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Sandia National Laboratories

Improving the Laser-Induced Damage Thresholds of Beam Splitter Coatings for High Transmission (527 nm) and High Reflection (1054 nm)

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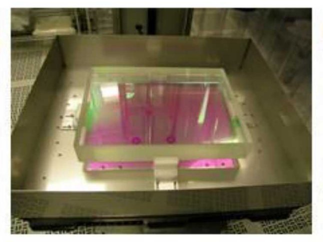
2019 International Laser Operations Workshop

1 Sandia's Large Optics Coating Team

Provides high laser damage resistant optical coatings for large optics in support of Z-Backlighter terawatt/petawatt laser operations

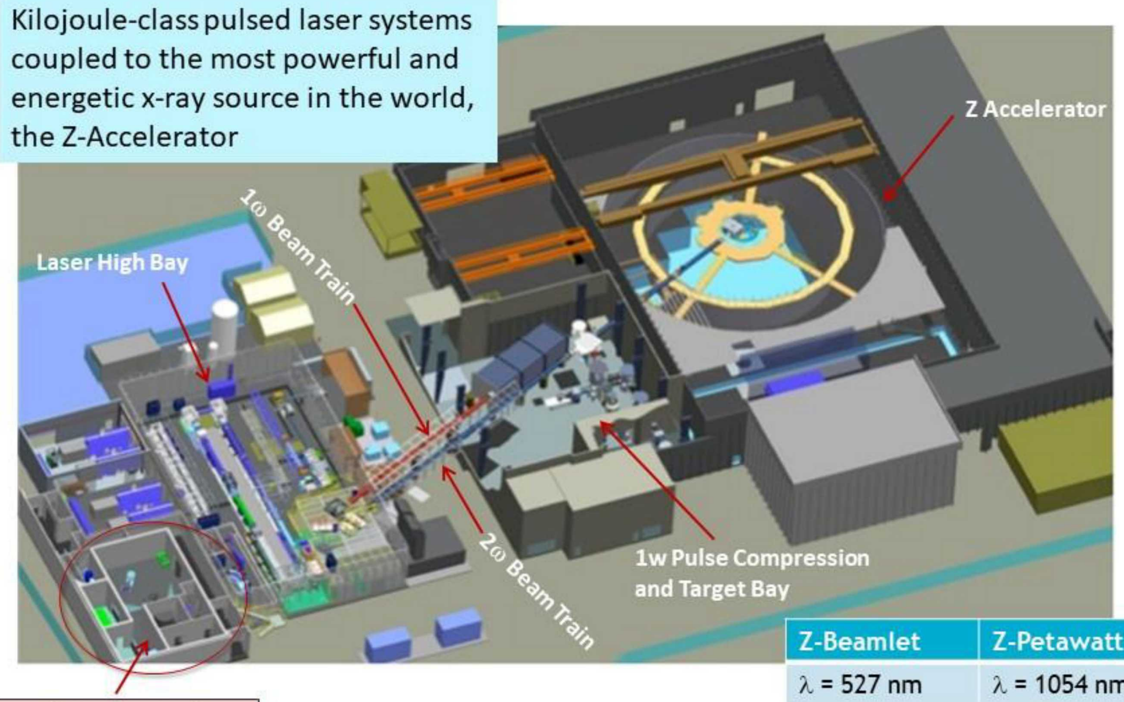
Production: 50 – 100 anti-reflection (AR) coated debris shields & vacuum windows needed by backlighting operations per year, plus high reflection (HR) and polarizer coatings



- Ella Field: Operations, Process Development, Engineering
- Damon Kletecka: Optical Coating Technologist

2 Sandia's Z-Backlighter Laser Facility

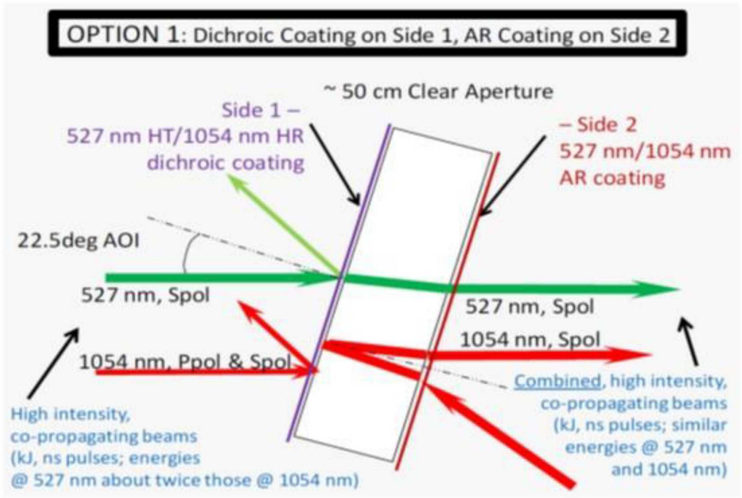
Kilojoule-class pulsed laser systems coupled to the most powerful and energetic x-ray source in the world, the Z-Accelerator



Optical Support Facility and Large Optics Coater (Class 100 Clean Area)

Z-Beamlet	Z-Petawatt
λ = 527 nm	λ = 1054 nm
τ = 0.3 - 6 ns	τ = 500 fs
I = 10^{16} W/cm²	I = 10^{20} W/cm²
E = 4 kJ	E = 500 J

3 Dichroic coating for combining 527 nm and 1054 nm Z-Backlighter laser beams



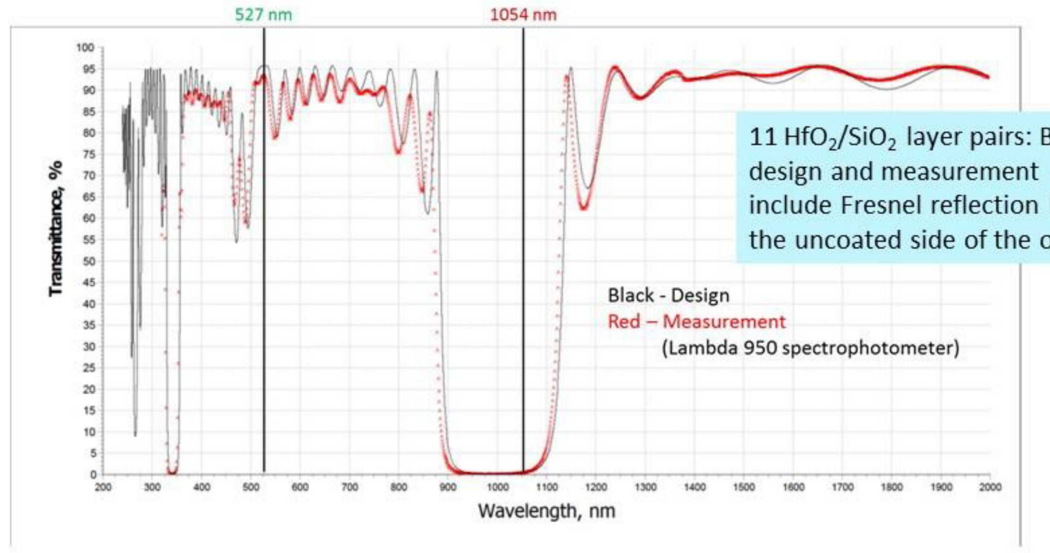
Coating Requirements:

- 22.5° angle of incidence (AOI)
- High transmission (HT) for 527 nm, S polarization (Spol)
- High reflection (HR) for 1054 nm, Spol
- High laser-induced damage threshold (LIDT)

4 Dichroic Coating History at Sandia

11 HfO_2/SiO_2 layer pairs → LIDT: 7 J/cm² (532 nm, 22.5° Spol, 3.5 ns NIF-MEL protocol). 7 J/cm² LIDT was attributed to the E-field intensity peaks in the outer two HfO_2 layers. Therefore, the outer two hafnia layers were replaced with a higher bandgap material Al_2O_3. The coating with Al_2O_3 layers did not show notable improvement (LIDT 7 – 10 J/cm²). [1]

[1] J. Bellum, et al, "Use of Al_2O_3 layers for higher laser damage threshold at 22.5° incidence, S polarization of a 527 nm/1054 nm dichroic coating" in SPIE Proceedings Volume 10014, Laser-Induced Damage in Optical Materials, 2016. doi: 10.1117/12.2257607



11 HfO_2/SiO_2 layer pairs: Both design and measurement data include Fresnel reflection losses at the uncoated side of the optic

5 Strategies for Increasing Laser Damage Threshold

Defects became the suspected cause of low LIDT because the E-field characteristics were already optimized in the 22-layer HfO_2/SiO_2 coating

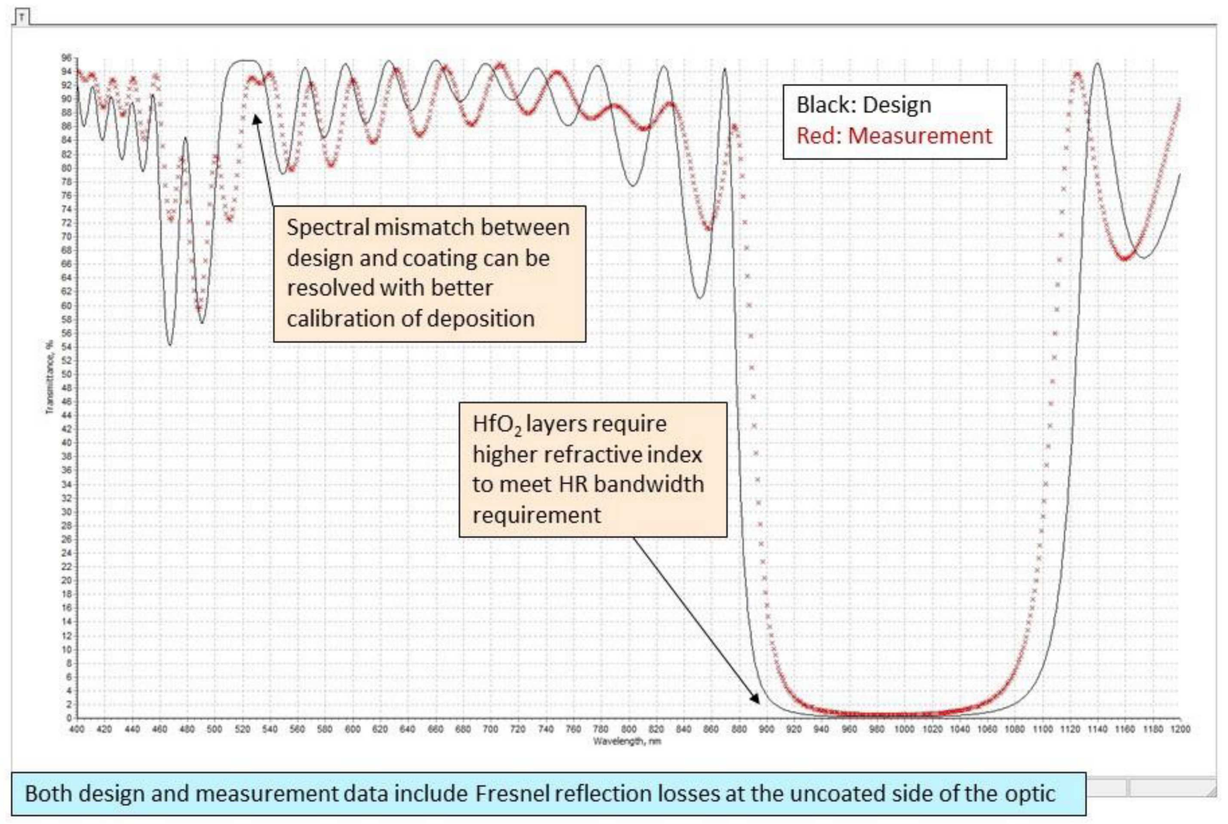
Therefore, our coating efforts focused on minimization of defects…

We used the same 22-layer HfO_2/SiO_2 coating design as before, but introduced the following changes in the deposition process:

- 100 nm silica adhesion layer → provide better foundation for first HfO_2 layer
- Slower hafnia deposition rate (from 3 Å/s to 2 Å/s) → minimize spitting
- No-IAD → minimize roughness; lower density coatings

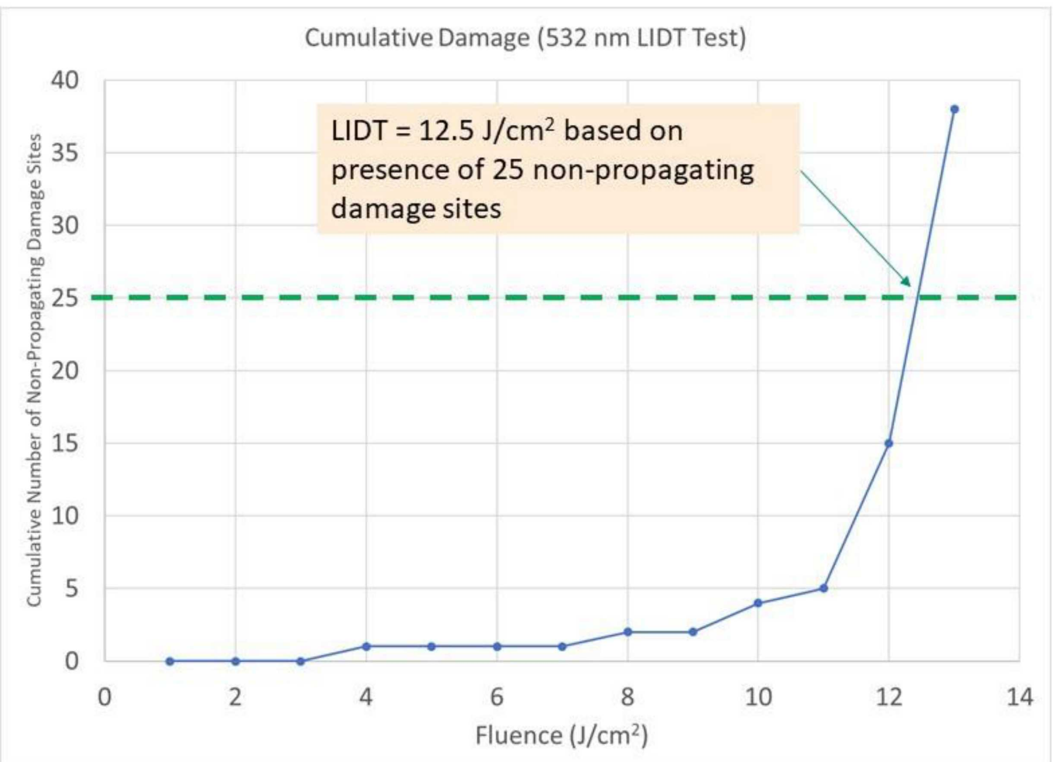
Note: All of the above changes to the deposition process were performed in the same coating. We prefer to address each variable one at a time, in separate coatings, and we will conduct our experiment this way when the production schedule has flexibility.

6 Spectral Characteristics

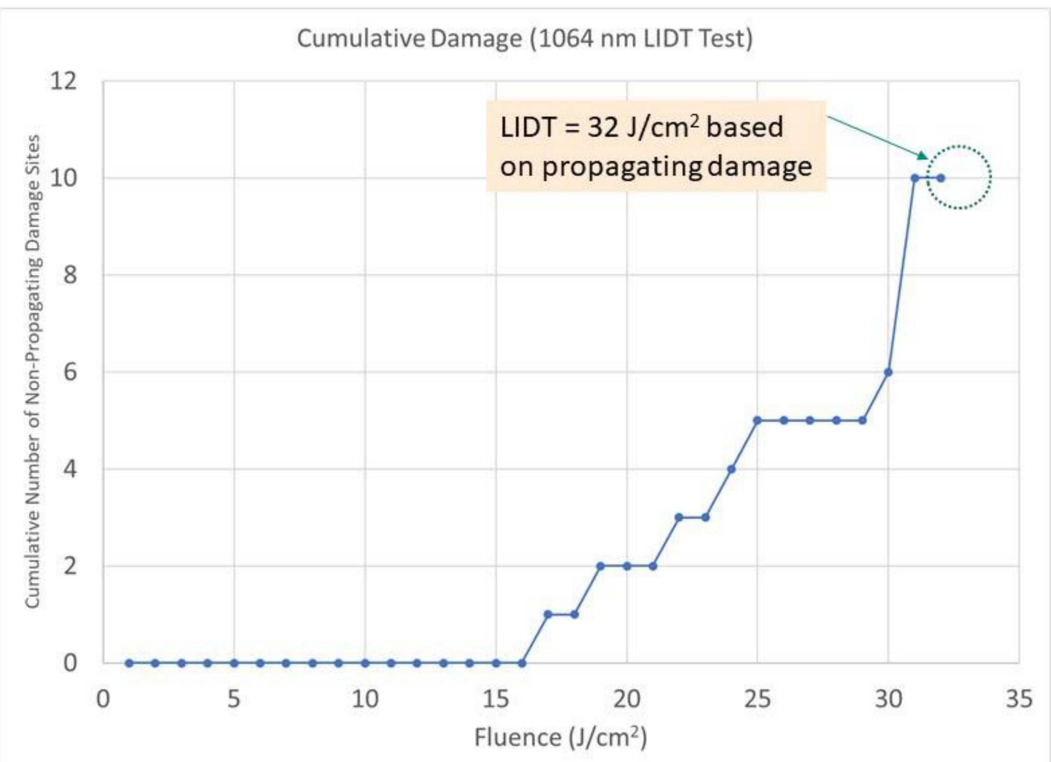


Both design and measurement data include Fresnel reflection losses at the uncoated side of the optic

7 Laser Damage Performance: 532 nm



8 Laser Damage Performance: 1064 nm



9 Conclusions

At 532 nm, the LIDT of 12.5 J/cm² is the highest we have achieved so far for a dichroic coating, however…

- The LIDT was based on the accumulation of defects rather than intrinsic damage. We expect to see even higher LIDTs when more of the defects are mitigated. The source(s) of the defects have yet to be determined.
- More investigation is needed to understand how each variable contributed to this positive result (lower hafnia deposition rate, addition of 100 nm silica adhesion layer, and no IAD).
- The refractive index of HfO_2 needs to be increased to meet the HR bandwidth requirement. However, the lower refractive index of HfO_2 in the current coating may be responsible for increasing the LIDT.

Next Steps:

- Damage testing of dichroic coating with HfO_2 refractive index correction (in process, expect results in a couple weeks)
- Deposit the dichroic coating on a large piece of float glass to determine if there are coating stress issues.

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Z Backlighter

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