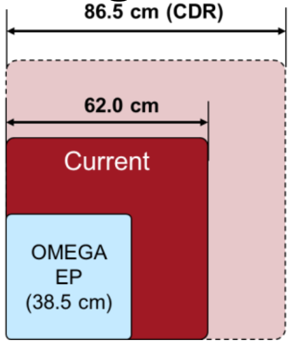
NSF OPAL – Reaching for the Brightest Light
Community Update – 03 September 2025

This material is based upon work supported by the U.S. National Science Foundation under Cooperative Agreement No. (PHY-2329970).
Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Community Update Agenda

- **Introduction – Elizabeth Hill**
  - Call for Support
  - Update Overview & Workshops
- **Laser System Updates – Jake Bromage**
  - Progress since CDR
    With a focus on reduction in beam size and progress with 2w



- **Experimental System Updates – Mike Krieger* and Request for Input**
  - Updates on the Main Target Chamber design
  - Request for user input and support

2025-09 Community Update Slack

[Slack Channel Link for today's Community Update]

Zoom chat is disabled.

Please use the NSF OPAL Slack channel (nsf-opal.slack.com) for discussion.

*Systems Engineer Matthew Barczys is filling in for Mike who is under the weather

NSF OPAL will not happen without your help!
But what can we do?

1. **Include NSF OPAL in your papers and presentations**
   - Standard slides available on NSF OPAL website
2. **Sign the Open Letter of Support** (link/QR on slide 4)
3. **Join a Frontier Science Working Group Experimental Meeting**
4. **Keep coming to our updates**
5. **Follow NSF OPAL on LinkedIn** (link/QR on slide 5)
6. **Sign-up for the Friends of OPAL mailing list**

NSF OPAL will not get funded without a clear and consistent *Scientific Outcry* for the capability

NSF OPAL needs you
to sign an Open Letter of Support

This letter advocates for the funding of a future NSF OPAL user facility, highlighting its importance to the science community and U.S. scientific leadership. Please consider signing and forwarding this link to others interested in supporting NSF OPAL.

NSF OPAL Open Letter of Support

SIGN THE LETTER OF SUPPORT →

https://nsf-opal.rochester.edu/letter-of-support

Follow on LinkedIn
to stay up-to-date on all things NSF OPAL

NSF OPAL
232 followers
5d •

NSF OPAL, a multi-institutional initiative, joins the LinkedIn community and will share an inside look at the evolution of a potential world-leading laser user facility at the University of Rochester. The design aims to push the boundaries of what's possible in ultrahigh-intensity laser science, featuring two 25-petawatt lasers using optical parametric chirped-pulse amplification, along with novel experimental and diagnostic systems. Follow our page for information on events, design updates, and more!
#laserscience #NSF

NSF OPAL has joined the LinkedIn community and will be sharing an inside look at events, design updates, and more!

NSF OPAL
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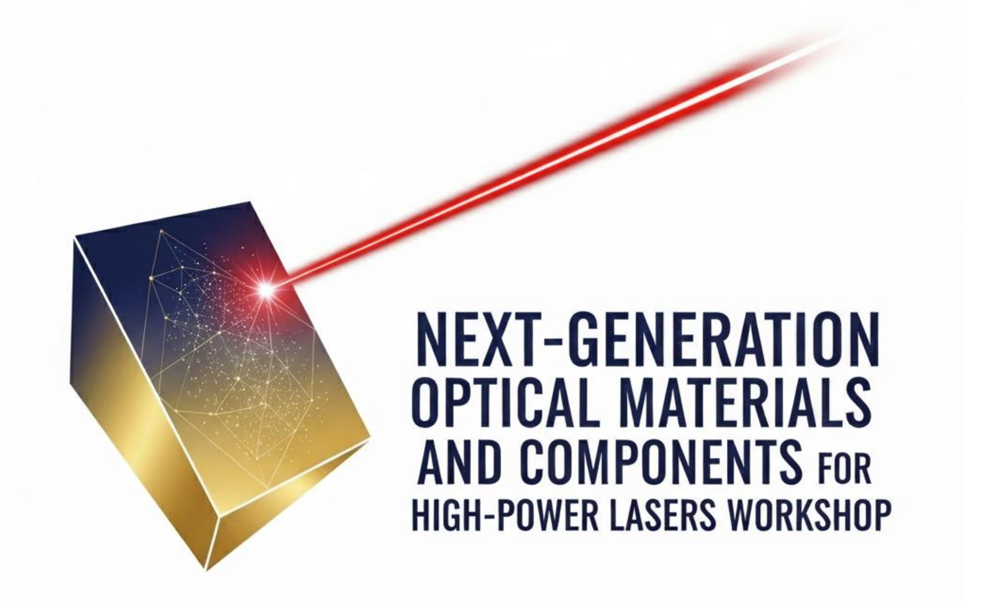
The NSF OPAL initiative currently collaborates with multiple institutions. Our principal investigators are each from University of Rochester, University at Buffalo, UC Irvine, and University of Notre Dame. Other partners include: University of Maryland, University of Michigan, The Ohio State University and Plymouth Grating Laboratory, Inc., who play a vital role in developing technologies crucial for supporting flagship experiments.

Read more about our project team: https://lnkd.in/eXYPhAZW

https://linkedin.com/company/nsf-opal

NSF OPAL is co-sponsoring the Next-Generation Optical Materials and Components for High-Power Lasers Workshop

- **Goals of the workshop**
  - **Address critical limitations in material damage thresholds currently hindering high-power lasers**
  - **Focusing on topical areas:**
    - Modeling
    - Physics-based fabrication
    - Gratings for pulse compression and beam combining
    - Diagnostics and lifetime prediction
- **Will solicit whitepapers for up to four “seedling” R&D efforts**
- **Held in January in Arlington, VA**



<u>This workshop is invitation only.</u>
<u>Contact Stavros Demos if interested</u>
Stavros Demos, sdemos@lle.rochester.edu

2026 Diagnostic Community Workshop

- **Goals of workshop:**
  - **Understand and identify diagnostic technologies that will be used to address scientific frontiers for multi-petawatt facilities**
  - **Evaluate the needs in diagnostic technology and develop a roadmap required to address these needs**
  - **Identify technical gaps in bridging present diagnostic solutions to the multi-petawatt scale**
  - **Develop and connect diagnostic-related areas of strong mutual interest across the multi-petawatt physics community**
- **Will be soliciting whitepapers on above topics**
- **Aiming to build a network of interested diagnostic scientists, engineers, and technical leaders to usher in technologies for next-generation multi-petawatt facilities**

If interested in getting more involved, contact one of the co-chairs

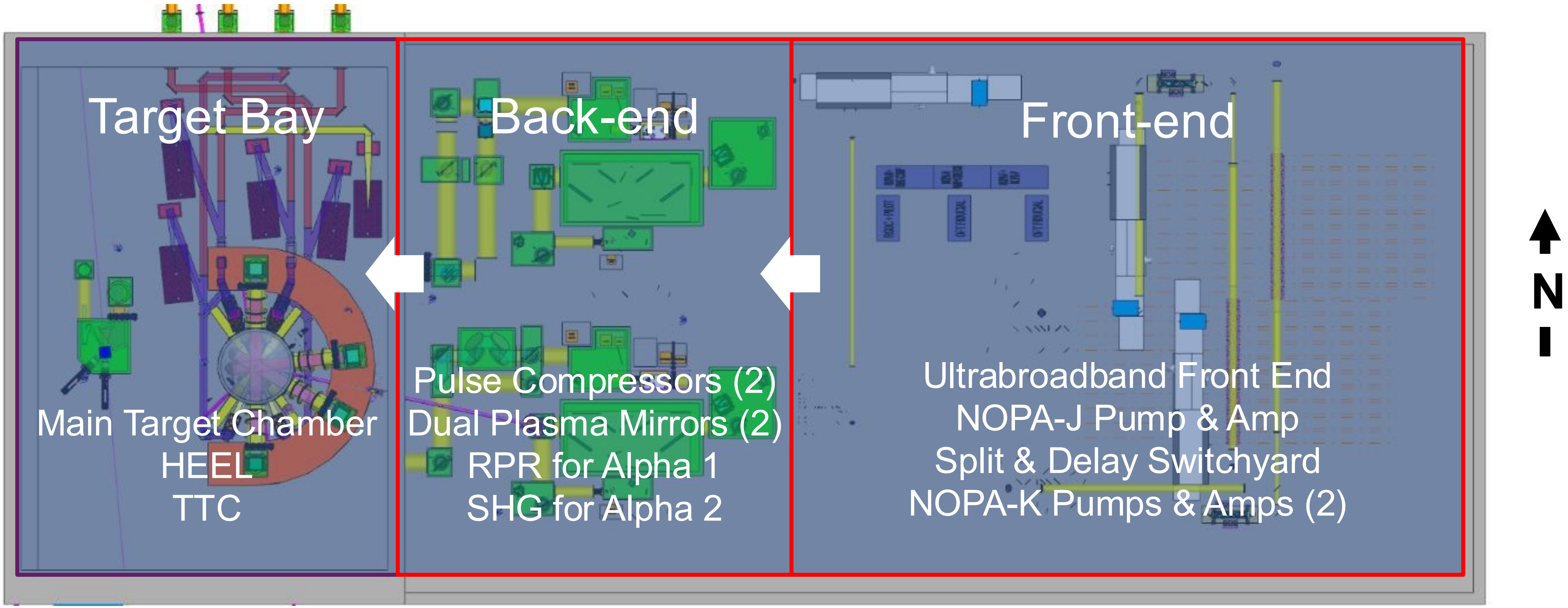
Steve Ivancic, steve.ivancic@rochester.edu

Louse Willingale wlouise@umich.edu

Mike Downer downer@physics.utexas.edu

Post-CDR Changes to Laser Design

Jake Bromage



This talk focuses on high-level changes in the back-end section

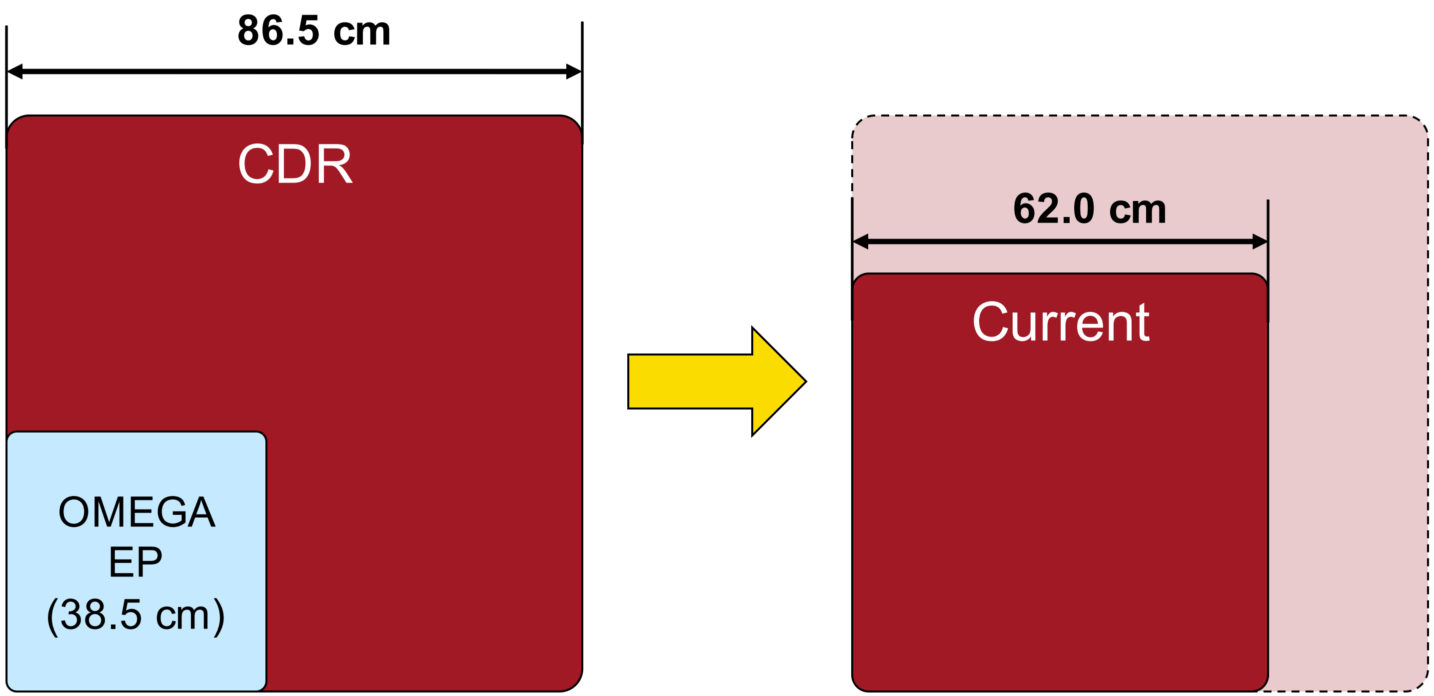
The team has continued to optimize the laser design to meet system performance levels with acceptable costs and risks

- **After the CDR, opportunities were identified to reduce costs**
  - **Use novel manufacturing techniques for back-end optics (e.g., light weighting, additive manufacturing)**
  - **Reduce the beam size through back-end**
- **Reducing the beam size trades off technical risks of damage for reduced cost**
- **Plans are underway for a workshop in early 2026 focused on next-generation optics**
- **Progress continues on second-harmonic generation option**
  - **Required for photon-photon scattering flagship**
  - **Provides high temporal contrast**
  - **Added parallel beam path for second-harmonic generation section**

2025-09 Community Update Slack

Slack Channel Link for today's Community Update

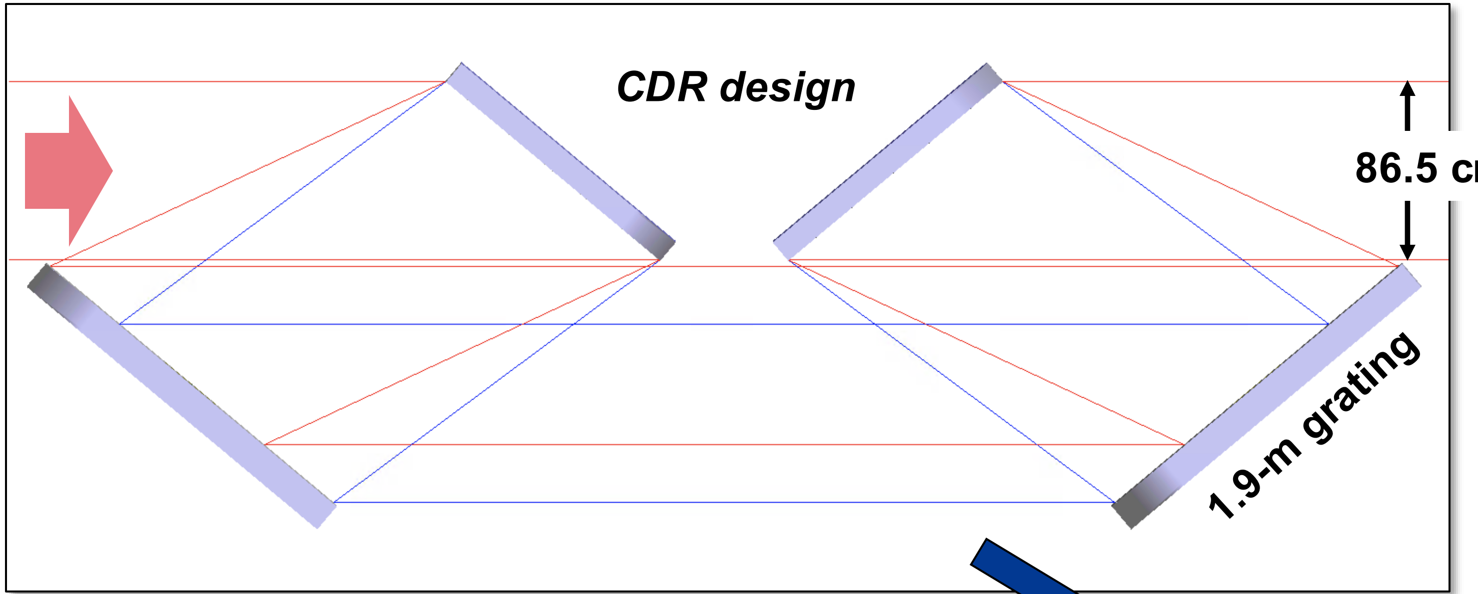
The beam size through the laser back-end portion was reduced to lower costs for an acceptable increase in technical risk



- Beam size was reduced to 62-cm (FW1%), comparable to 10-PW ELI L4 Aton
- Increases technical risk as 25-PW operation requires higher fluence at the final grating than demonstrated to date
  - RI-1 funding will be used to test gratings specifically designed for NSF OPAL
  - RI-1 will also fund a workshop and R&D on higher performing optics
- Based on optics used on Ti:Sa systems, on-target peak powers of at least 20 PW should be achieved

NSF OPAL's peak power requirement of 25 PW per Alpha beam remains unchanged

The compressor was redesigned to take advantage of the smaller beam, and can use smaller gratings with higher line densities and higher diffraction efficiency

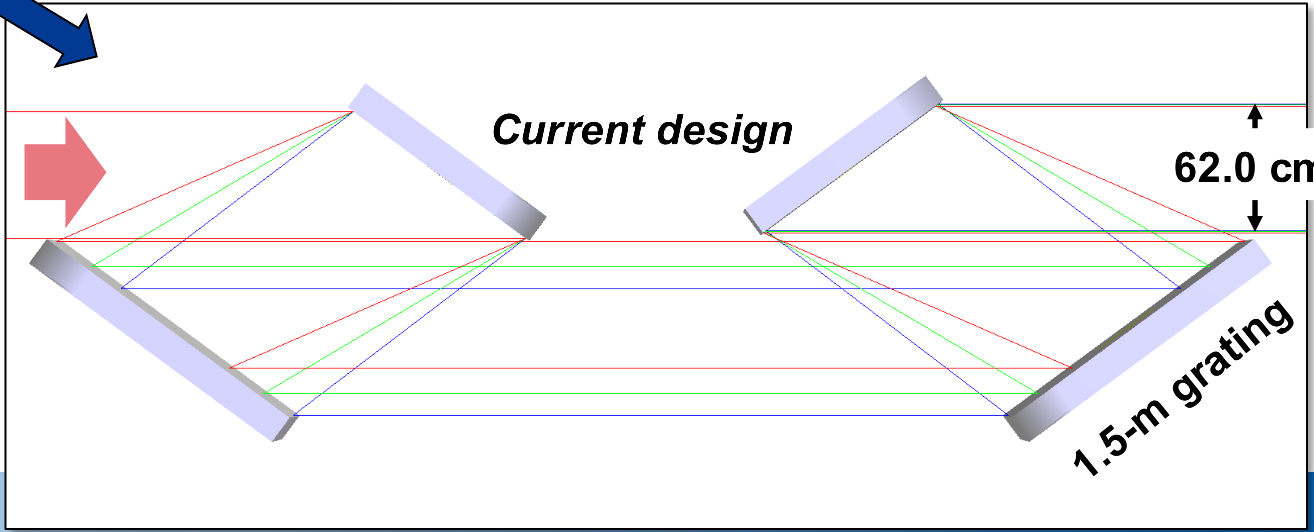


Original design for 86.5-cm beam

- 1165 l/mm gratings at 50-deg incidence
- 1.9-m grating required
- 100 mJ/cm^2 fluence at G4

New design for 62.0-cm beam

- 1285 l/mm gratings at 54-deg incidence
- 1.5-m grating required
- 175 mJ/cm^2 fluence at G4
- Added 1-cm spatial chirp for beam smoothing
- Stretcher was redesigned to match



The resulting increased fluence (the 'max-mean') on the fourth grating is considered achievable based on scaling from two Ti:Sa PW systems in operation

- Fluence limit is primarily set by the fourth grating, where there the pulse is recompressed
- Plausible basis for increased risk:
  - Ti:Sa systems (800 nm) use 1480 l/mm gold gratings that are 'damage free' at 140 mJ/cm^2 after 1000's of shots
    - Apollon (France) and ELI-NP (Romania)
  - NSF OPAL (930 nm) uses different gratings (1285 l/mm), but compressor geometry is very similar
- Post-CDR, the max-mean fluence has been increased, accounting for refined transport losses and on-target energy
  - CDR: 100 mJ/cm^2
  - Current: 175 mJ/cm^2
- Need margin above the max-mean fluence to allow for:
  - Beam modulation: typically assumed to be ~1.8:1, which demands strict attention in design & operation
  - Grating defects: not known for gratings at this scale, and may require 'spot shadowing' to limit damage growth

NSF RI-1 funding is being used to buy and test conventional gold-coated gratings to establish a baseline

High-performance mirrors are also required, and the 2023 SPIE Damage Competition focused on OPAL-type high-reflector coatings

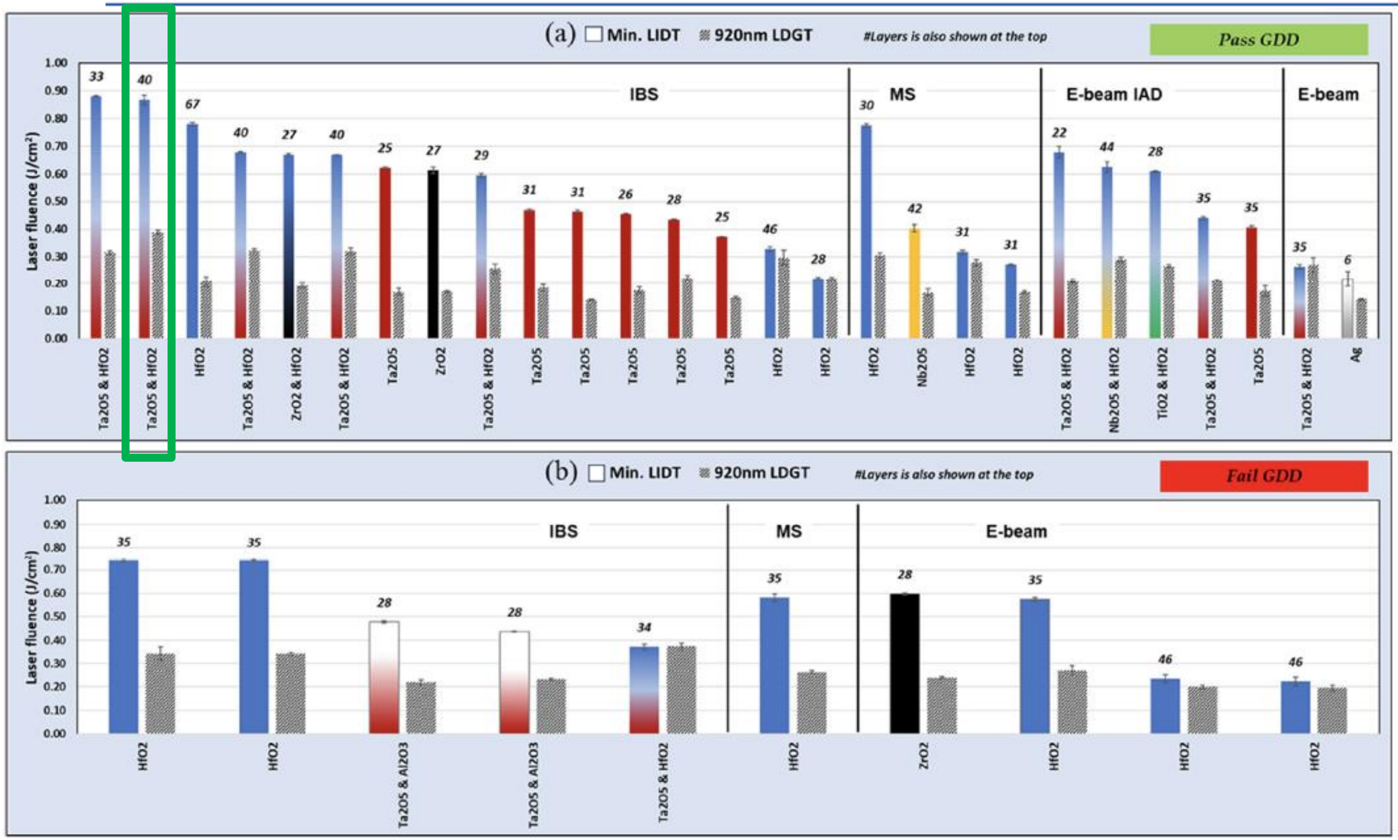


Figure 9. Damage testing results grouped by manufacturing technology, and labeled/colored to indicate the materials used in the coating. IBS = ion beam sputtering, MS = magnetron sputtering, E-beam = electron beam evaporation, E-beam IAD = E-beam ion-assisted deposition.

- **Small-spot damage testing performed at LLE (K. Kafka)**
  - **100-on-1 initiation (LIDT)**
  - **100-pulse growth (LDGT)**
  - **GDD measurements**
- **Threshold for laser-damage *growth* (LDGT) typically much less than *initiation* (< 50%)**
- **Large range of values over samples for both**
  - **LIDT: 220 to 880 mJ/cm^2**
  - **LDGT: 140 to 390 mJ/cm^2**
- **Highest LDGT = 390 mJ/cm^2**
- ***No submissions for p-polarized beams***

Although care is required when applying small-spot results to full-scale operation, these results nonetheless provide cause for optimism with better design, fabrication and other material options

UNIVERSITY OF ROCHESTER OPAL

A multi-faceted strategy is needed to enable operation at higher back-end fluences that would benefit all CPA lasers, not just NSF OPAL

Materials

- Systematically explore new materials and composites, both metals & dielectrics

Design

- Develop advanced modeling tools, calibrated by testing, for searching design space that address all aspects of optic function & failure

Fabrication

- Develop better and novel approaches that enable new materials with less contamination

Testing

- Make testing more relevant for system design & operation

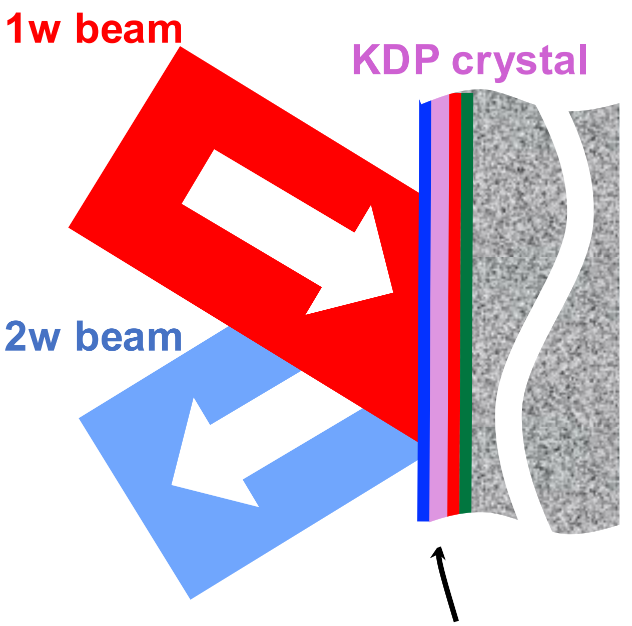
Operations

- Ensure laser operation is optimized

The NSF RI-1 will fund a two-day workshop in early 2026 dedicated to these topics

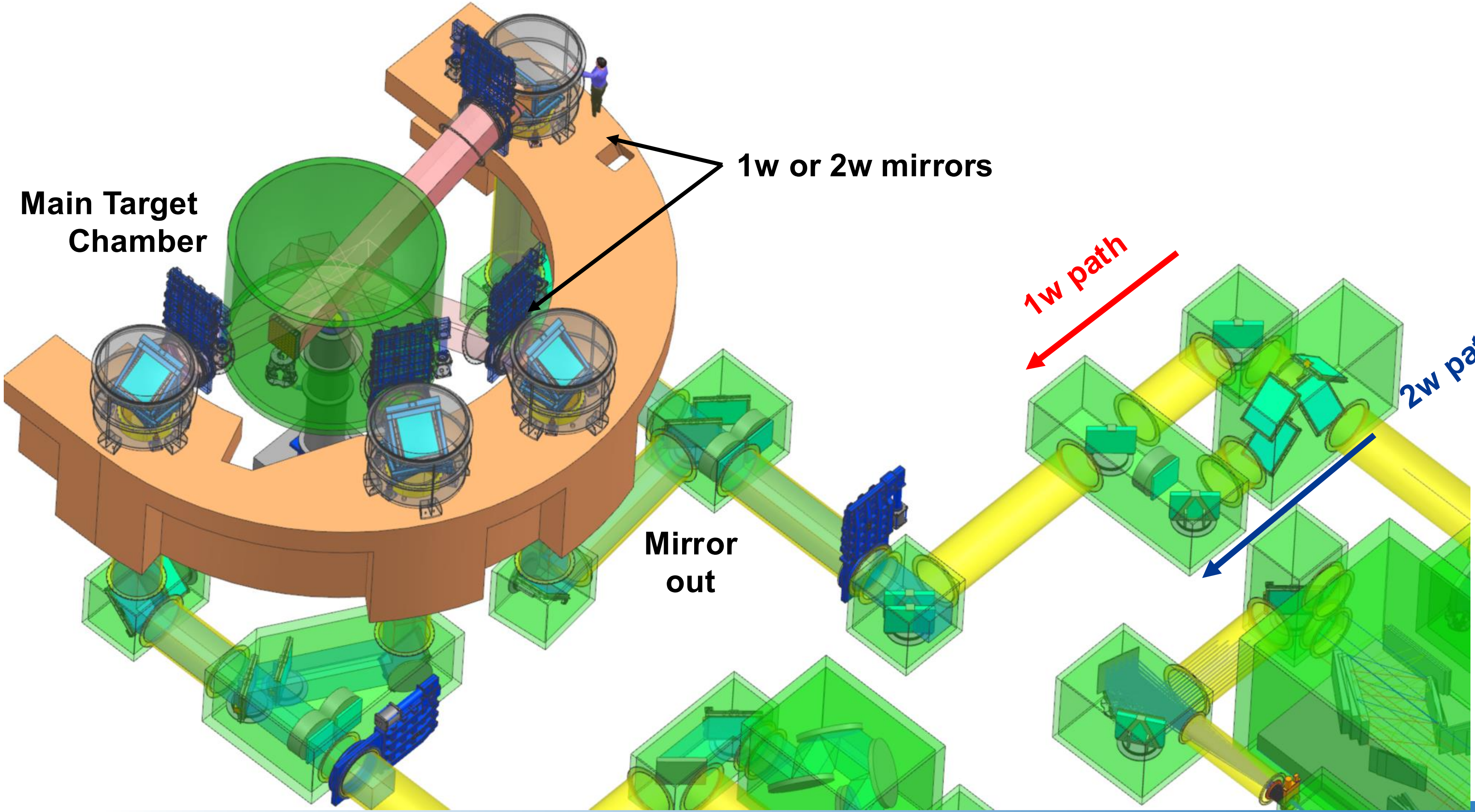
Frequency doubling a short-pulse beam is highly desirable

- Required for the photon-photon scattering flagship experiment to shift signal to 3w
- Can achieve high temporal contrast(e.g., Orion, MTW):
  - Must frequency double after compression
  - Must use dichroic 2w mirrors that pass residual 1w
- Efficient conversion of 25-PW beams sets requirement for sub-mm crystals
  - Concept: *Support sub-mm thick crystals on a reflective substrate (SHG mirror)*
- Since CDR, R&D continues the SHG mirror concept and demonstration:
  - *Models*: Developed new computational models for all-reflective geometry
  - *Design*: Identified optimum thickness for KDP: 0.2 mm
  - *Performance*: Predict best-case 1D efficiency for 1w bandwidth, χ3 effects: 45%
  - *Samples*: In-house and vendors working on small-scale demo on MTW-OPAL
- Also continued developing back-end design for implementation in the Alpha 2 beam:
  - *Transport*: Modified Alpha 2 beam transport for optimum 2w polarization in MTC
  - *Diagnostics:* Adding sub-systems to support 2w operation (in progress)

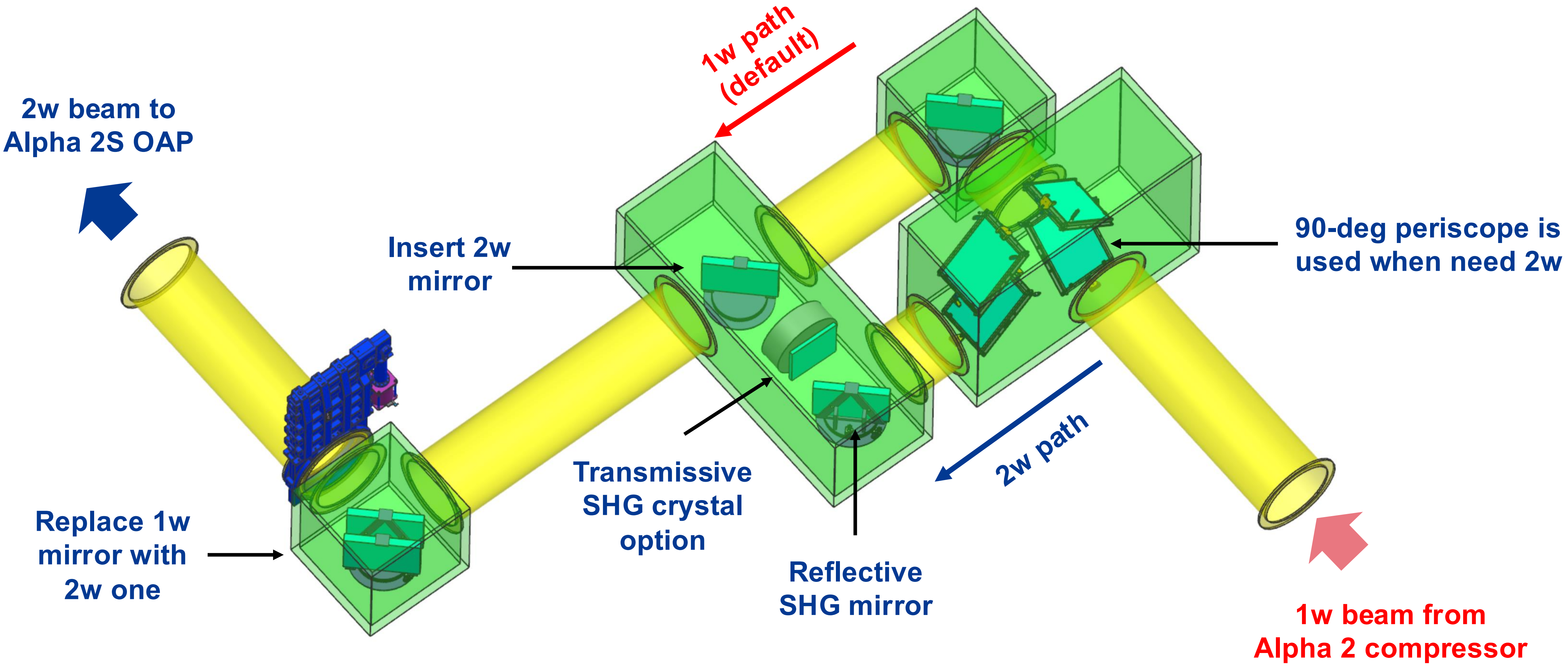


Thin AR-coated KDP crystal segments mounted on a thick reflective substrate

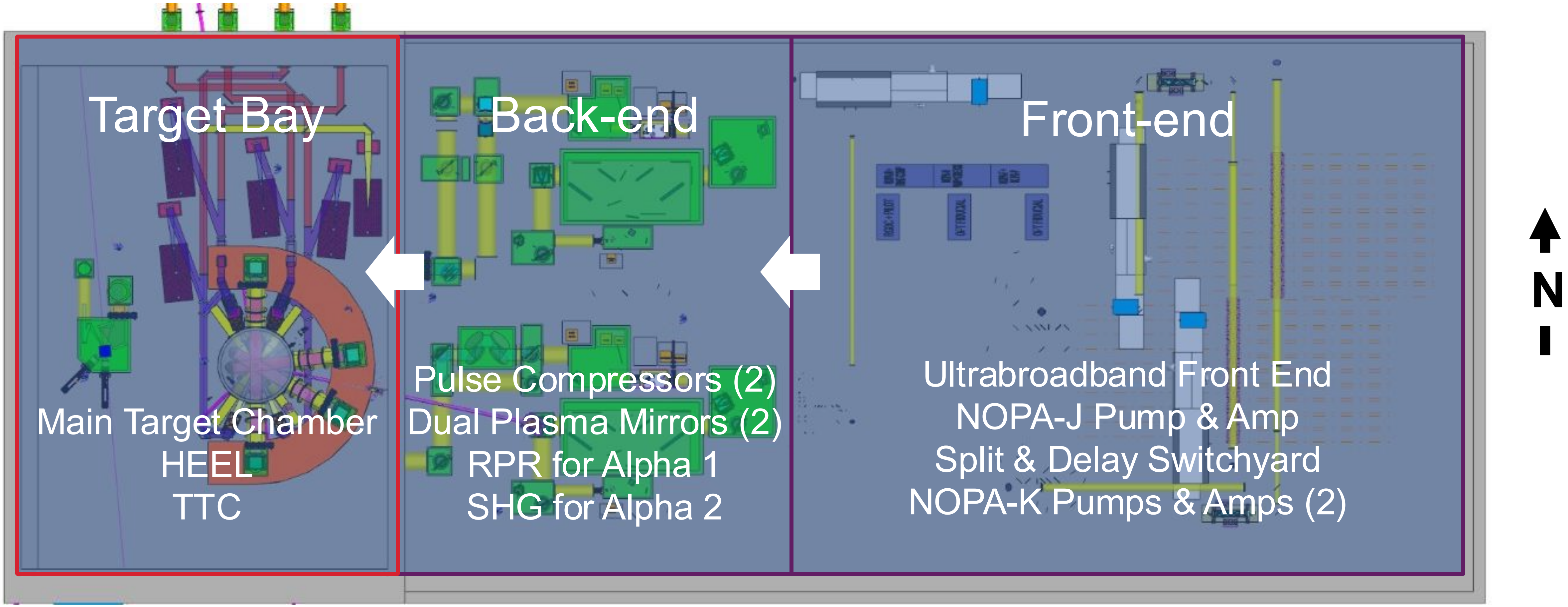
The Alpha 2 beam path was changed to match polarization rotation requirements (Type-1 second-harmonic generation)



The Alpha 2 beam path was changed to match polarization rotation requirements (Type-1 second-harmonic generation) – cont'd



Post-CDR Changes to Experimental Systems
Mike Krieger



This talk focuses on design updates and capabilities of the MTC in the Target Bay

MTC – Main/Multipurpose Target Chamber; HEEL – High Energy Electron Line; TTC – Tritium Target Chamber

Overview

- **Progress highlights since CDR**
- **MTC capabilities**
  - **Beam layout and configuration**
  - **Stay out zones and LOS limitations**
  - **Diagnostic deployment locations**
  - **FXPI capabilities and design progress**
  - **ODI capabilities and design progress**
- **Known system limitations and experimental constraints**
- **Introduce Experimental Use Case Template**

2025-09 Community Update Slack

Slack Channel Link for today's Community Update

Please ask questions throughout the presentation via Slack, or raise your hand on Zoom.

MTC – Main Target Chamber; FXPI – Flexible Platen Interface; ODI – OPAL Diagnostic Inserter

OPAL beam configuration options and parameters for MTC

	MTC					
OPAL Beam	Alpha 1 (S Beamline)		Alpha 2 (N Beamline)		Beta (N Beamline)	
Final Focusing Optic	N OAP	NW OAP	S OAP	W OAP	S OAP	W OAP
Nominal	X	X	X	X	X	X
DPM	X	X	X	X	*	*
RPR	X	**				
2w			X	***	X	***
2-UV coaxial			X		X	
4-UV coaxial	X					
Pointing/Focusing Volume (mm radius from TCC)	15		15		15	
Beam Shape & Size	Square (62 cm side)		Square (62 cm side)		Square (20 cm side) (optionally round)	
Energy Range (J) — *no DPM, RPR, or 2w*	100, 200, 300, 400, 500		100, 200, 300, 400, 500		8, 16, 24, 32, 40	
Energy Range (J) — *with DPM*	350		350		*	
Energy Range (J) — *A1 with RPR, A2/Beta with 2w*	70, 140, 210, 280, 350	**	185	***	20	***
Pulse Width Range (fs)	20 - 1000 (20 for DPM)		20 - 1000 (20 for DPM, 2w)		20 - 1000 (20 for 2w)	
Beam Timing Delay (relative to other OPAL beam)	Up to 1.5 ns		Up to 1.5 ns		Up to 1.5 ns	
Contrast (no DPM)	10^10 up to 300 ps before pulse					
Contrast (DPM)	>10^11 up to 5 ps before pulse		>10^11 up to 5 ps before pulse		*	
Contrast (2w)	*N/A*		*TBD*		*TBD*	

- **Beam location specifies OAP location within MTC**
  - **Example: A2-W is the Alpha 2 beam delivered via the western OAP**
- **All listed parameters are best estimates based on most current modeling**

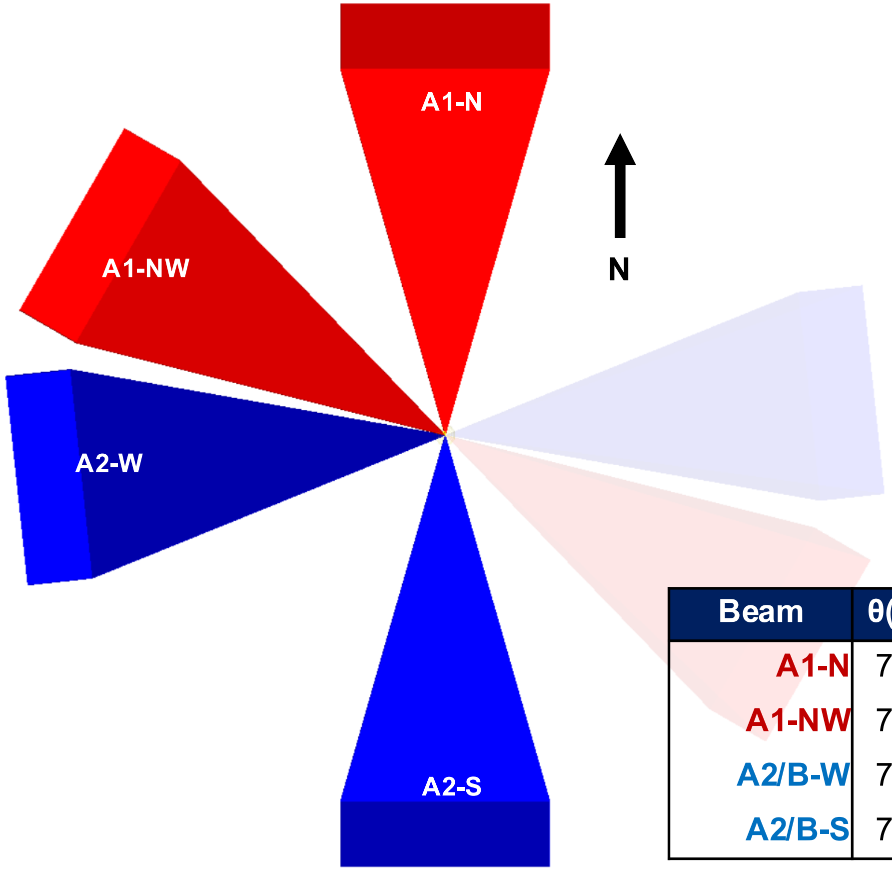
** Design does not preclude, but nominal DPM spacing will be optimized for Alpha beam*

*** Design does not preclude, but RPR coatings will only be optimized for phase delays in Alpha-1 N path*

**** Design does not preclude, but would require swapping out final transport mirrors and OAP with 2w HR's*

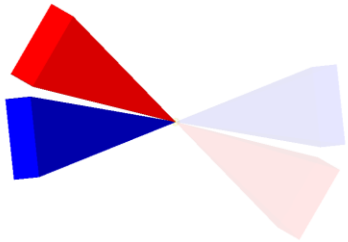
DPM – Dual Plasma Mirror; OAP – Off-Axis Parabola; RPR – Reflective Phase Retarder; TCC – Target Chamber Center

Main Target Chamber (MTC) beam geometry configurations are unchanged since CDR, however, have been mirrored about the E-W line



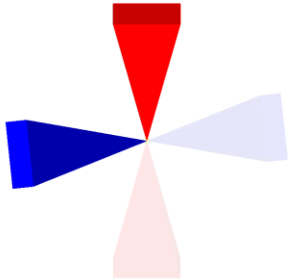
Beam	θ(°)	φ(°)
A1-N	72	0
A1-NW	72	60
A2/B-W	72	96
A2/B-S	72	180

All beams are angled down 18°

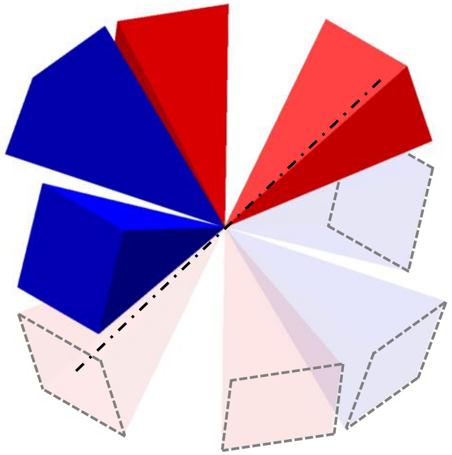


Near copropagating

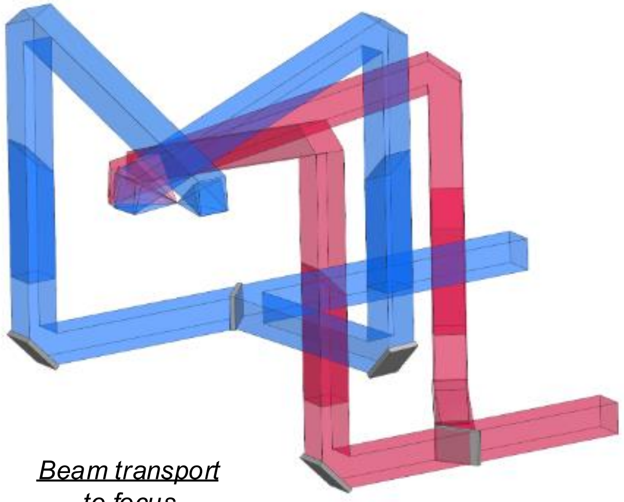
Near counterpropagating



Orthogonal

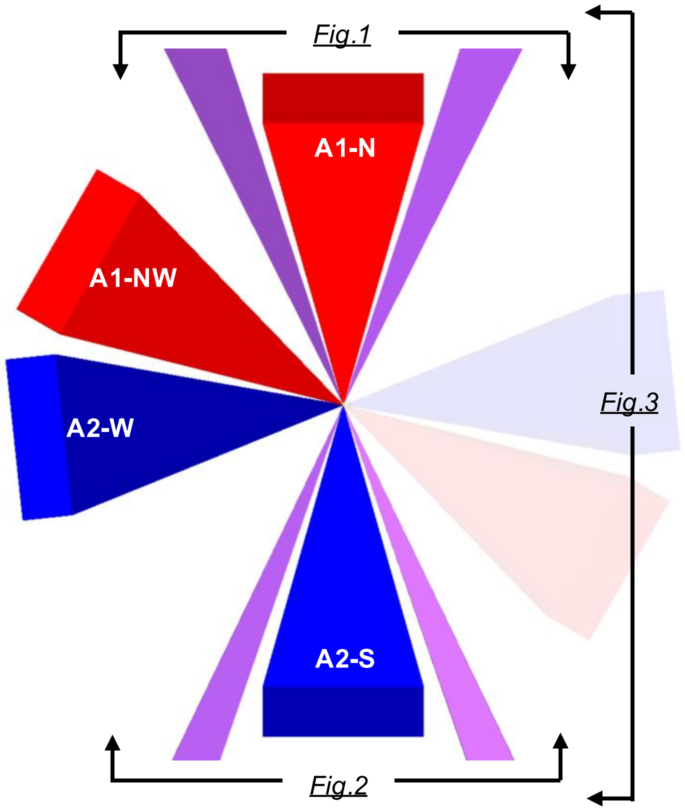


In-chamber focusing



Beam transport to focus

OMEGA EP Long Pulse (LP) UV beams may be terminated in the OPAL MTC



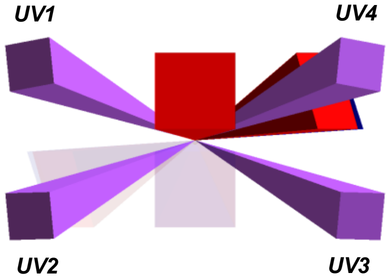


Fig.1: North UV (x4)

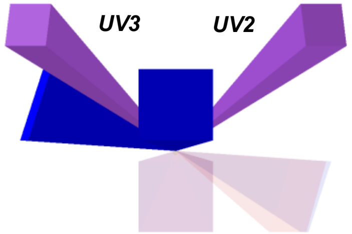


Fig.2: South UV (x2)

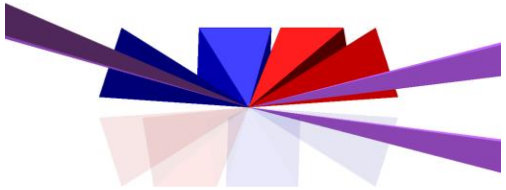
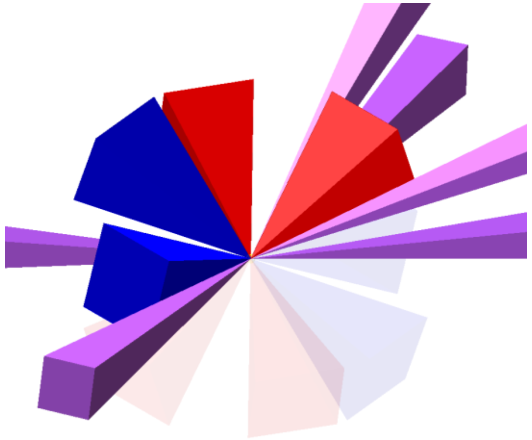
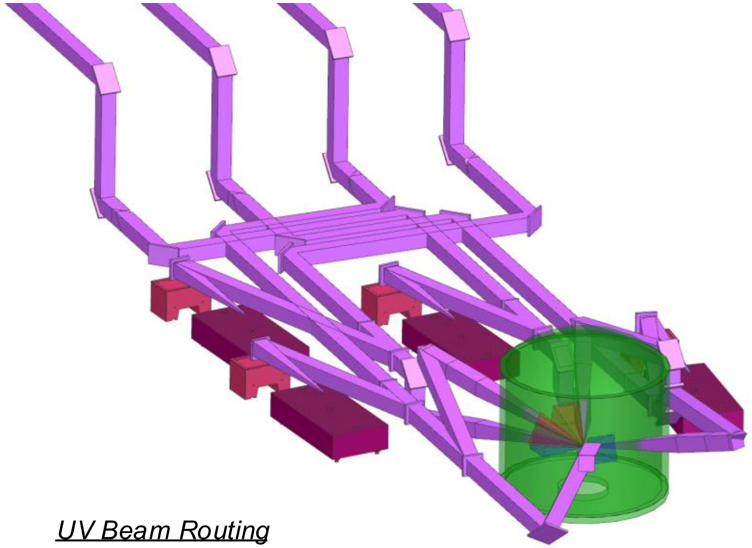


Fig.3: Looking West



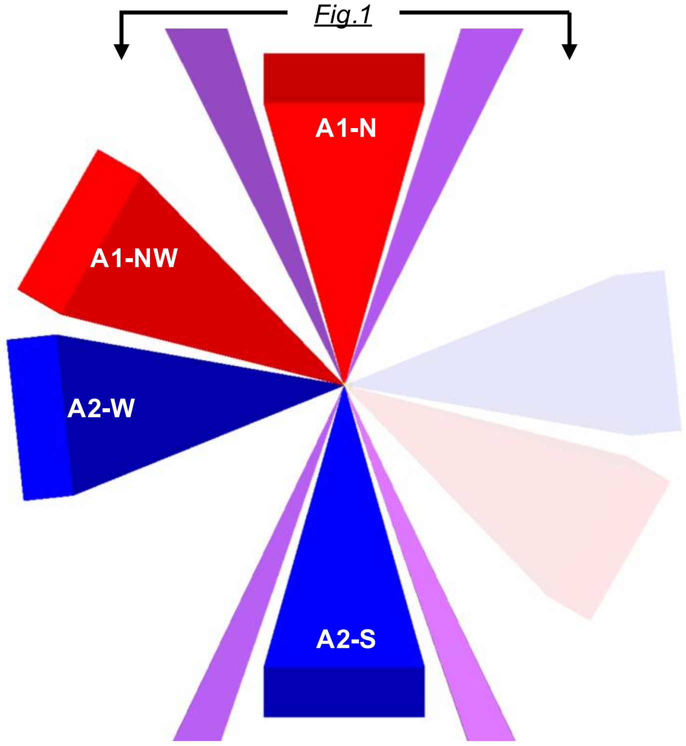
Southeast ISO

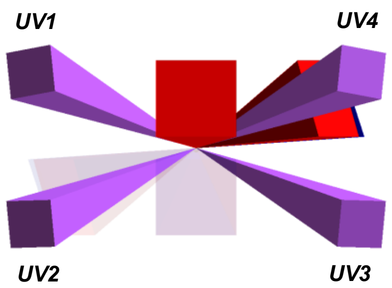


UV Beam Routing

OMEGA EP Long Pulse (LP) UV beams may be terminated in the OPAL MTC

- 4-UV North beams centered on equator
- 22.5° from Alpha axis in ϕ, 10° in θ





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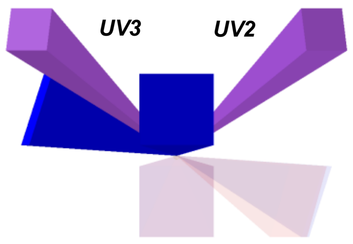
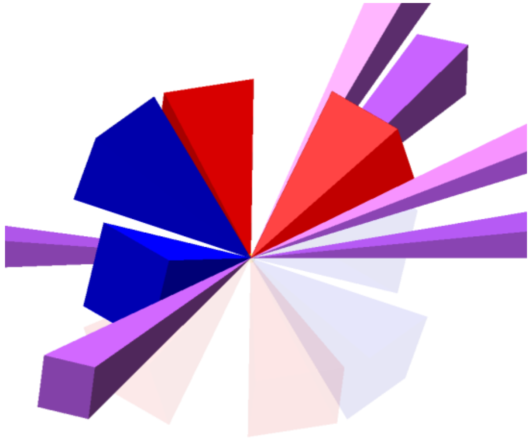


Fig.2: South UV (x2)


Fig.3: Looking West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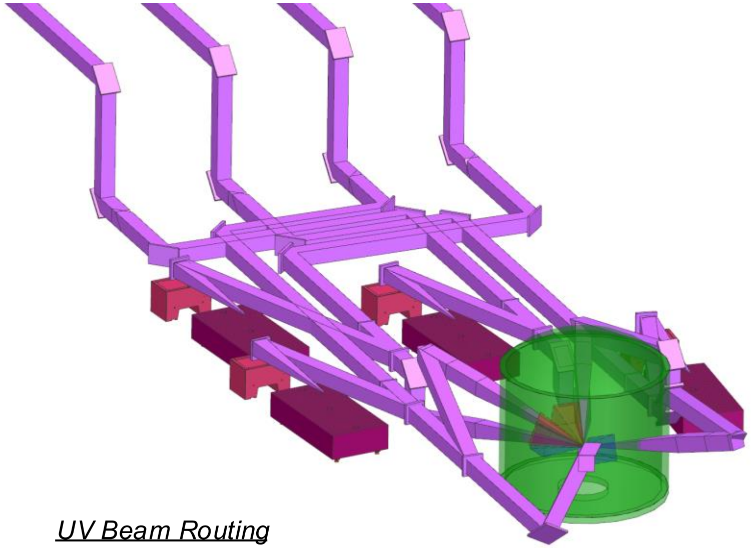

UV Beam Routing

OMEGA EP Long Pulse (LP) UV beams may be terminated in the OPAL MTC

- 2-UV South beams in-plane with A2-S (θ = 72°)
- 22.5° from Alpha axis

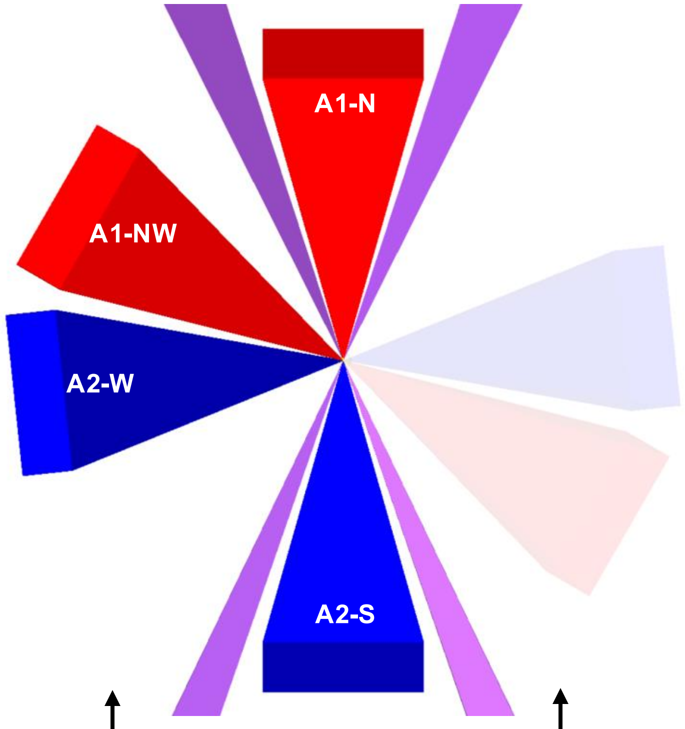
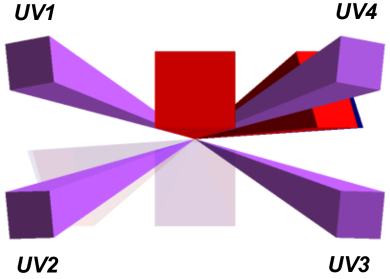


Fig.2



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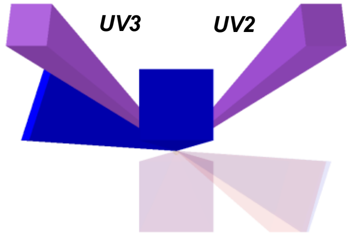

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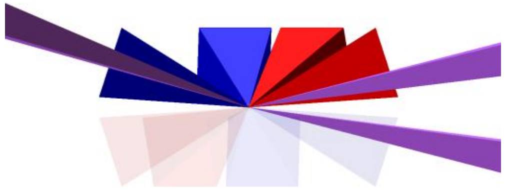

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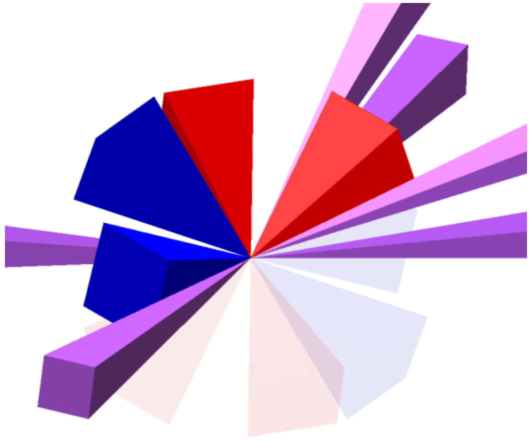

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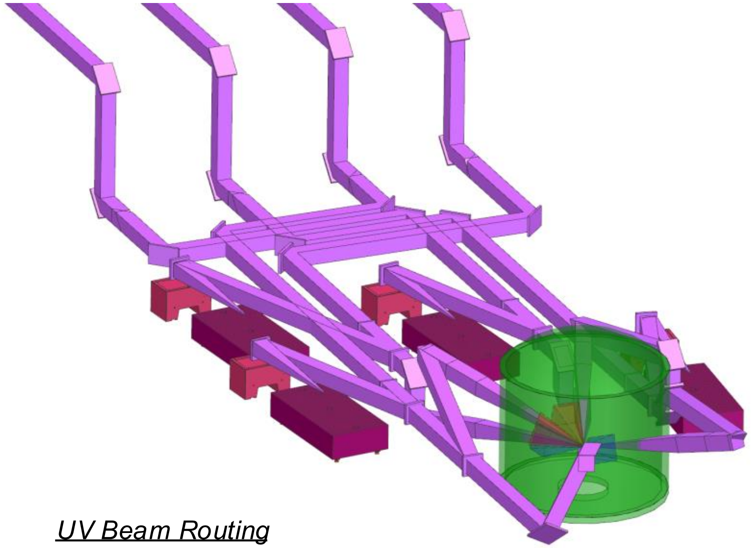
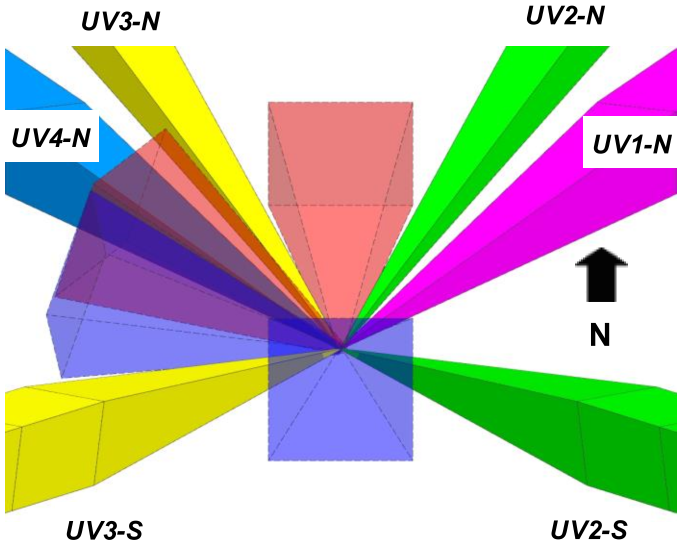


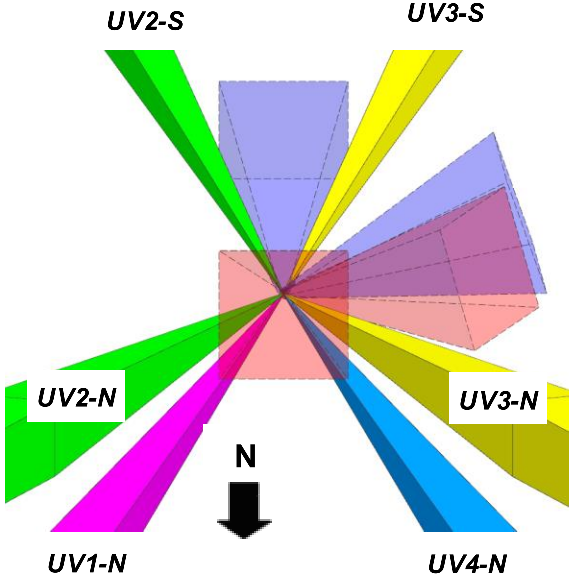
UV Beam Routing

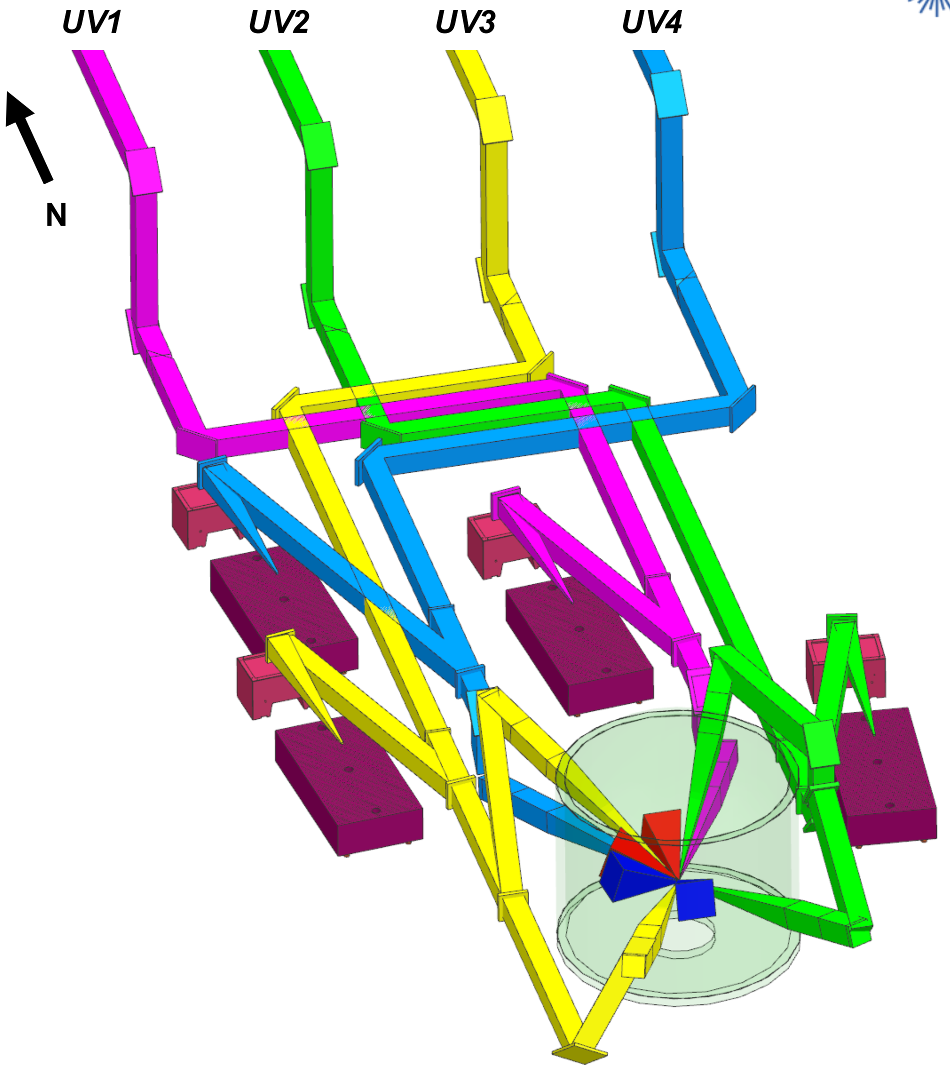
OMEGA EP beam mapping to NSF OPAL

- **EP long pulse (LP) beam performance is the same when terminated to the NSF OPAL MTC**
- **Beam 2 & 3 may terminate either from the North or South which permits a 4-beam array or a 2-by-2, opposing configuration**

Beam	θ(°)	φ(°)
UV1 North	100	337.5
UV2 North	80	337.5
UV3 North	80	22.5
UV4 North	100	22.5
UV2 South	72	202.5
UV3 South	72	157.5

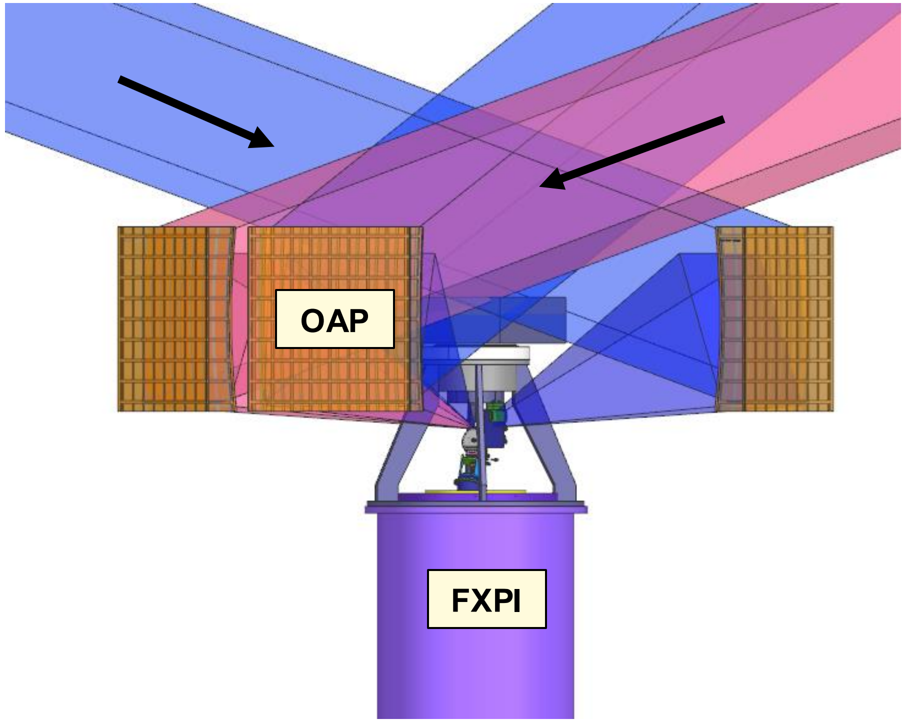






Several constraints must be accounted for when designing the experimental layout

(1) **Beam transport to the Off-Axis Parabolas (OAPs) is from above**

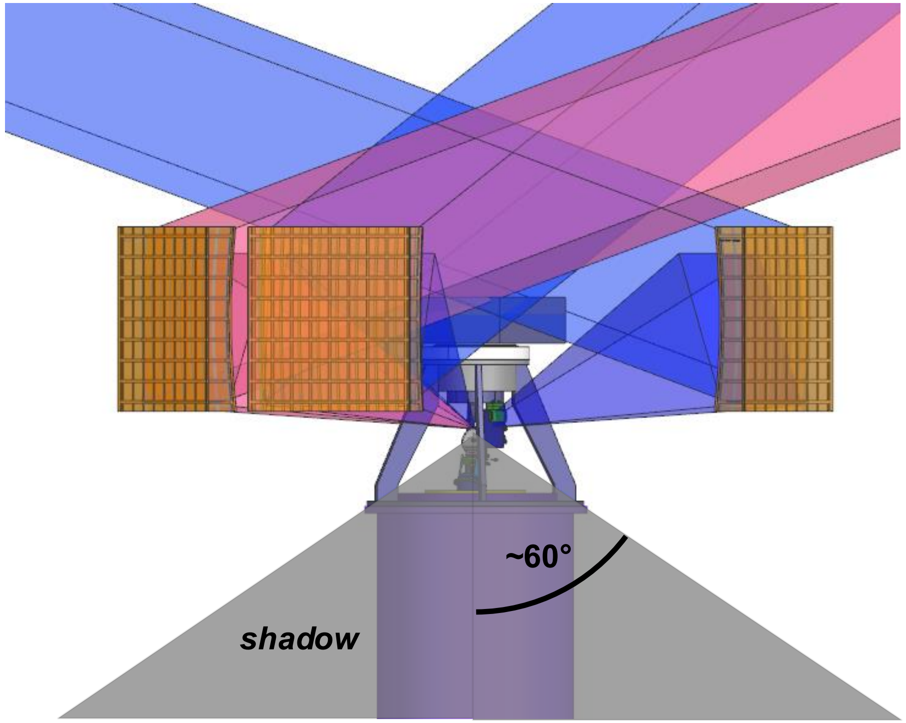


Some upper hemisphere diagnostics cannot be inserted or will have limited insertion depth.

Several constraints must be accounted for when designing the experimental layout

(1) Beam transport to the Off-Axis Parabolas (OAPs) is from above

(2) The Flexible Platen Interface (FXPI) blocks direct line-of-sight to Target Chamber Center (TCC) from lower hemisphere diagnostics



Some upper hemisphere diagnostics cannot be inserted or will have limited insertion depth. Diagnostics will not be deployed from 120° ≤ θ ≤ 180°.

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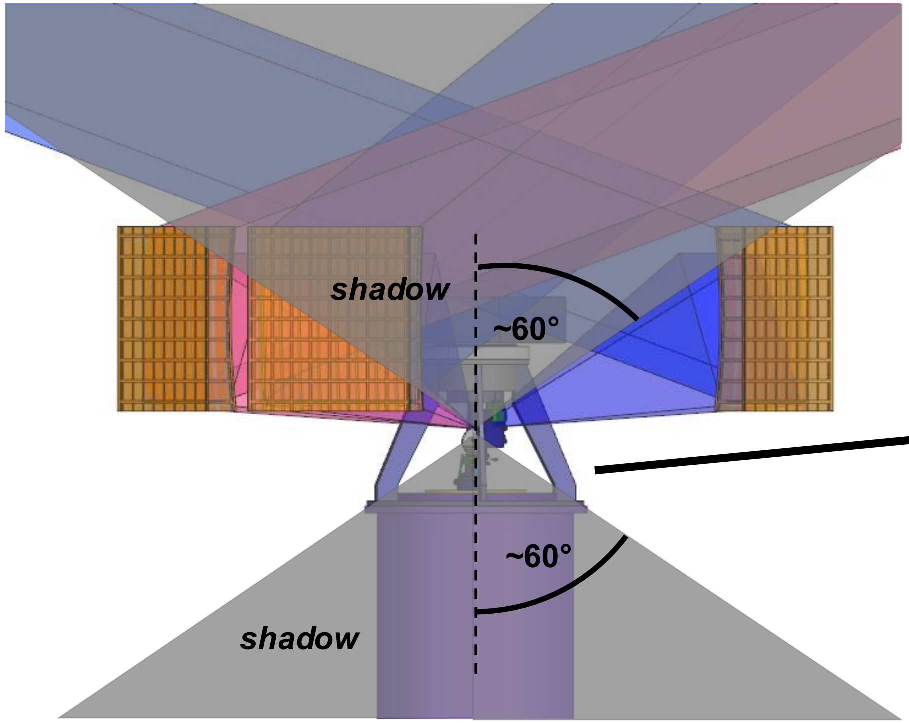

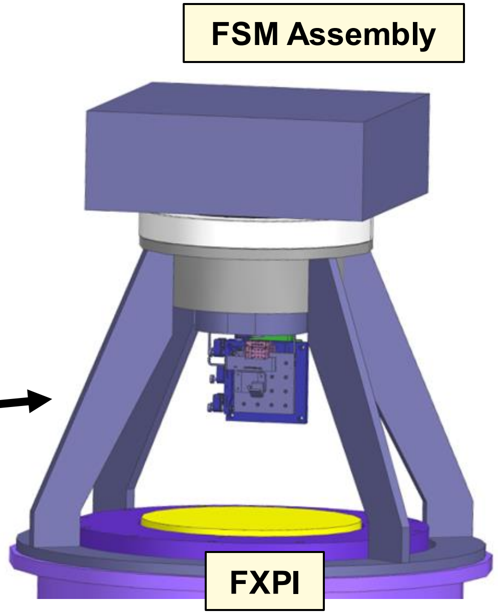

Some upper hemisphere diagnostics cannot be inserted or will have limited insertion depth.
Diagnostics will not be deployed from 120° ≤ θ ≤ 180°.
When FSM is installed, there will be no LOS availability from 0° ≤ θ ≤ 60°.

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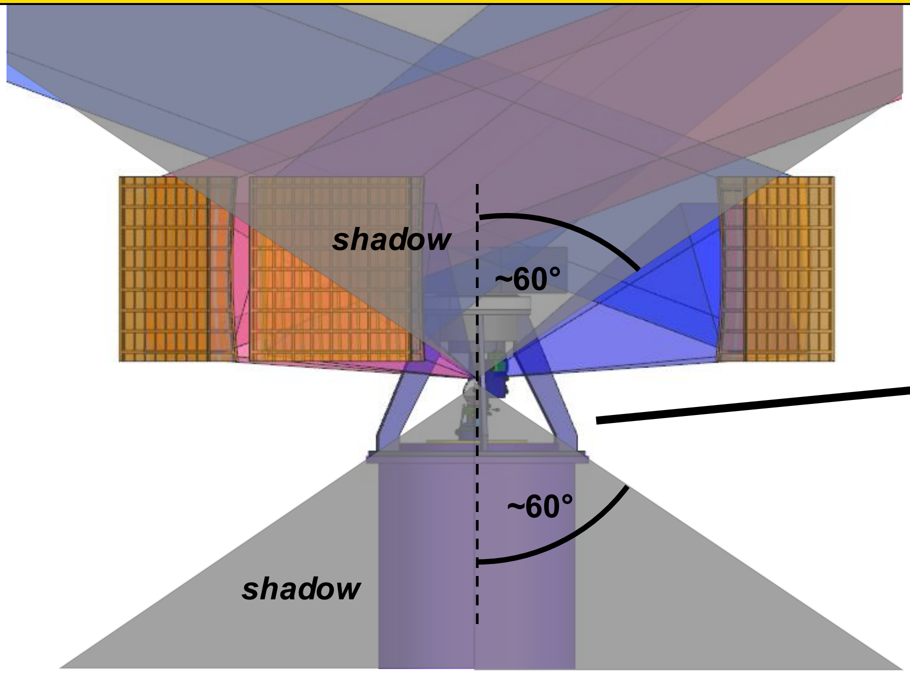
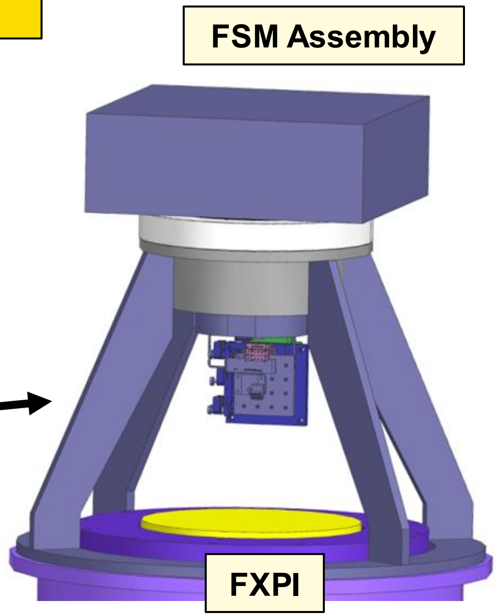
- Critical LOS from the top need to be identified very soon
- Note that FSM may not be used for all shot types





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Diagnostics will not be deployed from 120° ≤ θ ≤ 180°.
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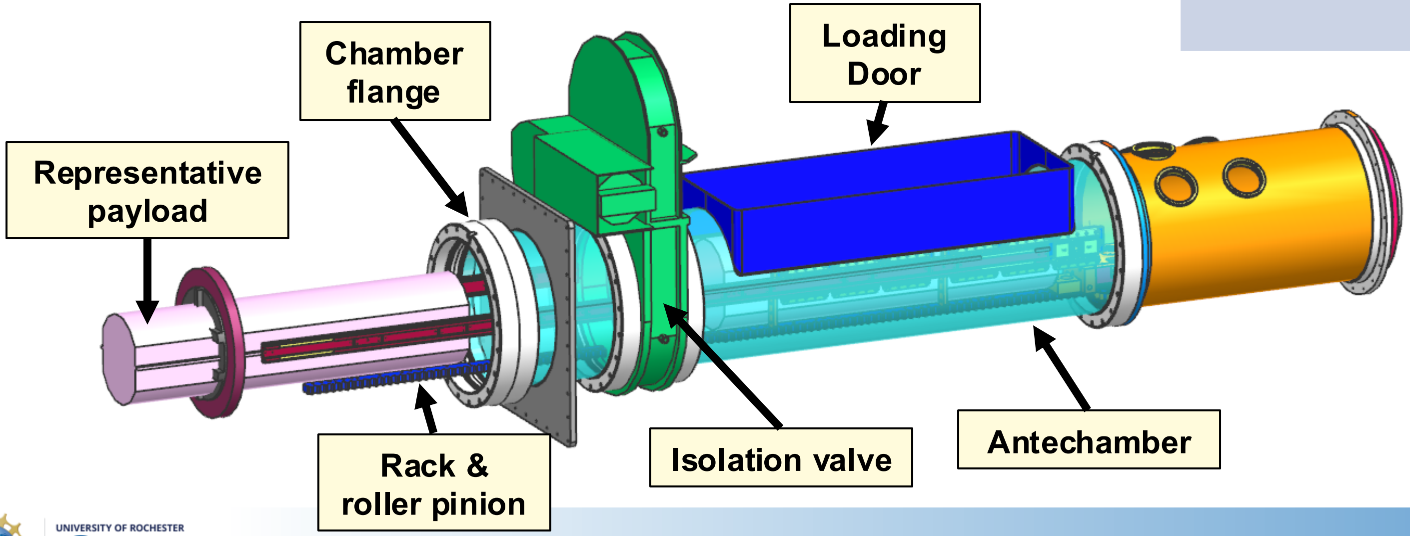
OPAL Diagnostic Inserters (ODIs) provide a platform to deploy modular diagnostics

- **Provides a standardized interface for deploying modular diagnostics**
- **Adaptable to field OMEGA TIM-based diagnostics**
  - ***This will be important when commissioning the system***
- **Allows IP/Film and other consumables to be swapped intervolley without breaking chamber vacuum**

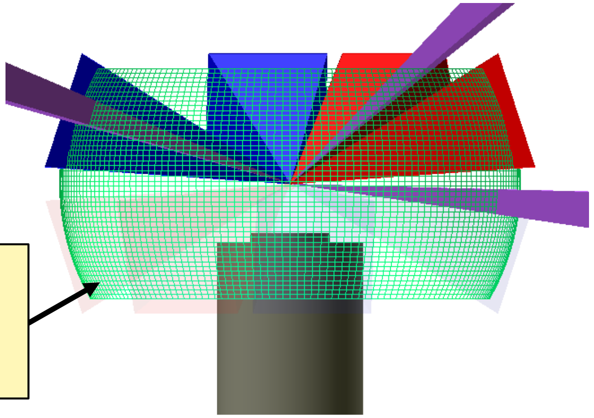
Requirement	Specification
Payload weight	400 lb.
Payload size	12 in. diameter, 42 in. length
Positioning	60 mm pointing range (U/D, L/R) <20 um insertion repeatability
Vacuum	10^{-6} Torr, independent from MTC
Utility services	Ethernet, high voltage (HV), low voltage, optical communication, optical supply, trigger/monitor, cooling

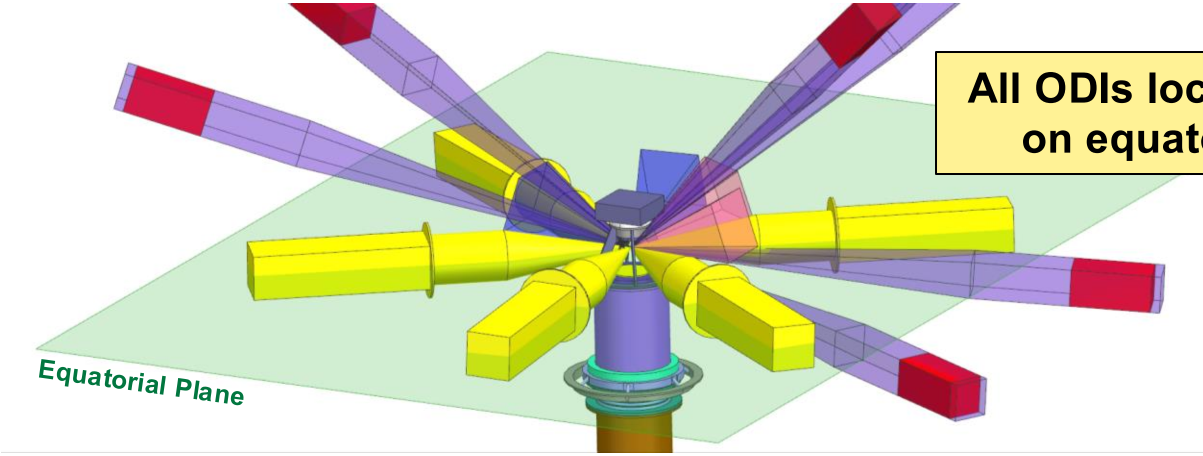


Five (5) ODIs are planned to be installed in support of MTC experiments

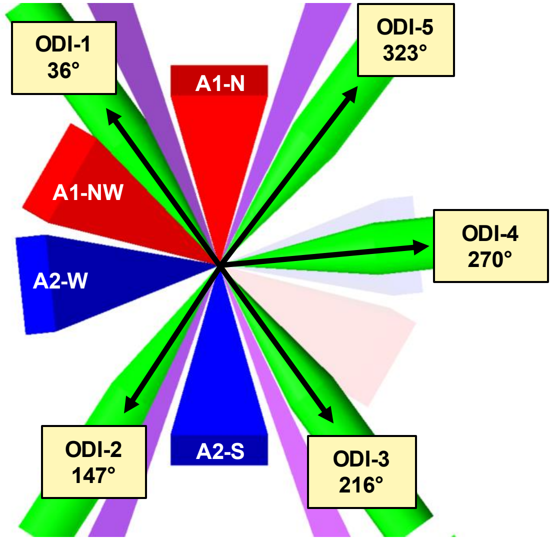
ODIs are located on the equator

Accessible solid angle for diagnostic LOS





All ODIs located on equator

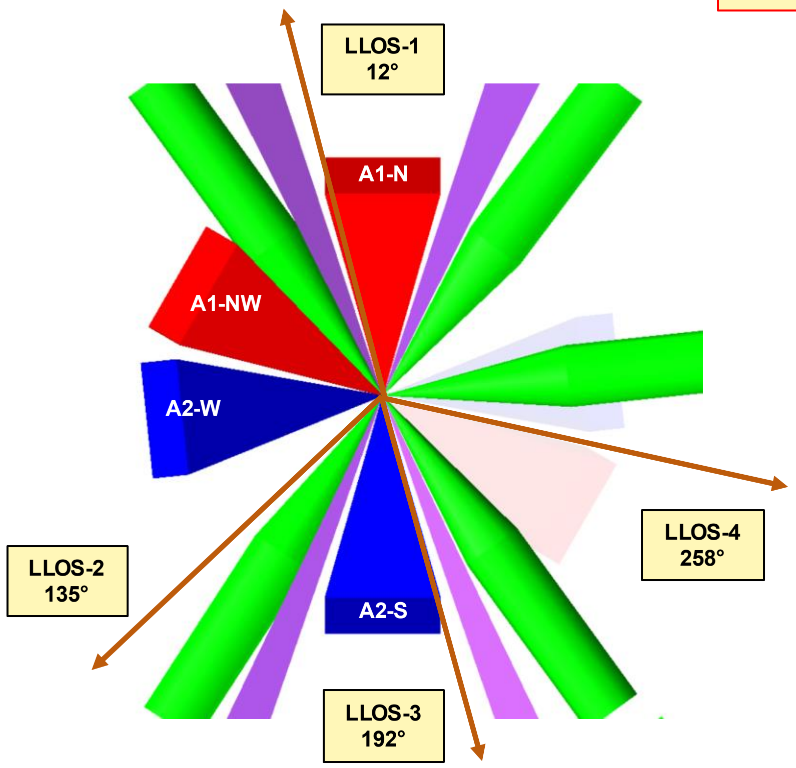


ODI Angles w.r.t. Alpha Beams

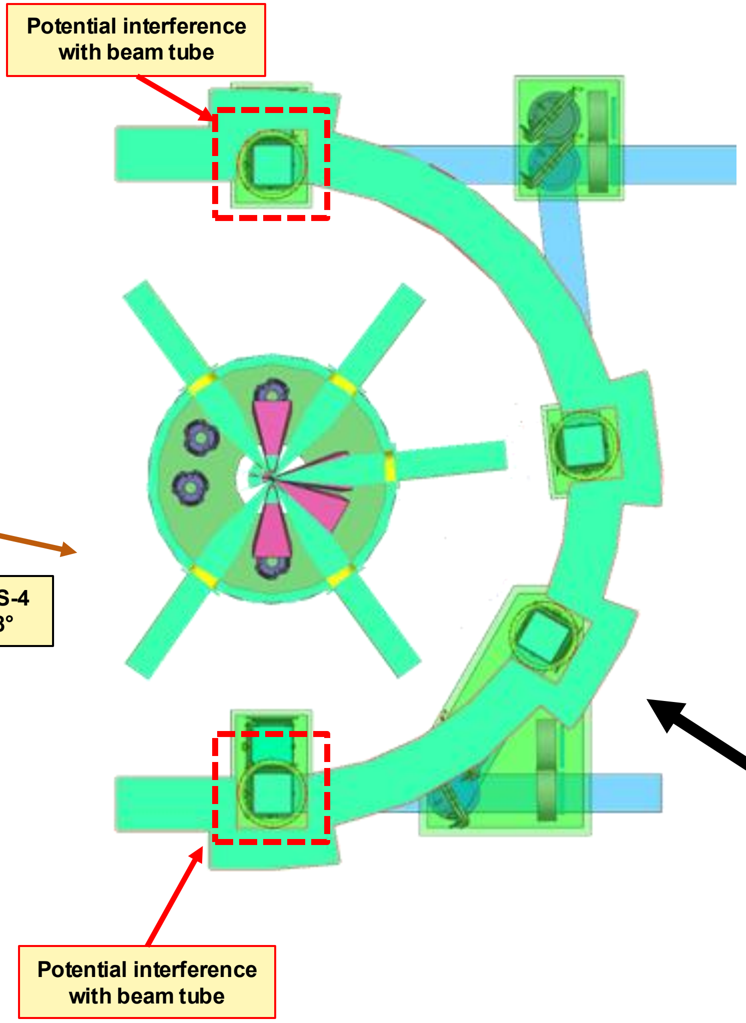
Beam	ODI-1	ODI-2†	ODI-3	ODI-4	ODI-5†
Alpha-1 N*	39.7	139.4	140.3	90	40.1
Alpha-1 NW	29.7	83.3‡	150.3	145.5	96.7‡
Alpha-2 W	56.1	49.5	118.3	161	130.5
Alpha-2 S	140.3	40.6	39.7	90	139.4

** Assumed to be the first beam brought online and the primary beam moving forward*
† Antipodal to one another
‡ Moving A1-NW could make these 90°

Long Lines of Sight (LLOS) allow diagnostic standoff distances up to 20m

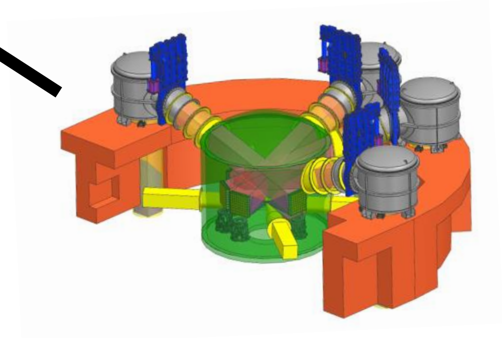


All LLOS are angled down 18°

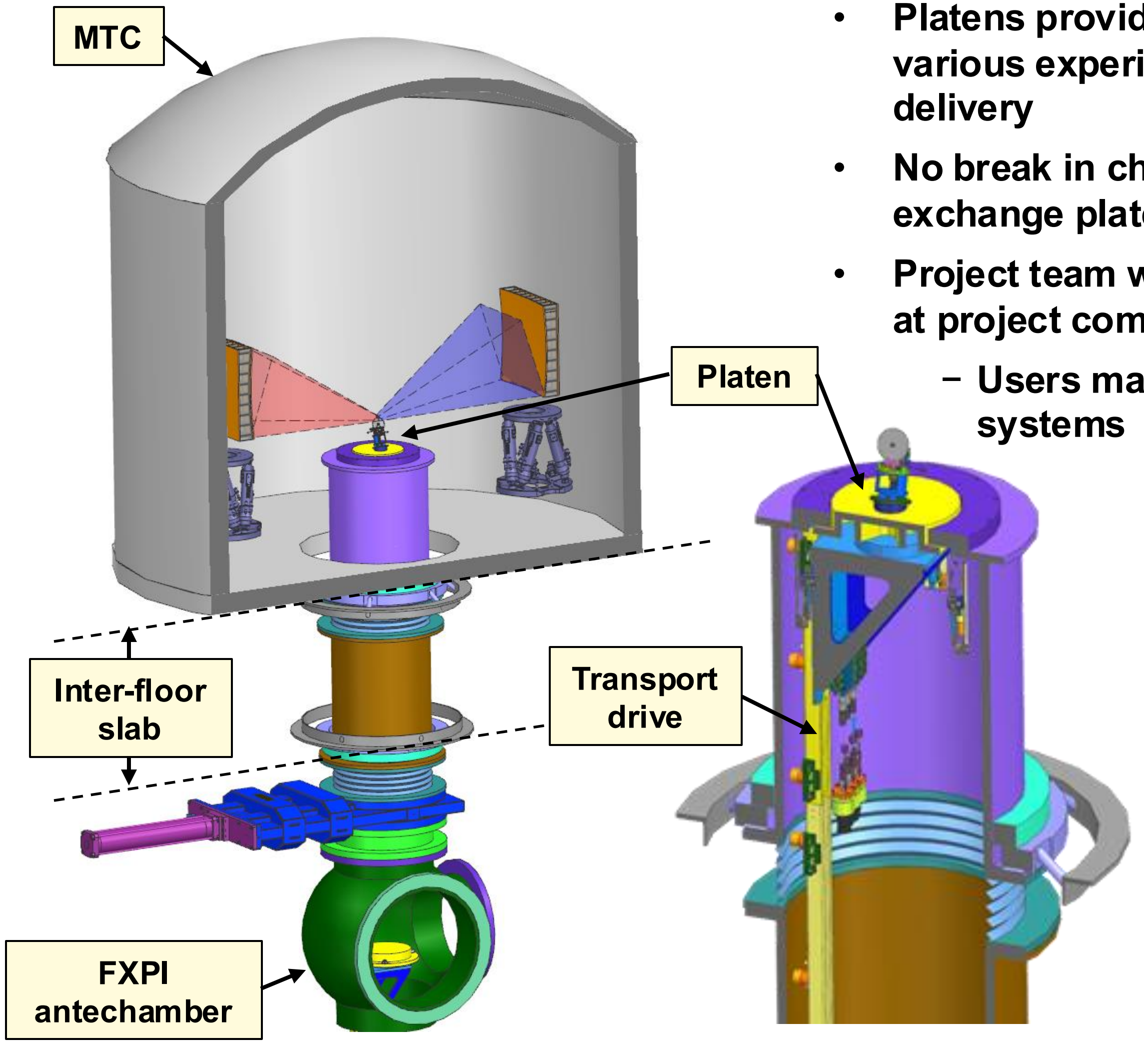


LLOS Parameter	Value
Standoff distance	20m +/- 5m
LOS tube diameter	20cm
Vacuum level	4 x 10^{-5} Torr

- Long Lines of Sight will be used for diagnostics that require a large SOD, such as nTOF
- Listed locations are ***preliminary***
- Considerations for determining placement include interferences with beam periscope tubes and minimum incident angle of beam on target

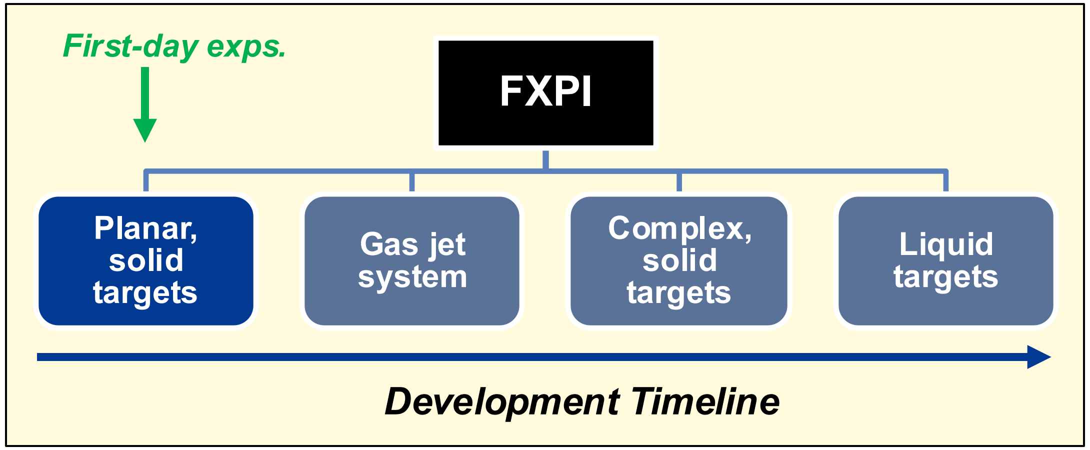


The Flexible Platen Interface (FXPI) provides a stable platform that deploys payloads near TCC

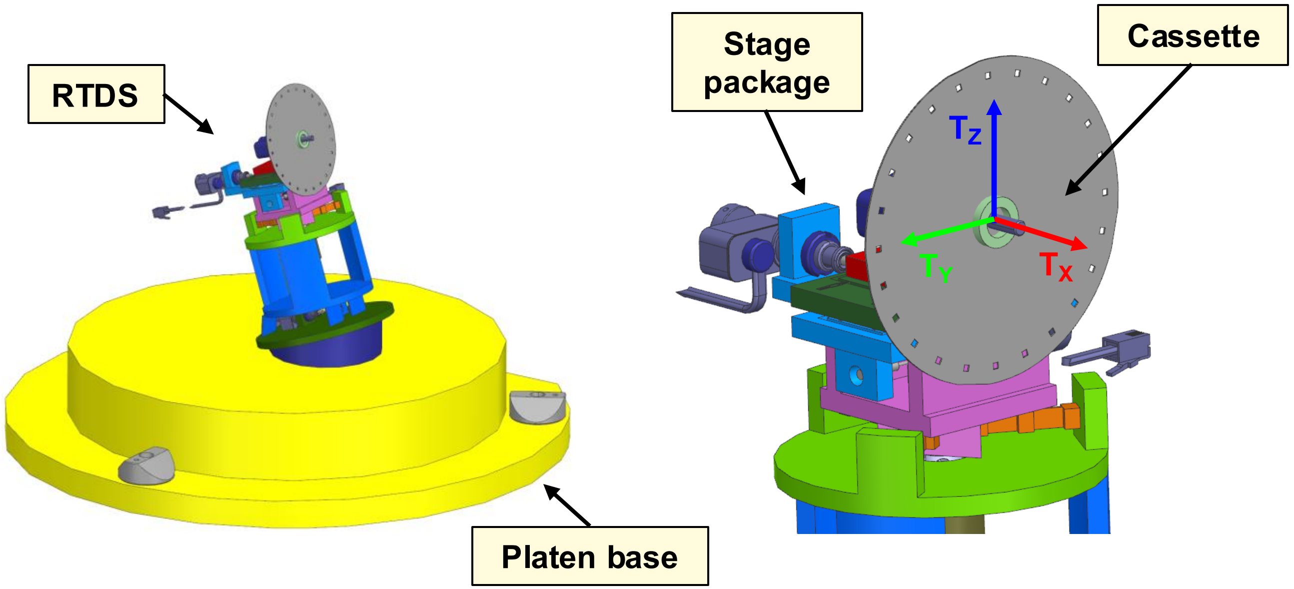


- Platens provide a standardized interface for various experimental systems, such as target delivery
- No break in chamber vacuum is required to exchange platen components
- Project team will provide planar target system at project completion
  - Users may provide other platen-deployed systems

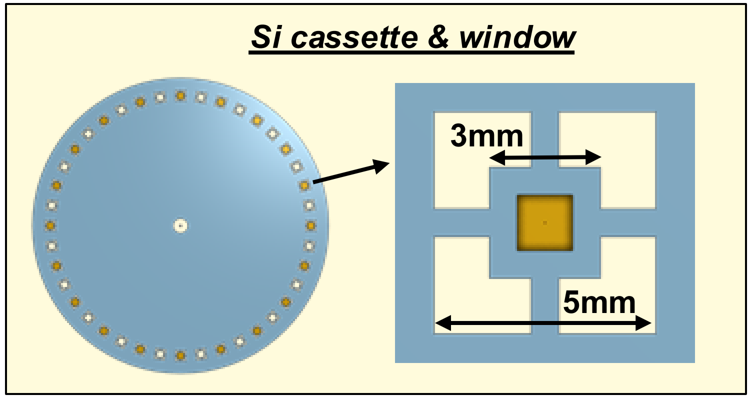
FXPI Parameter	Value
Platen Size	16 in.
Stability	< 1 um
Docking distance from TCC	12 in. below
Travel Time	< 10 min.
Load capacity	500 lb.
Utilities provided	Power, communication, HV, gas supply

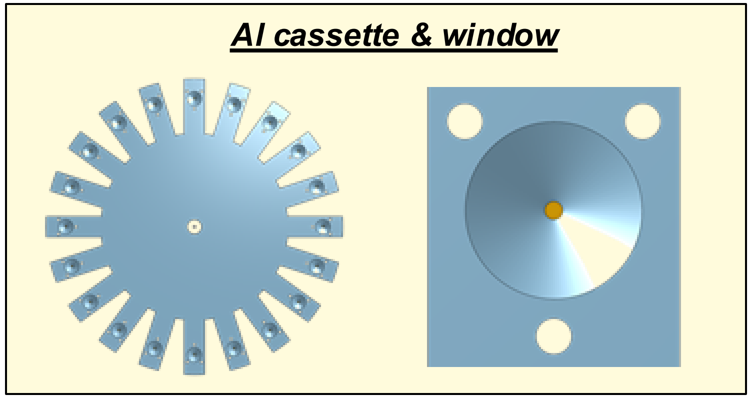


The Rapid Target Deployment System is capable of deploying solid targets with µm-level accuracy within a 5-minute shot cycle



RTDS Parameter	Value
Degrees of motion	*Preconfigured:* (R_Z/R_Y) *Dynamic:* ($T_X/T_Y/T_Z/R_X$)
Positional accuracy	< 1 um T_X (beam focal axis) ~ 5 um T_Y/T_Z (transverse to beam) < 1°R_Z/R_Y < 1' R_X
Cassette Material	Si or Al
Max. # of targets per cassette	20
Target window size	2.2mm square (Si) 500um circle (Al)
Cassette diameter	4 in.



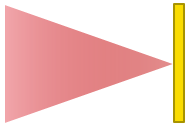


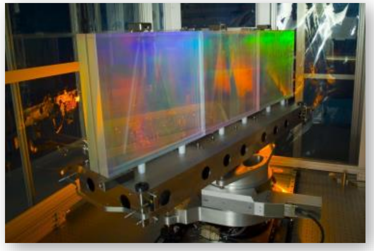
- **Fine adjustments are made along beam axis (T_X)**
- **Course adjustments are made transverse to the beam (T_Y/T_Z)**
- **RTDS assembly is roughly aligned offline to platen interface**

Other limitations have been set to protect the system from catastrophic damage

Targets may not be normal to any Alpha/Beta beam (at least initially)

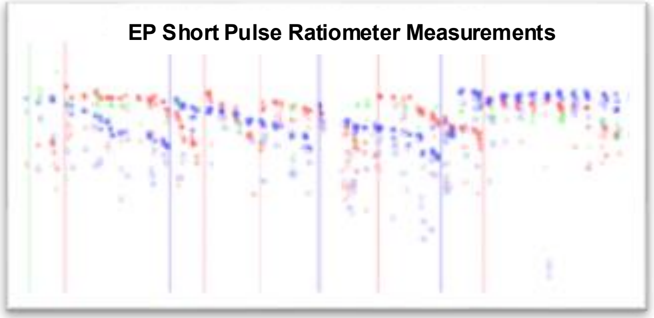
- A retro reflection directed back up the beamline could cause damage to gratings
- We are working on identifying a minimum angle to provide to users
- The use of Dual Plasma Mirrors (DPMs) is a potential mitigation strategy that will be pursued





Target mass will be limited for most OPAL campaigns

- OAP degradation and damage must be minimized due to the expected high cost of optics
- A 5-min. shot cycle amplifies this concern
- Sub-millimeter targets should become the norm



There will be a radiation dose limit imposed for each campaign

- Ionizing radiation will be managed using several methods:
  (1) a shield wall, (2) various campaign-specific shielding schemes,
  (3) controlling directionality of source terms, and
  (4) limiting number of shots taken.
- Each campaign will claim a portion of the annual facility dose limit.
- Pre-campaign source term estimates will be critical to inform this calculation.

Title 10, Part 20, of the *Code of Federal Regulations* (10 CFR Part 20):
- **Non Radiation Worker Dose Limit:**
  - 100 mrem/year*
  - 2 mrem / hour

*For radiation workers, the limit is 5 rem

The design team needs your input to ensure the NSF OPAL facility can accommodate your experiments!

- The design team has bounded the facility's design around the Flagship Experiments.
  - In order to maximize experimental compatibility, other Experimental Use Cases must be defined
- An EUC Proposal Template is available here: https://nsf-opal.rochester.edu/wp-content/uploads/2025/09/Experimental-Use-Case-Summary-Template-2025-09.pptx
  - Please fill out template for each experimental use case you would like considered
  - Submissions should be uploaded here: https://rochester.app.box.com/f/e61914d25b3048b68a6c6dbc842db003

Other resources are available:

- An interactive web-based model of the MTC is available here: *https://kgib.github.io/lle-model-viewer/*
- CDR content and other NSF OPAL documentation is available here: https://nsf-opal.rochester.edu/documentation/

Questions?

Head to the NSF OPAL website – https://nsf-opal.rochester.edu - for more information on today's updates

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- **Contact Mike Krieger to join Experimental System Meetings**
  mkri@lle.rochester.edu