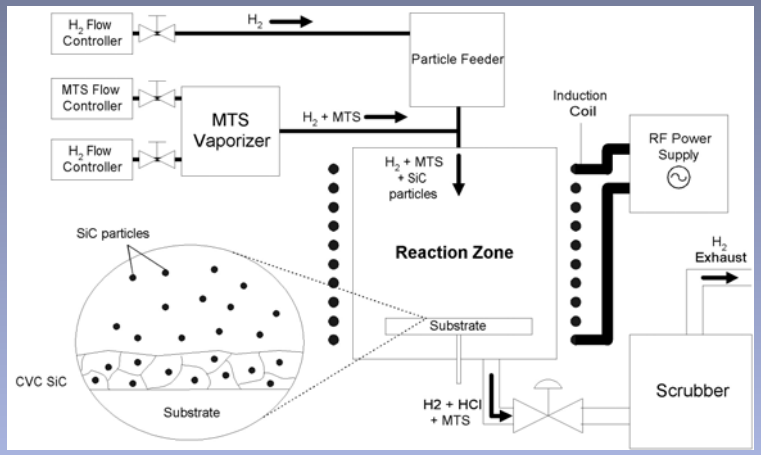
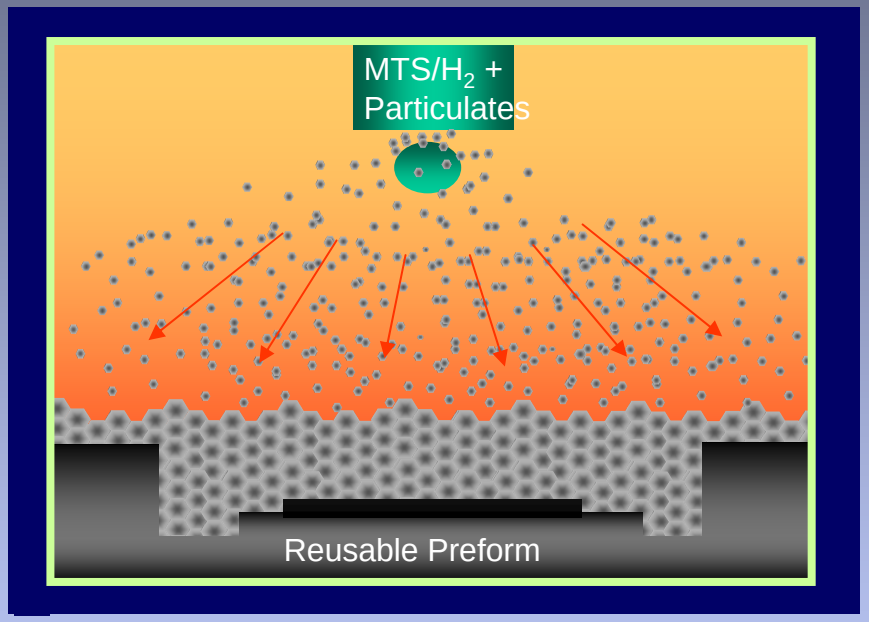
CVC SiC for Advanced Optical Systems

Reliable, Repeatable, Reproducible, and Deliverable

The Chemical Vapor Composites Process





$$CH_3SiCl_{3(g)} \rightarrow SiC_{(s)} + 3HCl_{(g)}$$

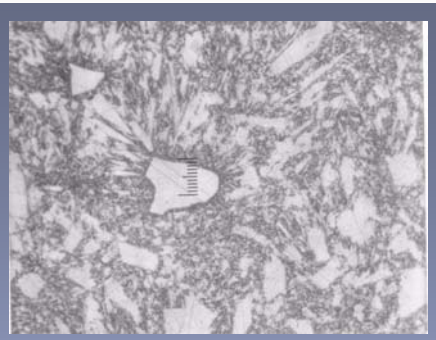
- Particles added to CVD stream lead to equiaxial grain growth and low intrinsic stress

US Patent No. 5,348,765

CVD and CVC Silicon Carbide: Grain Structure

CVD SiC

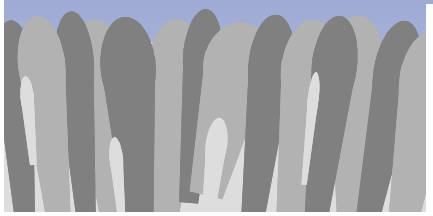
scale bar = 15 μm



Trex CVC SiC

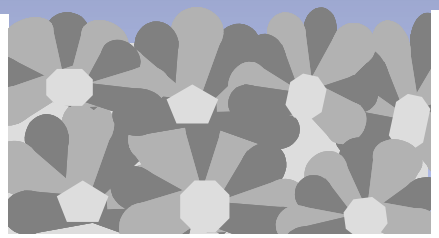
scale bar = 15 μm

Deposition Surface



Face Formerly Attached
To substrate

Conventional CVD

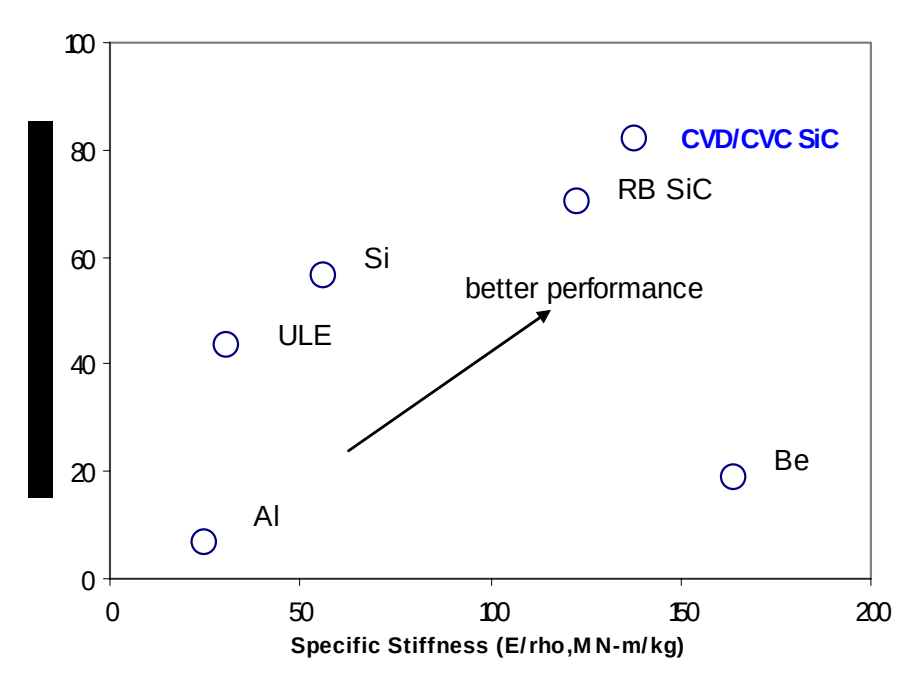


Trex CVC

SiC Particulates added to CVD reaction stream relieve intrinsic stress, but also reduce average grain size.

Mirror Applications

Comparison of mirror material performance parameters*



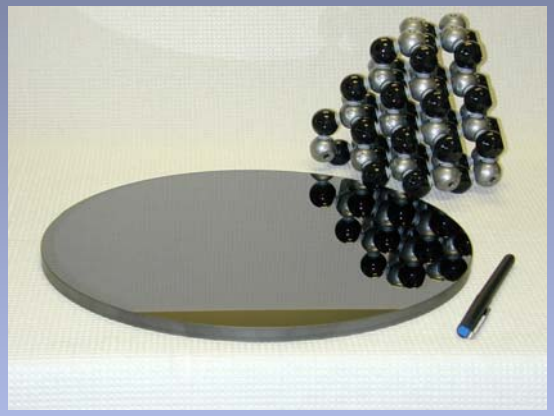
*Ealey, M.A.; Wellman, J.A.; Weaver, G. "CERAFORM SiC: Roadmap to 2 Meters and 2 kg/m2 Areal Density", in *Advanced Materials for Optics and Precision Structures*, M.A. Ealey, R.A. Paquin, and T.B. Parsonage, Eds., SPIE: Bellingham, WA, 1997.

RB SiC polishable to < 20 A rms. < 3 A rms with amorph. Si overcoat

Additional Advantages:

1. Fine polish possible with CVC SiC
2. Near net shape possible
3. **Highly reflective in vac. UV and X-ray regions of EM spectrum.**

Trex CVC SiC Mirrors



380 mm plano

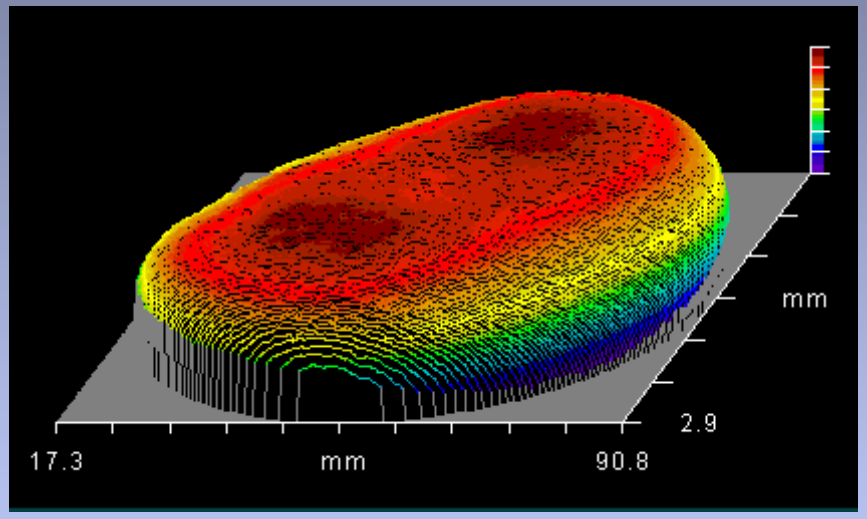
254 mm aperture

1.0 m roc powered mirror

254 mm composite

Trex CVC SiC Optical Properties

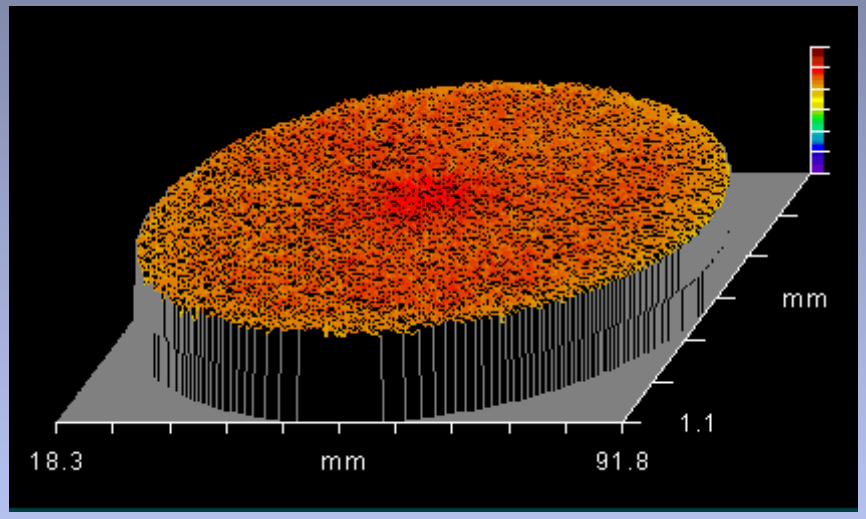
Initial Condition



0.122 λ P-V

0.022 λ rms

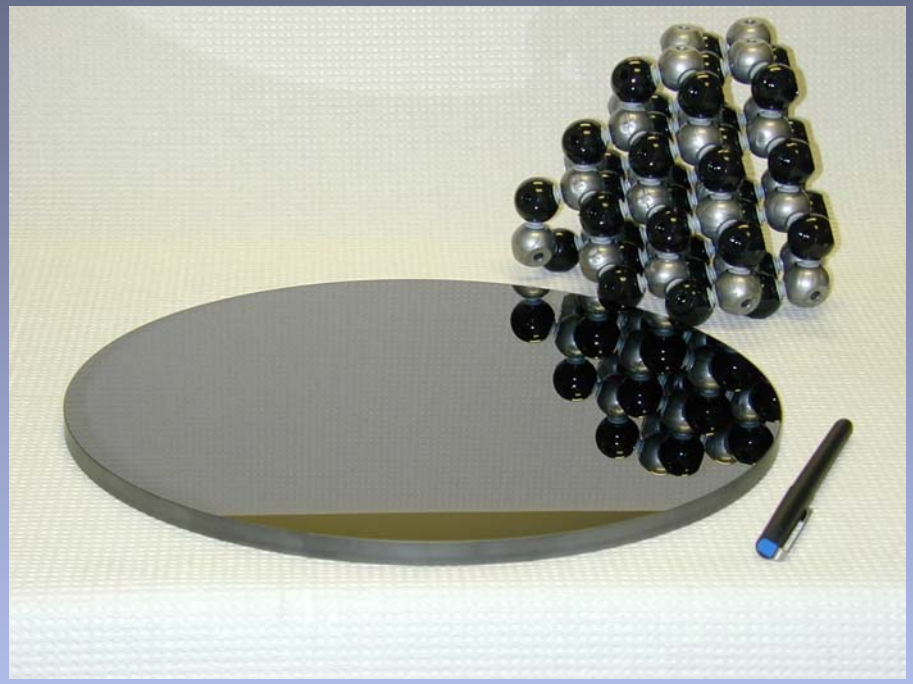
Single 11.3 minute Correction

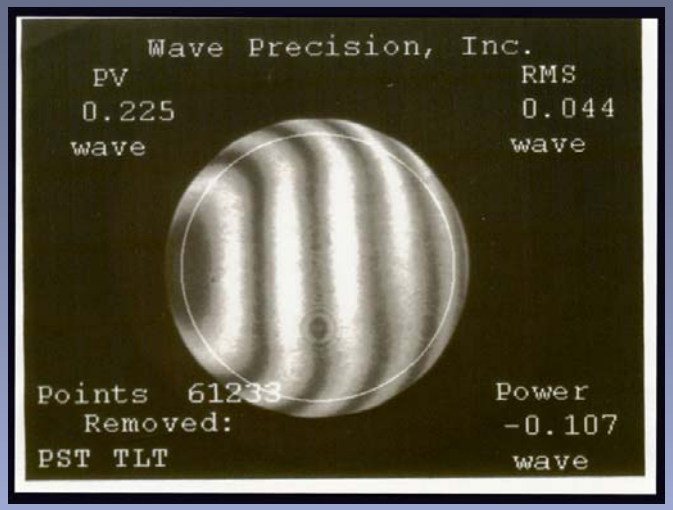


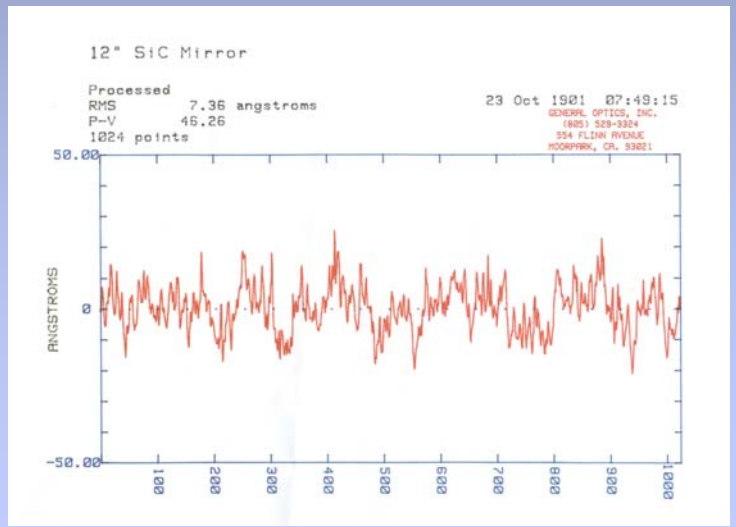
0.042 λ P-V

0.003 λ rms

Mirror Fabrication
Interference and Profile Analysis on 304 mm Monolithic Mirror







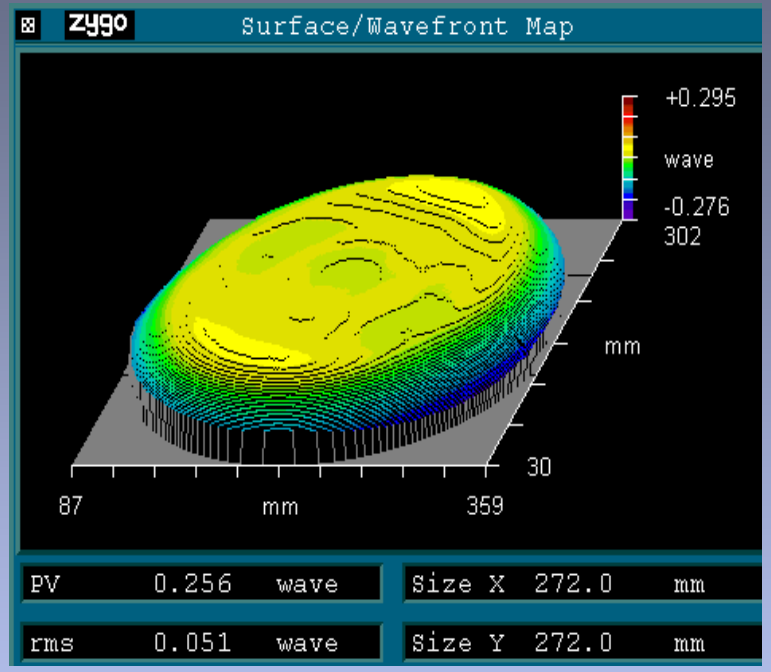
304 mm diameter 10 mm thick flat.

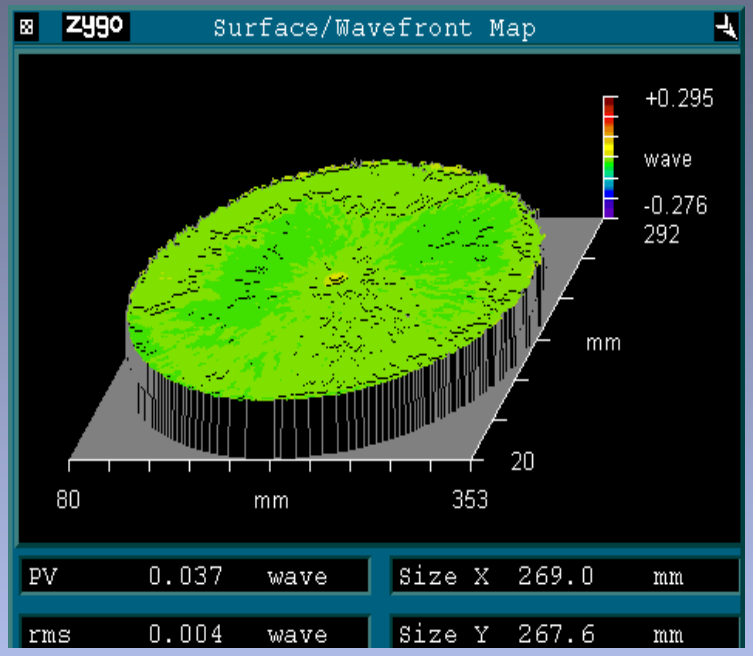
Areal density 32 kg/m^{-2}

Flatness 0.225 λ

RMS Roughness 7.36 Å

304 mm Monolithic Mirror
Super Polished



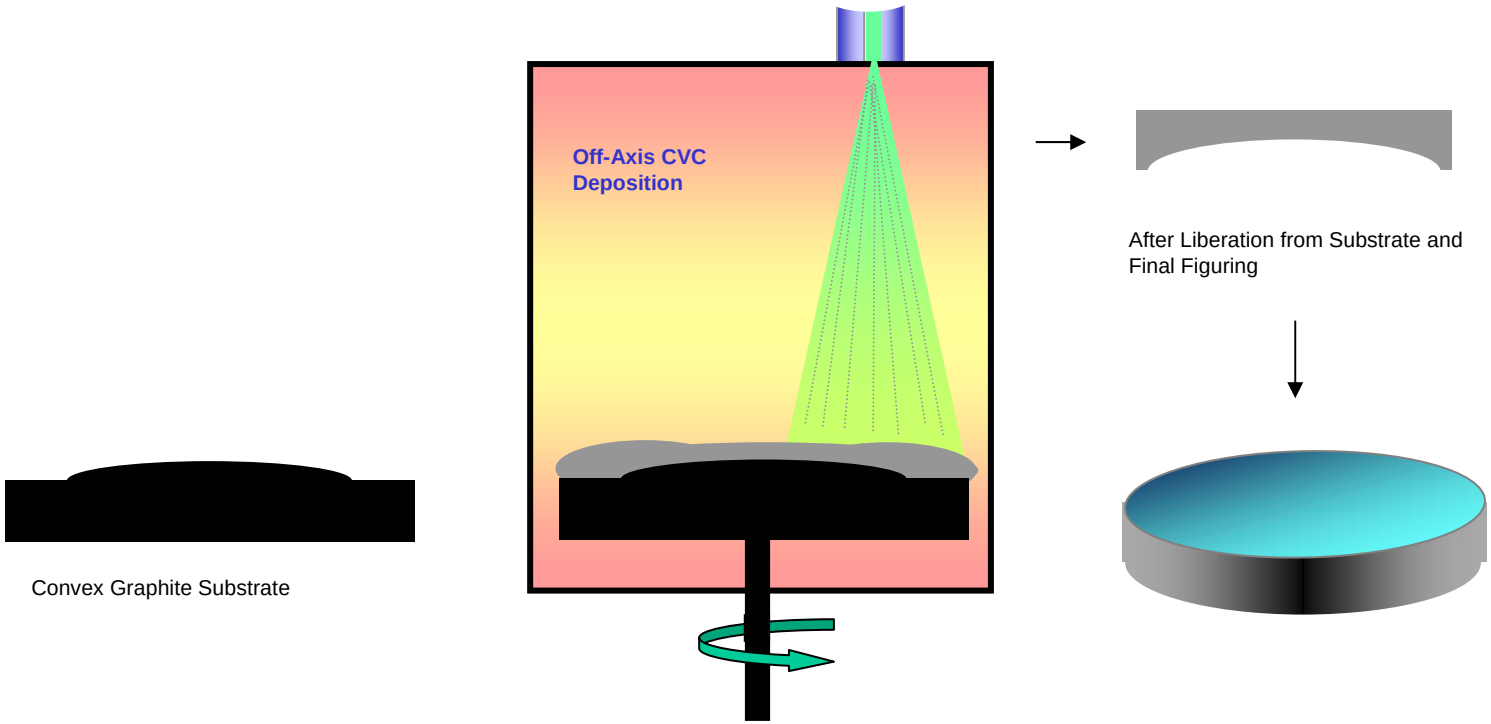


304 mm diameter 10 mm thick flat.

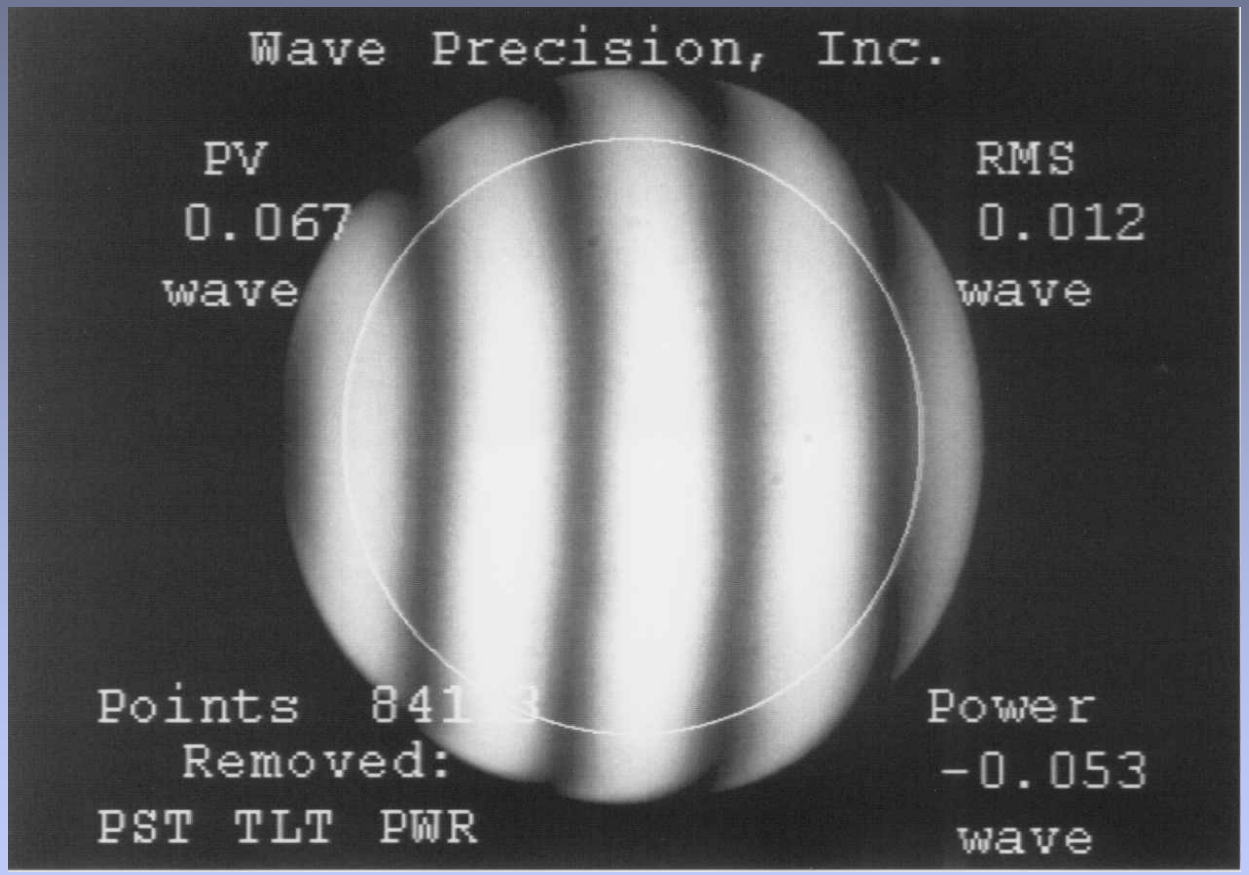
Areal density 32 kg m^{-2}

Flatness 0.037 λ P-V and 0.004 λ

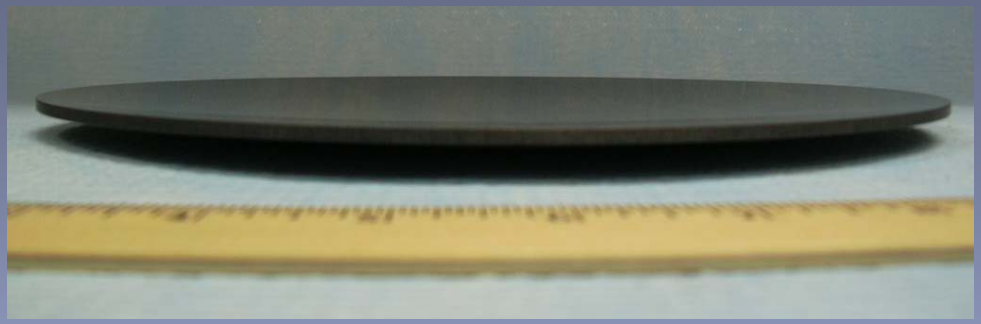
Net Shaped Deposition of Powered Silicon Carbide Mirrors

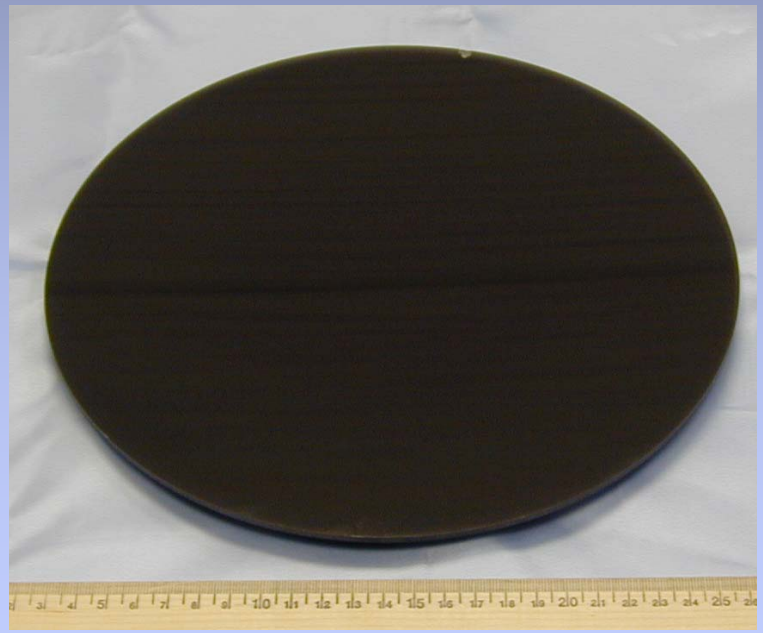


Interference Analysis of 254 mm Curved Mirror

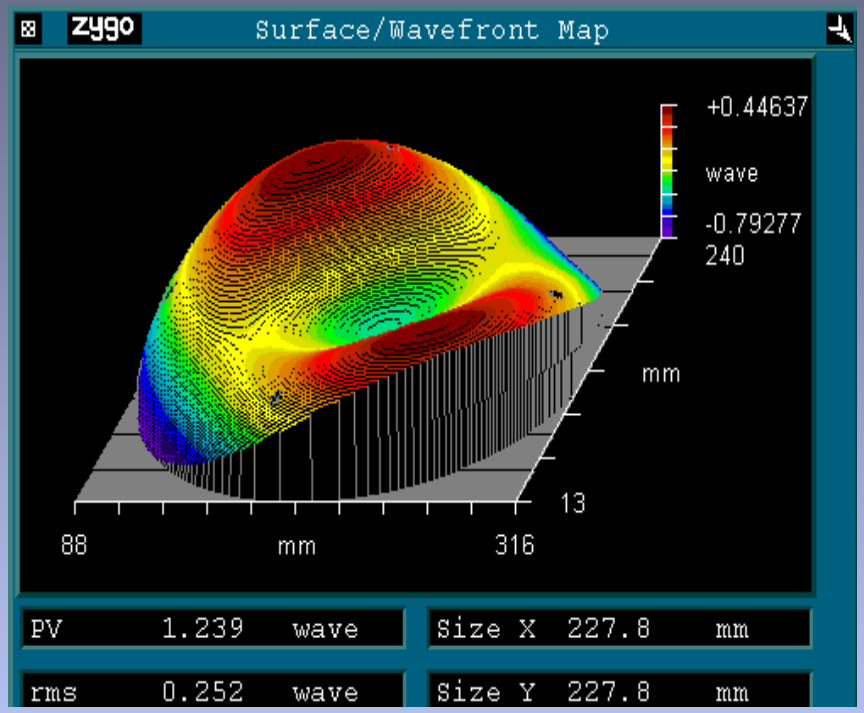


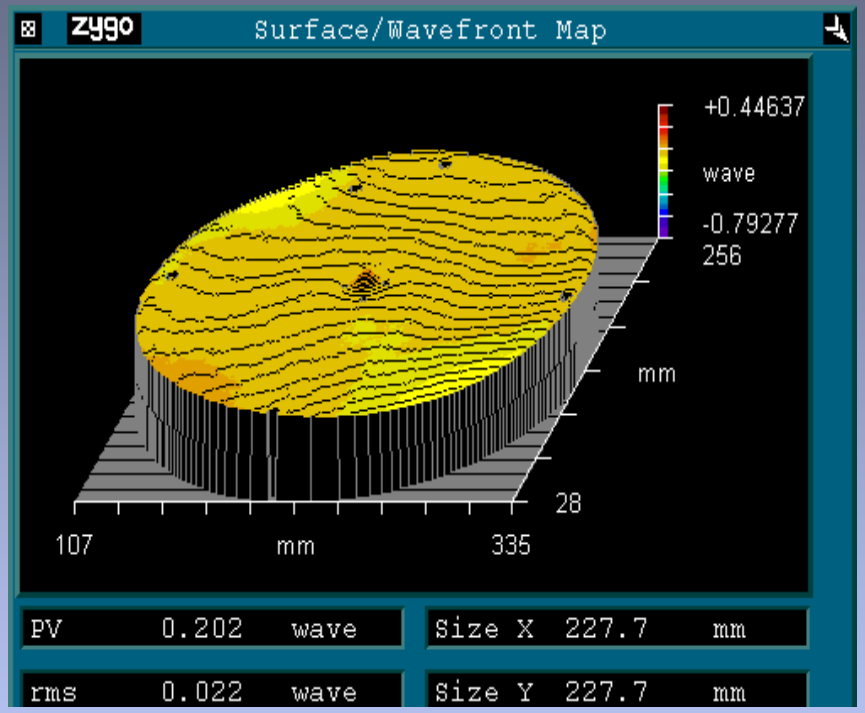
254 mm Curved mirror (1m r.o.c.) thickness of 3mm
Areal Density 8.1 kg/m^2





Optical Properties of 3mm thick Powered Mirror (Advanced Polishing)

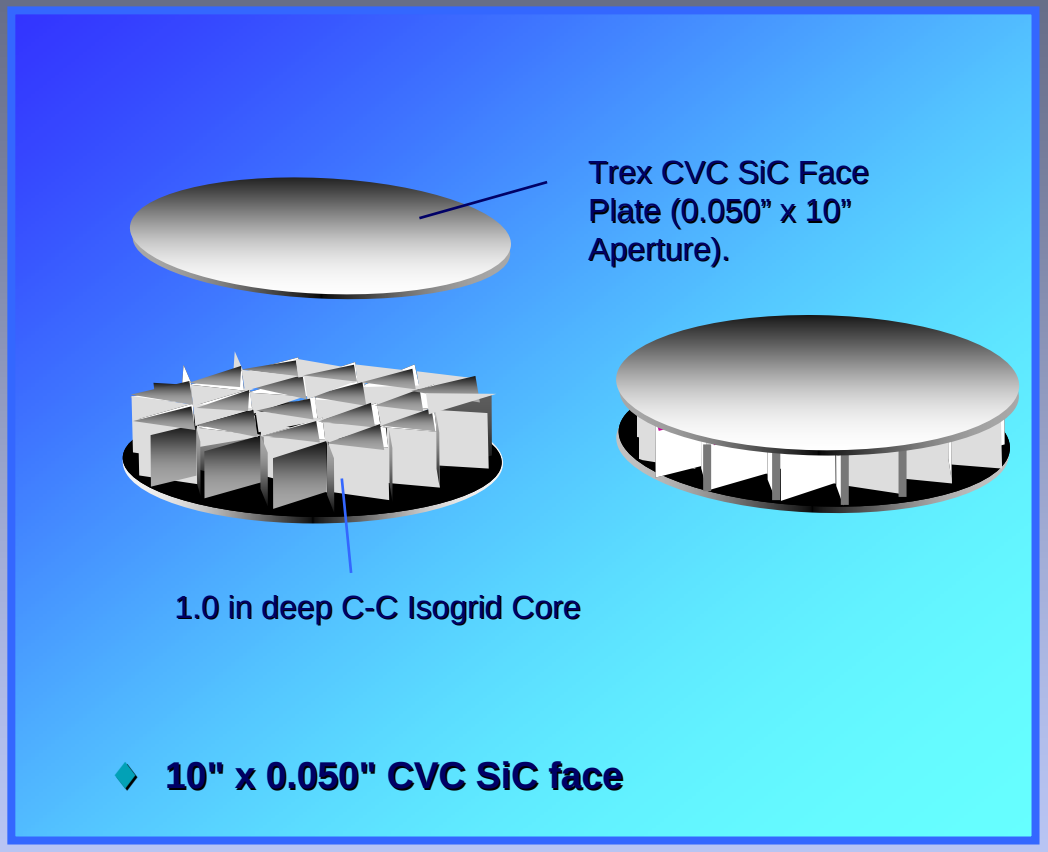




126 nm rms

11 nm rms

Mirror Fabrication: Lightweight Composite

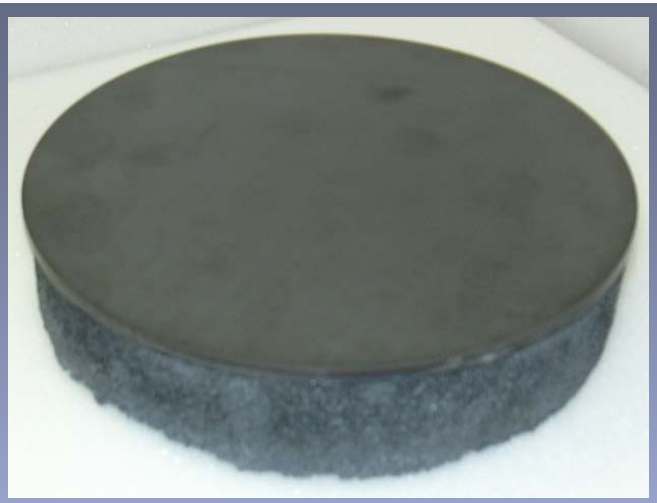


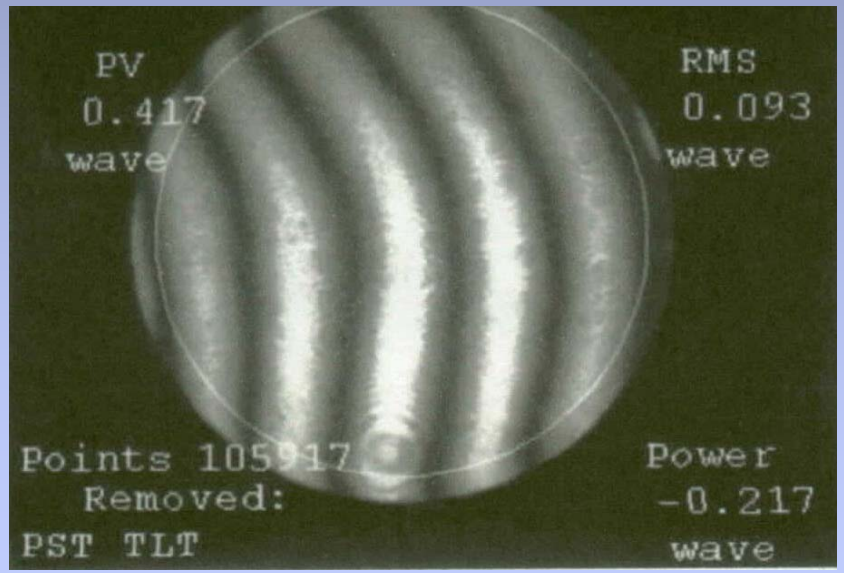
Areal Density 13.1 kg m^{-2}

Presented at SPIE

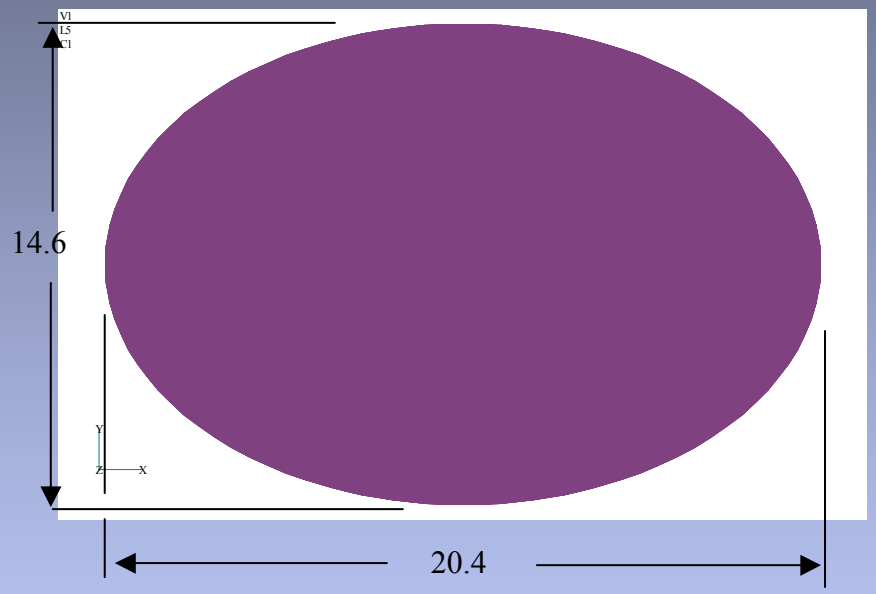
CVC SiC facesheet 2 mm thick, ca. 50% of total mass. 1 mm is feasible (AD < 10 kg m^{-2} within reach).

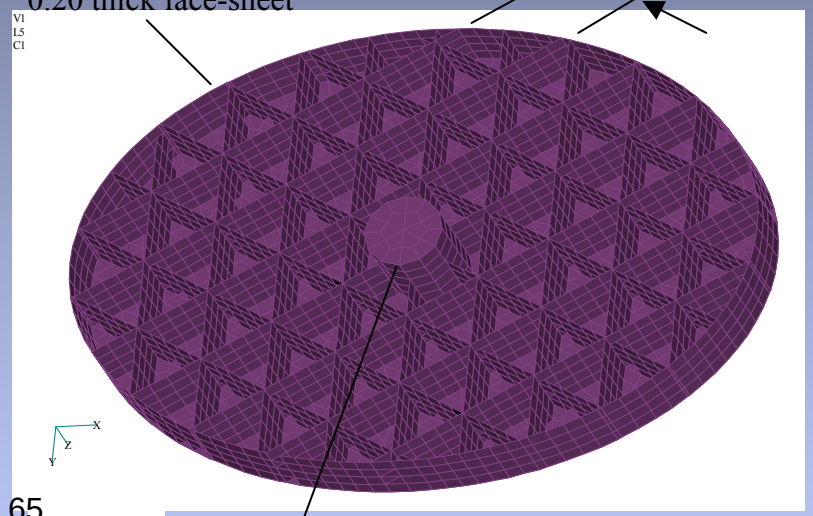
CVC SiC Foam Backed Mirror
Carbon and SiC Foams

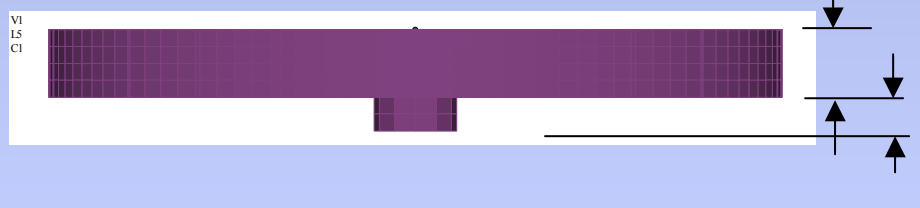




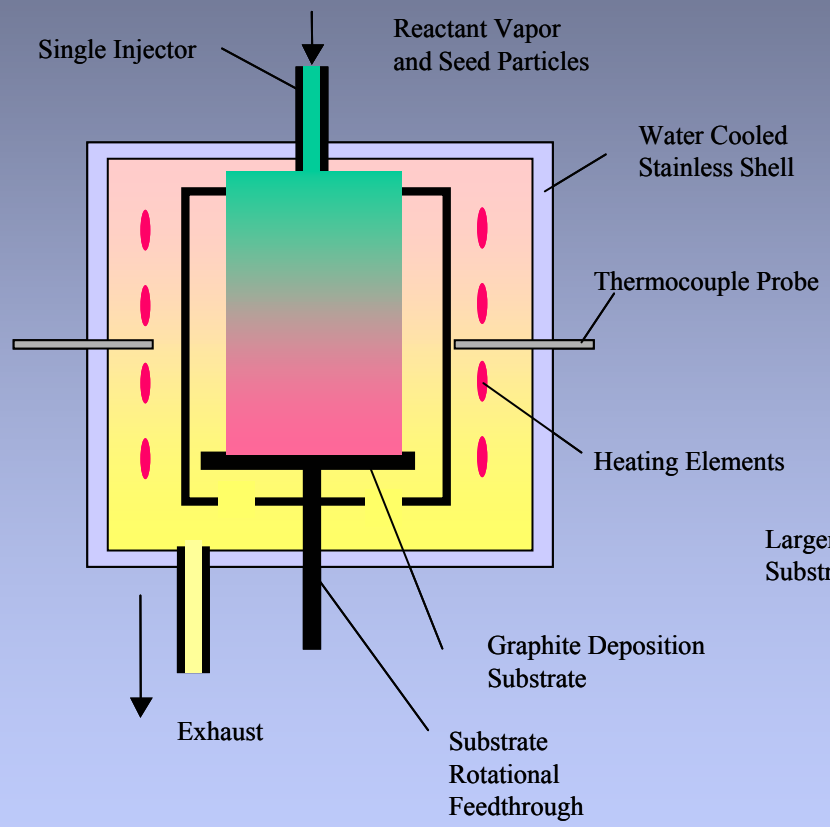
Lightweighted Near Net Shaped CVC SiC Mirror

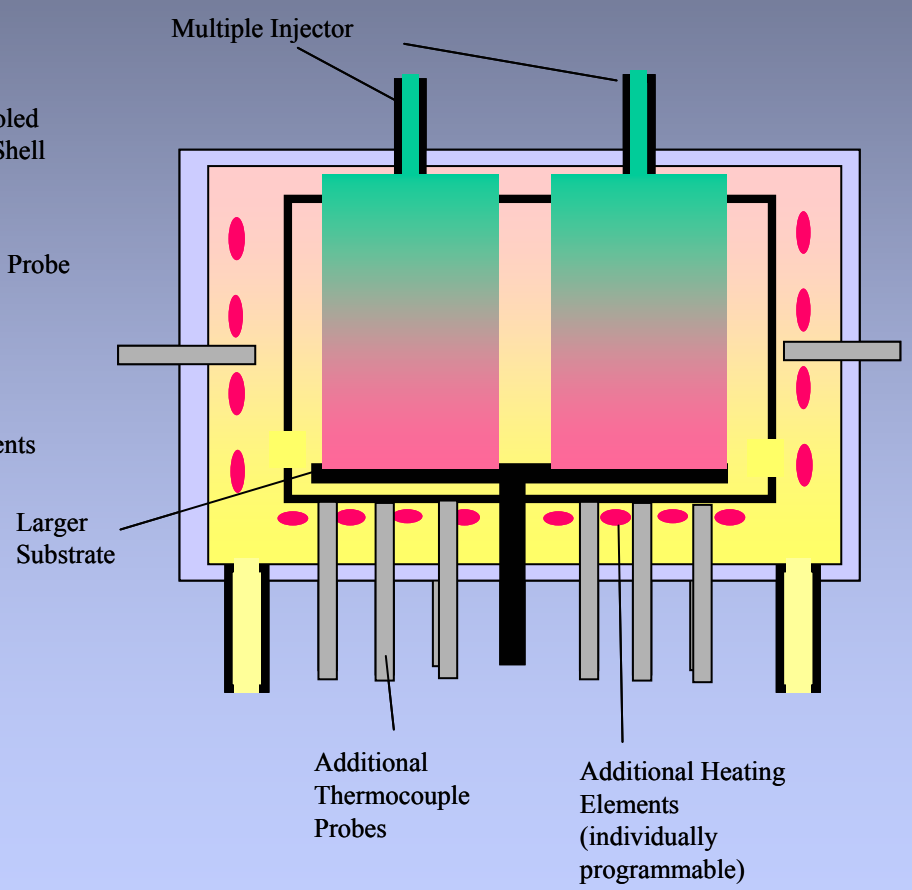






Expansion to Larger Reactor for >1.0 m Deposition





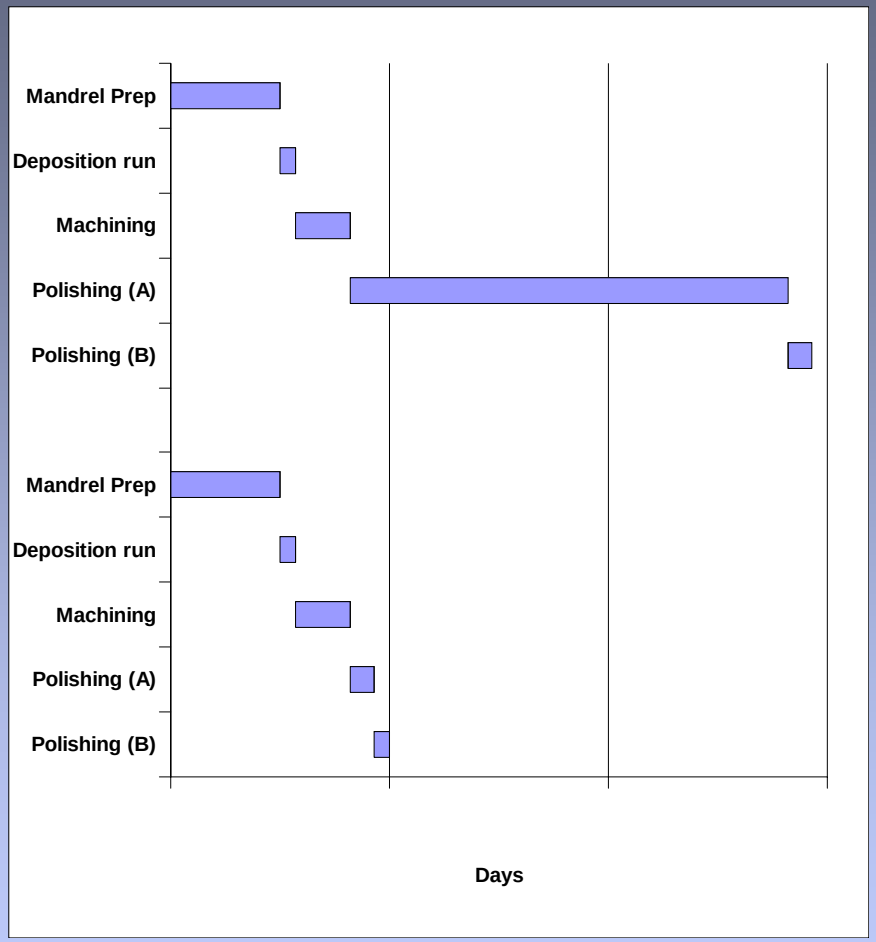
MATERIAL PROPERTIES
CVC SILICON CARBIDE

Density (g/cc) (% theoretical)	3.2 (99%+)
Grain size (microns)	5-10
Flexural Strength (MPa) @ RT	450
Young's Modulus (GPa)	466
Hardness HV (0.3) kg/mm squared	2850
Fracture toughness (MPa $m^{1/2}$)	3.39
Thermal conductivity (W/m-°K) @ 25C	205-250
CTE ($x10^{-6}$/°C)	3.5
Heat capacity (J/kg-°K)	640
Total impurities	< 5 ppm

OPTICAL PROPERTIES
CVC SILICON CARBIDE

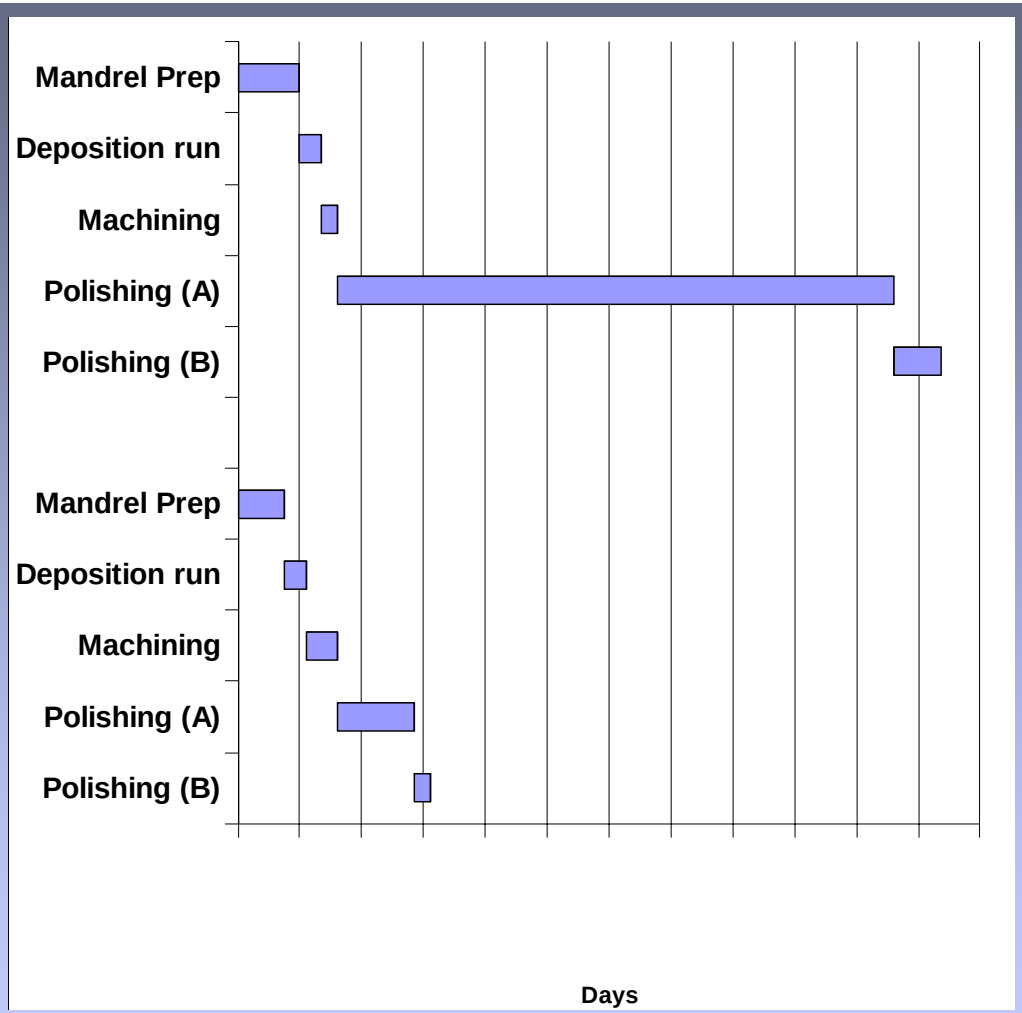
	Current	Future (<1 yr)	Potential
Surface Figure (P-V & rms)	23.4 & 2.5 nm	6 nm P-V	2-3 nm P-V
Surface Roughness (rms)	2 Å	1 Å	<1 Å
Areal Density (@ 300 mm	8 kg/m^2	3-7 kg/m^2	2-3 kg/m^2
Areal Density (@ 1m)	N/A	10-15 kg/m^2	3-7 kg/m^2

Nominal 300 mm Aperture CVC SiC Mirror



Virtually Figure Independent, e.g plano, powered, aspherical

CVC SiC Meter Class Optics Projected Schedule



Virtually Figure Independent, e.g plano, powered, aspherical