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SAND2015-8042C

Z Backlighter

U.S. DEPARTMENT OF ENERGY

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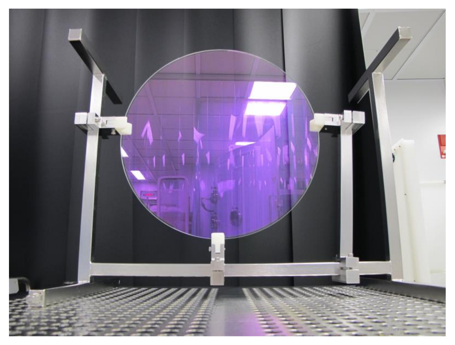
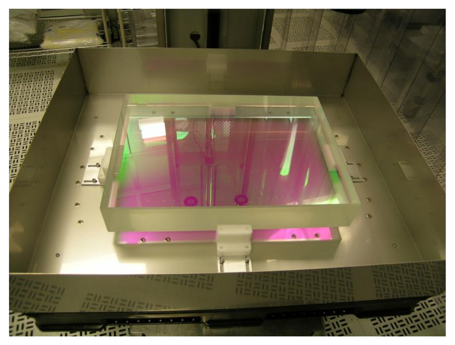
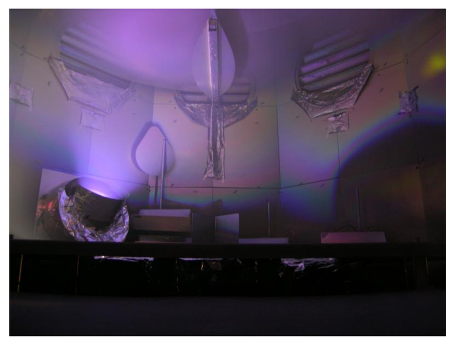
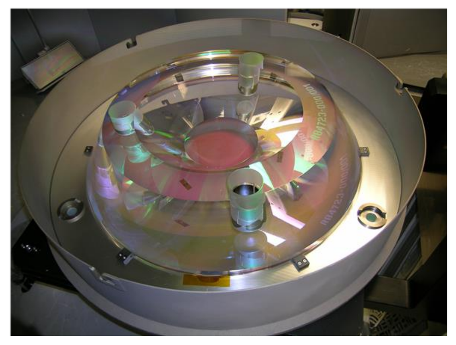





SPIE Laser Damage Symposium 2015

How reduced vacuum pumping capability in a coating chamber affects the laser damage resistance of HfO_2/SiO_2 antireflection and high-reflection coatings

Ella Field, John Bellum, and Damon Kletecka

Z-Backlighter Laser Facility, Sandia National Laboratories

Introduction

About Sandia's Large Optics Coating Operation:

- We deposit optical coatings consisting of HfO_2/SiO_2 layer-pairs on large optics for Sandia's Z-Backlighter Lasers using e-beam evaporation. HfO_2 is deposited by reactive evaporation of Hf in O_2 back pressure; sometimes we use ion-assisted deposition (IAD). The coatings must have high laser damage resistance.

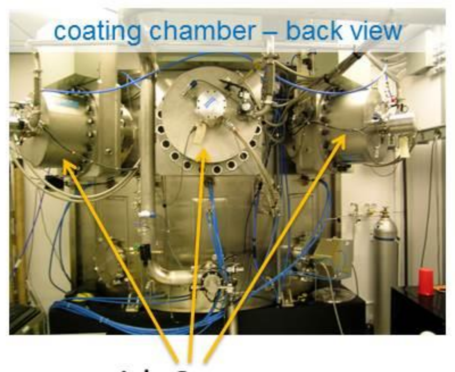
About Sandia's Z-Backlighter Lasers:

- The kilojoule-class pulsed laser system is coupled to the most powerful and energetic x-ray source in the world, the Z-Accelerator

Z-Beamlet	Z-Petawatt
λ = 527 nm	λ = 1054 nm
τ = 0.3 – 8 ns	τ = 500 fs
I = 10^{17} W/cm^2	I = 10^{19} W/cm^2

http://www.z-beamlet.sandia.gov/

How many vacuum pumps does a coating chamber need to produce coatings with high laser-induced damaged thresholds?



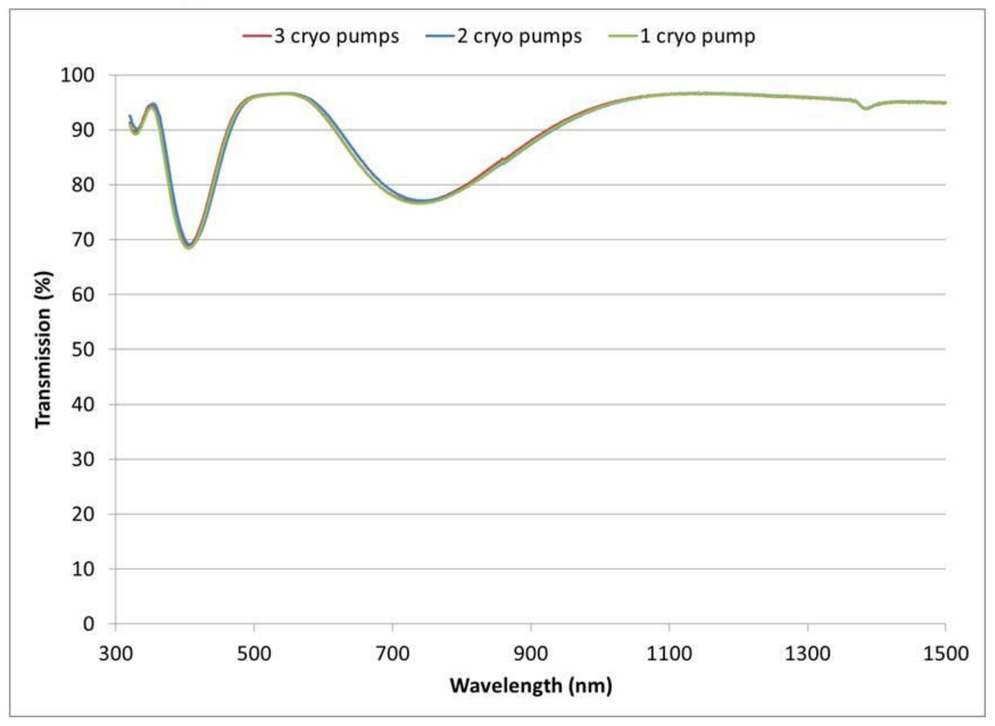
- Coating chamber normally operates with 3 cryo pumps
- On rare occasions, cryo pump maintenance is required while a coating is in progress. While pump is out of service, the remainder of the coating must be deposited with support from fewer cryo pumps.

Deposition of our most common coatings with reduced vacuum pumping capability

- Each coating performed with 1, 2, and 3 cryo pumps
- Deposition: HfO_2/SiO_2 layers, 200^0 C, O_2 backfill pressure 1.1e-4 Torr during HfO_2 layers
- Substrates: fused silica 50 mm dia. X 10 mm thk.

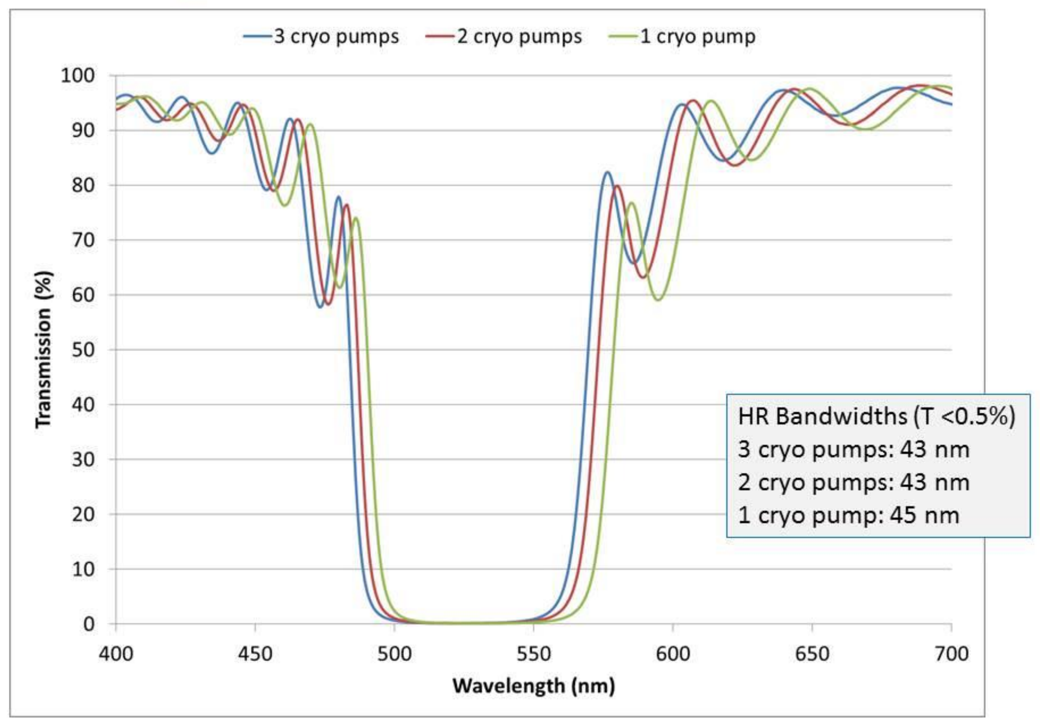
AR Coating for 532 nm, 0^0 AOI	HR Coating for 532 nm, 45^0 AOI, P-polarization
4 layers → 565.3 nm thick	34 layers - Quarterwave design with outermost layer ½ wave SiO_2 → 3194.7 nm thick
SiO_2: 7 Å/s deposition rate	SiO_2: 7 Å/s
HfO_2: 1 Å/s (layer 1), 2 Å/s (layer 3)	HfO_2: 3 Å/s
Deposition time: 46 min.	Deposition time: 4 hrs 53 min.
Base pressure: ~3e-6 Torr	Base Pressure ~5e-6 Torr

AR Coatings: Transmission Characteristics



Transmission scans acquired ~1 month after deposition to account for spectral shifts due to aging

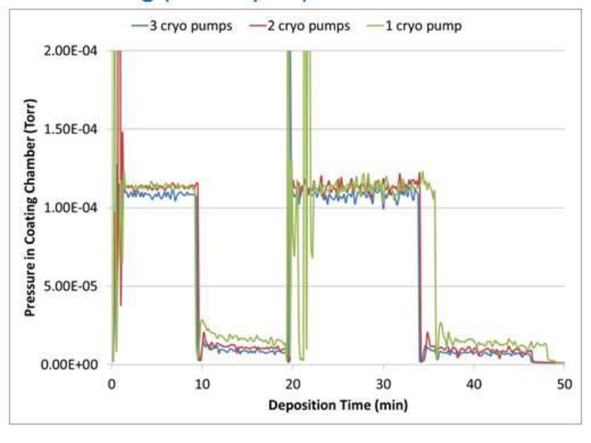
HR Coatings: Transmission Characteristics



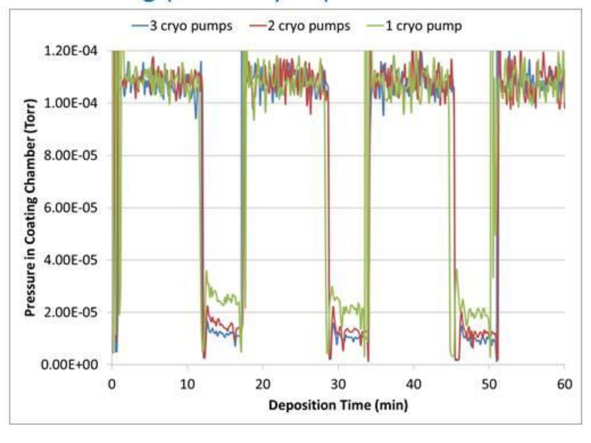
Transmission scans acquired ~1 month after deposition to account for spectral shifts due to aging

Deposition Pressure

AR Coating (all 4 layers):

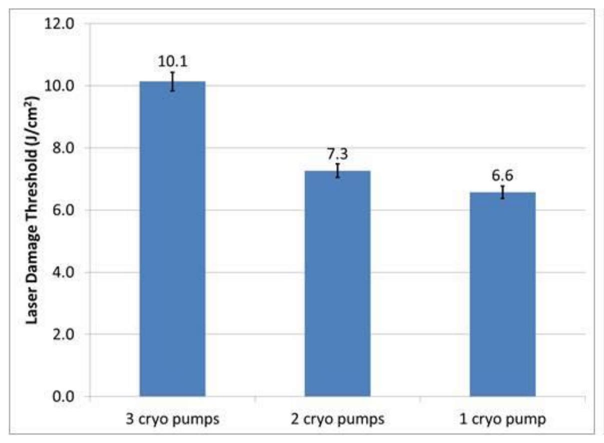


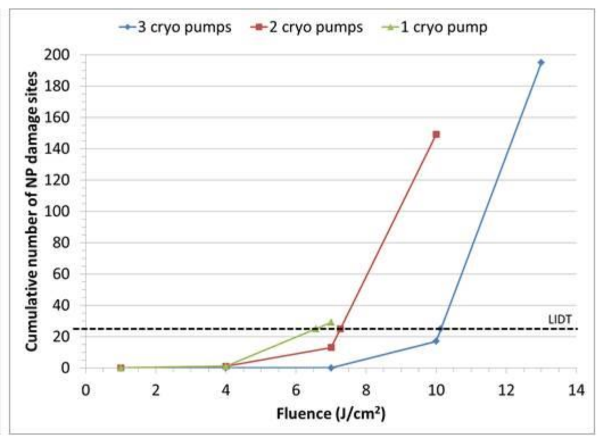
HR Coating (first 7 layers):



- Fewer cryo pumps lead to higher pressure during deposition, especially in SiO_2 layers.
- The pressure during HfO_2 deposition was governed by the back pressure controller. However, we do not know the partial pressure of the O_2 backfill, therefore it is unclear how much the oxygen content is affected by fewer vacuum pumps.

AR Coatings: Laser-Induced Damage Thresholds

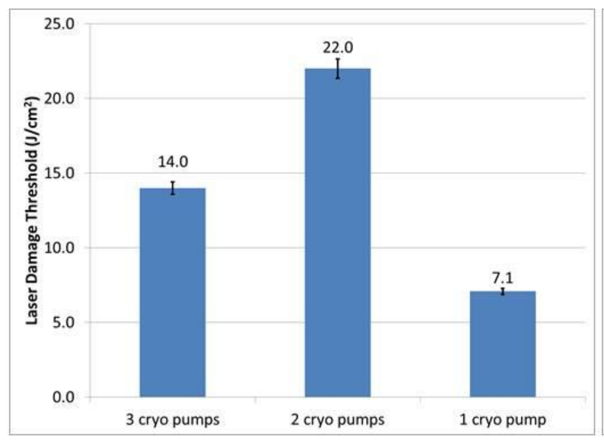


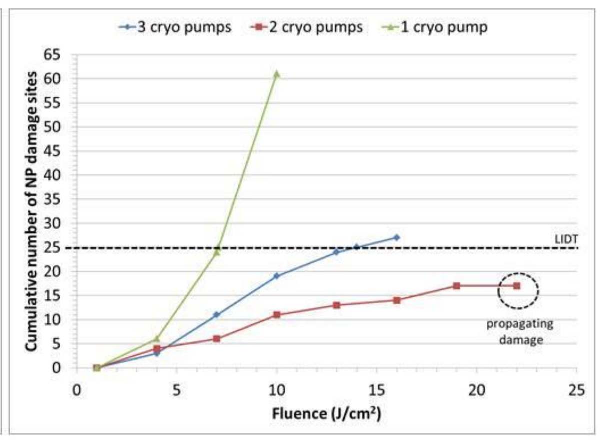


Laser damage thresholds decline with fewer cryo pumps operating during the coating deposition. >25 Non-propagating defects caused the coatings to reach their damage thresholds. Fewer cryo pumps → more defects.

NIF-MEL Damage testing protocol:
*3.5 ns pulse width, 0º, 532 nm
*Damage definition: propagating damage, or 25 non-propagating (NP) damage sites
*Performed by Spica Technologies Inc.

HR Coatings: Laser-Induced Damage Thresholds





The highest laser damage threshold was achieved with 2 cryo pumps rather than 3. The coating deposited with 3 cryo pumps reached its damage threshold due to the accumulation of >25 non-propagating defects – the substrate may not have been cleaned as thoroughly as it could have been.

NIF-MEL Damage testing protocol:
*3.5 ns pulse width, 45º, P-polarization, 532 nm
*Damage definition: propagating damage, or 25 non-propagating (NP) damage sites
*Performed by Spica Technologies Inc.

Conclusions

- The increasingly higher pressures associated with fewer cryo pumps cause slight differences in the deposition processes, especially for the SiO_2 layers.
  - HfO_2 layers deposited with O_2 backfill were less affected by overall pressure increases due to fewer cryo pumps because the pressure was managed by a mass flow controller during HfO_2 deposition. However, the O_2 partial pressure may actually be lower with fewer cryo pumps, leading to poorer oxidation of Hf and the lower laser damage thresholds that we observed.
- The number of vacuum pumps needed to achieve a certain damage threshold depends on the type of coating.
  - HR coatings more sensitive than AR coatings to laser damage threshold decline with fewer cryo pumps.
- The number of vacuum pumps in operation may affect the spectral characteristics of the coating.
  - The transmission spectra of the thinner AR coatings appear nearly identical, while the transmission spectra of the HR coatings shift to longer wavelength when fewer cryo pumps are in operation.