Optimization of VISAR Mirrors for NIF Targets

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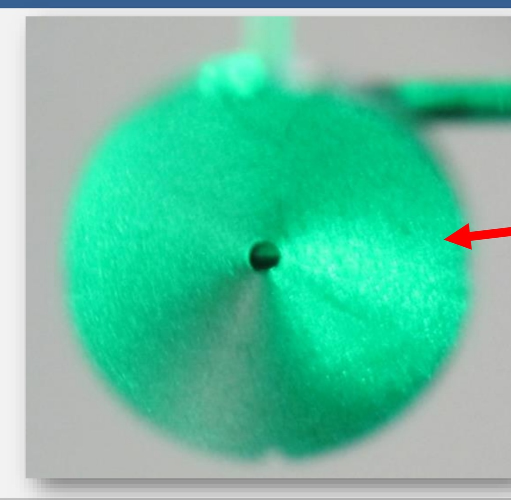
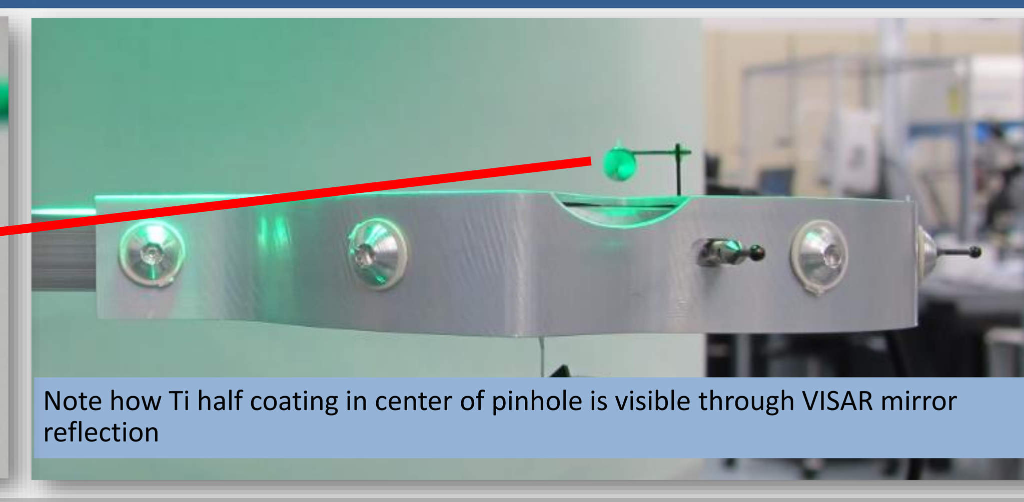
What are NIF VISAR mirrors & what are they used for?

- NIF VISAR (Velocity Interferometer System for Any Reflector) is a critical diagnostic used for measuring shock propagation
  - Was developed two decades ago *(UCRL-CONF-206587)* and is predated by even earlier systems at Omega *(UCRL-JRNL-202213)*
- As NIF shots have become more complex with increased frequency, the desire to collect **more data** using **more diagnostics** in **fewer shots** has led to an increased use of VISAR mirrors, introducing new challenges to be solved

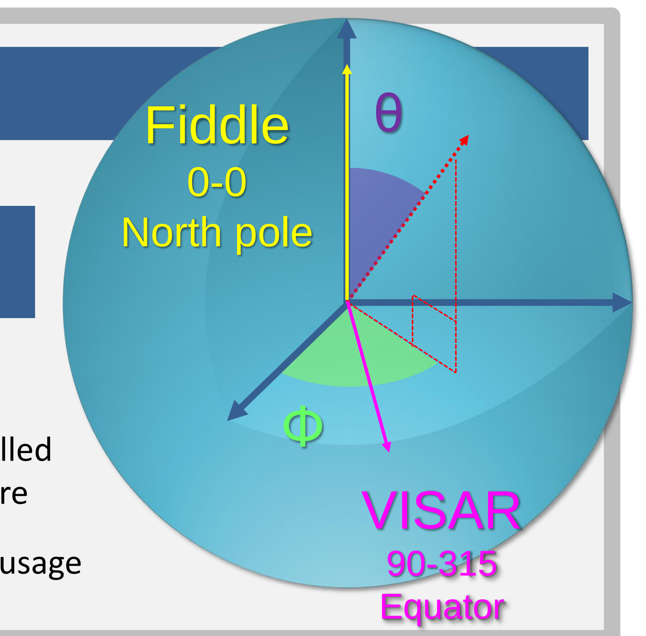




Note how Ti half coating in center of pinhole is visible through VISAR mirror reflection

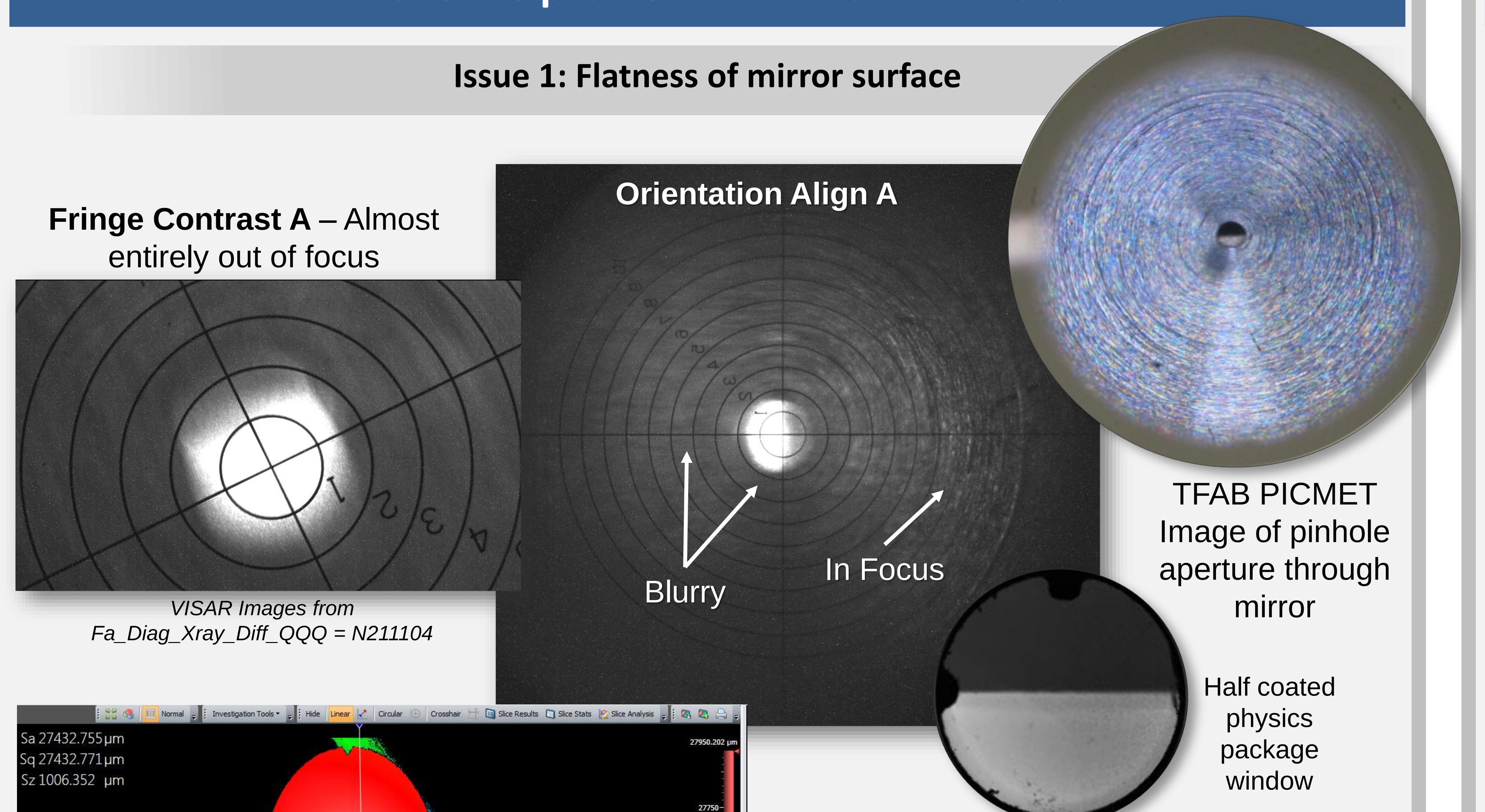
*VISAR mirrors are used when we want to make VISAR measurements **without** the line of sight facing VISAR (90°-315°)*

- VISAR is a NIF diagnostic with a permanent location along the equator → 90°-315°
  - E.g., XRDt platform has primary diagnostic (FIDDLE) at north pole θ=0°, so a 45° Si mirror is installed facing towards 90°-315° to allow observation of the physics package through the pinhole aperture
  - Limits on required drive beams, debris issues, and other concerns can also lead to VISAR mirror usage

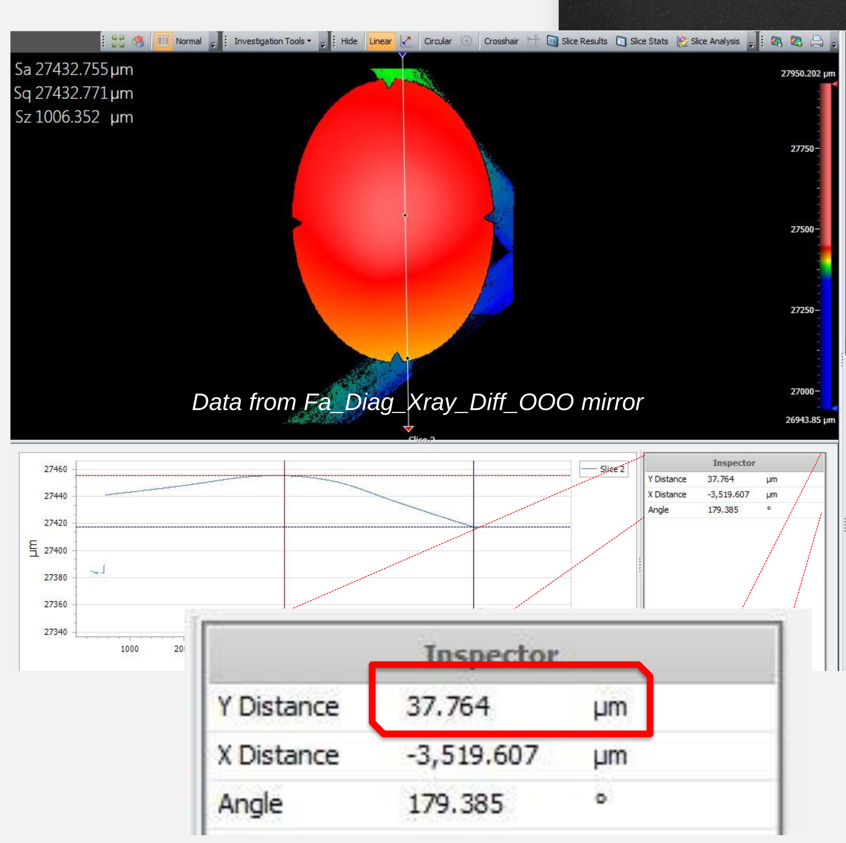


What's the problem with VISAR mirrors?

Issue 1: Flatness of mirror surface



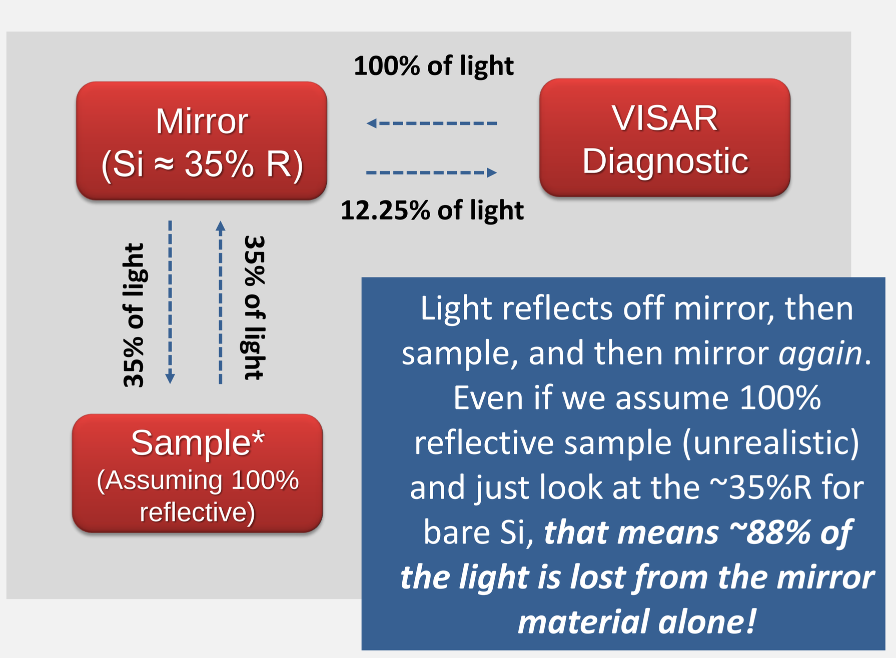
VISAR Images from Fa_Diag_Xray_Diff_QQQ = N211104



- Efforts began in 2021 to start quantifying how flat was 'flat enough' for the large area Si VISAR mirrors used on the XRDt (Time Resolved X-ray diffraction) target, DAC (Diamond Anvil Cell), etc.
- Most mirrors at the time used 50 um thick Silicon wafers, laser-cut or ion-etched to shape
  - Typical measured flatness (Interferometer) of ~30-40 um (*with some as high as ~80+ um!*)
- These mirrors caused severe distortion/defocus when aligning VISAR, and it was suspected that the high flatness value played a critical role in this

Issue 2: Amount of light returned from the mirror

- Over time and with an increased number of high yield shots, several VISAR components such as fiber optics have degraded, reducing performance
- Also, some newer platforms use a much shorter sweep (e.g., DAC at 10-14 ns compared to most other campaigns at ~30-90 ns), collecting a much lower fringe intensity
- This is on top of the inherent light lost just from the fact that VISAR is self-lighting, requiring single pass reflection on sample + double pass off mirror

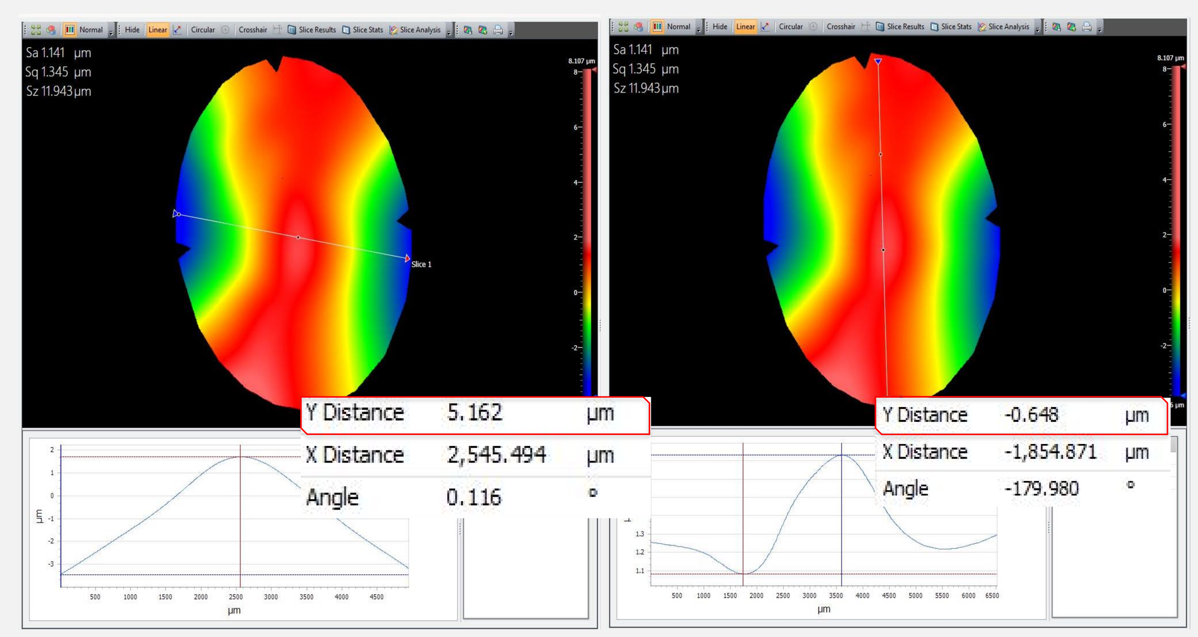


Light reflects off mirror, then sample, and then mirror *again*. Even if we assume 100% reflective sample (unrealistic) and just look at the ~35%R for bare Si, ***that means ~88% of the light is lost from the mirror material alone!***

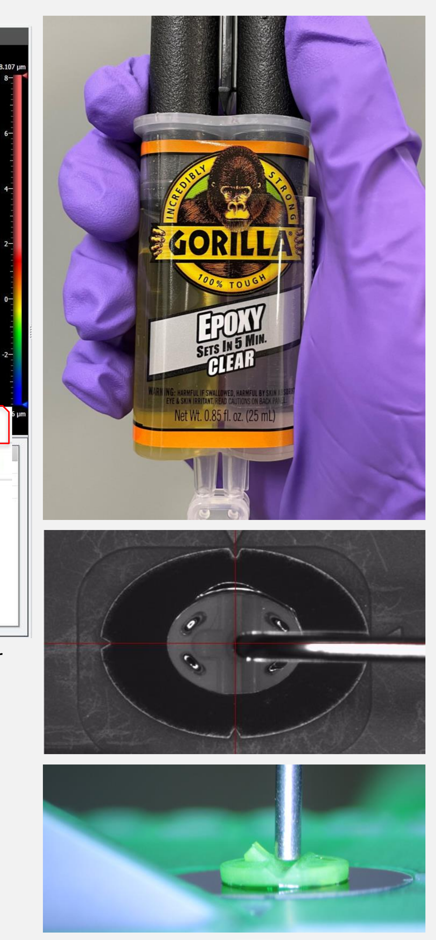
Improving Flatness

Changes to assembly procedure and materials

- UV glues replaced with Epoxy (Gorilla) to help stop mirror 'curling' due to glue shrinkage
- Vacuum during curing stage removed to further reduce surface warp during curing



Data from Fa_Diag_Xray_Diff_PPP Mirror

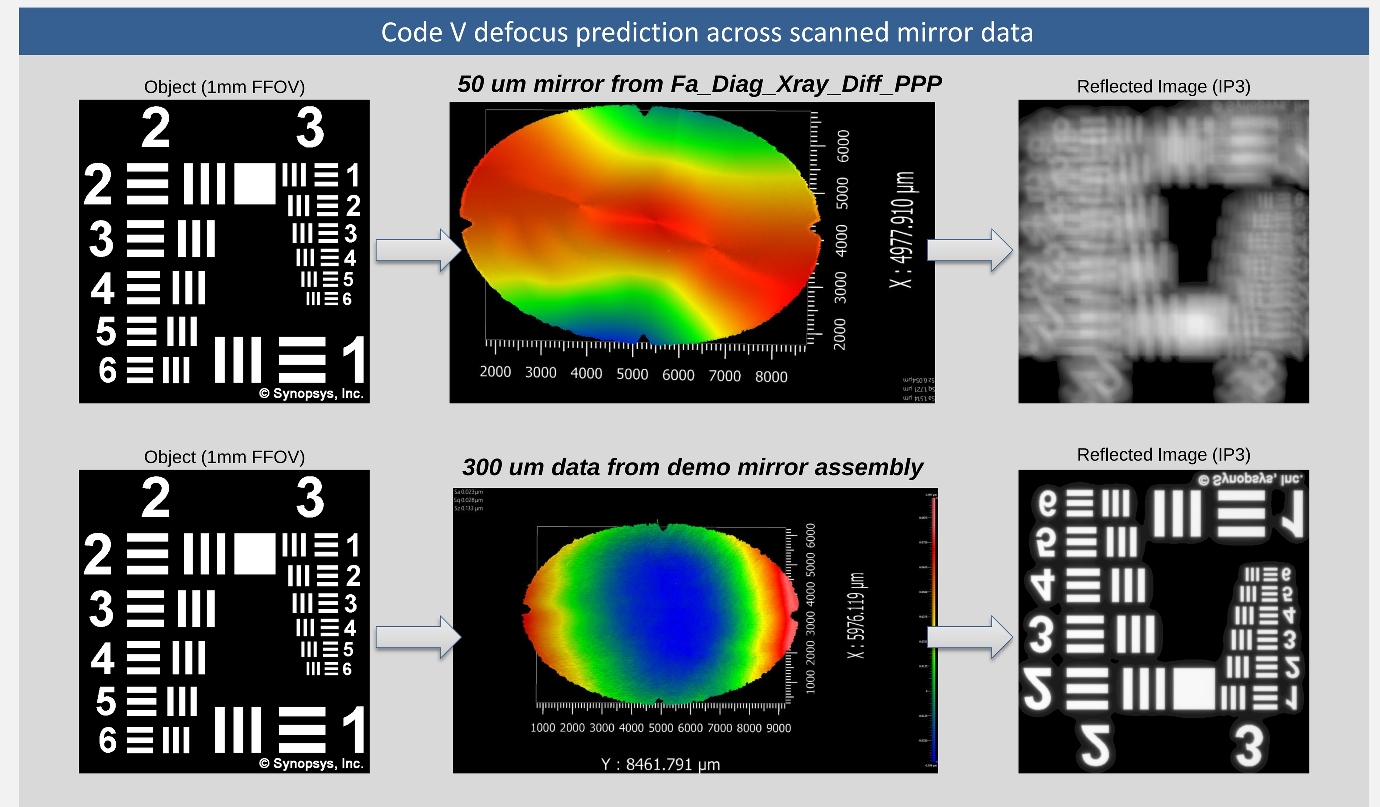


- These changes alone brought surface flatness of the mirror **down to the order of ~5 um or lower**
- However, VISAR alignment *still* proved challenging even with these much flatter parts

Changes to mirror substrate

- With support of Optics Engineer Stacie Manuel, simulations were performed in Code V to model how flatness impacted VISAR focus, using data from 50um to 300um thick Si test assemblies
  - The simulations found even the best 50 um parts to be severely lacking, producing largely unfocused results with wide spot diagram spread
  - However, it was found that the minimal warping of the 300 um Si sample parts provided ideal focus for even the longest mirror standoffs used in XRDt/DAC

Code V defocus prediction across scanned mirror data



NOTE – Image flips across mirror

Improving Reflectivity

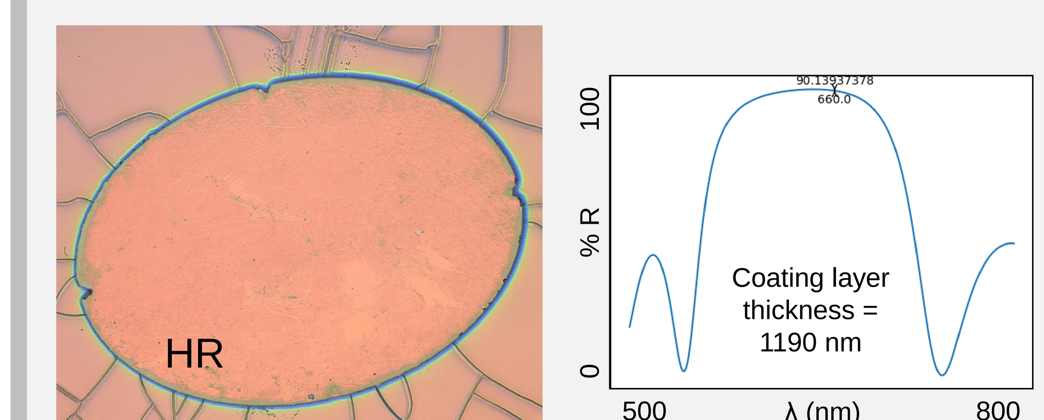
Thin film/dielectric coatings

Pros:

- Can provide extremely high and controlled % R values → 90 %R for this test run in only 12 layers
- Well established method; easily predictable results

Cons:

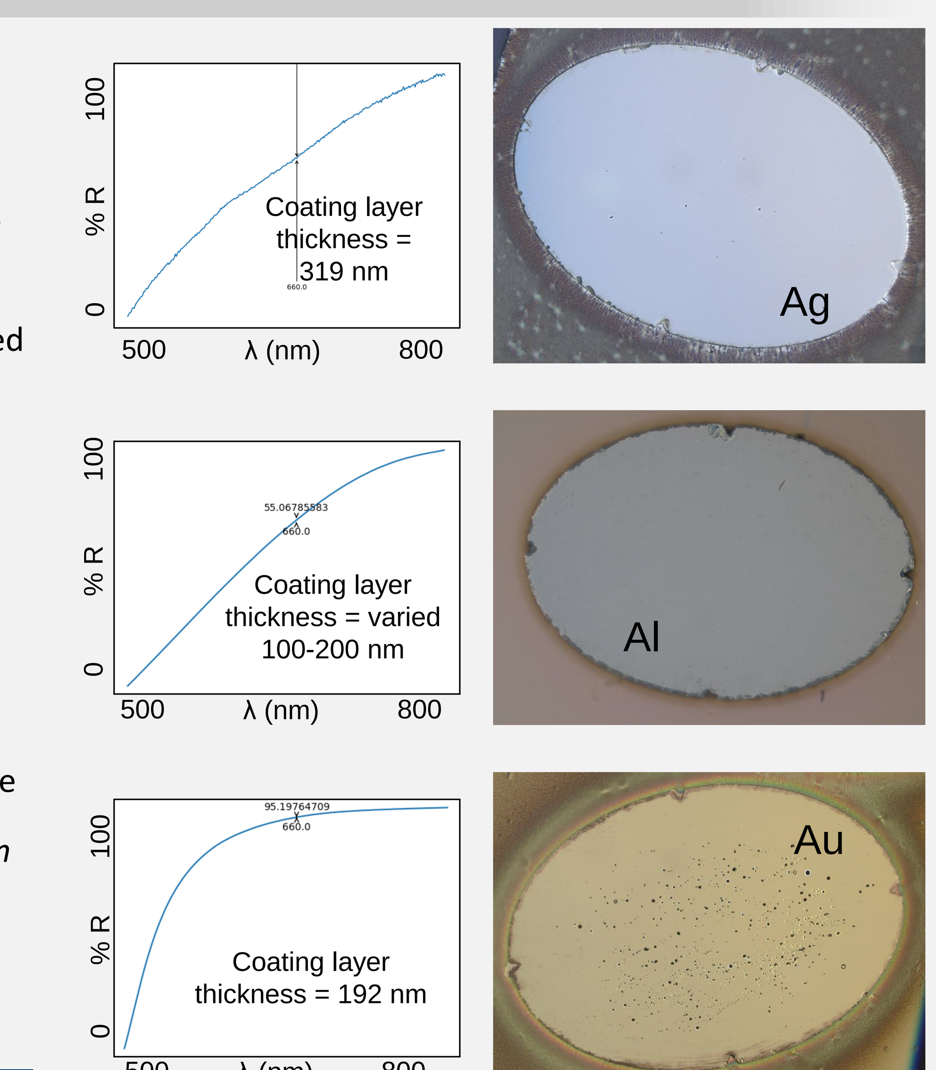
- Thick, multiplayer coatings → a 12-layer alternating pattern of SiO_2 & HfO_2 coated onto the test Si mirrors gave a total thickness of 1190 nm
  - Mid & higher-Z materials like Hf can interfere with data
  - λ vs %R curve heavily dependent on angle of incidence → not an issue for XRDt/DAC due to 45° angle of incidence & reflection, but possibly other campaigns



Metal coatings

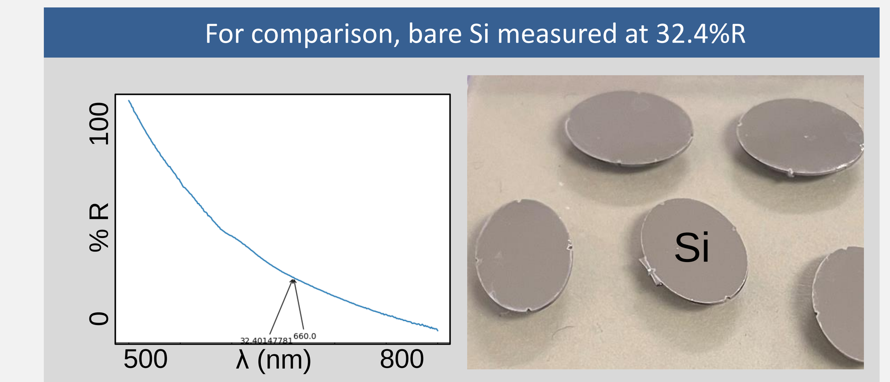
Thin (100-400 nm) metal coatings:

- As expected from literature, Ag and Au performed in the upper 95+ %R range for target wavelength of ~660 nm
- Al, however, had varied results that ranged from mid 50's to low 80's in terms of %R
  - While the exact cause is still under investigation, the two most likely suspects are surface roughness and possible contamination pre-coat
- Al was ultimately selected as the primary coating for the first coated-mirror Diamond Anvil Cell (DAC) shot as it was lowest Z metal and least likely to fluoresce
  - *With this mirror (~60%R on production batch of parts), **DAC campaign was able to record usable VISAR data for the first time***



Material	%R	$\%R^2$
Silver (Ag)	98.1%	96.2%
Gold (Au)	95.2%	90.6%
High Reflectance (HR)	90.1%	81.3%
Aluminum (Al) high	84.3%	71.1%
Aluminum (Al) low	55.1%	30.3%
Bare Silicon (Si)	*32.4%*	*10.5%*

For comparison, bare Si measured at 32.4%R



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