An Advanced Material System:
Stable Substrates with Be-38Al with Electroless Nickel

SBIR Efforts
Presented at Mirror Technology Days
November 2016

PEREGRINE

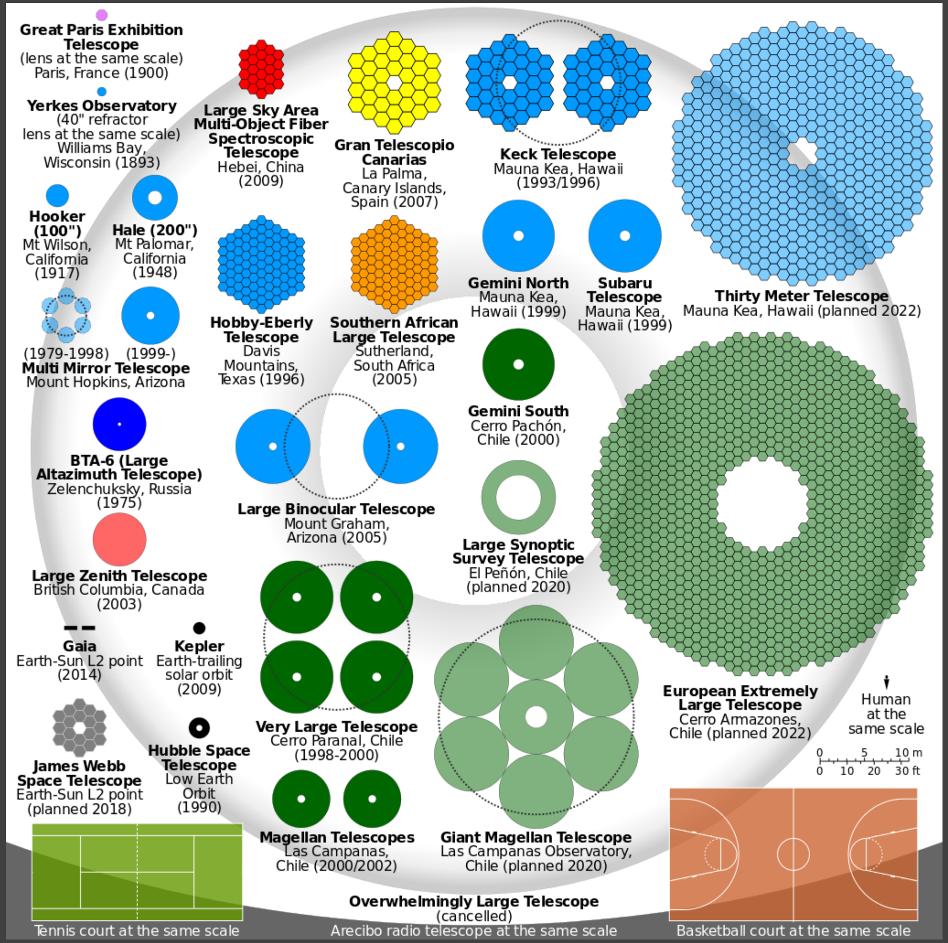
PRECISION ENGINEERED PRODUCTS SINCE 1994

Resulting in an athermal method to fabricate low cost, low risk and high quality, large lightweight aperture substrates/mirrors and telescopes within a manageable timeframe.

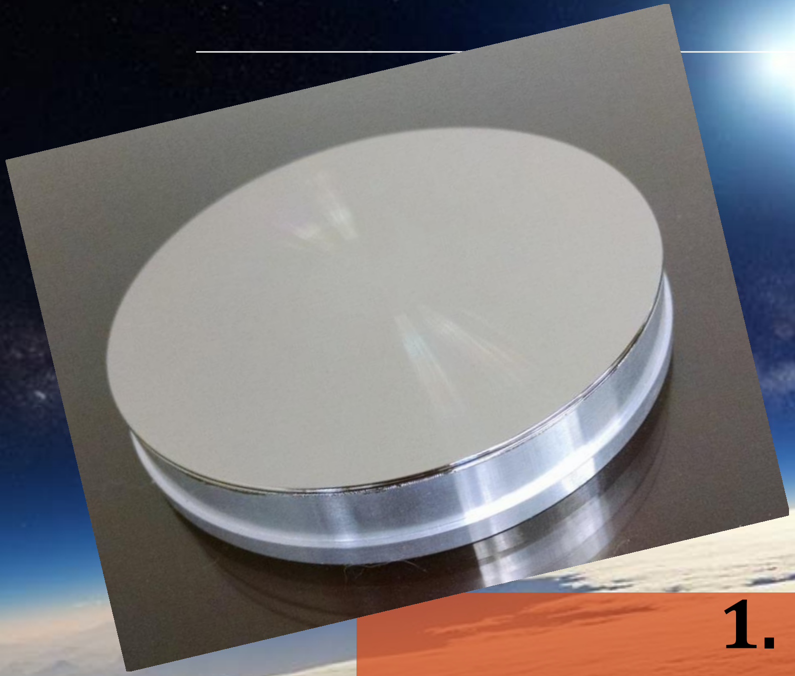
Objective: Develop a More Cost Effective Solution for Substrates (Large Mirrors)

James Webb Space Telescope = $6.5/m²

Our objective is a 75% reduction ($6.5/m²/4)

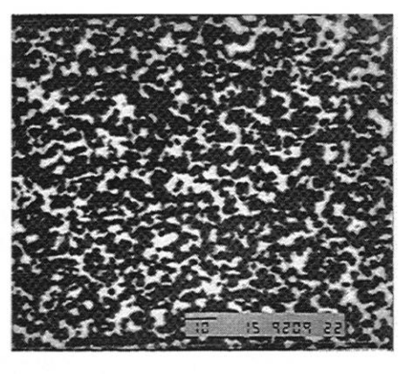


This method to provide low cost, low risk and high quality, lightweight substrates and, in turn, optics relies upon converging specific elements…

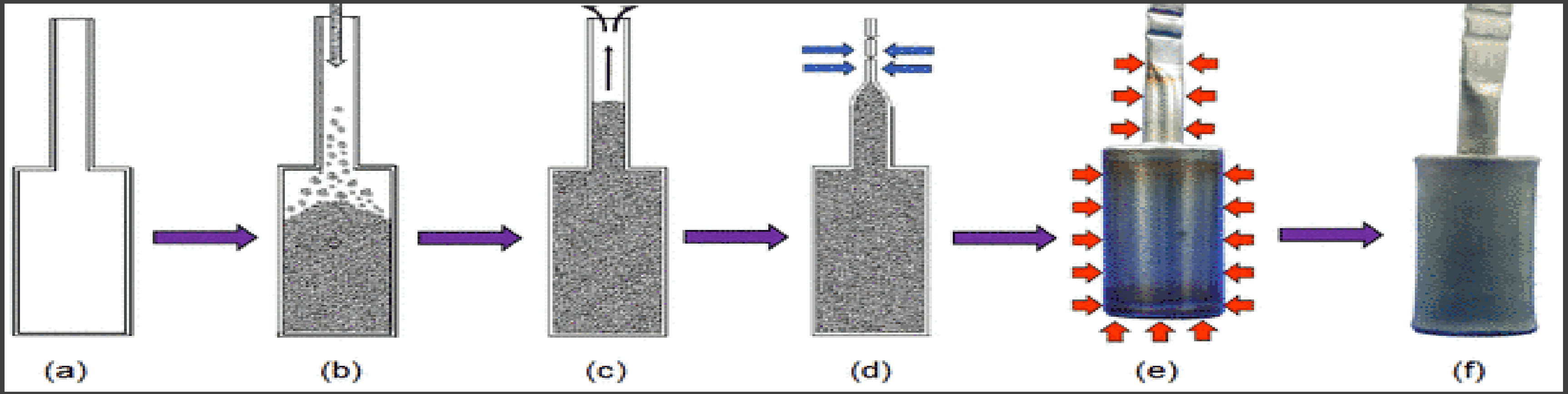


1. **Be-38Al (Lightweight & Stiff Substrate)**
2. **Joining (Liquid Interface Diffusion Bonding)**
3. **Electroless Nickel (To Create an Amorphous Surface)**
4. **Single Point Diamond Turning (To Create an Optical Surface)**

Be-38Al
(Highly Characterized Material - Initial Use 1964)



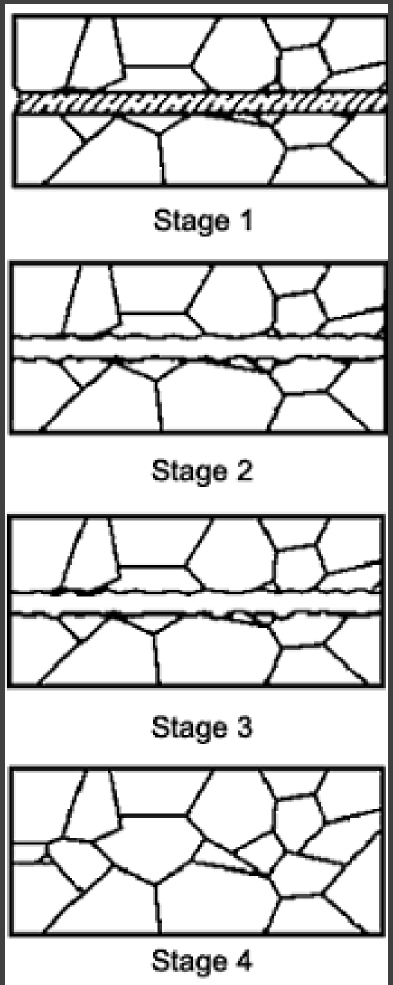
- Low cost substitute for beryllium. (Density 1.85 gm/cc Be; 2.1 gm/cc Be-38Al)
- Be-38Al is a powdered metallurgy material. Each particle of spherical powder is 62% beryllium / 38% aluminum.

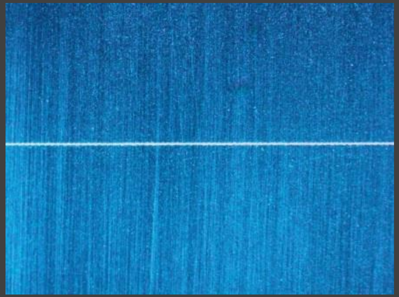


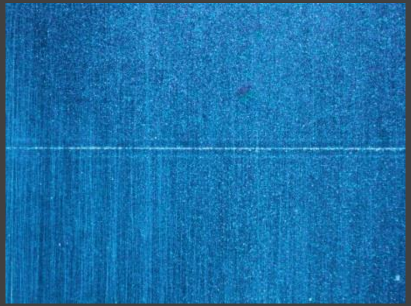
Process
Hot Isostatic Press (HIP)

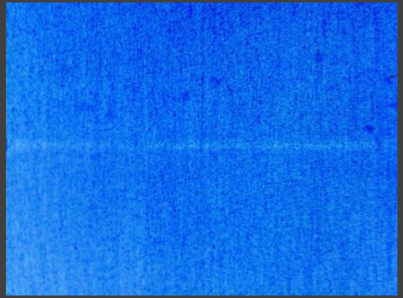
Phase II: Liquid Interface Diffusion Bond

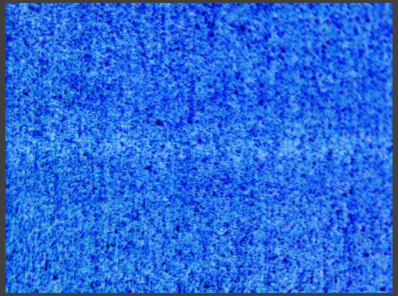
Time, Temperature and Pressure Dependent



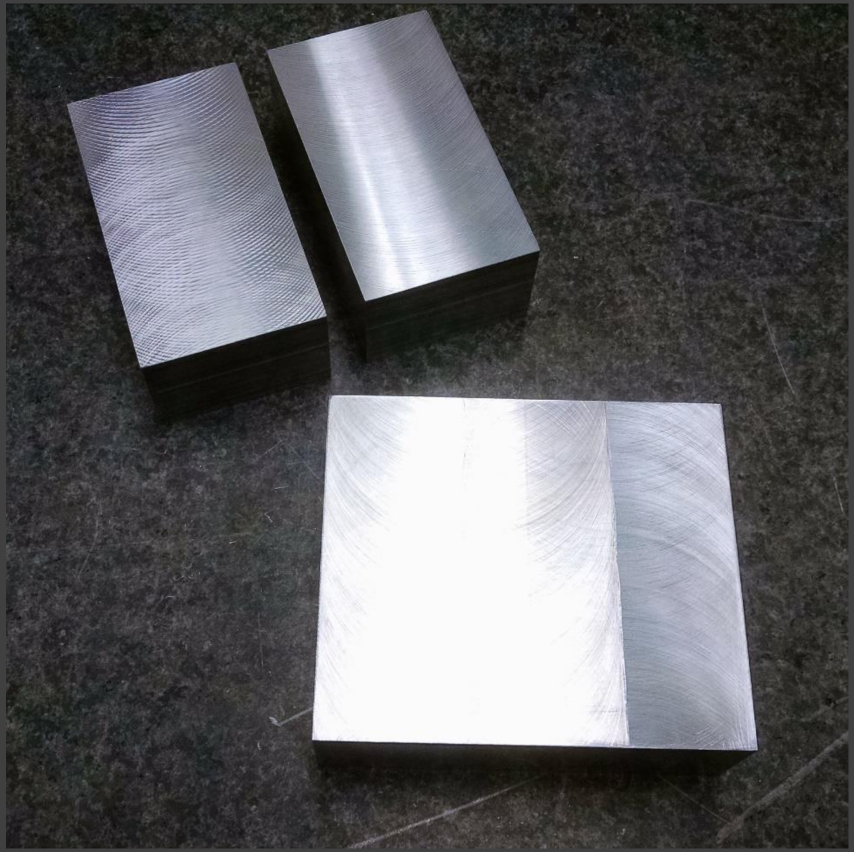






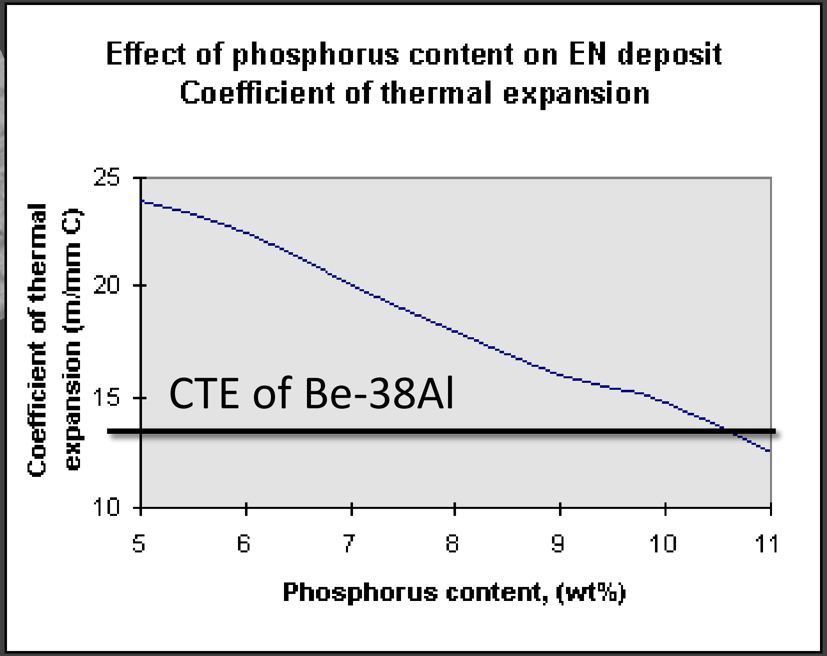


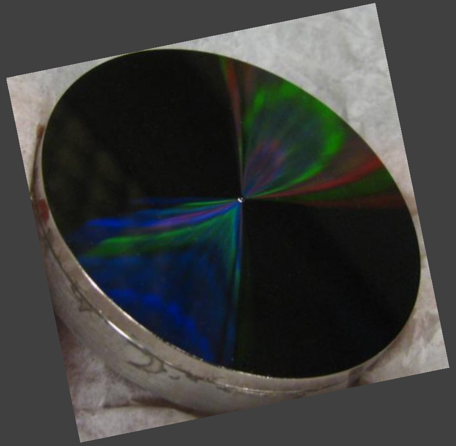
Phase II: LID Bond Applied to Substrate Coupons



Electroless Nickel
(A Highly Characterized Process - Developed in 1942)

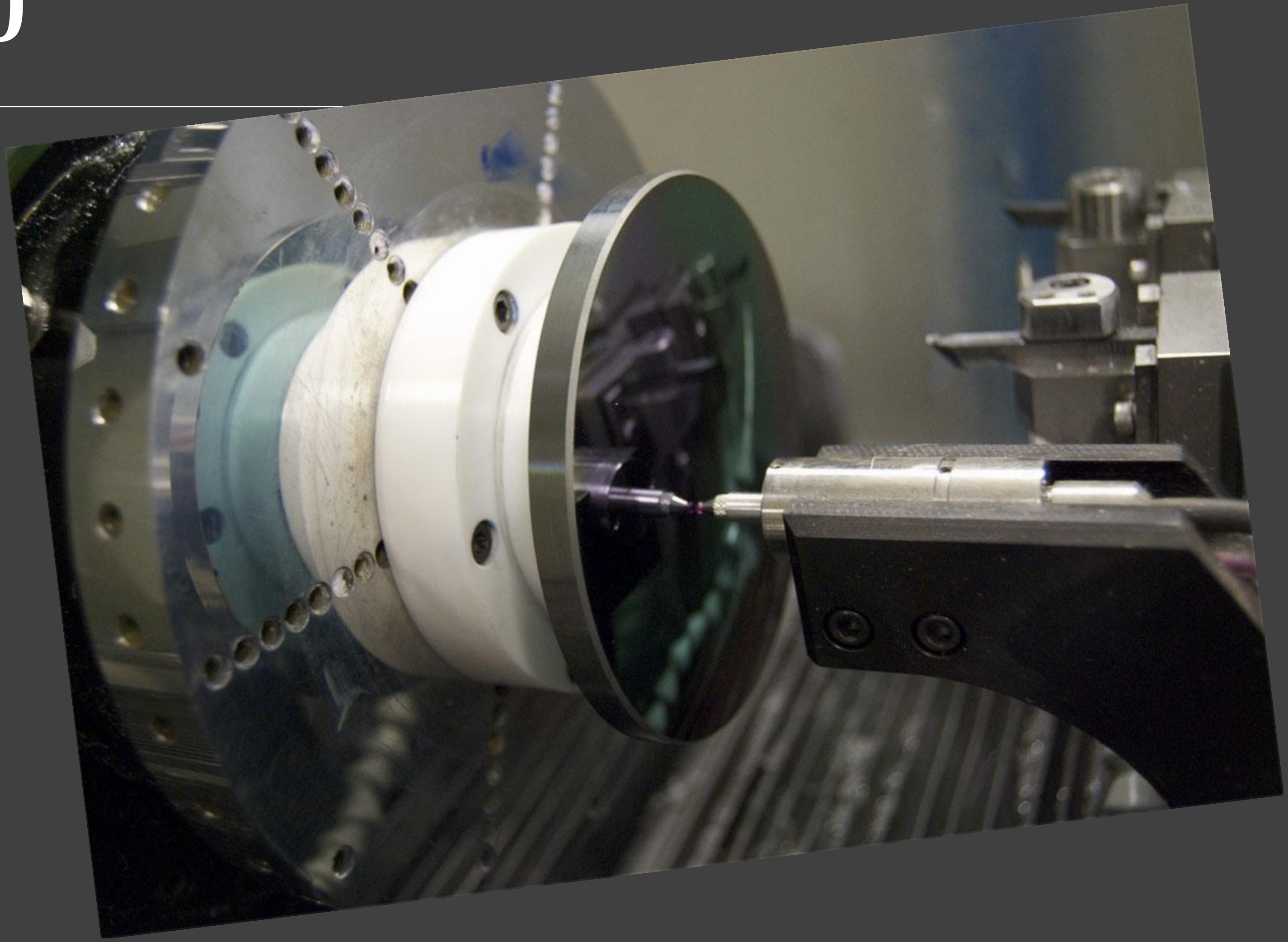
- An autocatalytic process that uniformly deposits and replicates the receiving surface.
- It is amorphous layer, leading to the term "metal glass."
- Highly machinable.



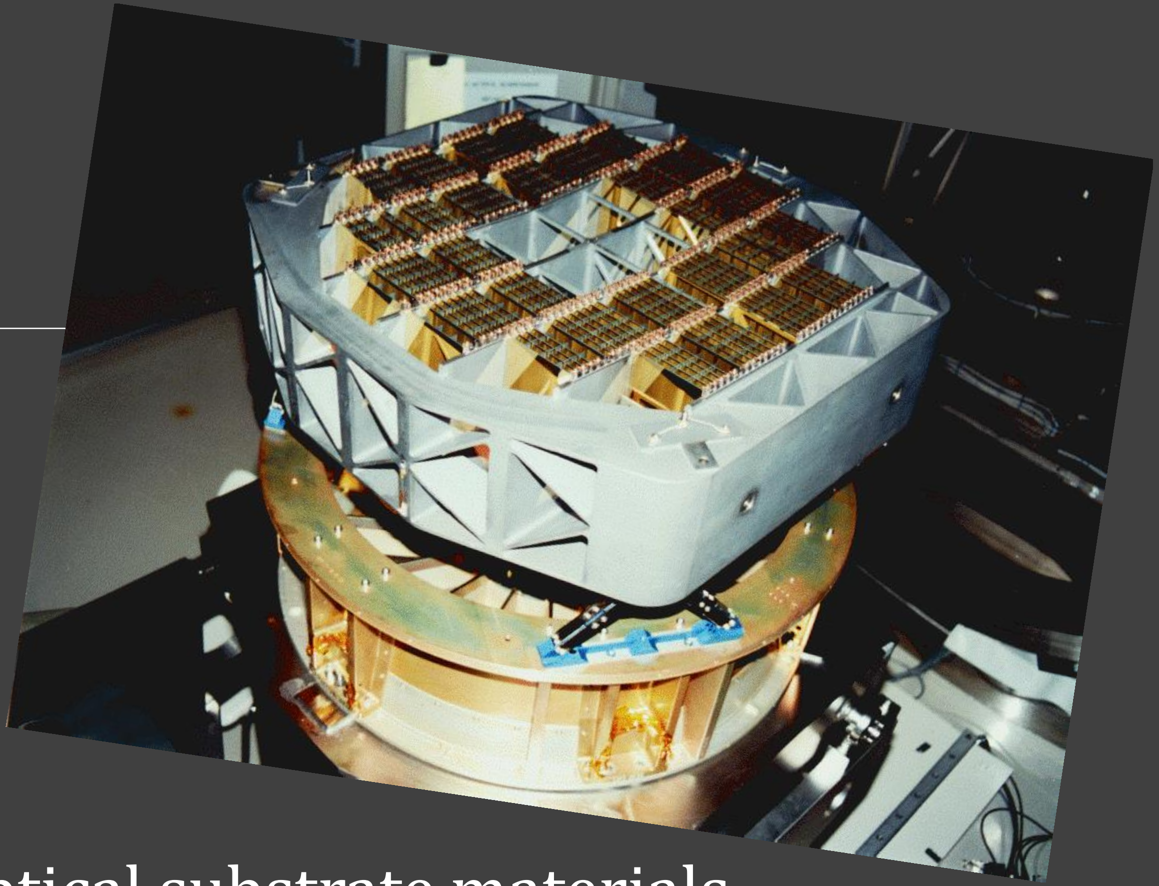


Single Point Diamond Turning
(An Established Process)

- Surface Figure < 10 nm
- Surface Roughness < 5 nm
- A manageable process, single point diamond turning, after setup, will take days on very large surfaces to produce. This is compared to years for conventional grinding and polishing.
- No roll off on edges of the mirror provides full use of the optical surface potentially yielding zero straight light.
- Initial single point contact needs more support than the continuous cut, allowing for the substrate to be so designed.



Recovery



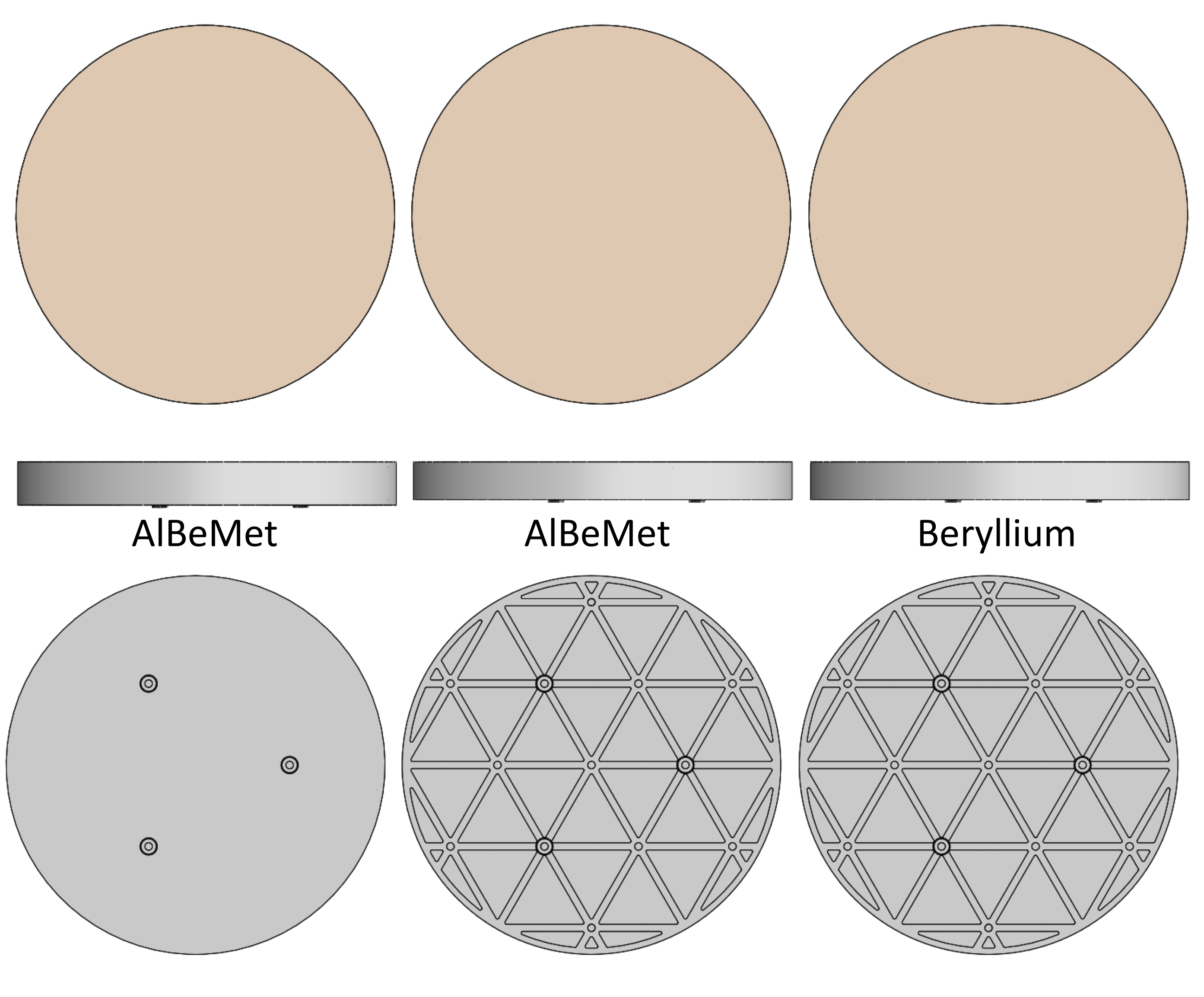
- Be-38Al is not brittle like Be and other optical substrate materials.
- Be-38Al (*Tougher*); repaired by welding/brazing/epoxy bonding/other.
- LID Bonding; a stepable process
- NiP plating can be mechanically removed and re-plated.

Material Comparison Table

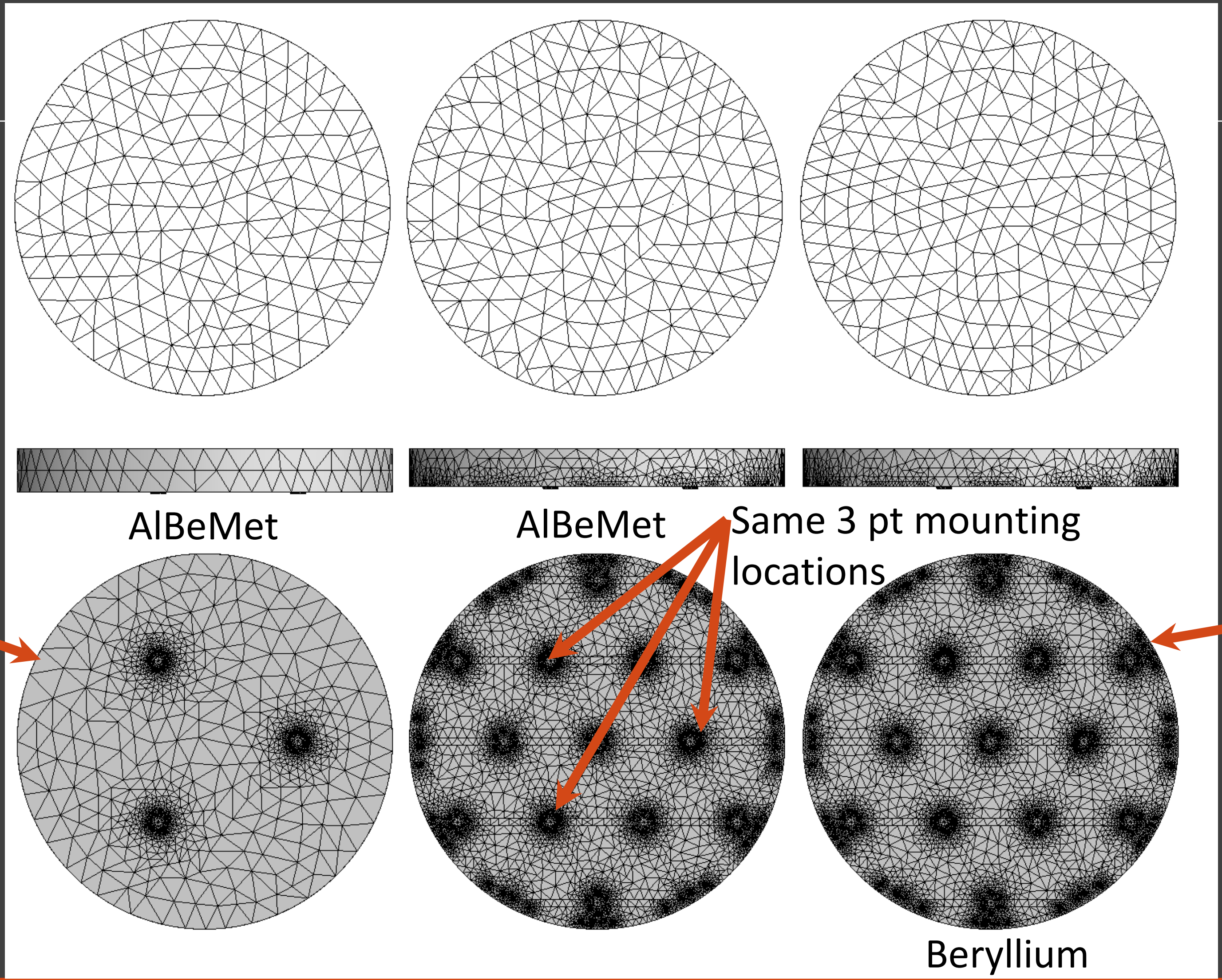
Material	Thermal Conductivity W/mK	Young's Modulus GPa	Density gm/cc	Specific Modulus	PEL MPa
Zerodur	1.46	90.3	2.53	35.7	NA
Silicon Carbide (CVD)	152	311	2.95	105.4	NA
Beryllium	216	303	1.85	163.8	30
ULE	1.3	68	2.21	30.8	NA
Be-38Al	210	192	2.10	91.4	17.3

Phase II: Half Meter Optics Design Effort

10 g load simulations



Phase II: Half Meter Design - Model Meshing

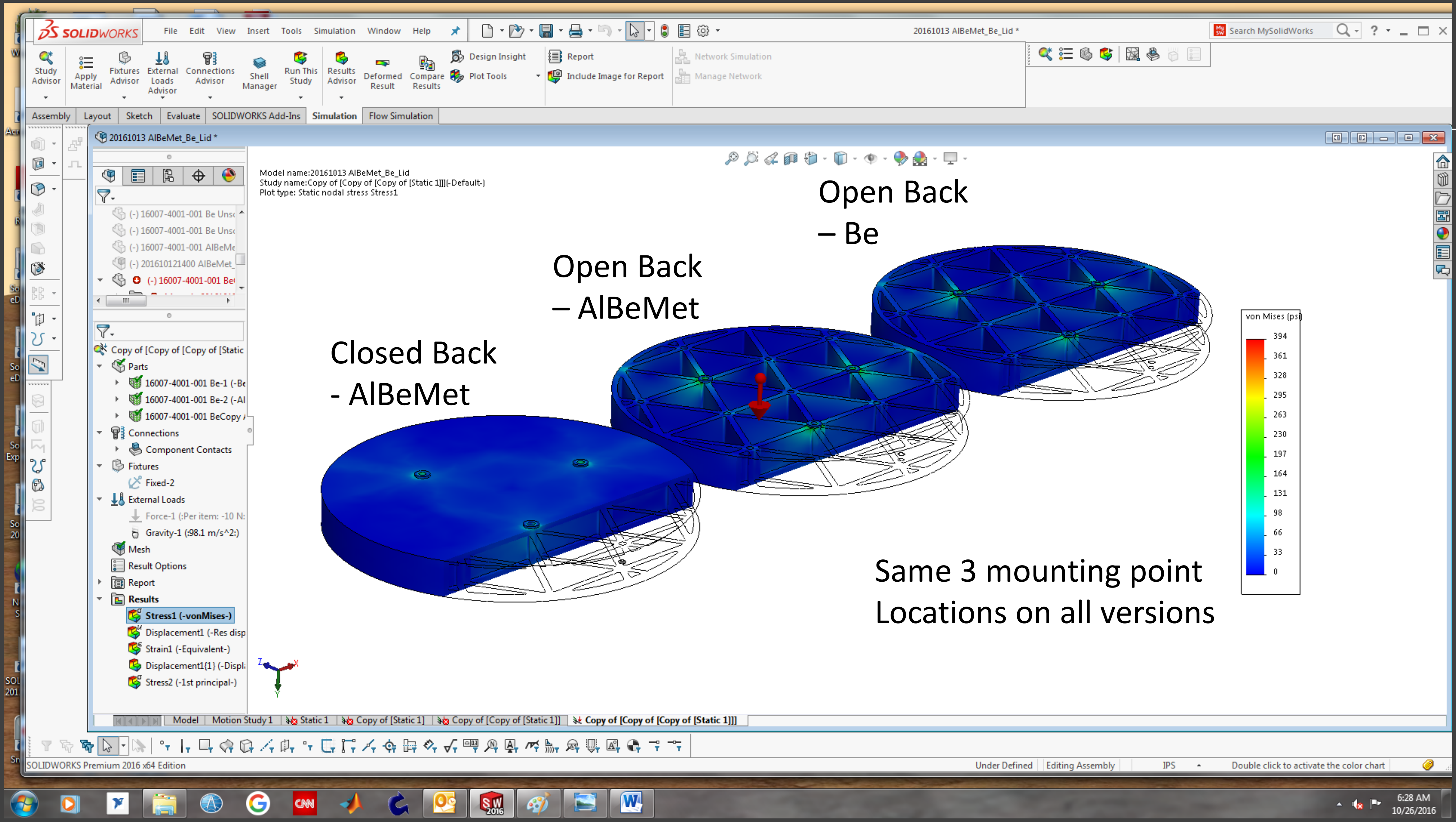


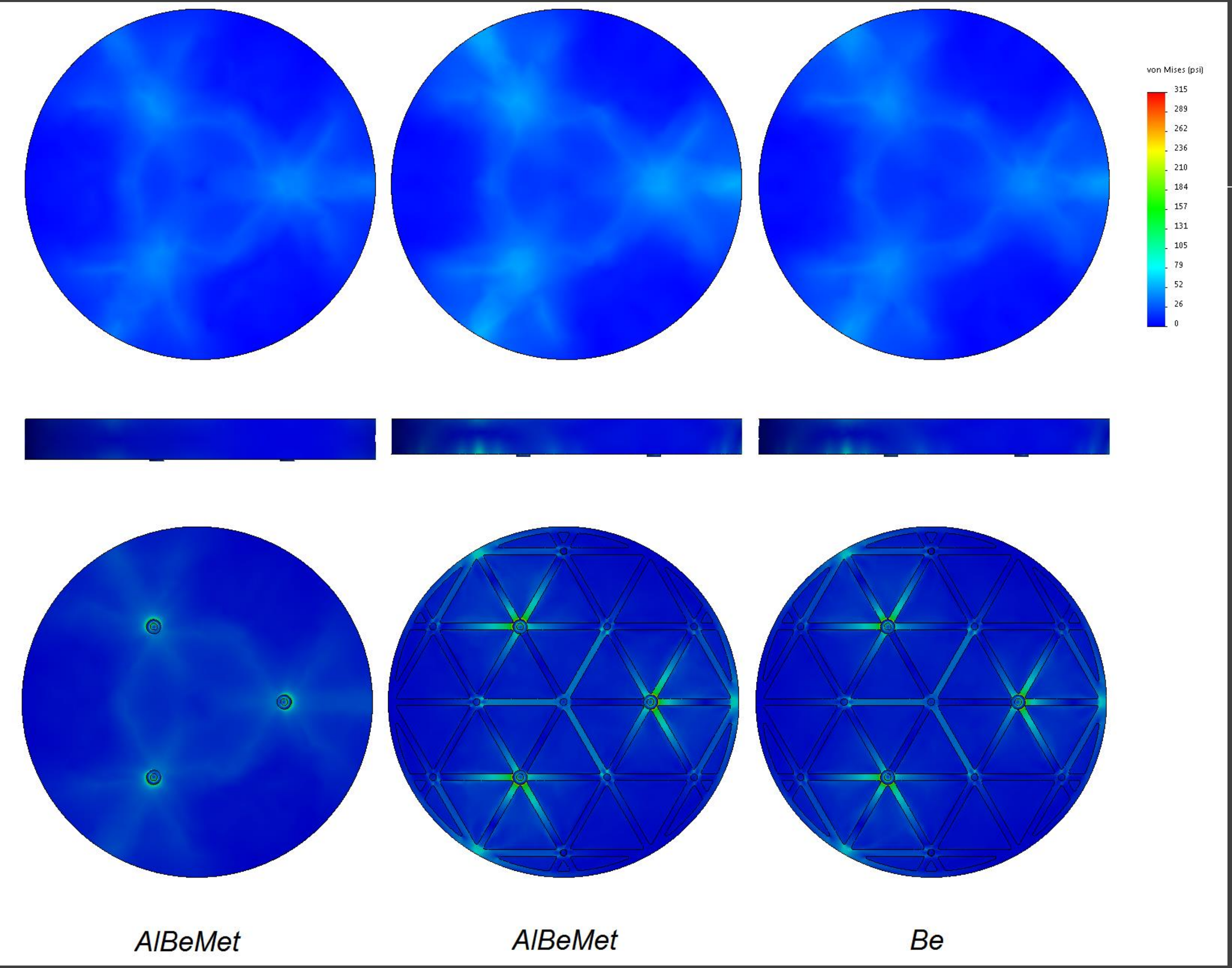
The three designs show similar meshing on the optical face.

The meshing operation establishes the load paths.

Closed back design shows the meshing/nodes establishing the load paths across the back surface.

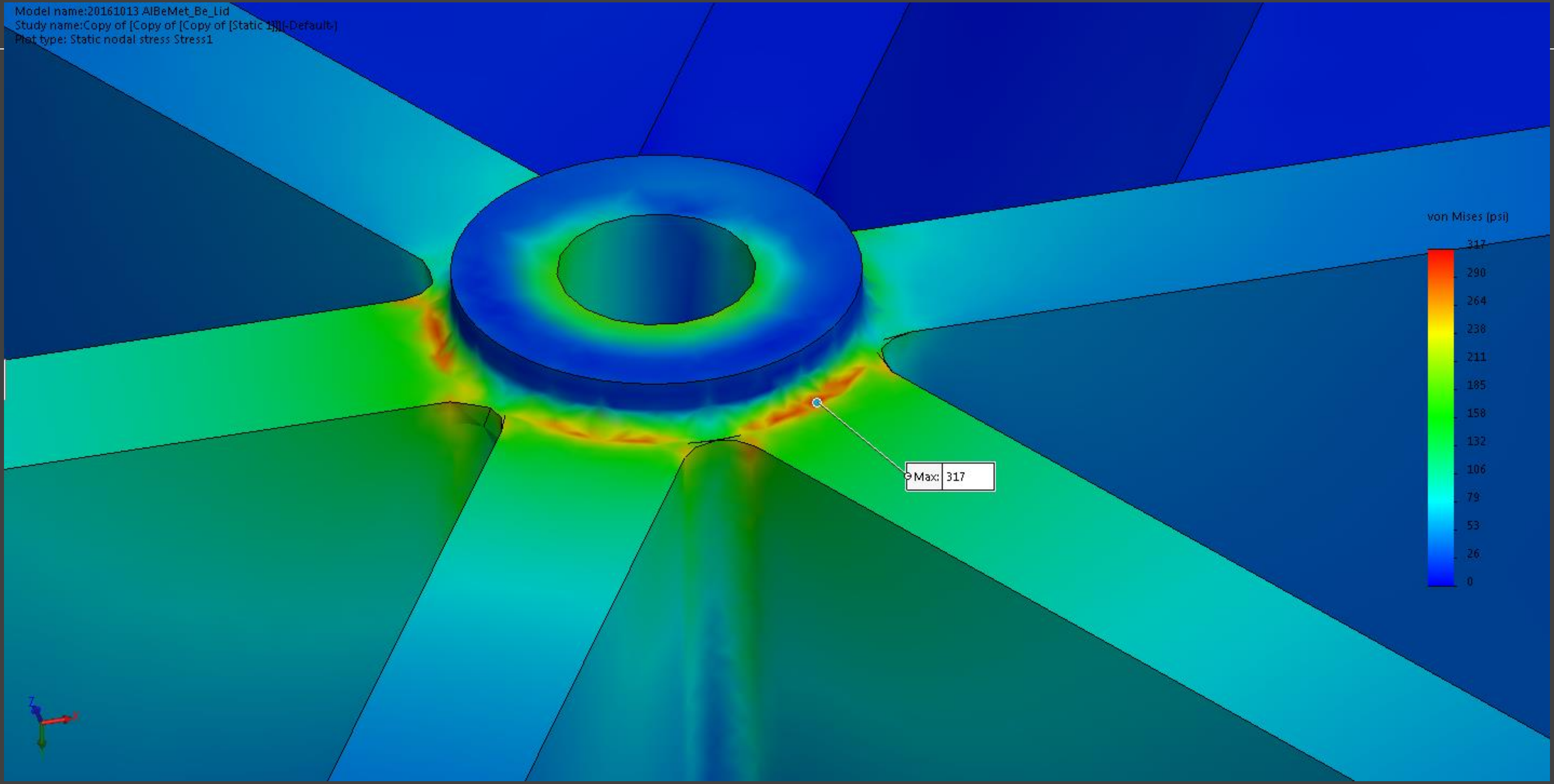
Open back designs show the meshing/node concentrations around the intersecting ribs on the back side of the mirror


Model name:20161013 AlBeMet_Be_Lid
Study name:Copy of [Copy of [Copy of [Static 1]]](-Default-)
Plot type: Static nodal stress Stress1
Open Back – Be
Open Back – AlBeMet
Closed Back - AlBeMet
Same 3 mounting point Locations on all versions
von Mises (psi)
394
361
328
295
263
230
197
164
131
98
66
33
0

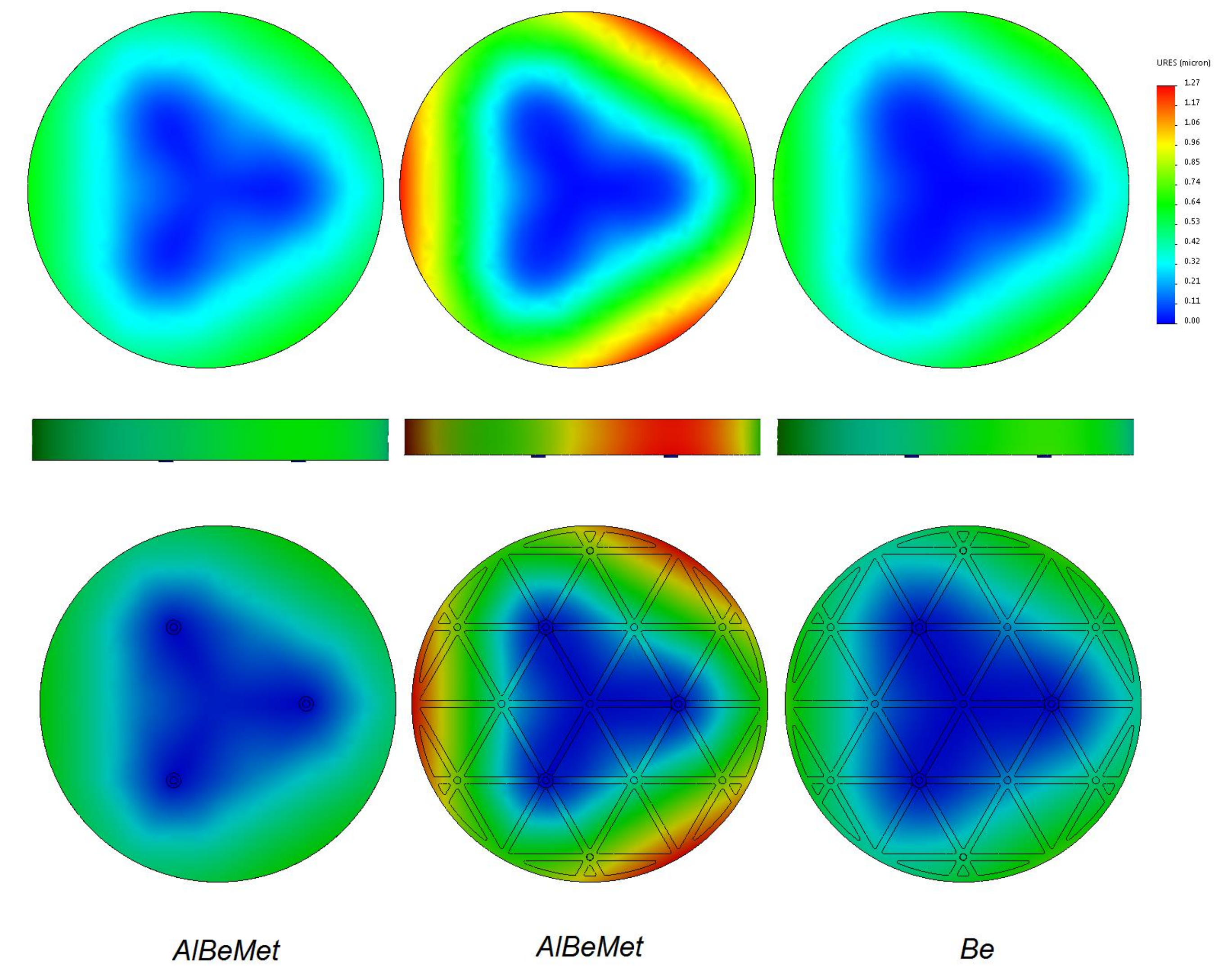


Peak loads are in the 315 psi range for the open back designs, lower in closed back.

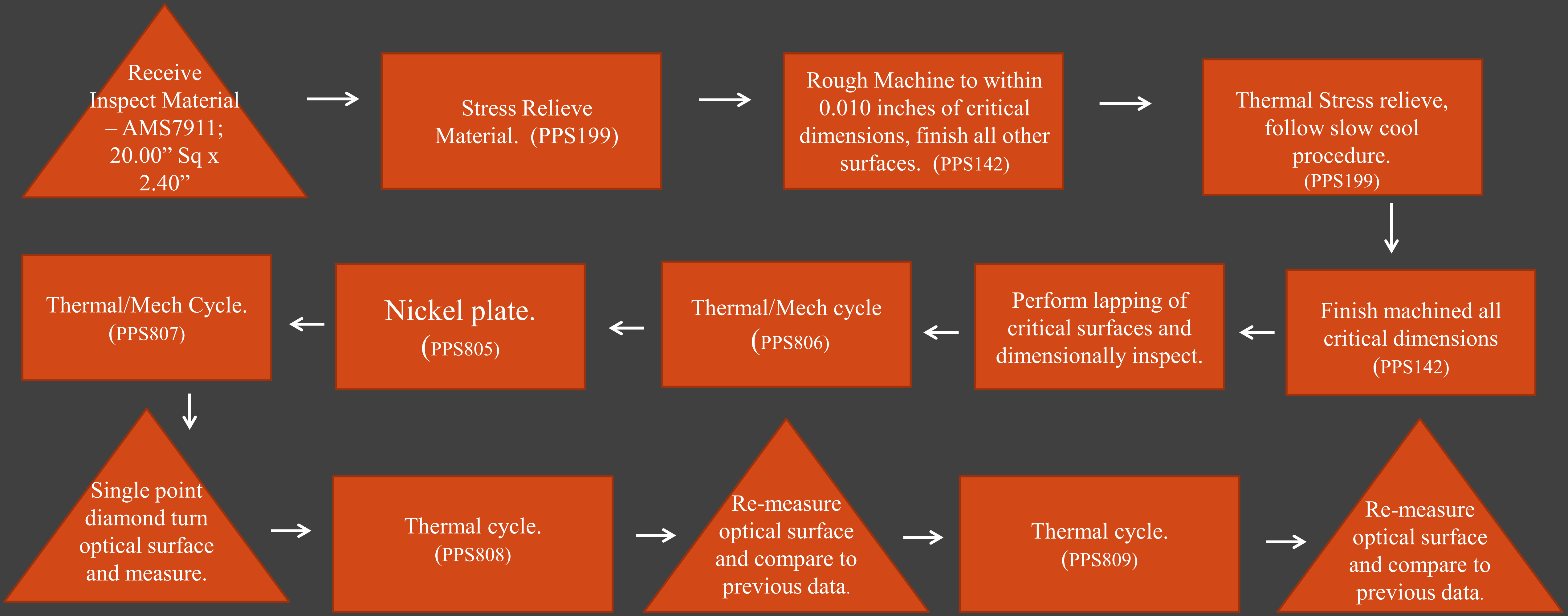
Peak Stress – Open Back AlBeMet Design



Deflection in Microns – Be and Closed Back AlBeMet Similar



Phase II: Fabrication, Key Operations

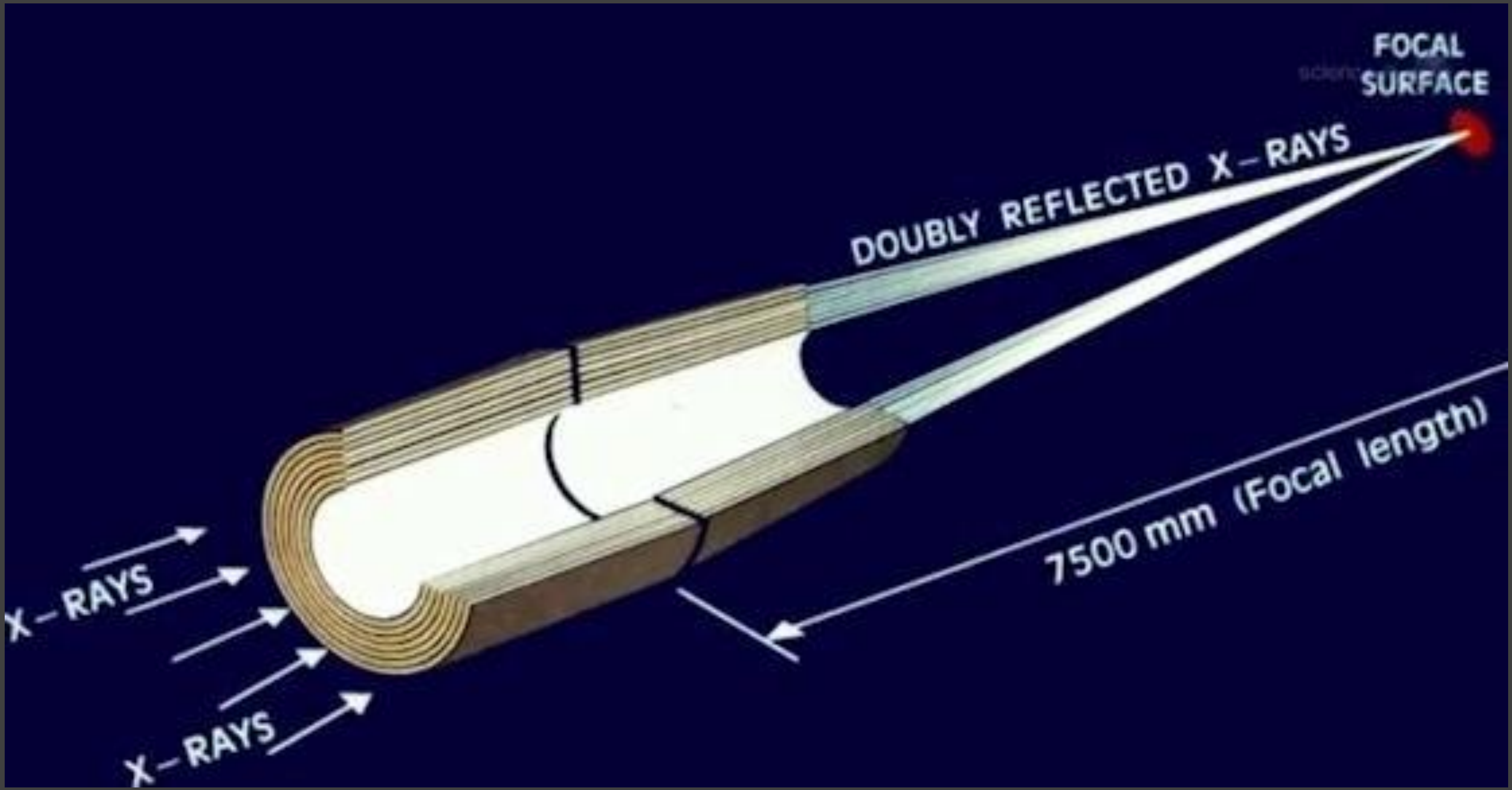


Advantages

The Be-38Al/LID/NiP/SPDT system provides the following advantages:

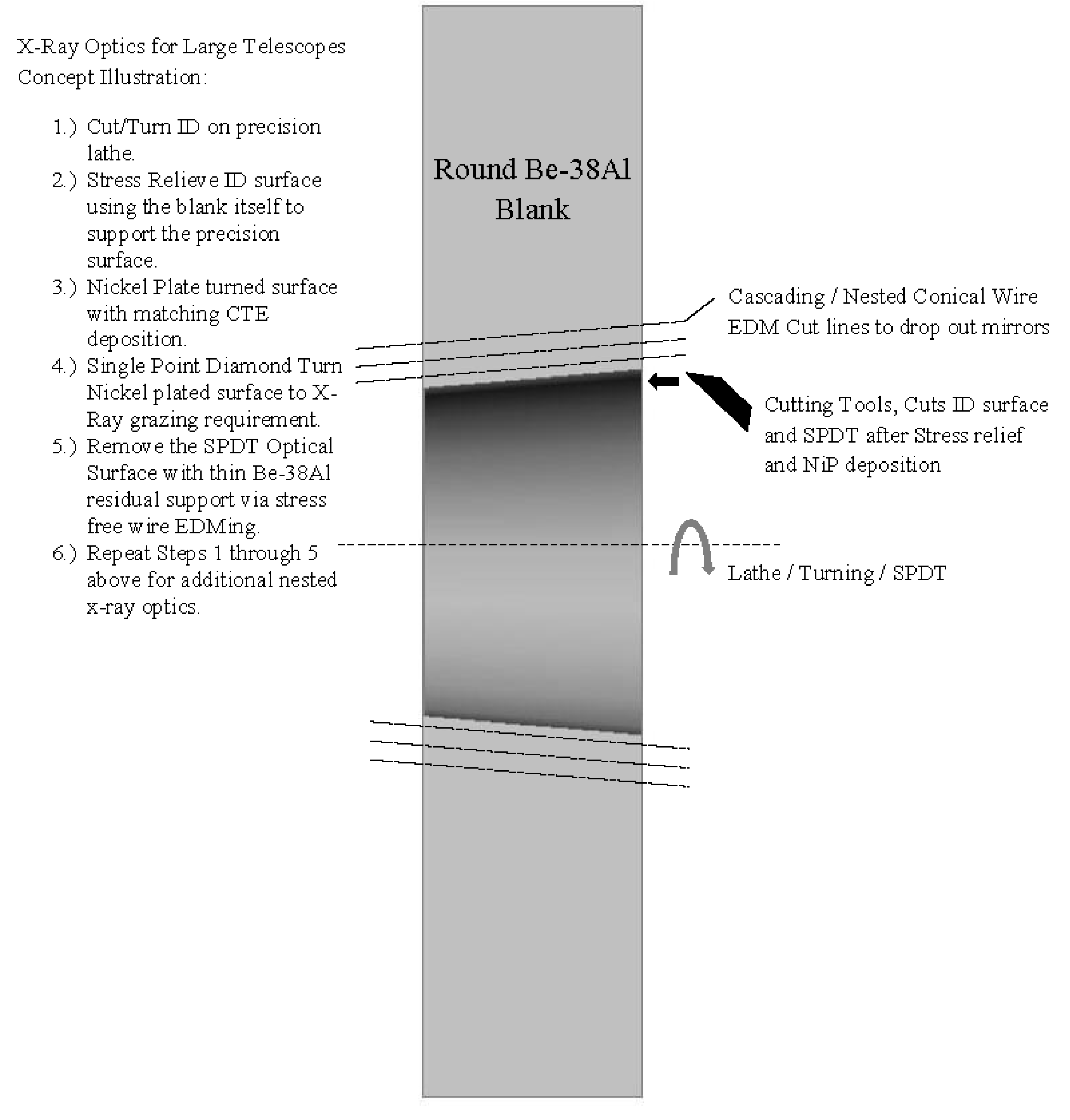
- Closed back substrates can be produced (Aspect ratios < 10 to 1; Large section modulus).
- Segmented substrates and structure can be produced (very large).
- Low areal density designs (Lightweight substrates to survive launch).
- NiP provides an amorphous optical surface (Can be Single Point Diamond Turned, SPTD).
- SPDT to the edge uses entire optical surface and eliminates stray light (Most efficient).
- Robust; it's durable and repairable (Reduces risk in schedule).
- Allows for the design of an athermal telescope (No dissimilar metal CTE issues).

X-Ray Grazing Substrates

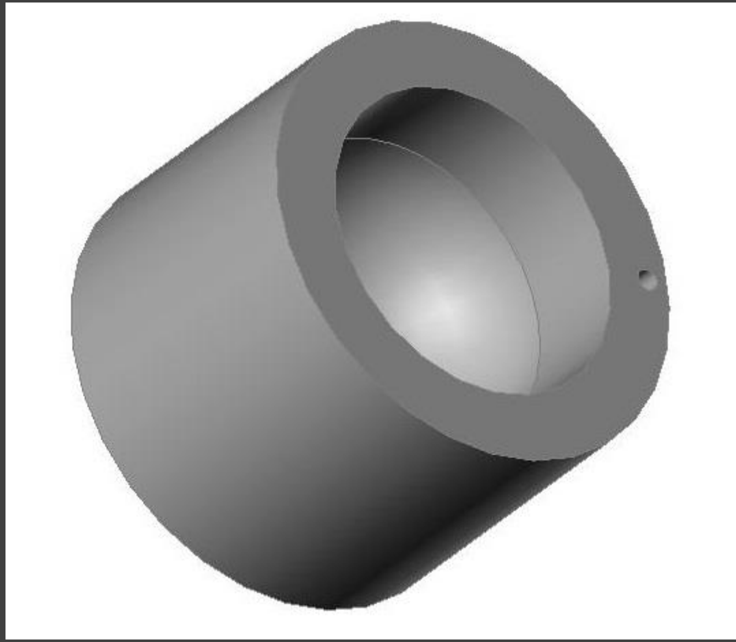


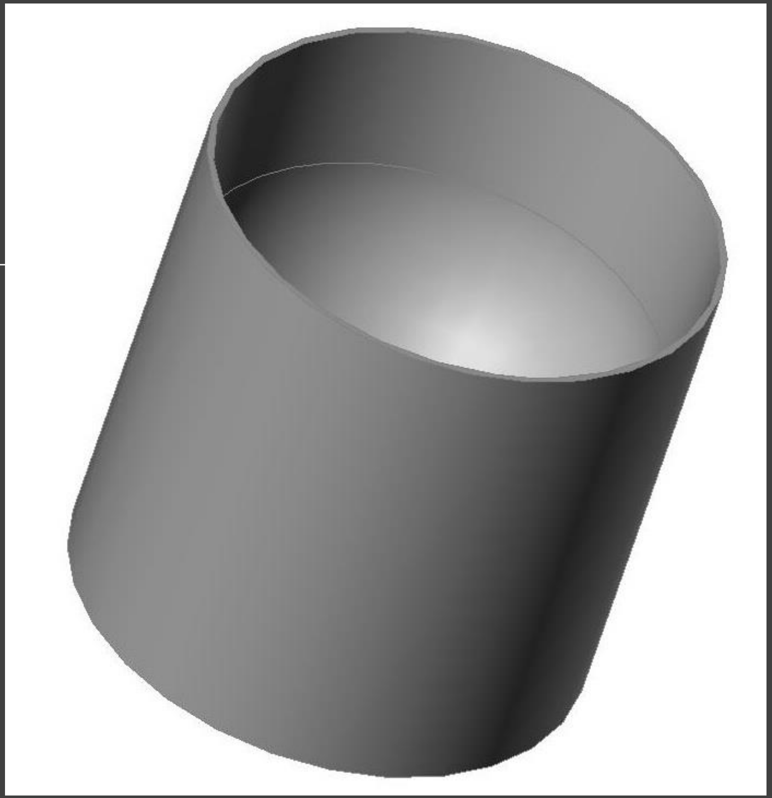
X-Ray Surveyor
may be 3 m in Size

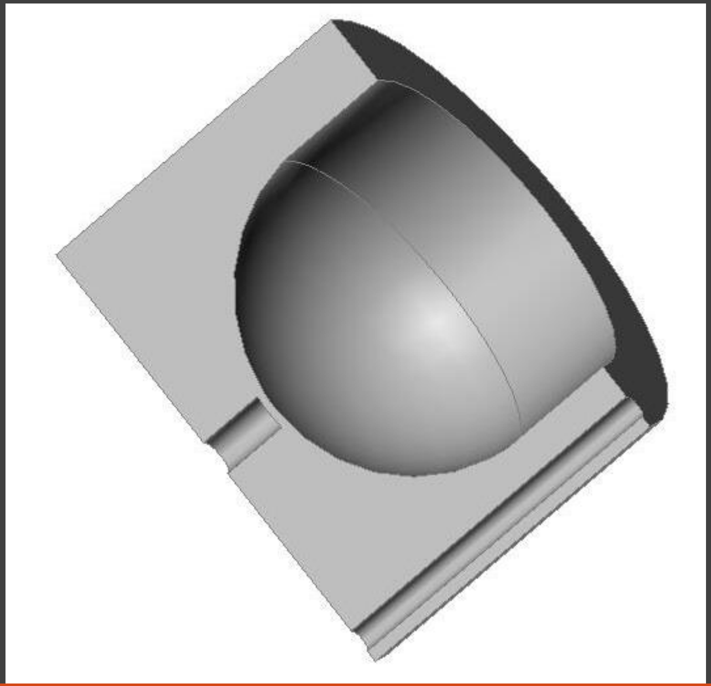
Phase I: Substrate Production Concept



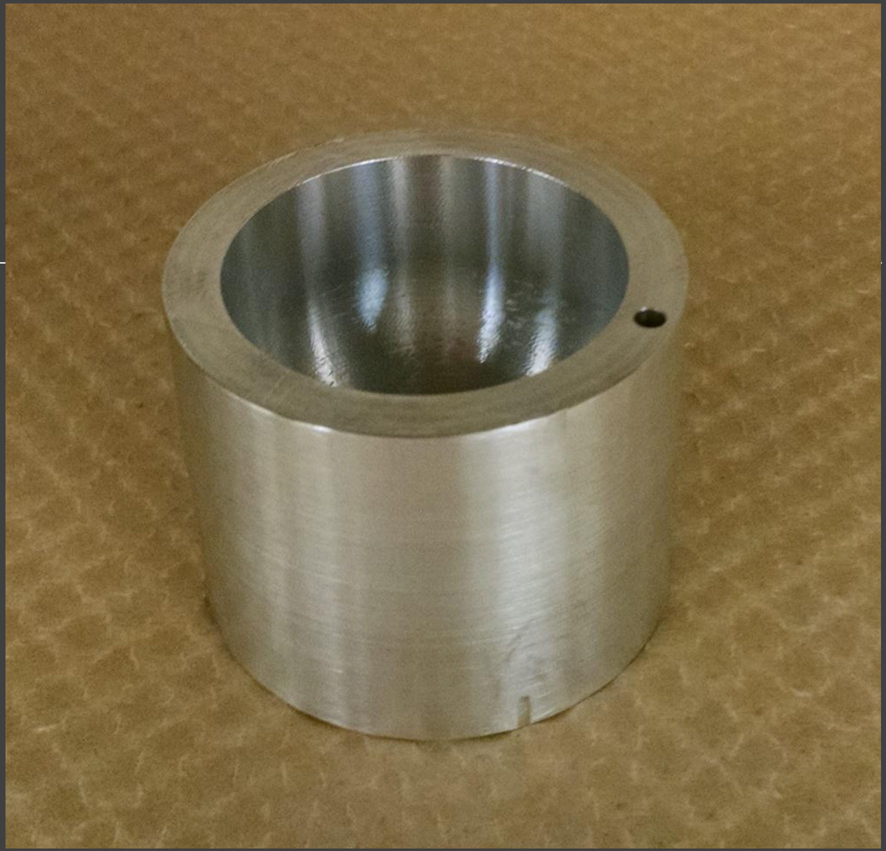
Phase I: Configuration







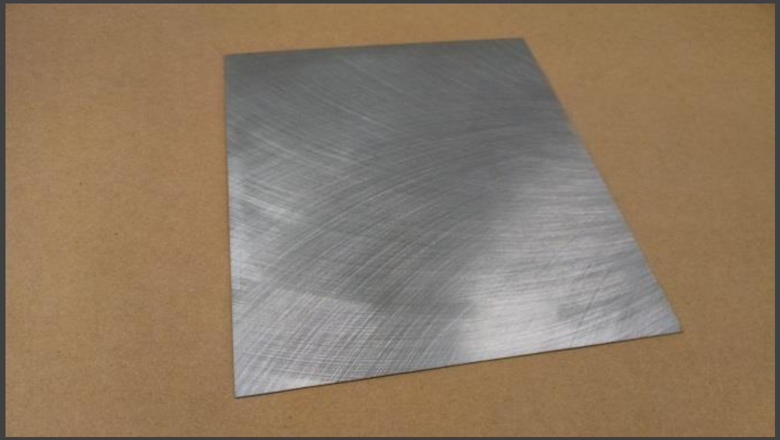
Phase I: Progress



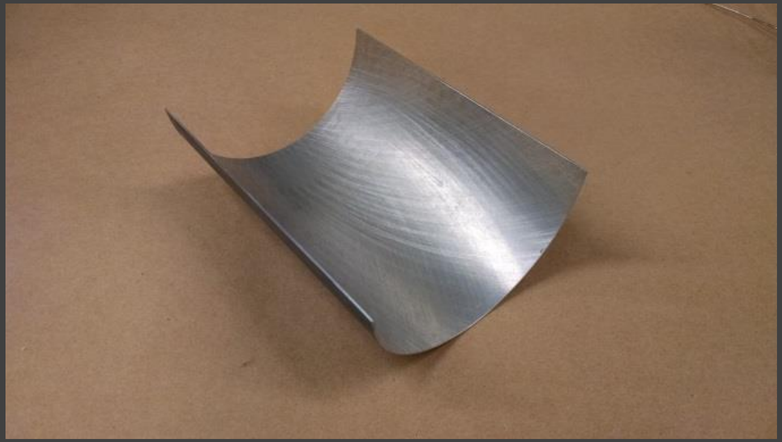
- Substrate Coupons Machined
- Substrate Coupons Stress Relieved
- Substrate Coupons Electroless Nickel Plated
- Substrate Coupons Thermally Cycled
- Next SPDT and Measure
- Then Wire EDM Release and Re-measure

Electroless Nickel Plating – Stress Relief Operations

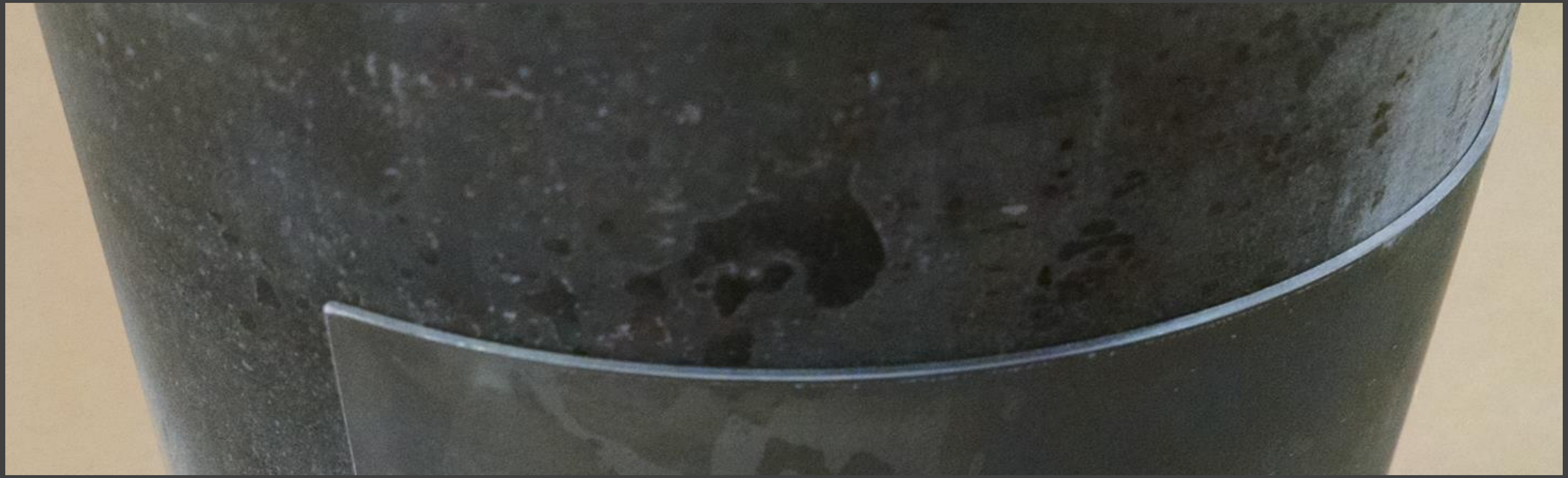
Test Coupon	Condition	Hardness - HRB
Bare AlBeMet	Stress Relieved, 925° F, 1 hour	67
AlBeMet with NiP	As Plated	75
AlBeMet with NiP	Stress Relieved, 925° F, 1 hour	71



1 mm thick Ground Segment



Creep Formed



Thermally Sized Against Mandrel – No Measurable Spring-back

Goals

Future optical and x-ray telescopes planned by NASA are all growing in size to substantial large diameters. This requires stable substrates and the production of telescopes well beyond the sizes previously produced. Due to their large size, the design parameters that are typically in contradiction of low cost, low weight, longterm stability, and high precision need to converge.

The successful development of this Advanced Material System will give designers the means to meet the upcoming challenges for future large NASA space borne telescopes.

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