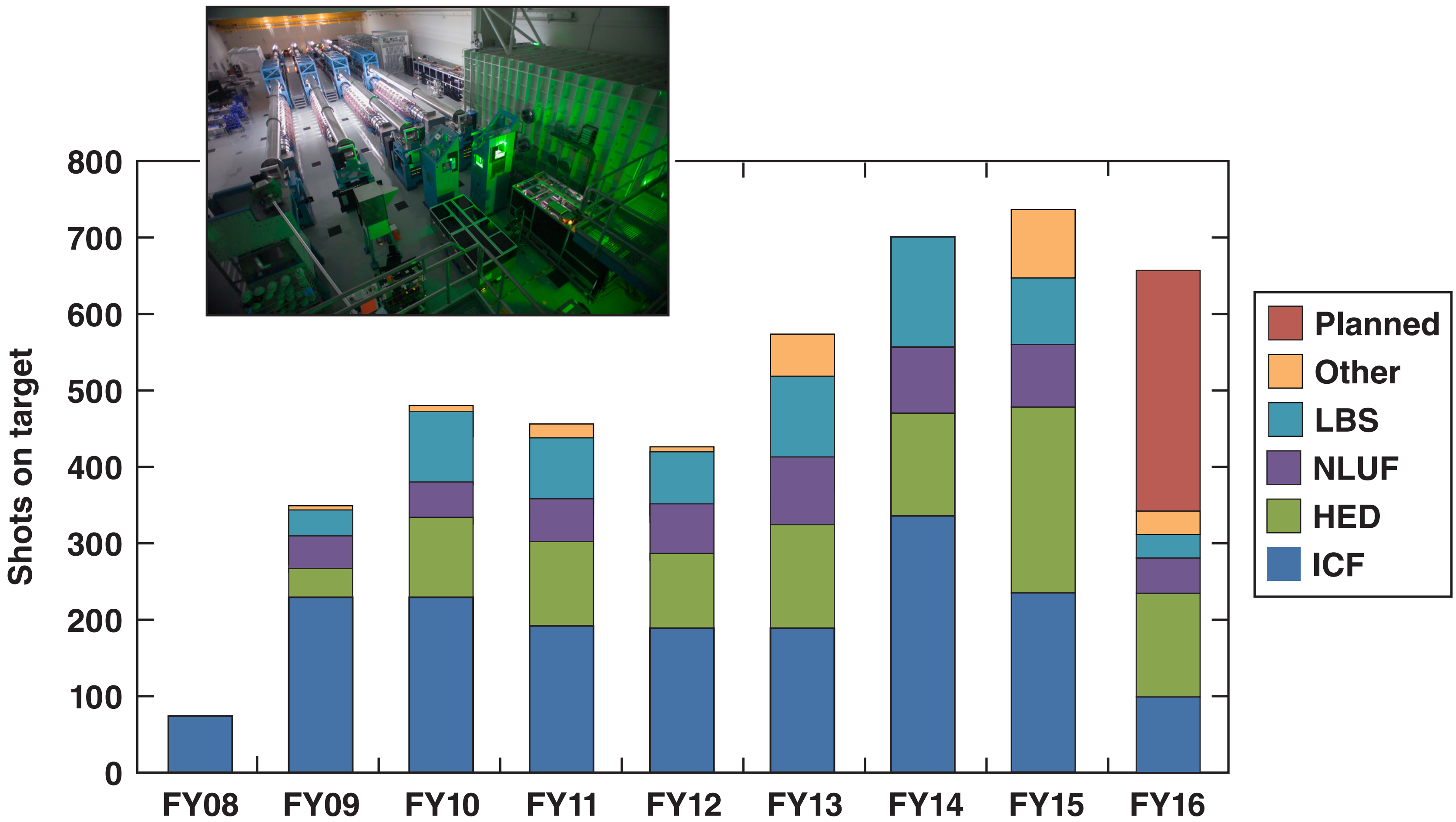
# OMEGA EP has performed 4400 shots in the eight years since commissioning in May 2008

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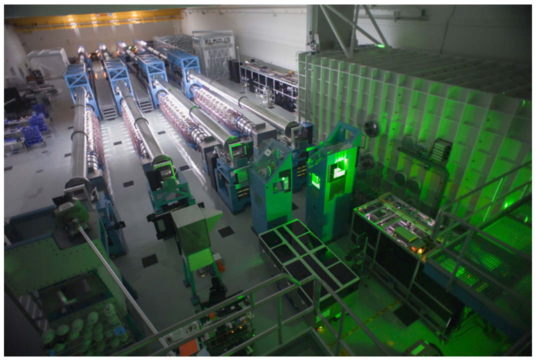
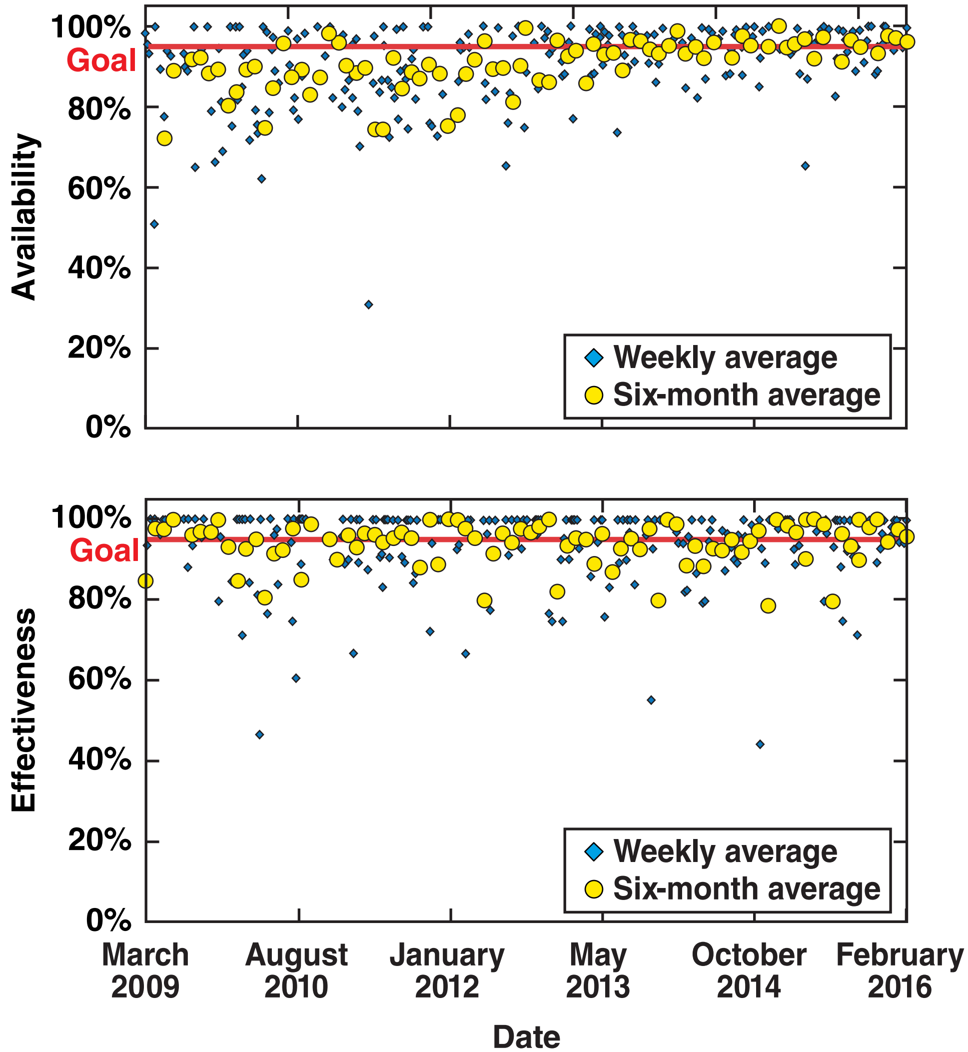
# OMEGA EP operational statistics have been tracked since FY09 and show continued improvement

UR LLE



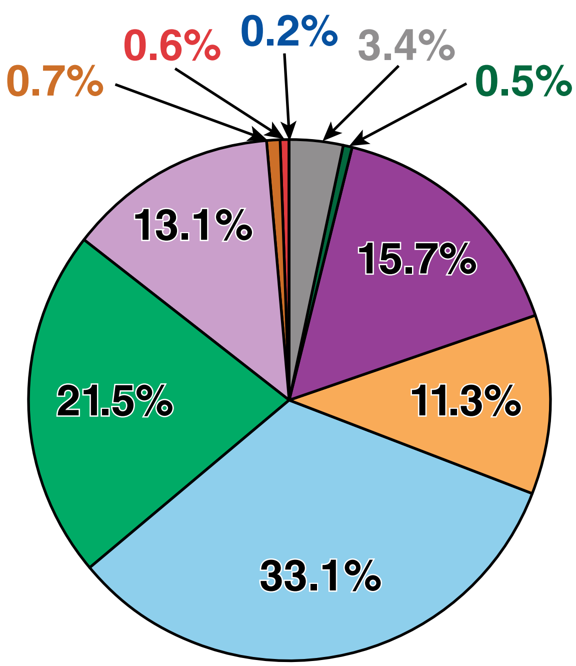



- **Availability:** quantitative schedule performance metric
  - first shot goal varies by configuration
  - 105-min shot interval
- **Effectiveness:** initial response of the PI as to whether the shot produced good data
- **FY15:**
  - availability = 95.4%
  - effectiveness = 93.4%

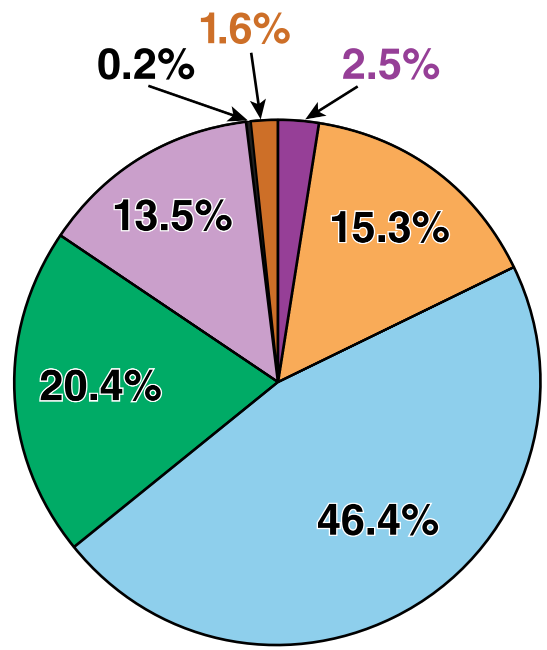
G10427c

# Five-year history shows that the OMEGA and OMEGA EP Laser Facilities shoot for outside users >50% of the time

### OMEGA-60 target shots by lab (FY12 to FY16 year to date)




### OMEGA EP target shots by lab (FY12 to FY16 year to date)




- Laboratory for Laser Energetics (LLE)
- Lawrence Livermore National Laboratory (LLNL)
- Los Alamos National Laboratory (LANL)
- The National Laser Users' Facility (NLUF)
- Commissariat à l'énergie atomique (CEA)
- Laboratory Basic Science (LBS)
- Center for Radiative Shock Hydrodynamics (CRASH)
- United Kingdom Atomic Weapons Establishment (AWE)
- Defense Threat Reduction Agency (DTRA)
- Sandia National Laboratories (SNL)
- Naval Research Laboratory (NRL)

G10774

# Thirteen Findings and Recommendations from the April 2015 OLUG Workshop

1. Student and postdoc panel Findings and Recommendations
2. Smaller-focal-diameter phase plate (400 to 500 $\mu$m) on OMEGA EP
3. Capability to measure low-energy, low-yield charged-particle spectra with high resolution
4. Improved capability to measure low-energy neutron spectra on OMEGA
5. Status of the classification update (spectroscopy of high-Z plasmas)
6. Beam blocks on OMEGA
7. Optical diagnostics on OMEGA EP to characterize laser–plasma instabilities
8. Opposing beam configuration on OMEGA EP
9. TIM-15 qualification on OMEGA EP
10. Rotating frame for the x-ray spectrometer (XRS)
11. Target-preheat capability for Materials Science experiments
12. Expanded capability for CR-39 etching and scanning
13. Gas jetter

TIM: ten-inch manipulator

# 1. Findings and Recommendations from the student and postdoc panel

1. Continue the Wednesday evening "tutorial" session. *Provided last night!*

2. The topic for the April 2016 workshop should be "*Diagnostic capabilities and techniques relevant to the OLUG community*" with round-table discussions led by experts—streak cameras and magneto-inertial fusion electrical discharge system (MIFEDS) development were discussed

3. Reinstate a career session aimed at students and postdocs with representatives from the national laboratories giving overview talks; include a job board. *10:00 Friday session led by Mingsheng Wei*

4. Continue to improve and expand web-based resources for users. In particular, implement a search capability by keywords or configuration parameters on upcoming proposals (facilitate ride-along opportunities), and implement a database for software tools used to analyze data. *LLE will commit to the implementation of these requests and appreciates the specificity; Rick Kidder, head of the Omega Informatics Group, is leading the implementation.*

G10776

# Informatics continues to add features to the PI portal to address OLUG recommendations and user requests

**Additional PI-centric features added to enhance information and simplify navigation**

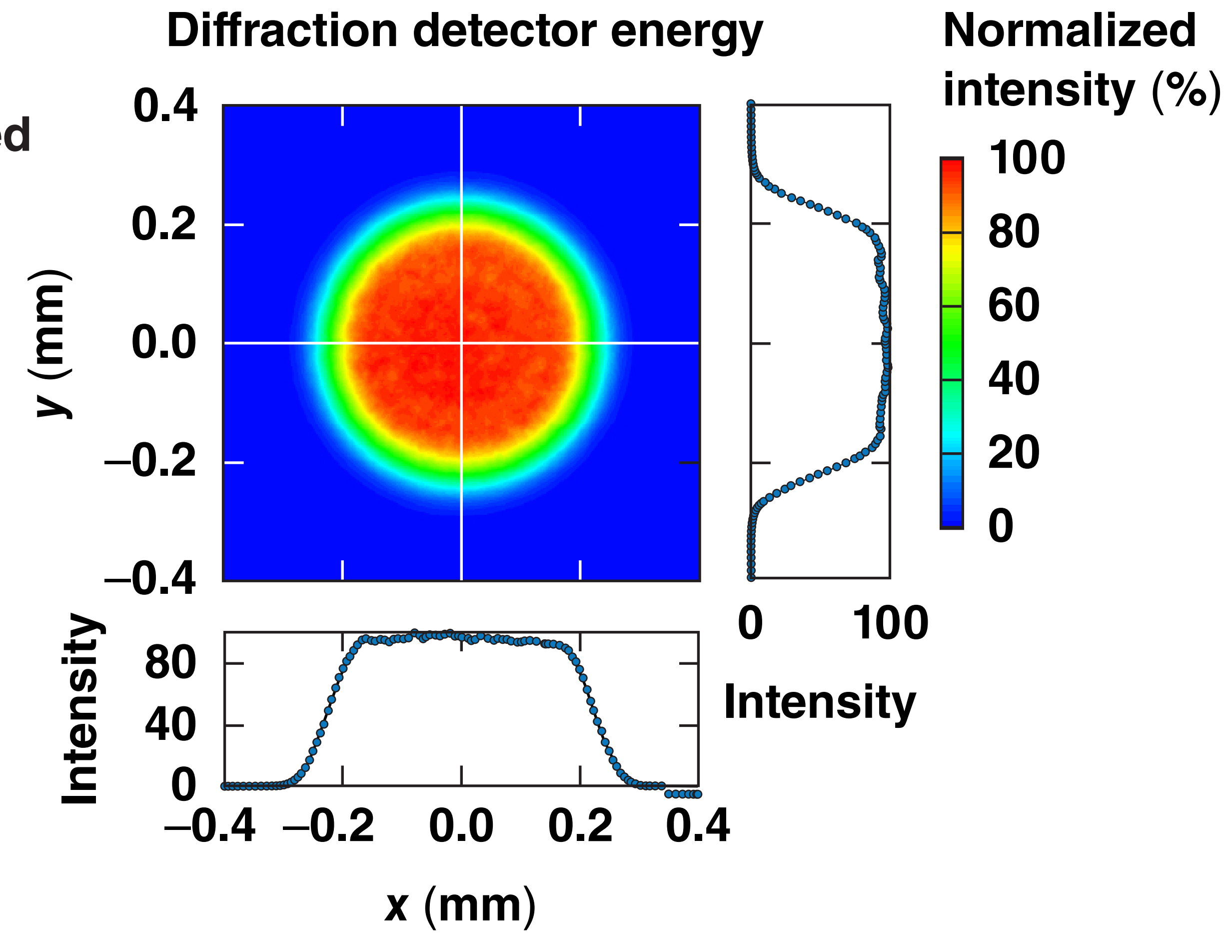
- **Header shows current shot state and 0.1-Hz system heartbeat**
- **New status page shows upcoming request identification (RID) information and system state with link to previous shot**
- **Three-dimensional view of target diagnostic and beam ports**
- **Facility calendar linked to PI proposals**
- **New diagnostic imaging-analysis tools**


G10777

R. W. Kidder *et al.*, this conference (Poster Session III).

# 2. Smaller-focal-diameter phase plates on OMEGA EP

- Recommendation: Design and fabricate a smaller-spot phase plate for use on OMEGA EP, eighth-order super-Gaussian with a diameter of 400 to 500 $\mu$m
- Action: The phase plate was designed, acquired, and activated on OMEGA EP in January 2016
- Result
  - $D_{95}$ = 462 $\mu$m
  - $D_{90}$ = 438 $\mu$m
  - $D_{80}$ = 408 $\mu$m
  - $D_{50}$ = 325 $\mu$m

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# 3. Capability to measure low-energy, low-yield charged-particle spectra with high resolution

**Overview: Add the capability to measure charged-particle spectra at low yields ($10^5$ to $10^8$) and low energy (<5 MeV) with high resolution on OMEGA. We propose that a TIM-based, compact charged-particle spectrometer be implemented to fulfill this role. Current spectrometers at OMEGA can measure high-energy charged particles for yields of ~$10^6$ and above, and low-energy charged particles for yields from ~$10^8$ and above. The new detector would complement the existing charged-particle suite by adding a missing capability.**

**Current charged-particle spectrometers including the wedge-range-filter (WRF) spectrometers, charged-particle spectrometers (CPS's), and the magnetic recoil spectrometer (MRS), run in charged-particle mode.**

| Diagnostic | Particles | Energy | Yield |
|---|---|---|---|
| MRS | p, D | 6 to 30 MeV | $10^8$ to $10^{10}$ |
| CPS | $\alpha$, p, D... | 1 to 30 MeV | $10^9$ to $10^{11}$ |
| WRF | p | 4 to 20 MeV | $10^6$ to $10^{10}$ |

**Action: The MIT HED group is leading design and construction of such a spectrometer. The prototype, "Mini Orange Spectrometer," is expected to fulfill this need when implemented on OMEGA. LLE will support implementation and has assigned C. Forrest for additional scientific support.**

# 4. Improved capability to measure low-energy neutron spectra on OMEGA

UR LLE

Overview: Improve the existing capability to measure low-energy neutron spectra in a DT background on OMEGA. These measurements are currently done with a neutron time-of-flight (nTOF) scintillator detector on a collimated line-of-sight in LaCave.* Proper operation of this detector requires clear line-of-sight in TIM-6, precluding the use for other diagnostics that only operate in TIM-6.

Recommended improvements:

(a) Dedicated, recurring x-ray and low-$\rho R$ DT and DD neutron-producing shots to determine the response of the detector and track sensitivity changes over time. J. Knauer coordinating

(b) Provide effort to understand the impact of rescattering on the measurements—how much does, e.g., a diagnostic in TIM-4 impact the measurement at low energy in TIM-6? J. Knauer to coordinate. C. Forrest has found that the XRS in TIM-4 adds a significant background into the (n,T) backscatter region on layered-DT implosions. May require neutron transport simulations [Monte Carlo neutron-particle (MCNP)].

(c) Effort to validate signal output versus neutron energy, in particular with regard to the simulated correction required for material in the line of sight, which varies more than 25% as a function of energy and is highly structured in the important region below $E_n \sim 2$ MeV. C. Forrest will work with users to quantify the corrections.

(d) Optimize the capability to measure the neutron spectrum below 2 MeV. This is a very challenging measurement and requires, e.g., MCNP simulations to understand where on OMEGA the background is small enough and whether an evacuated line of sight is needed. Also, the choice of detector technology should consider the capability to measure these low-statistics signals at late flight times. C. Forrest coordinating.

(e) Implementation of a second detector on a non-TIM–based line of sight for complementary measurements, considering the information from point (4). LLE, C. Forrest, V. Glebov, and Engineering are working on a second shielded nTOF line of sight.

G10780

*C. J. Forrest *et al.*, Rev. Sci. Instrum. 83, 10D919 (2012).

# 5. Status of the classification update spectroscopy of high-*Z* plasmas

UR LLE

- There ***have not*** been any changes to the NNSA guidelines concerning the acquisition of spectral data
- ***All*** experiments on OMEGA and OMEGA EP will continue to be reviewed for classification issues pursuant to standing NNSA guidelines
- *Currently* at LLE there are three decision points related to experiments acquiring spectroscopic data
  - experiments employing materials with $Z < 37$—no review
  - open-geometry experiments for $Z > 36$—review may be necessary
  - closed-geometry experiments for $Z > 36$—full configuration review

G10781

# 6. Beam blocks on OMEGA

UR LLE

Overview: Increase the available number of (opposed port) beam blocks on OMEGA. For specific experiments (for example, with low-density foam targets), there could be a part of the laser energy that is transmitted and could go to the opposite port. The beam blocks are set up on the opposite port to stop the beam light and avoid facility damages.

**Action: LLE acquired nine additional beam blocks in FY16; they are available for deployment and presently scheduled for first use in Q4 FY16.**

G10782

# 7. Optical diagnostics on OMEGA EP to characterize laser–plasma instabilities

<u>Overview</u>: Implement optical diagnostics on OMEGA EP to measure reflected and scattered-light spectra and energy. Specifically, backscatter measurements of one or two UV beams equipped with a full-aperture backscatter station (FABS) are requested to provide time-resolved spectra covering the wavelength ranges of 353±3 $\mu$m for stimulated Brillouin scattering (SBS), ~500 to 700 $\mu$m for stimulated Raman scattering (SRS), and 234±4 $\mu$m for two-plasmon–decay (TPD) $3\omega/2$ emission. In addition, near-backscatter-imaging (NBI) and time-integrated scatter calorimeters (SCAL's) are also desired on OMEGA EP. The setup of the optical diagnostic system can be identical or similar to those already available on OMEGA or the NIF.

The design of the OMEGA and NIF backscatter stations do not readily overlay onto the OMEGA EP architecture. LLE has developed a sub-aperture scheme that is realistically feasible—sub-aperture backscatter station (SABS) and expects the first phase to be completed in FY16.

G10783

# 8. Opposing beam configuration on OMEGA EP

<u>Overview</u>: Re-route one or more of the OMEGA EP UV beams to the opposite side of the chamber for an opposing beam-illumination configuration. Currently, all four long-pulse UV beams on OMEGA EP originate from the same front side of the chamber. This fixed-UV configuration limits flexibility and usually compromises energy coupling to target caused by the non-normal angle of incidence. A community-wide survey has identified a strong need for the UV beam operation with the opposing beam configuration from both internal PI's at LLE and external PI's from national labs, academic, and private sectors. OLUG has strongly recommended its implementation since 2011.

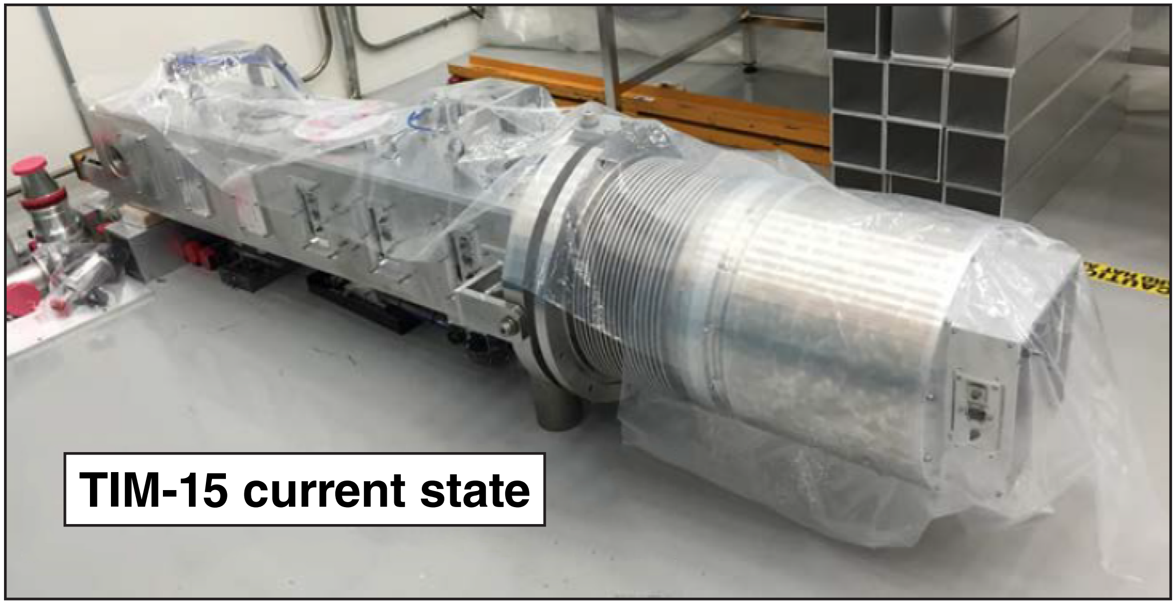
Action: This request, pending since 2011, is a straightforward engineering project. The cost was estimated at ~$2 M. This easily exceeds the annual allocation for all diagnostic projects at LLE. LLE will continue to advocate for this capability with the NNSA and welcomes support from the user community for advocacy outside of NNSA.

G10784

# 9. TIM-15 qualification on OMEGA EP

UR LLE

__Overview__: Commission TIM-15 on OMEGA EP already!




The location for the TIM must be determined with user input. The initial assignment (made years ago) does not appear to be optimal for the experimental configurations being used today. As a start, an alternative location on the TIM-14 sidelighter great circle has been proposed. This is also a resource intensive (engineering) project and has been deferred to FY17.

G10785

# 10. Rotating frame for the XRS

<u>Overview</u>: Implement a rotating frame for the existing XRS. With a single orientation, experiments using the XRS diagnostic are constrained in how they can be designed. Using a rotating frame, which has been implemented on many other diagnostics, will remove the diagnostic orientation constraint, making it easier to design experiments requiring spatially resolved spectra.

Action: This project started in FY16; a first use date will be determined.

# 11. Target preheat capability for Materials Science experiments

<u>Overview</u>: Implement a system capable of preheating a portion of a target prior to laser illumination and monitoring the target temperature. There are a number of methods (laser heating, induction heating, resistance heating) for preheating a section of the target, such as the 2- to 3-mm-diam physics package of the broadband x-ray diffraction diagnostic (BBXRD) or powder x-ray diffraction image plate (PXRDIP). The temperature measurement could likely be done remotely using a thermal imaging camera.

**Action: The use of this capability appears to be exclusive to recent and current LLNL LBS proposals. LLE recommends that LLNL conduct a requirements review with the relevant users and propose a working concept. LLE will support the design and implementation of this capability.**

G10787

# 12. Expanded capability for CR-39 etching and scanning

<u>Overview</u>: Proton radiography is a powerful and widely used diagnostic technique on OMEGA and OMEGA EP. This technique requires a tedious and costly process to "develop" the images from CR-39 detectors. The processing time often exceeds four weeks because of throughput capabilities at MIT and LLE. We request that LLE allocate more resources to the CR-39 etch/scan lab to better support an increasing number of OMEGA/OMEGA EP experiments that rely on CR-39.

Action: The MIT HED group coordinates the work in LLE's CR-39 laboratory. This laboratory was designed to support the etch-scan requirements of the direct-drive program (MIT maintains exclusive control on the interpretation). Excess capacity is available to non-LLE users with MIT's much larger laboratory providing the "base load" for external CR-39 diagnostic users who typically support or collaborate with MIT's HED group. LLE could possibly add marginal capability by cross-training additional personnel but the facility is already operating near capacity. To significantly increase the throughput at LLE would require an additional work shift and two additional hires (off-hours work). LLE will continue to discuss options with the MIT group. Judicious scheduling of experiments may alleviate some of the long queue times; judicious use of the diagnostic is also recommended (it is easy to take data). LLE will continue to field the diagnostics and handle/ship the exposed CR-39 for external users.

G10788

# 13. Implement a gas-jet target capability

Overview: Implement a gas-jet target capability on OMEGA and OMEGA EP to create low-density ambient plasmas for a variety of HED experiments. The low-density ionized plasma environment is ideal to study the plasma interactions relevant to ICF kinetics, laboratory astrophysics, and high-altitude plasma physics. The gas bags can be an option to produce such an environment (e.g., GasCoSphere-14A campaign). However, they tend to be expensive and more importantly, very often the membrane mass generates more mass than the required gas density, creating undesirable conditions. Gas jets are used on many other laser facilities (e.g., Janus and Vulcan) and have produced important scientific results. We request to furbish a gas jetter on OMEGA and OMEGA EP.

**Action: Implementation of gas-jet targets on LLE's facilities is constrained by operational and diagnostic requirements. LLE is pursuing concepts and will supply the engineering effort to implement if a cost-effective solution can be identified.**

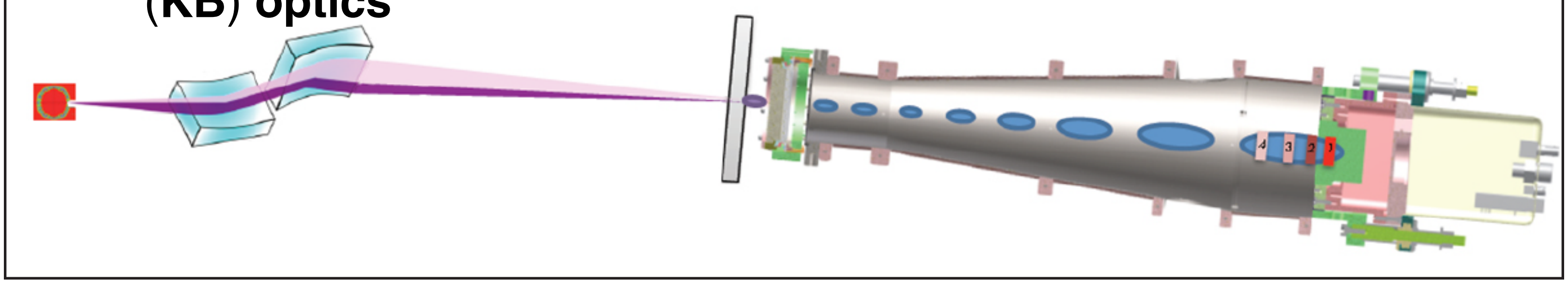
**D. Froula will lead a breakout session on this topic later today.**

# The 100-Gbar initiative motivated improvements in beam timing, pulse shaping, and beam balance

- Pulse-shaping controls and on-shot measurement (P510 streak system) are being improved, particularly to support picket power balance
- The new 3$\omega$ beam-timing diagnostic has been used to time Omega to less than 5-ps rms
- Beam-balance improvements are being made through improvements to
  - frequency-conversion optimization
  - beam-splitter balance improvements
  - increased beamline and amplifier maintenance

rms: root mean square

# An new single line-of-sight (SLOS) instrument is being developed with SNL, General Atomics (GA), Kentek, and LLE



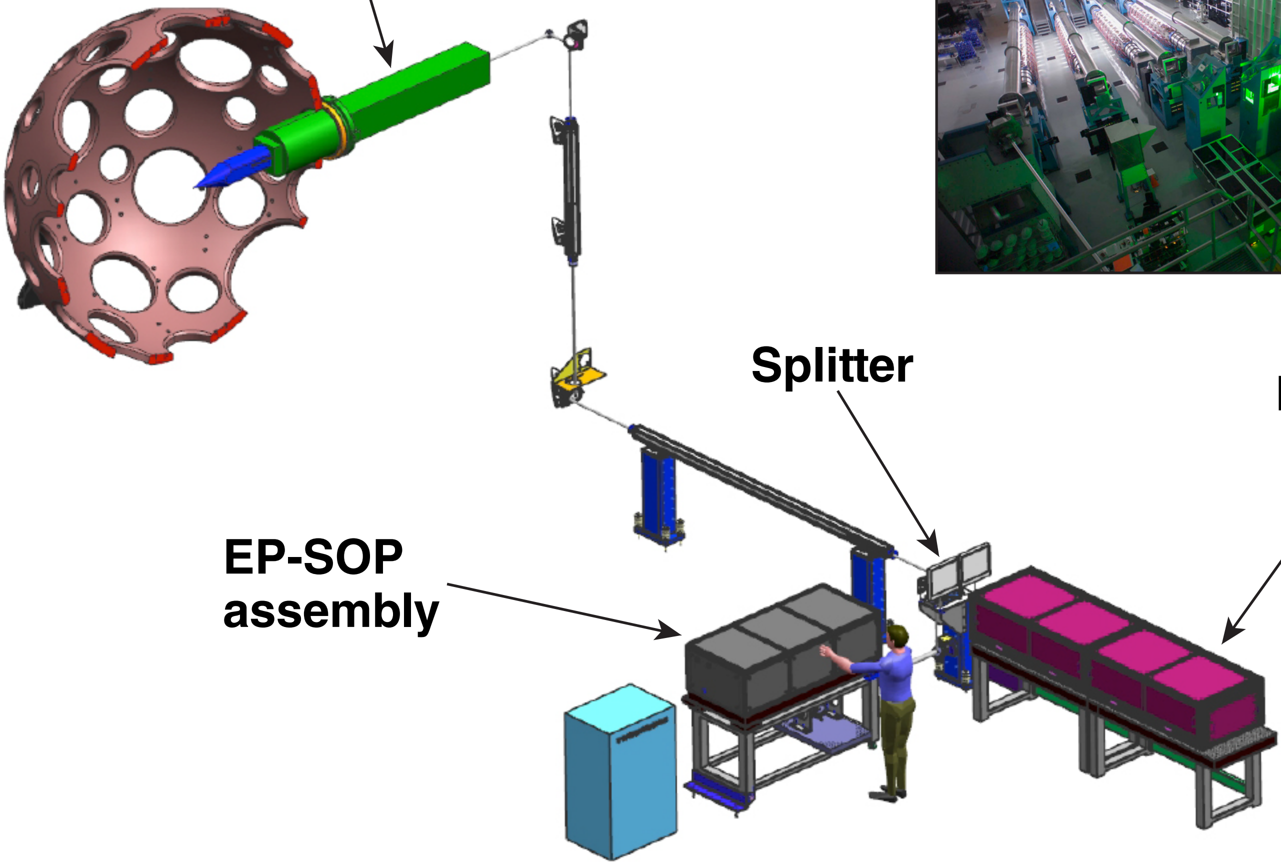

- Target physics requirements for DT cryogenic implosions
  - image hot spot
  - temporal resolution <20 ps
  - eight frames to sample ~100-ps neutron burnwidth
  - 5-$\mu$m spatial resolution for ~20-$\mu$m hot-spot radius
  - $M$ ~20 [field of view (FOV) $\phi$ ~200±50 $\mu$m; detector area 6 × 6 mm$^2$]
  - photon-energy range 4 to 8 keV (compressed shell is optically thin to this band)

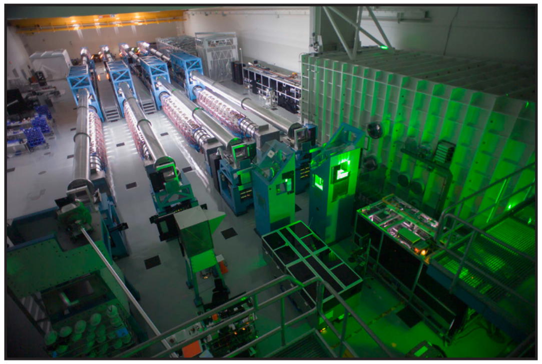
T. Hilsabeck *et al.*, presented at the National ICF Diagnostics Working Group Meeting, Rochester, NY, 6 October 2015.

* hCMOS: hybrid complementary metal-oxide semiconductor

G10791

# The OMEGA EP streaked optical pyrometer (EP-SOP) employs a splitter in the optical path of the OMEGA EP active shock breakout (EP-ASBO) from TIM 12



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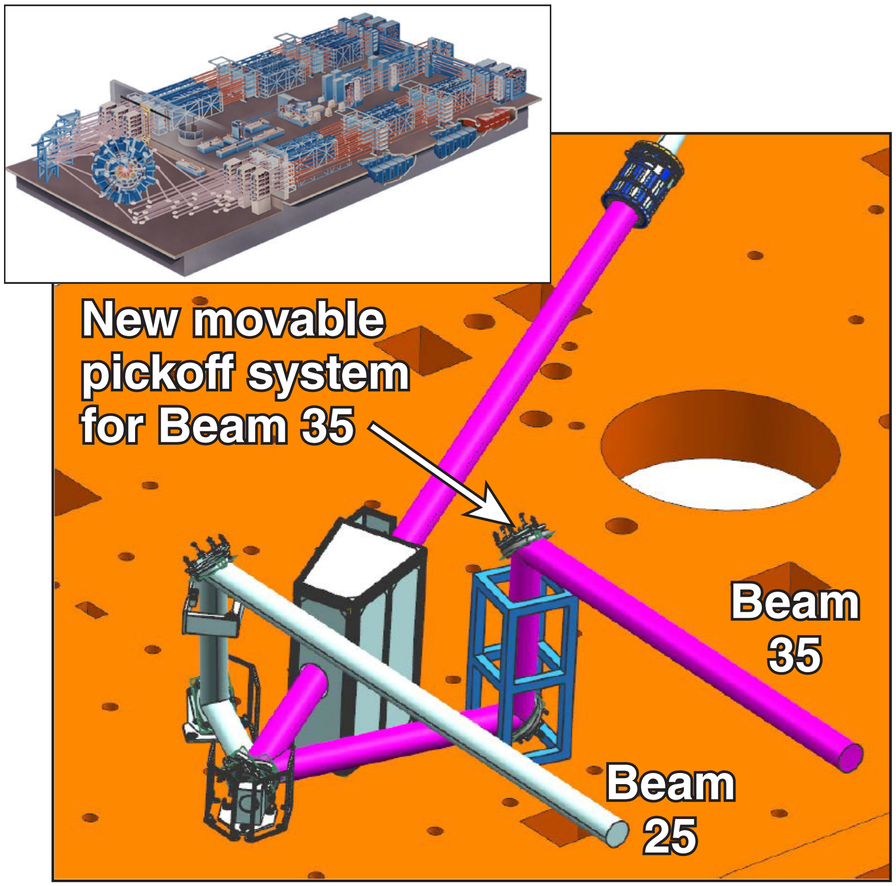
# Beam 35 will be diverted to provide 3$\omega$ irradiation in port P9—beam 25 will continue to be used for 2$\omega$ and 4$\omega$ in P9

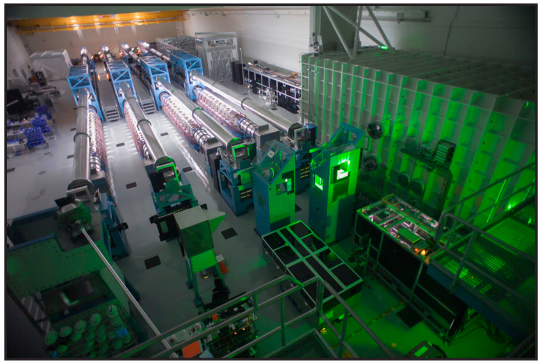



- Will be functionally identical to existing 3$\omega$ beams
- Supported to provide a preheated option for laser-driven magnetized liner inertial fusion (MagLIF) experiments
- Expected availability is 1 June 2016
- No optical diagnostics are part of this laser-capability effort

G10793

# The OMEGA EP short-pulse operational envelope was recently expanded into three configurations

- **A diagnostic beam attenuator was installed on the lower compressor, allowing increased energy at best compression and 10 ps**
- **The upper compressor was increased to 500 J at best compression**



**1000 J** **300 J** **500 J**

**OMEGA EP Performance Envelope descriptive values* - Standard Limits**

Revision Date: 25-Mar-2016 15:56:45

| Non-Copropagating Short-Pulse (IR) Beams | | Beam | | | |
|---|---|---|---|---|---|
| On Target Energy | Pulselength | 1 (Current) | 1 (Full Spec) | 2 (Current) | 2 (Full Spec) |
| No Disposable Debris Shield | .7 ps | 50 J | 700 J | 400 J | 700 J |
| | 10 ps | 850 J | 2600 J | 1250 J | 2600 J |
| | 20 ps | 1000 J | 2600 J | 1500 J | 2600 J |
| | 100 ps | 1000 J | 2600 J | 2600 J | 2600 J |
| With Disposable Debris Shield | .7 ps | 50 J | 50 J | 50 J | 50 J |
| | 10 ps | 850 J | 850 J | 850 J | 850 J |
| | 20 ps | 1000 J | 2600 J | 1500 J | 2600 J |
| | 100 ps | 1000 J | 2600 J | 2600 J | 2600 J |

Note: Beam 1 is also known as the "Sidelighter" or alternatively the "Lower Compressor"
Beam 2 is the "BackLighter" (OMEGA EP or OMEGA) or the "Upper Compressor"

| Copropagating Short-Pulse (IR) Beams | | Beam 1 on Target Energy (100ps) | | |
|---|---|---|---|---|
| | BL 2 Pulselength | 850 J - 1000 J | 750 J - 800 J | ≤ 650 J |
| BL2 on Target Energy, no DDS | .7 ps | 300 J | 300 J | 350 J |
| | 10 ps | 1000 J | 1250 J | 1250 J |
| | 100 ps | 1500 J | 1750 J | 1750 J |
| BL2 on Target Energy, with DDS | .7 ps | 50 J | 50 J | 50 J |
| | 10 ps | 850 J | 850 J | 850 J |
| | 100 ps | 1500 J | 1750 J | 1750 J |

G10794

Summary/Conclusions

# Omega is an effective and efficient facility and continues to evolve to meet user requirements

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