Laser Damage Comparisons of E-Beam Evaporated HfO_2/SiO_2 Antireflection Coatings at 0% and 40% Relative Humidity for 532 nm and 1064 nm

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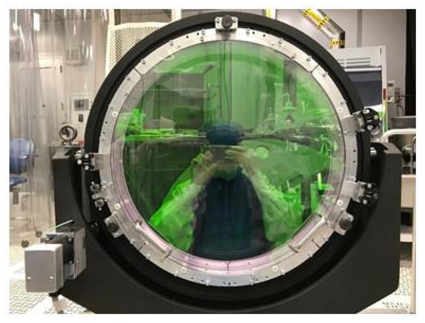
SPIE Laser Damage 2021

1 Why study the effect of humidity on laser damage?

- Our coated optics are used in a variety of environments, however, laser damage tests are typically conducted in a dry environment for standardization purposes.
- The coating process (electron beam evaporation) produces coatings that are porous and consequently absorb water from the ambient environment. In general, the absorbed water can impact a coating's spectral performance and electric field distribution, so an effect on laser damage is also likely.



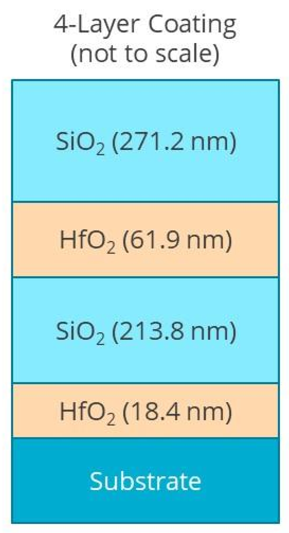

2 Project Outline:

Goal:

- Determine how humidity impacts the laser damage resistance of our optical coatings.

Method:

- Conduct a preliminary study involving our widely-used antireflection (AR) coatings for 532nm/1064 nm.
- Measure the laser damage thresholds of these coatings at 0% and 40% relative humidity (RH) in the nanosecond pulse regime.



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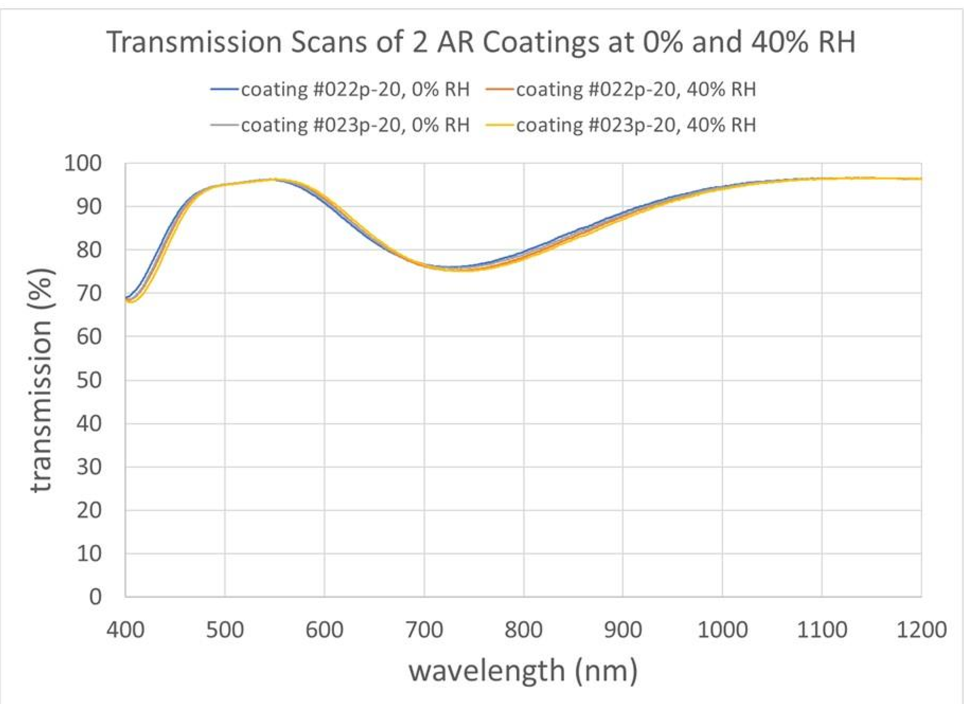
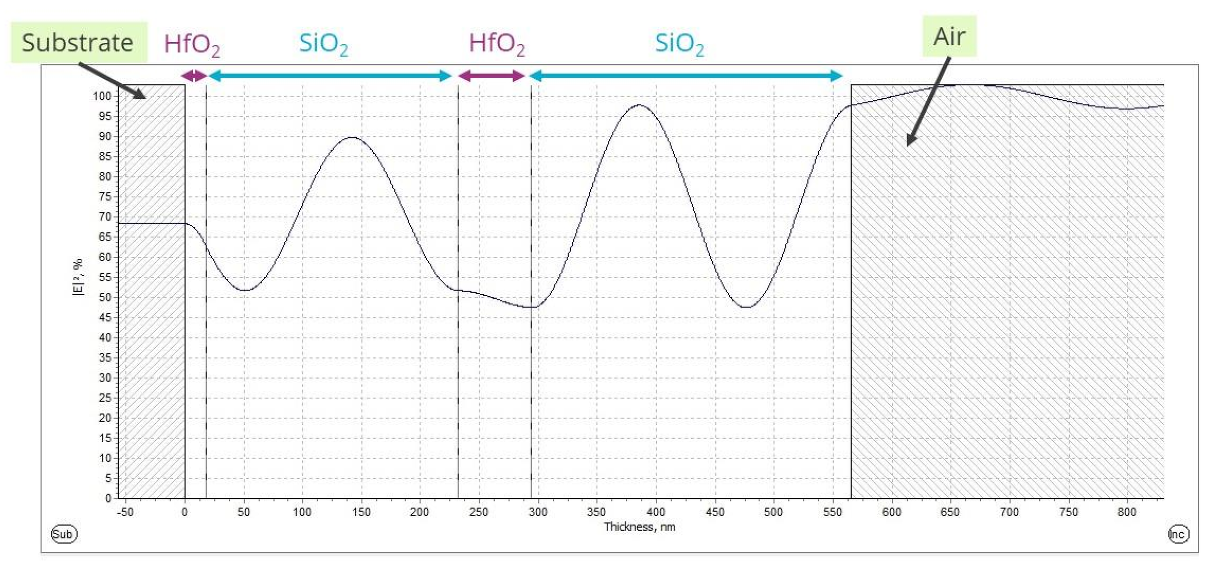
Spectral shift due to humidity is minimal

Notes:
Transmission scans were taken at normal incidence from witness samples coated on one side, so scans include the Fresnel reflection from the uncoated back side.

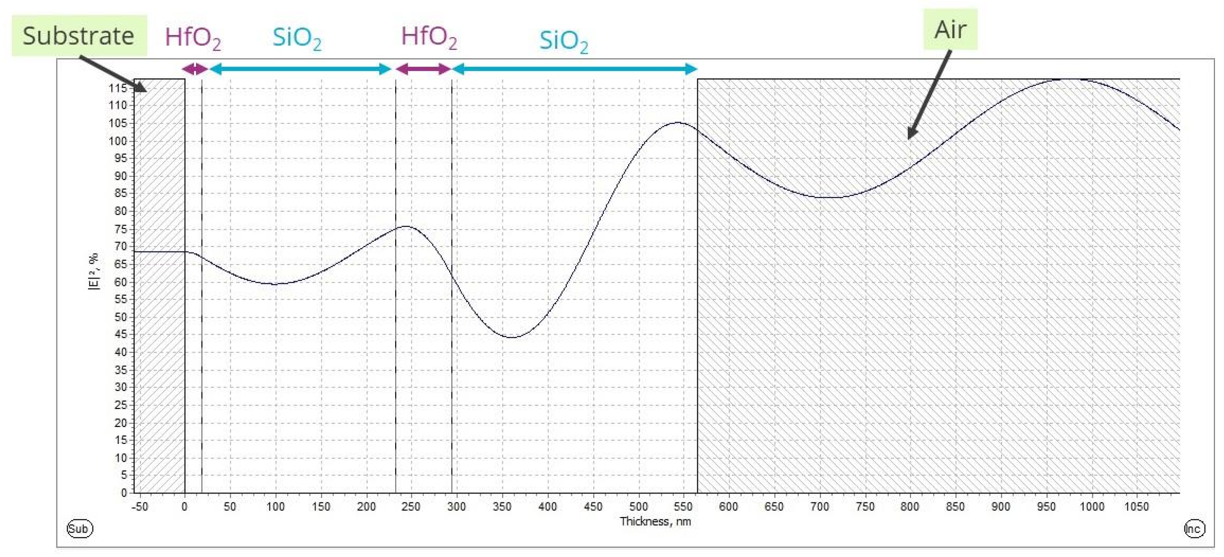
Equipment:
PerkinElmer "Lambda 950" spectrophotometer, error is +/- 0.3%



4 Electric Field Intensity for 532 nm, Normal Incidence (Optilayer model)



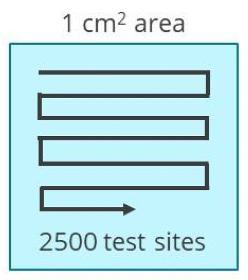
5 Electric Field Intensity for 1064 nm, Normal Incidence (Optilayer model)



6 Electric Field Discussion

- At both 532 nm and 1064 nm, peak intensities occur in SiO_2 layers. This is advantageous because SiO_2 has a higher damage threshold compared to HfO_2.
- The situation at 532 nm is a little worse since this is higher photon energy, and both SiO_2 layers experience peak intensities, so they are both vulnerable to damage. At 1064 nm, only the outermost SiO_2 layer experiences the peak intensity.
- Therefore, we expect laser damage thresholds to be lower at 532 nm.
- We do not expect significant changes in the electric field distribution between 0% and 40% relative humidity because there was negligible spectral shift.

7 Laser Damage Testing: Raster Scan Method



Performed by Spica Technologies (NIF-MEL protocol)

Raster-scan method includes 2500 overlapping sites in 1 cm² area

Spot diameter (1/e²):
- 1.04 mm (for wavelength 1064 nm)
- 1.01 mm (for wavelength 532 nm)

Pulsewidth (FWHF): 3.5 ns

Beam Profile: TEM_{00}

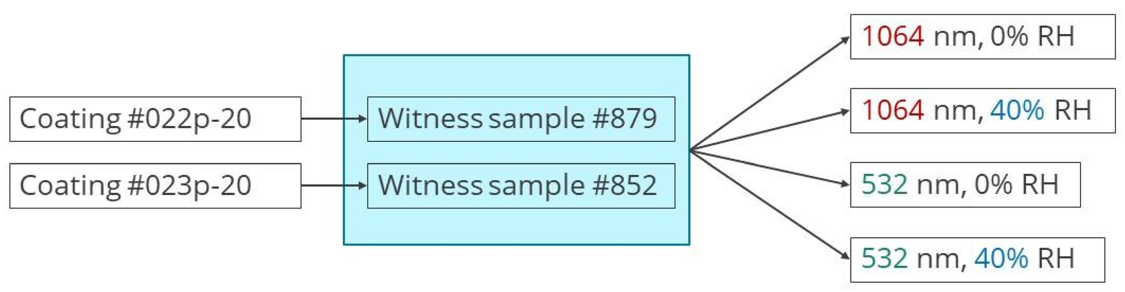
Initial fluence is set to 1 J/cm², and is increased in 1 J/cm² increments after each scan of the 2500 sites.

The tests were conducted at 0% and 40.5% relative humidity and normal incidence. Spica allowed each sample to reach a steady state with the environment by keeping the sample at the humidity condition for 12 hours before performing the laser damage test.

Laser damage threshold fluence is set by whichever occurs fist:
- Occurrence of 25 non-propagating damage sites (i.e. ~1% of the coating area is damaged)
- Occurrence of 1 propagating damage site

Reasons for using this type of damage test: it covers a "large" area, so damage due to defects are better accounted for.

8 Laser Damage Testing: 2 Coatings, 4 Tests Each



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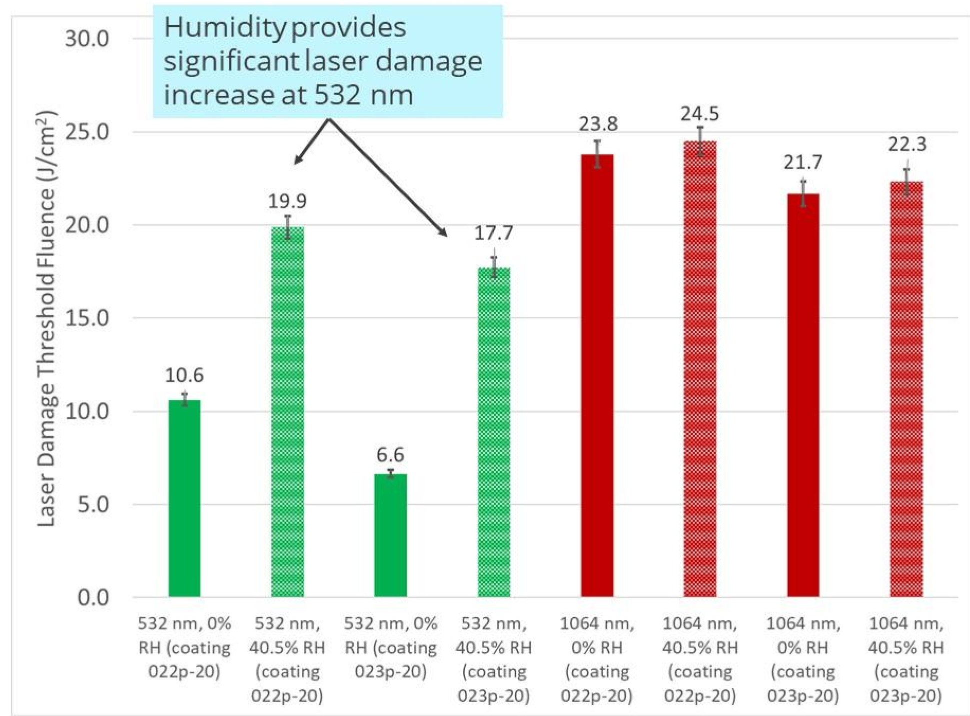

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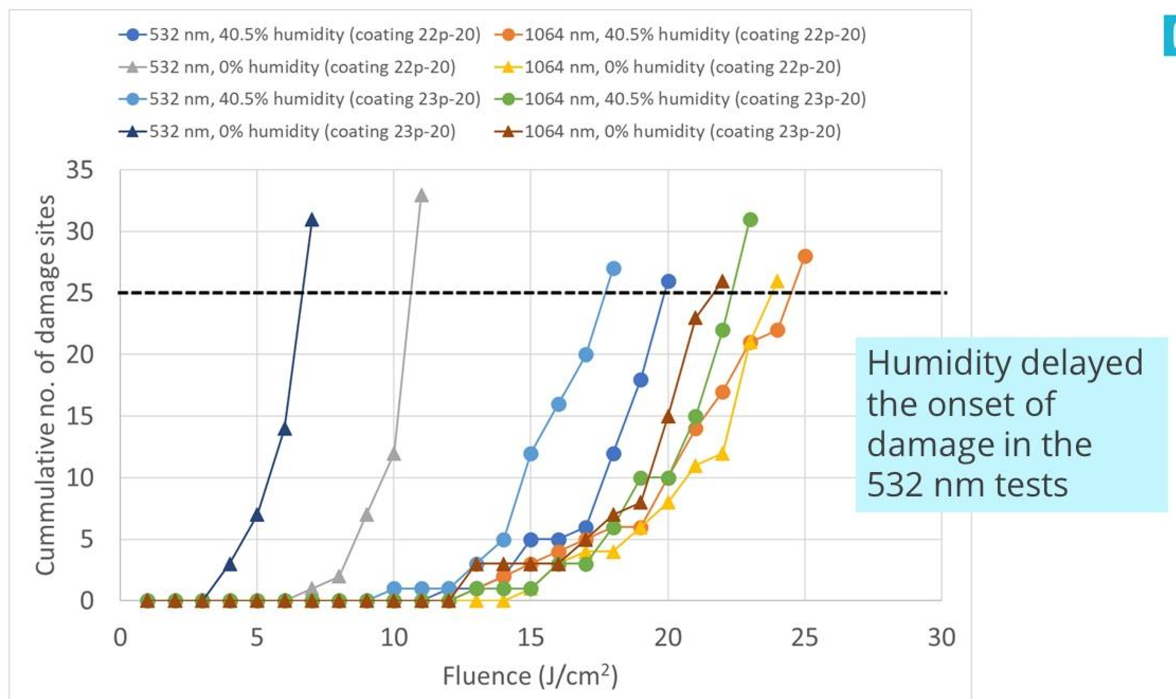

11 Results: Humidity can improve laser damage thresholds at 532 nm

- Damage was defect-based: both samples reached their damage threshold fluence due to the accumulation of 25 non-propagating damage sites.
- At 1064 nm, the laser-induced damage thresholds at 0% and 40.5% RH were similar. There was very slight improvement at 1064 nm.
- At 532 nm, the laser-induced damage thresholds at 40.5% RH were roughly two times higher than those measured at 0% RH. The underlying mechanisms are under investigation.

12 References

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