# UV Stray-Light Management on OMEGA EP


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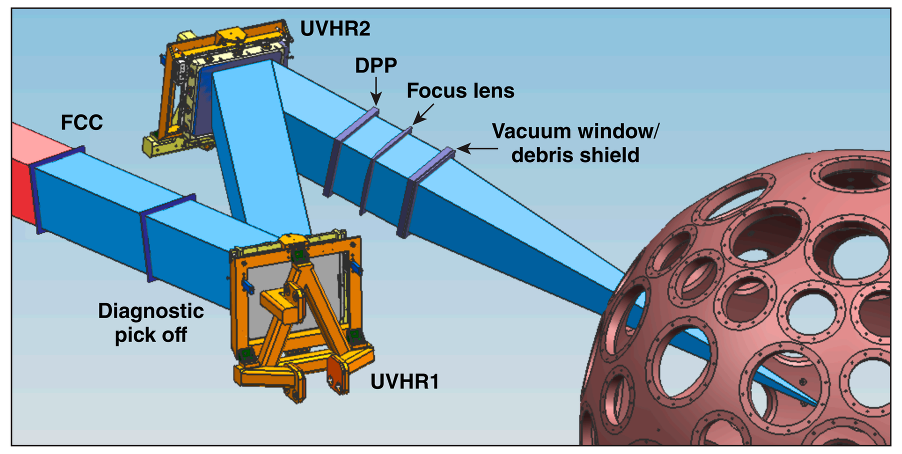
## UV transport mirrors began damaging at an increased rate mid-2014



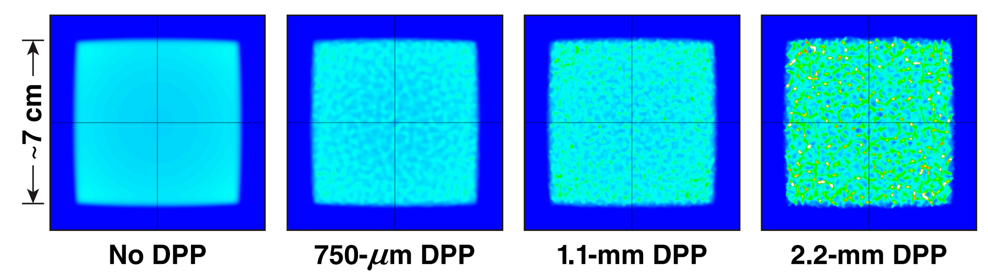

- The final UV transport mirror UVHR2 showed the most damage
- Energy limits had not recently been increased

UVHR: UV high reflecter
DPP: distributed phase plate
FCC: frequency-conversion crystal

G10328

## DPP design variation strongly influences near-field modulation

Ghost intensity profile on UVHR2




- Although the 750-$\mu$m DPP does not significantly increase the peak ghost fluence above that of the no-DPP case, the 1.1-mm and 2.0-mm DPP's produce much greater peak intensity
- The peak intensity of the 1.1-mm and 2.0-mm DPP's are ~5× and 25× that of the forward-going beam

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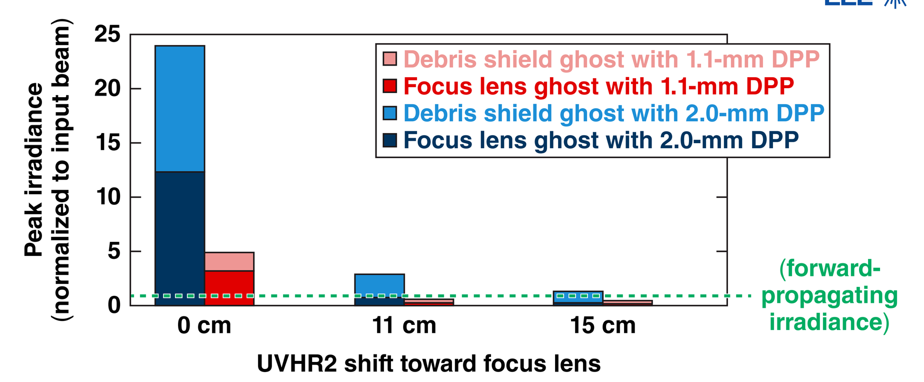
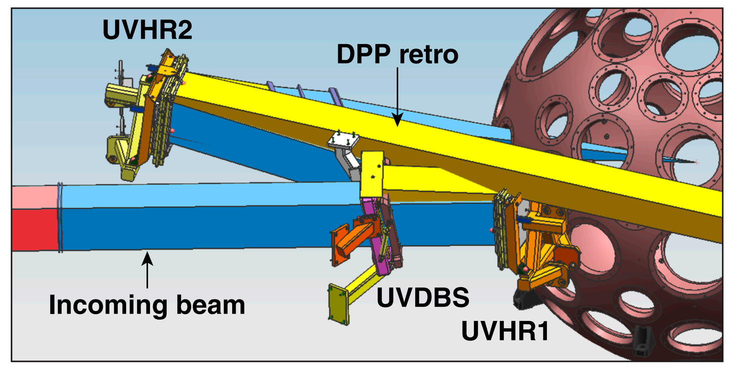
## A small translation in position reduces peak fluence on UVHR2




- The stacked bars represent the sum of fluence from multiple ghosts
- Equivalent propagation distance for DPP near-field modulation grows much faster than actual propagation distance in a converging beam resulting in significant changes in peak irradiance for small mirror translations

G10334

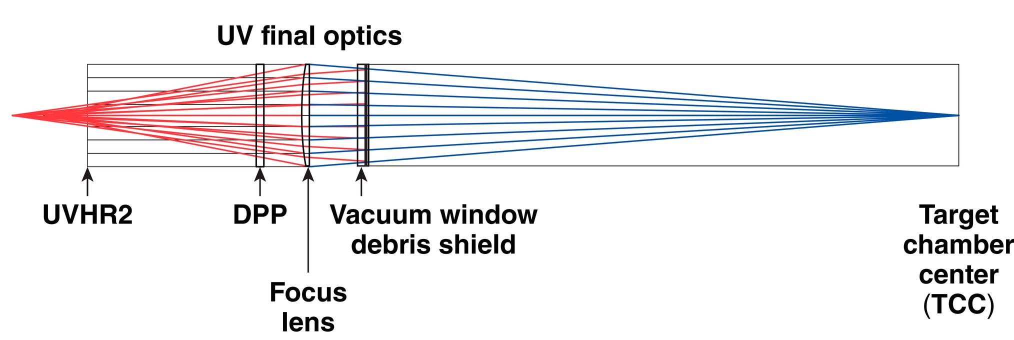
## A first-order ghost from an imprinted DPP surface is tilted to leave the beam path




- A 1.8° tilt ensures that the collimated ghost is out of the clear aperture prior to reaching the first transmissive optic, the UV diagnostic beam splitter (UVDBS)
- Removing collimated retro mitigates threat of small-scale self- focusing within the optic

G10446

## Damage was caused by counter-propagating ghosts




- The damage region was traced to match the area illuminated by converging ghosts from surfaces in the focus lens, vacuum window, and debris shields
- The expected ghost intensity was well below that of the forward-going beam

G10329

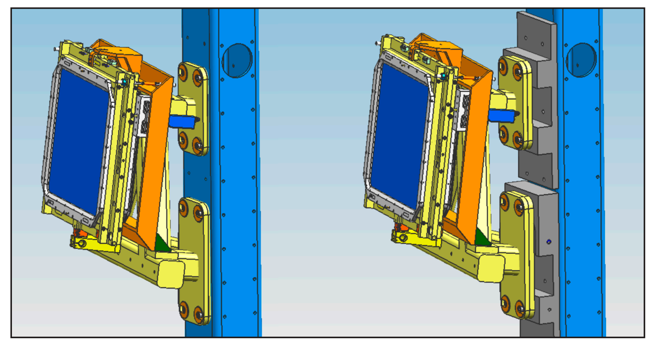
## Degradation of final-optic antireflective (AR) coating was a contributing factor that increased the rate of damage

- In an effort to reduce the ghost intensity, the AR coatings on debris shields, focus lenses, and vacuum windows were reapplied
- Ghost intensity at UVHR2 of the UV alignment laser was measured before and after the AR recoating were reapplied
- As a result ghost intensity was reduced by ~10×
- Debris shields are subject to the deposition of target materials and can exhibit significant increases in reflectivity to as high as 5% to 10%
- A program to monitor performance of and periodically replace AR coatings has been implemented

**Debris-shield AR performance can degrade significantly over a relatively small number of shots.**

G10332

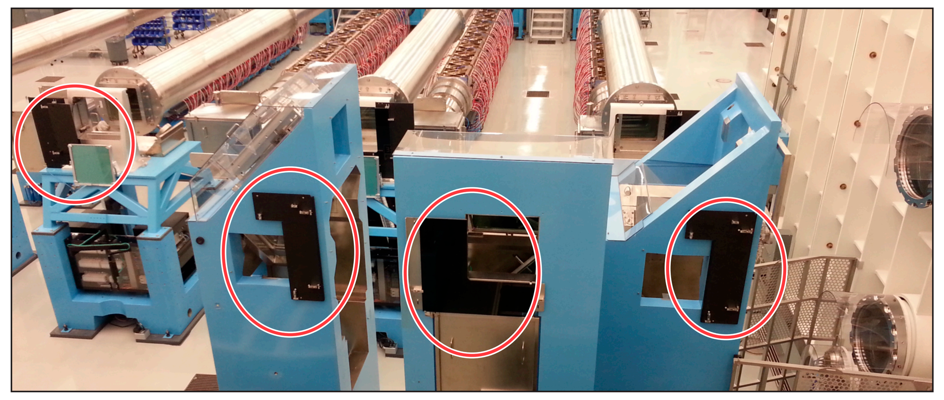
## An 11-cm shift of the UVHR2 position has been implemented



- Translation was accomplished by spacing existing mechanics off of the support column
- The cost to implement was significantly less than that to acquire a new set of 1.1-mm DPP's
- A 15-mm shift could have restored the existing 2.0-mm DPP to near full energy but would have required significantly more mechanical work and was not cost-effective

G10335

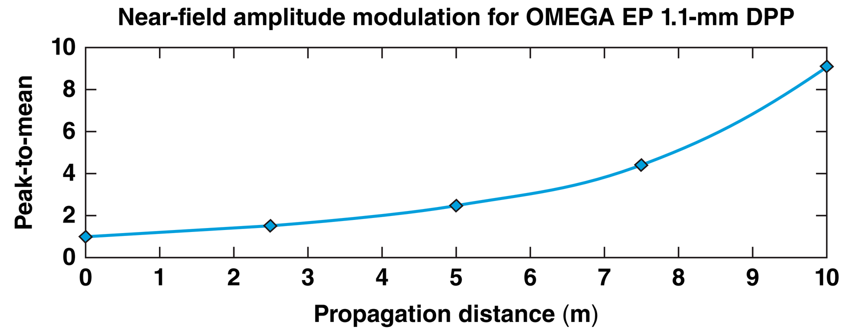
## Armoring is used in the IR/UV transport path to absorb collimated retroreflected light



- Areas potentially illuminated by light retroreflected by frequency-conversion crystal (FCC) surfaces were armored to protect metal and painted surfaces
- FCC retroreflections were expected to be as high as 1%

G10447

## DPP near-field amplitude modulation grows rapidly with propagation distance




- A converging beam exhibits effective propagation distances greater than the actual propagation distance as given by the Tanalov transformation $z' = \frac{z}{1 - \frac{z}{f}}$
- DPP designs developed for use on OMEGA EP were not adequately analyzed for their modulation effect on system ghosts
- When modulation from a DPP is present, ghost peak fluence is significantly greater than that of the forward-going beam

G10330

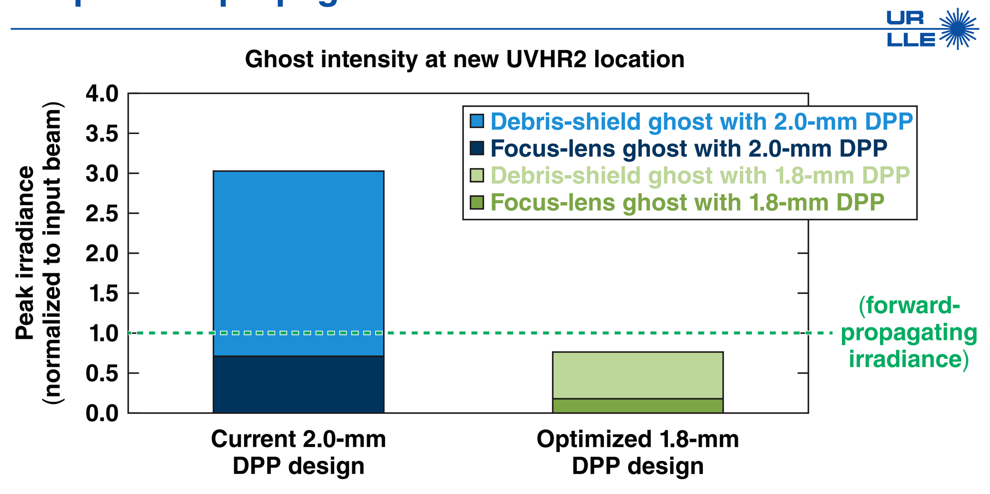
## Action was taken to protect downstream optics from modulation caused by damage on UVHR2

- Damaged UVHR2 mirrors were replaced to prevent downstream modulation from damaging DPP's, focus lenses, and vacuum windows
- Energy limits were significantly reduced when 1.1-mm and 2.0-mm DPP's were installed to prevent damage to new UVHR2 mirrors
- Other DPP's were not derated

| Long-pulse UV | | Energy limits (J) | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Any beam with | |
| On-target energy | Pulse length | Beam 1 | Beam 2 | Beam 3 | Beam 4 | 1.1-mm DPP | 2.0-mm DPP |
| Square pulse-shape values | 0.1 ns | 100 | 100 | 100 | 100 | 100 | 70 |
| | 1.0 ns | 1250 | 1200 | 1250 | 1250 | 620 | 220 |
| | 2.0 ns | 1950 | 1700 | 2250 | 2200 | 880 | 310 |
| | 2.5 ns | 2200 | 1900 | 2500 | 2450 | 980 | 350 |
| | 3.0 ns | 2400 | 2100 | 2750 | 2700 | 1080 | 380 |
| | 4.0 ns | 2800 | 2400 | 3150 | 3100 | 1240 | 440 |
| | 5.0 ns | 3100 | 2700 | 3550 | 3450 | 1390 | 490 |
| | 6.0 ns | 3400 | 2950 | 3850 | 3800 | 1520 | 540 |
| | 10.0 ns | 4400 | 3800 | 5000 | 4900 | 1970 | 700 |

G10333

## DPP design can be optimized to reduce modulation at specified propagation distances




- New 1.8-mm DPP's are being procured to replace the current 2.0-mm DPP and will be able to operate at full rated energy
- Modulation at the new UVHR2 location was minimized as a design criteria

G10336

## Collimated retroreflected light from tilted DPP's was not adequately managed

- Modulation on retroreflections from DPP's increases local intensity to a fluence capable of ablating painted and bare-metal surfaces
- Debris from paint ablation can contaminate optic surfaces and lead to plasma scalding
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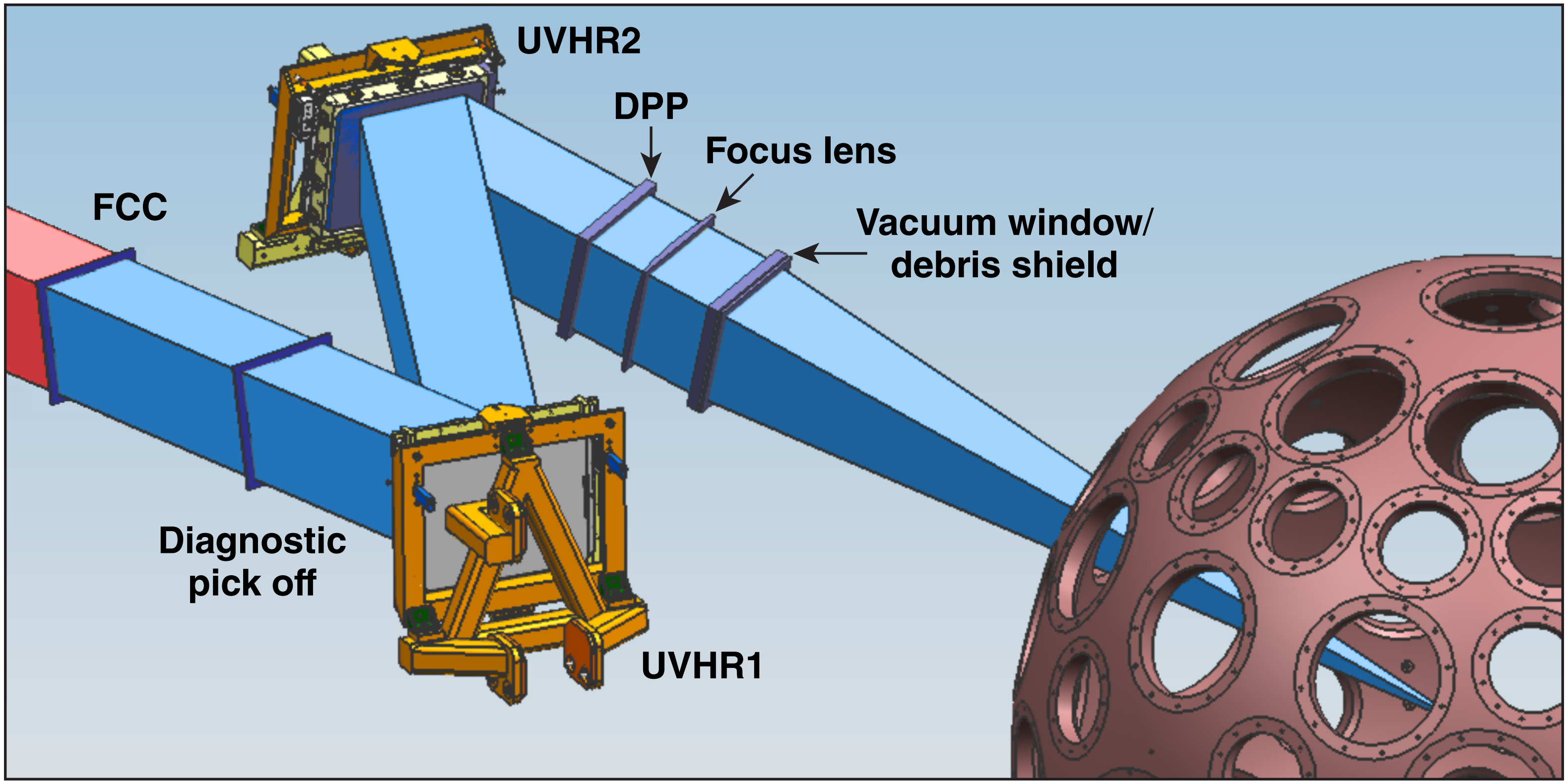


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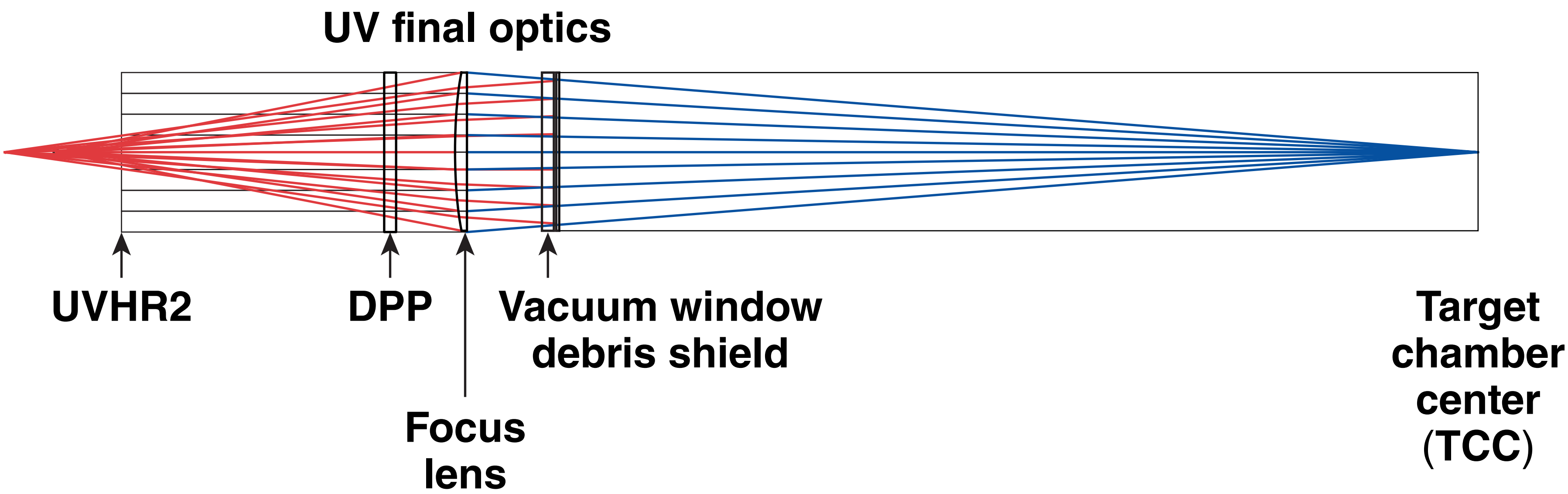


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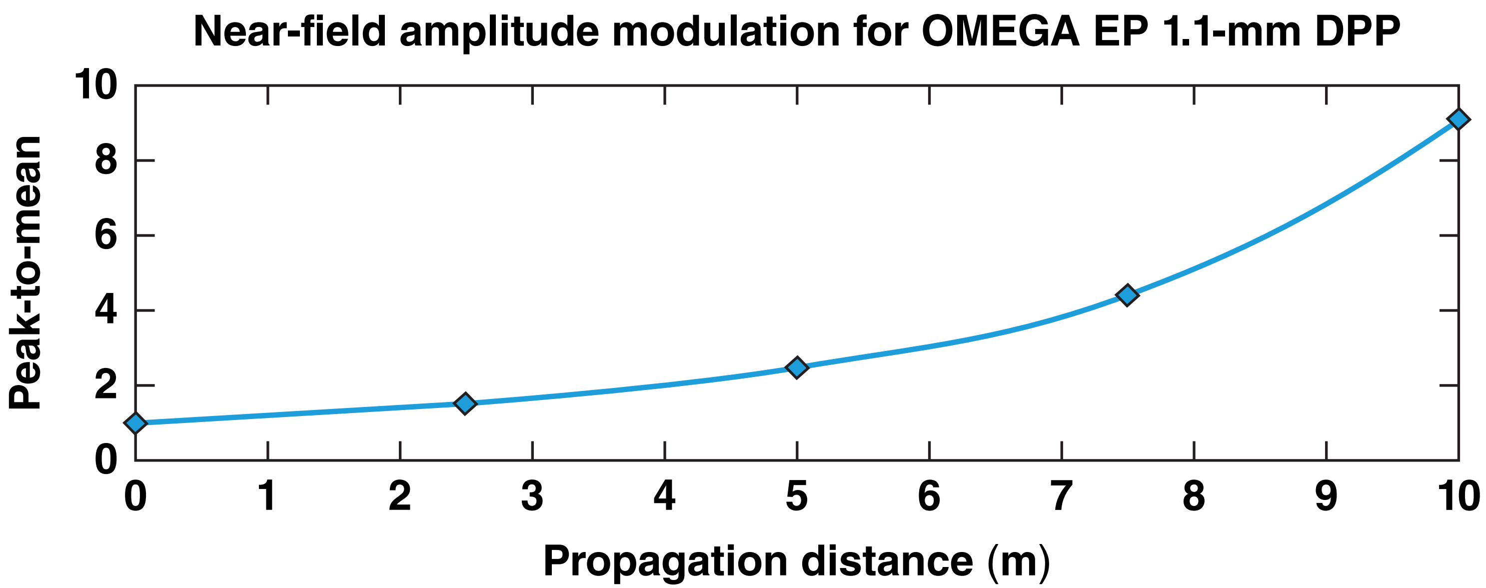


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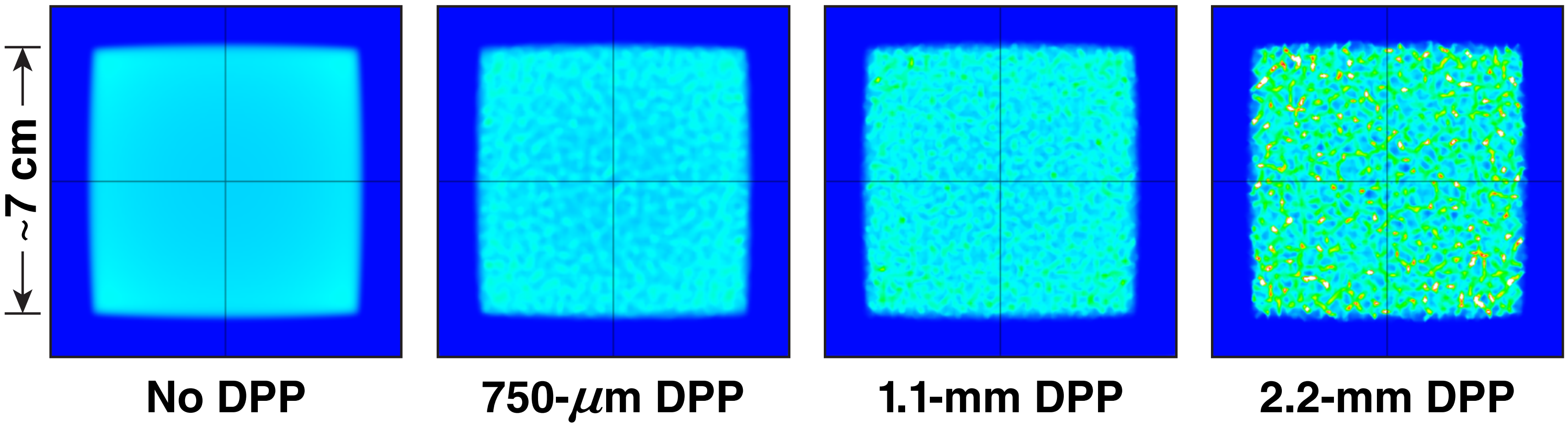


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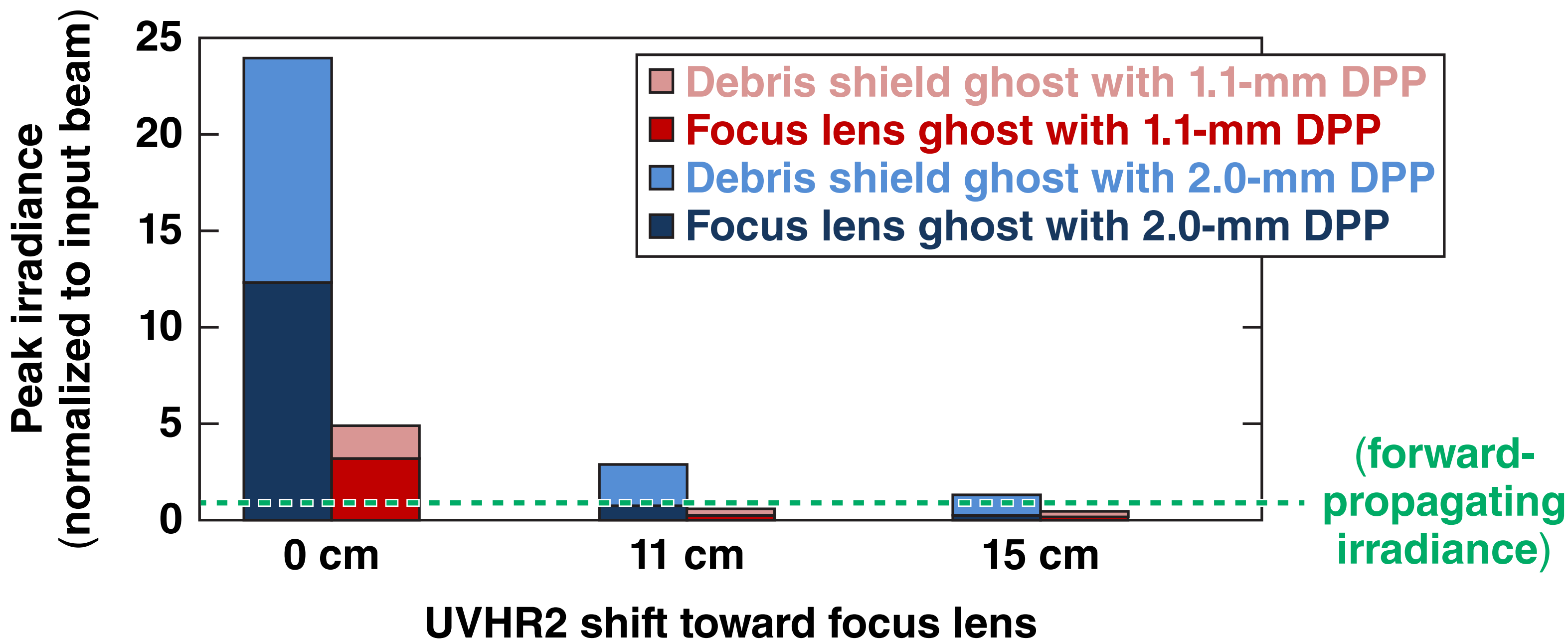


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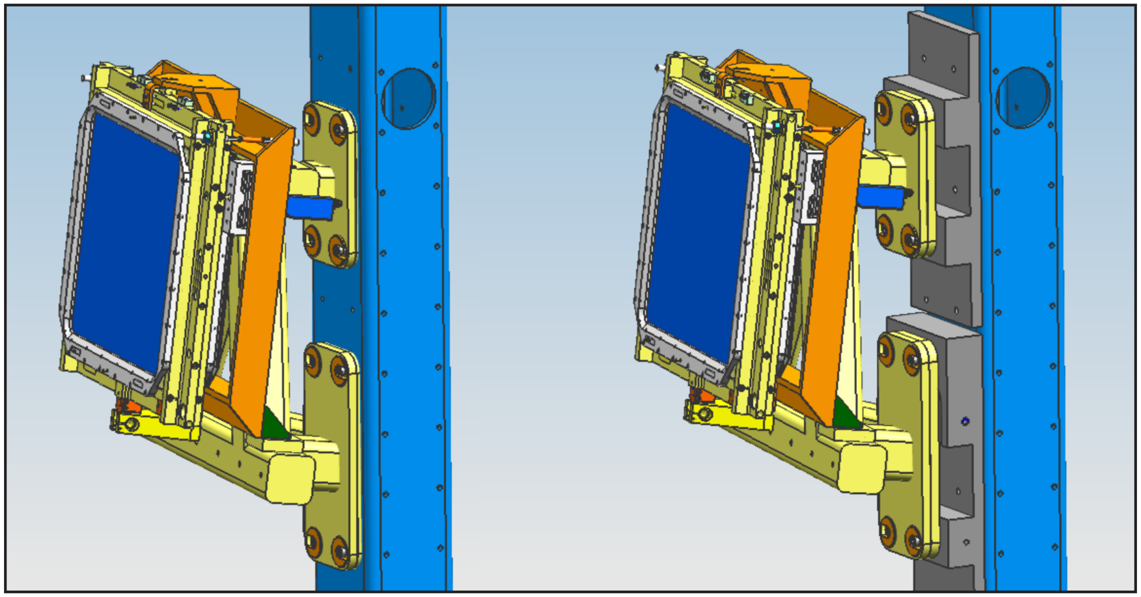

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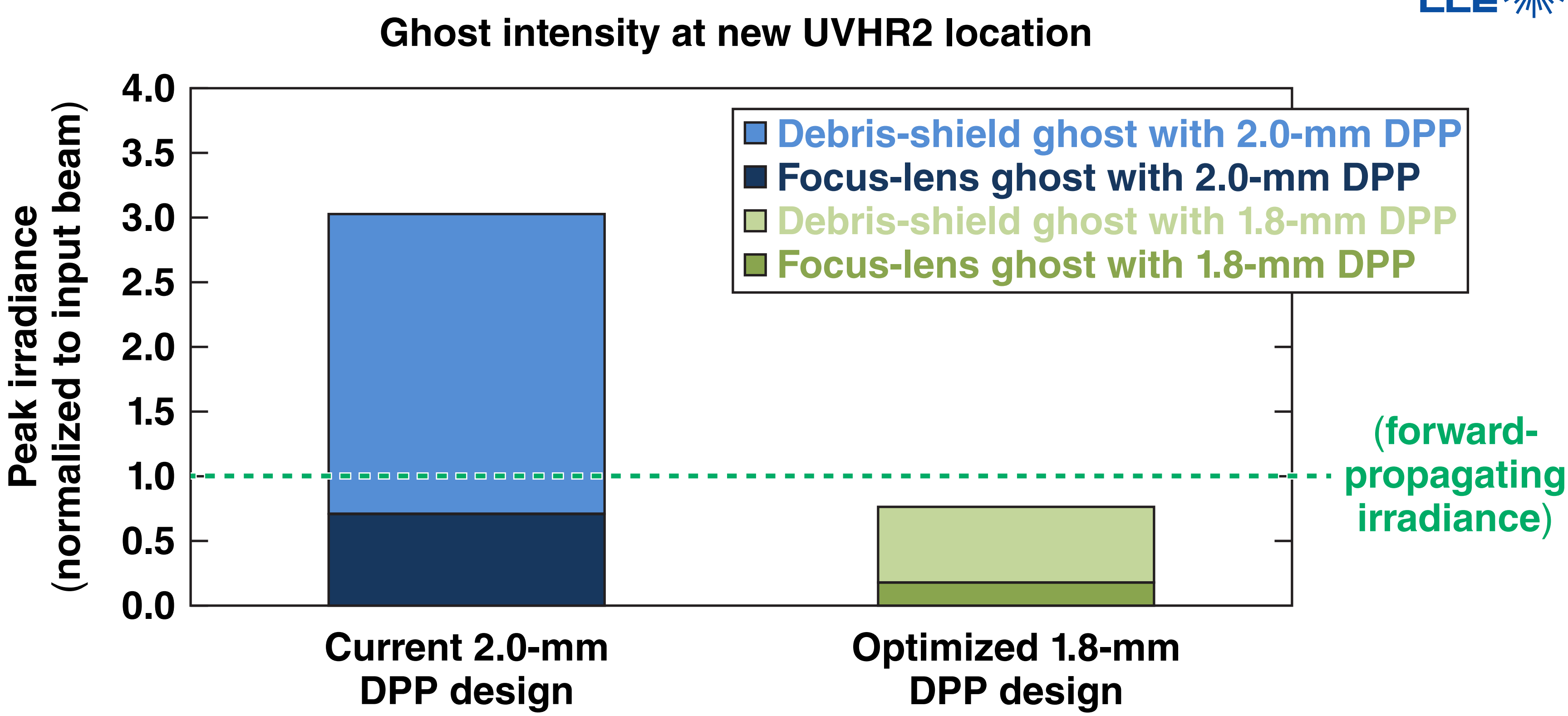


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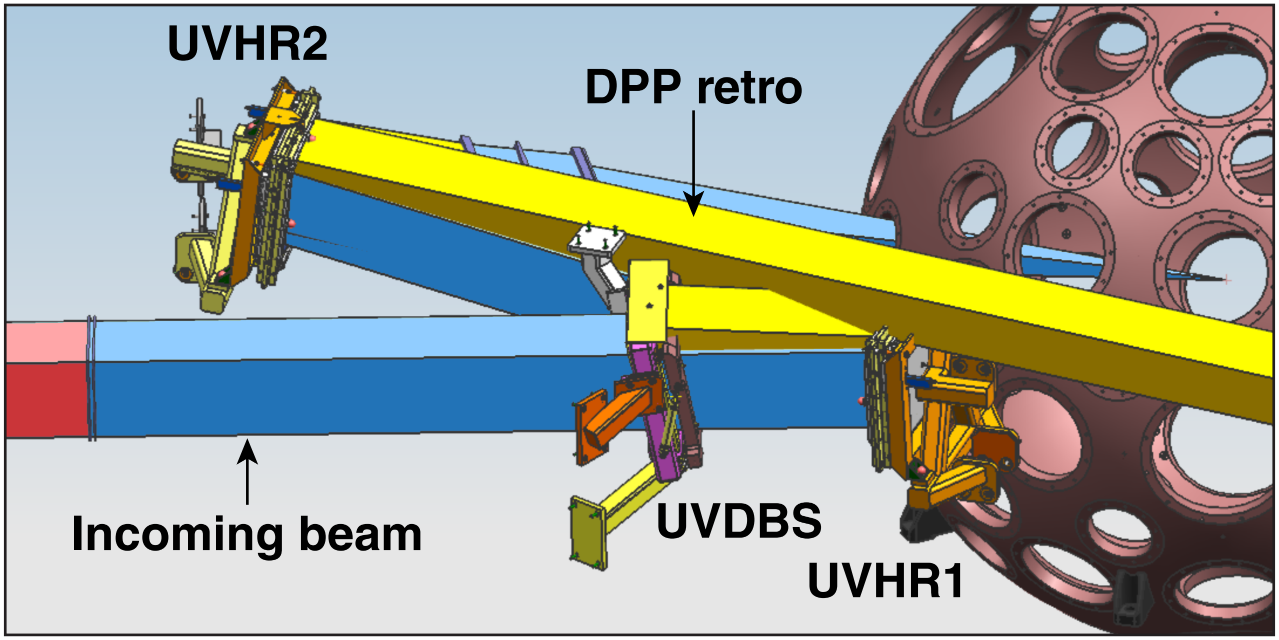


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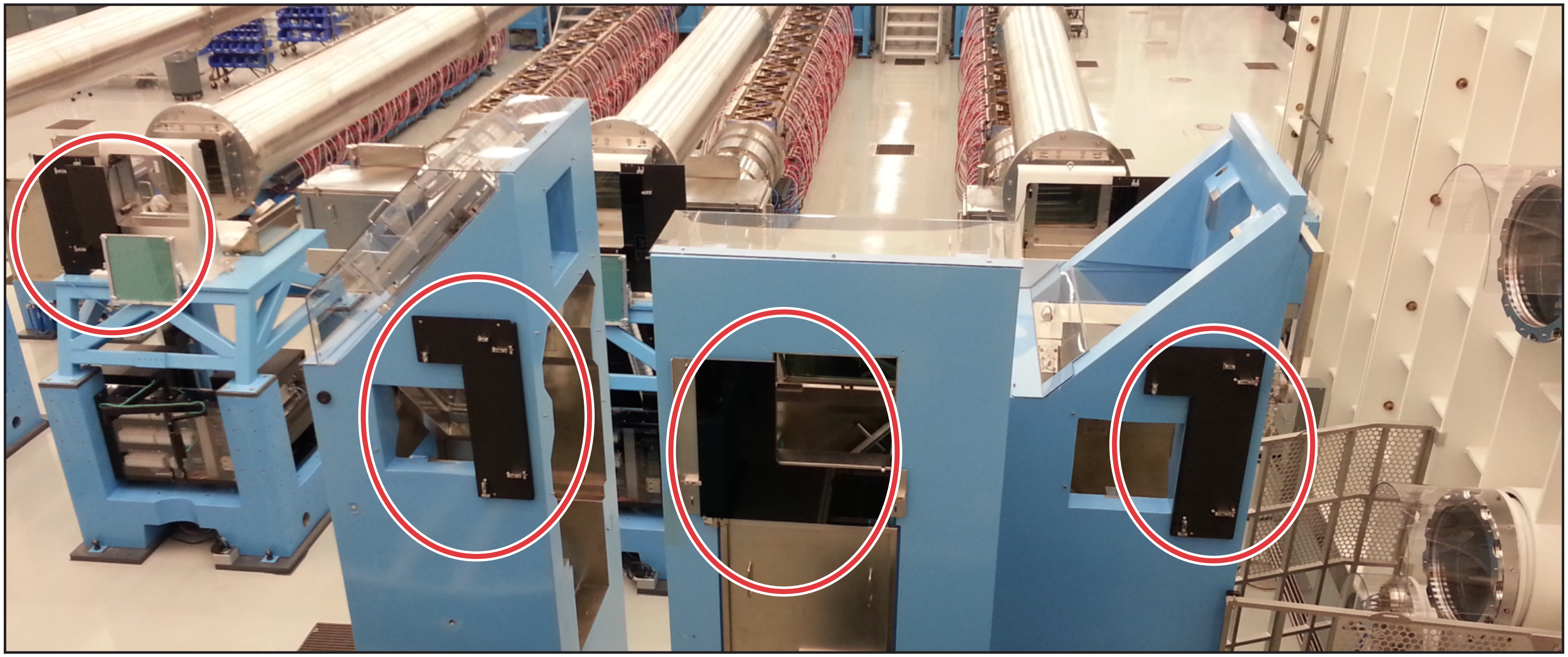

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