Metal Optics for Instrumentation

David Robertson
Durham University

CEOI-ST Workshop 1st May 2014

dpo durham precision optics

Durham University

Performance Drivers For Metal Optics

- Aspheres/Freeforms (Compact High Performance Designs)
- Multi-Spectral Applications (Mirrors)
- Improved Surface Form (Optical Performance)
- Improved Surface Roughness (Throughput)
- Lower Production Costs

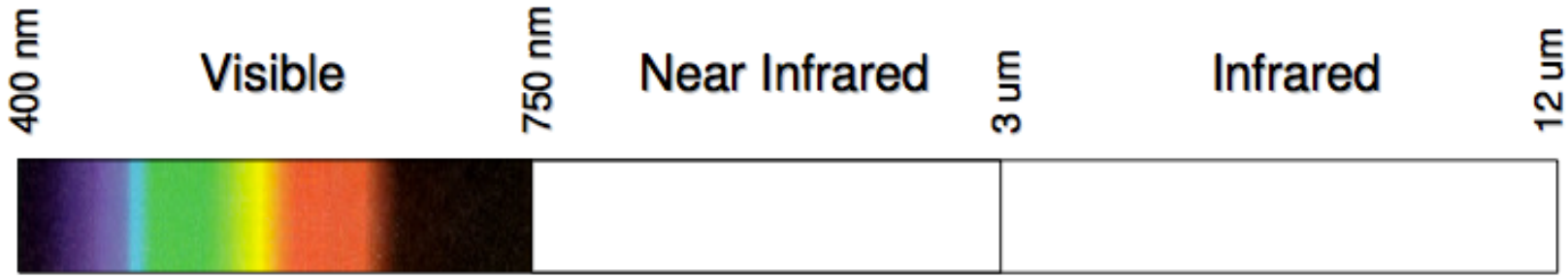
Typical Concerns About Using Metal (Diamond Machined) Optics

- Diffractive rather than specular scatter
- Relatively high surface roughness – low throughput at shorter wavelengths
- Relatively low surface form accuracy

Advantages of Using Metal Optics

- CNC pre- machining => Complex surface shapes and mounting geometries achievable
- Diamond Machining => high accuracy achievable on complex optical surface – machine mounting surfaces
- Aluminium => Lighter (although not as stiff)
- Easy Alignment => Optics integral with mounting structure – no adjustments
- Athermalisation => Optics and mounting structure in same material (same CTE)
- Typically faster and more cost effective manufacture

Wavelength Vs RMS Finish



RMS 1nm — 5nm — 10nm — 20nm

Today <2nm

1990 <20nm

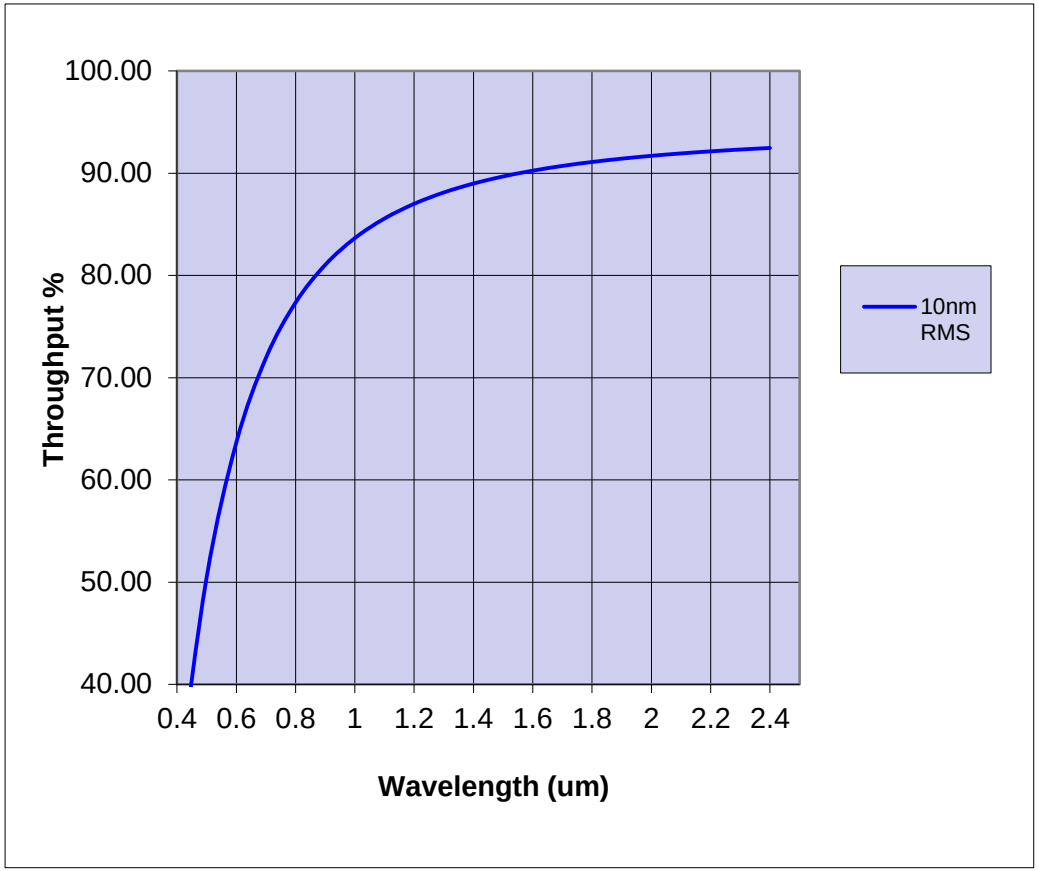
Manufacturing Improvements

- Machine Developments – sub-nm positioning, stiffer slides, better controllers
- Diamond Tool Improvements – more accurate profiles, more challenging geometries, better edge preparation
- New Materials – Rapidly Solidified Aluminium Alloys
- Ultra High Precision CAD/CAM – ability to extract all surfaces for machining – ready referenced

Throughput Vs Wavelength

- 6 Surfaces
- 98% Reflectivity

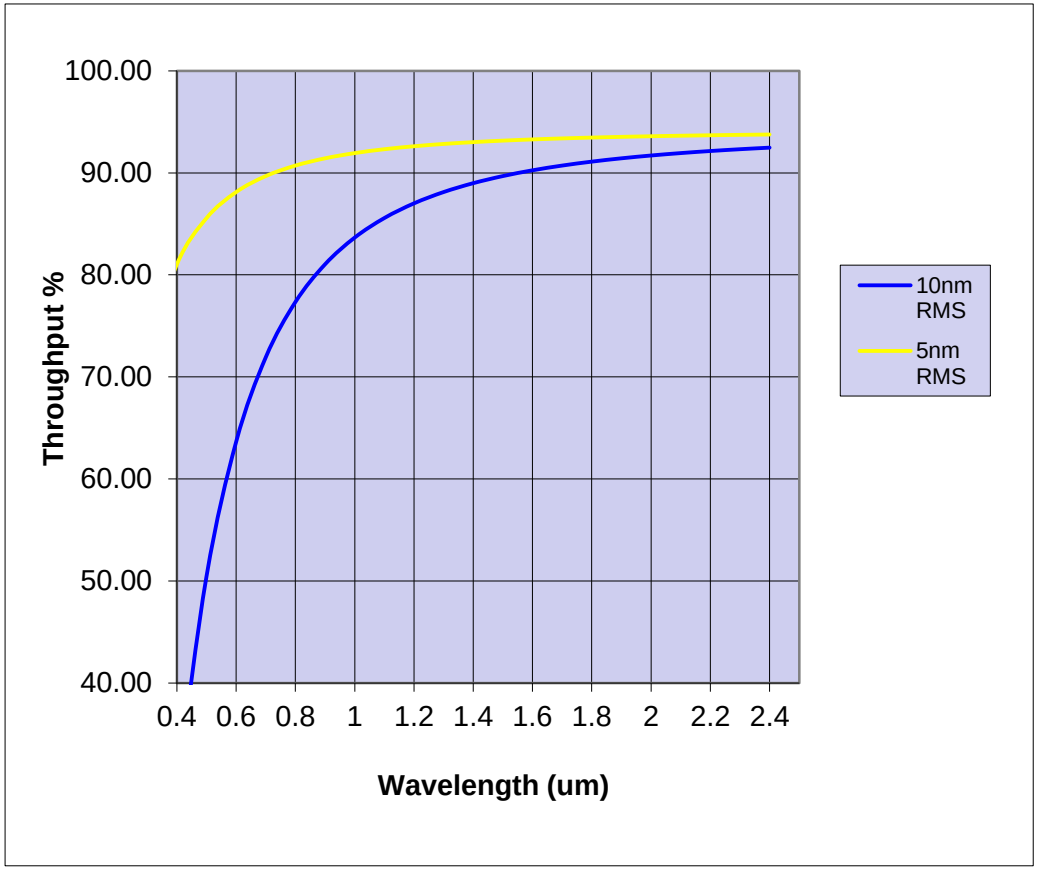
- Achievable in early 2000s with standard Al Alloy



Throughput Vs Wavelength

- 6 Surfaces
- 98% Reflectivity

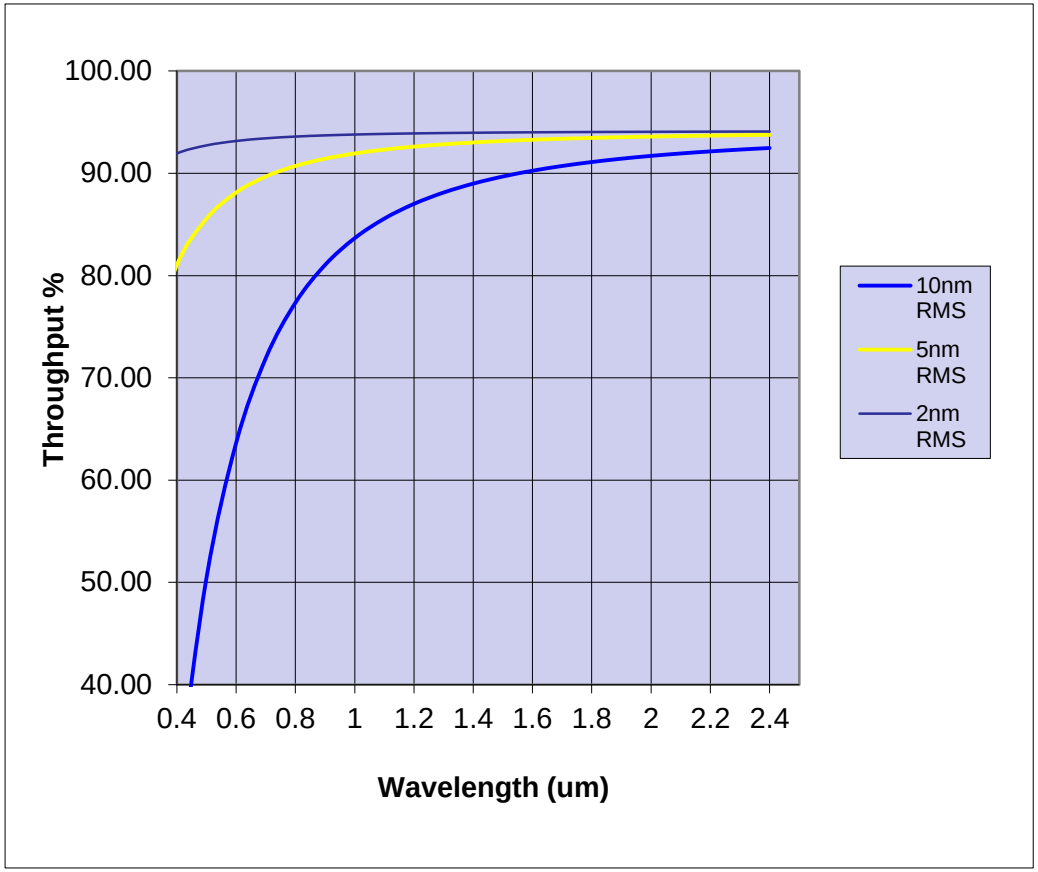
- Achievable in early 2000s with standard Al Alloy
- Achievable now with standard Al Alloy



Throughput Vs Wavelength

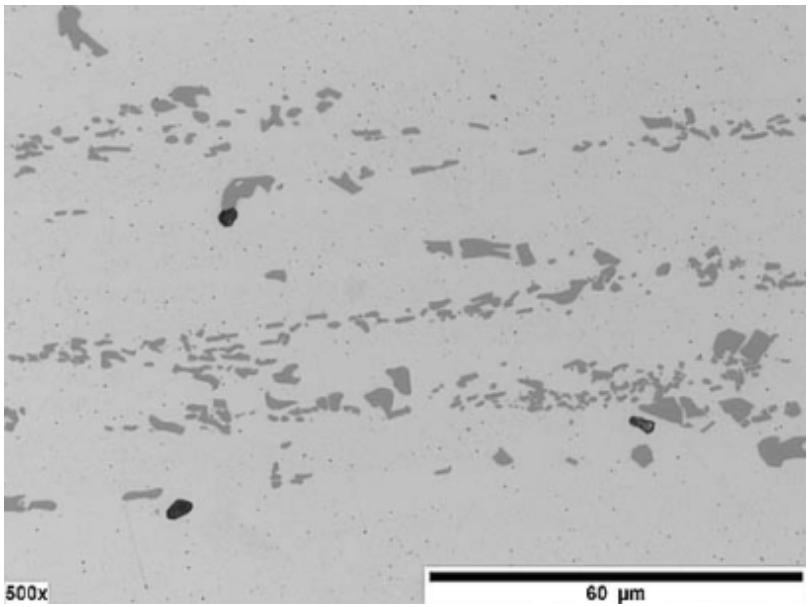
- 6 Surfaces
- 98% Reflectivity

- Achievable in early 2000s with standard Al Alloy
- Achievable now with standard Al Alloy
- Achievable now with RSA Al Alloy

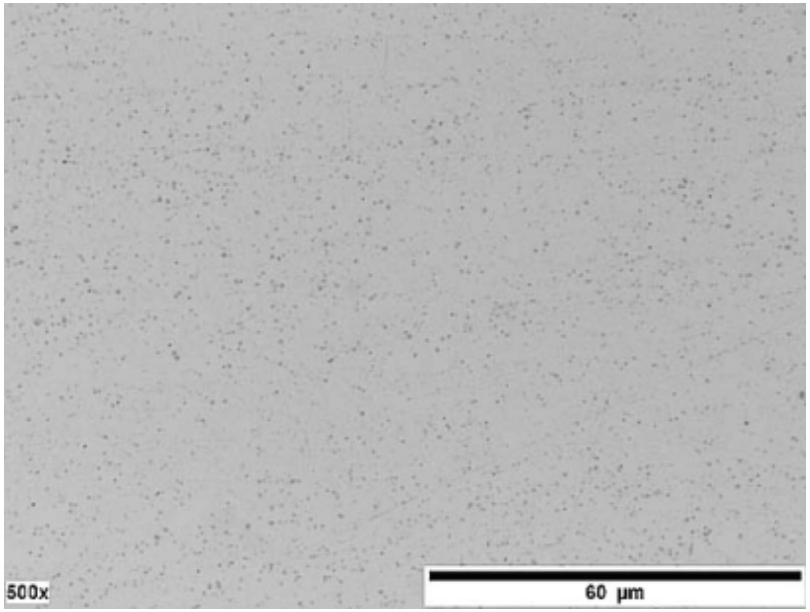


Rapidly Solidified Aluminium

Conventional 6061 Al

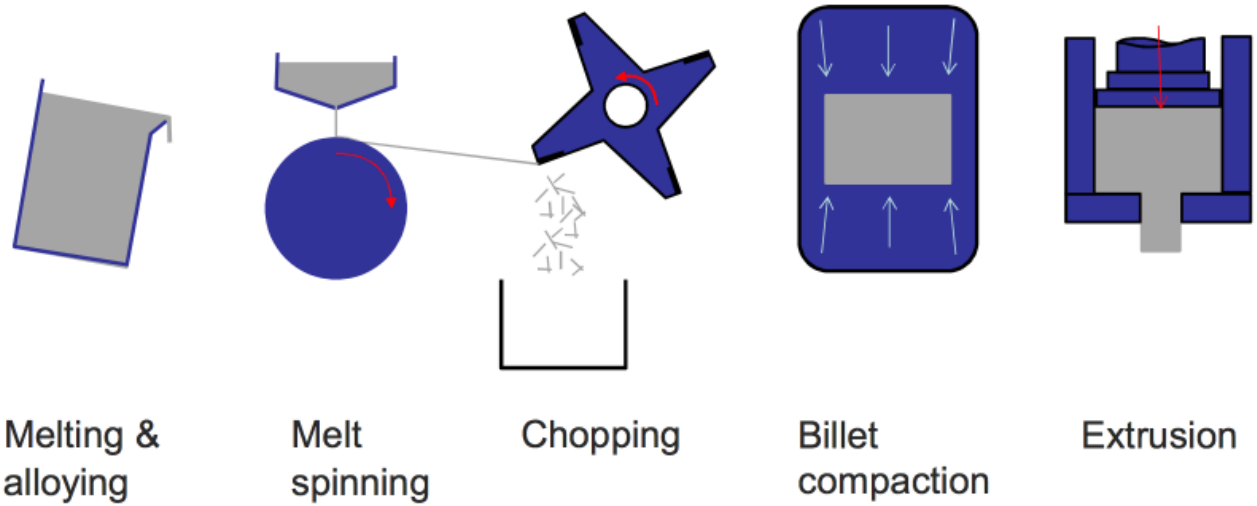


Melt Spun 6061 Al



Courtesy – RSP Technology

Rapidly Solidified Aluminium - Process



Melt Spin Process

Courtesy – RSP Technology

Rapidly Solidified Aluminium

Conventional 6061 Al

Surface Statistics:

Ra: 3.80 nm

Rq: 4.83 nm

Rz: 37.50 nm

Rt: 43.60 nm

Set-up Parameters:

Size: 640 X 480

Sampling: 492.21 nm

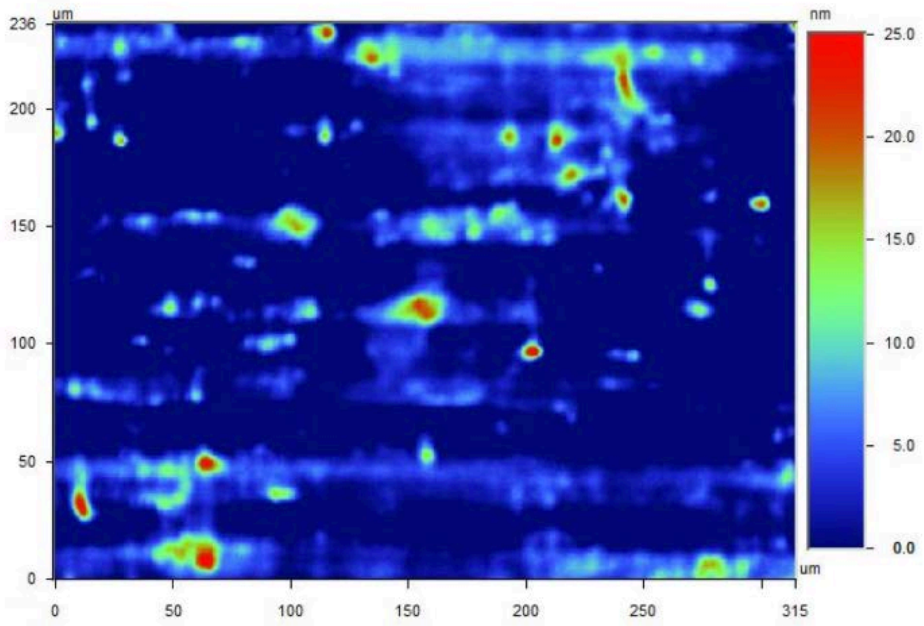
Processed Options:

Terms Removed:

Curvature & Tilt

Filtering:

None



Rapidly Solidified Aluminium

Spun Melt 6061 Al

Surface Statistics:

Ra: 0.73 nm

Rq: 0.92 nm

Rz: 8.66 nm

Rt: 12.60 nm

Set-up Parameters:

Size: 640 X 480

Sampling: 492.21 nm

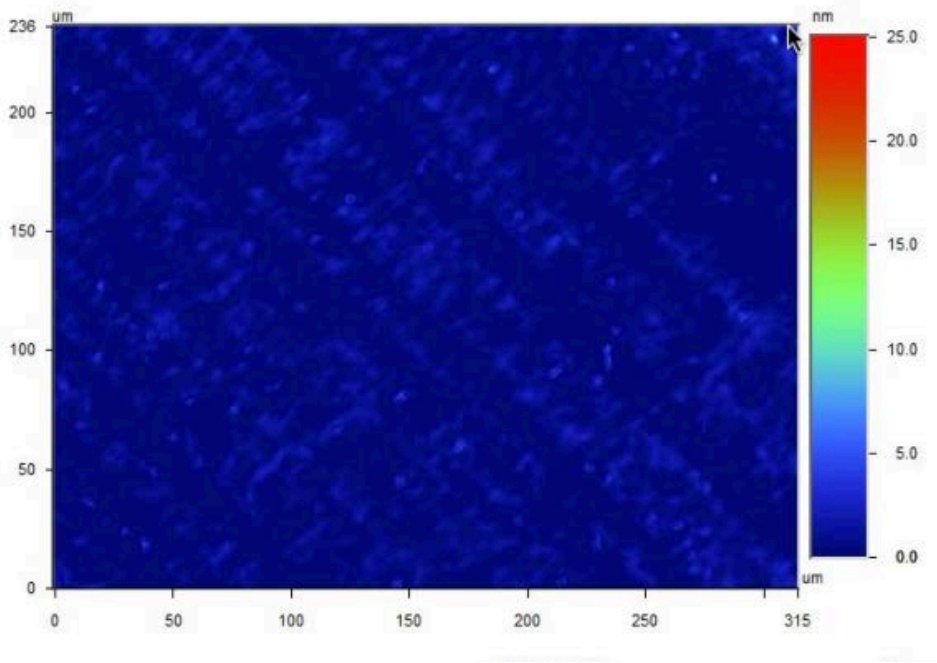
Processed Options:

Terms Removed:

Curvature & Tilt

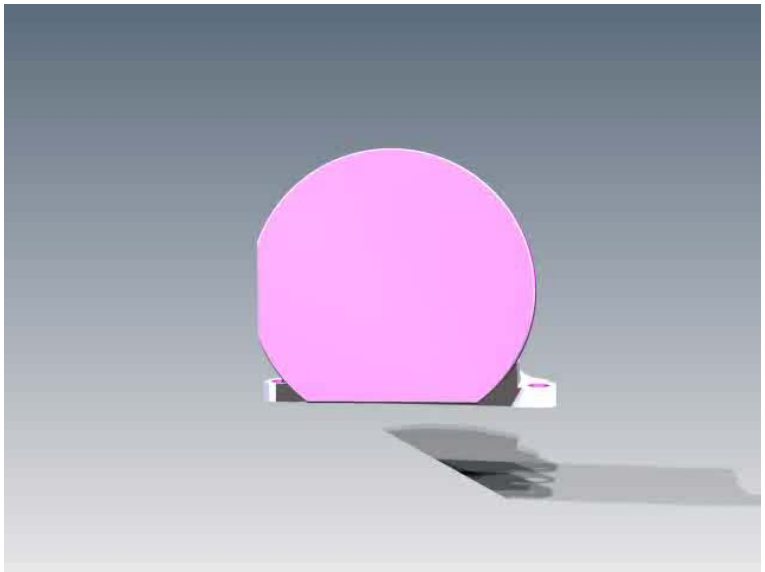
Filtering:

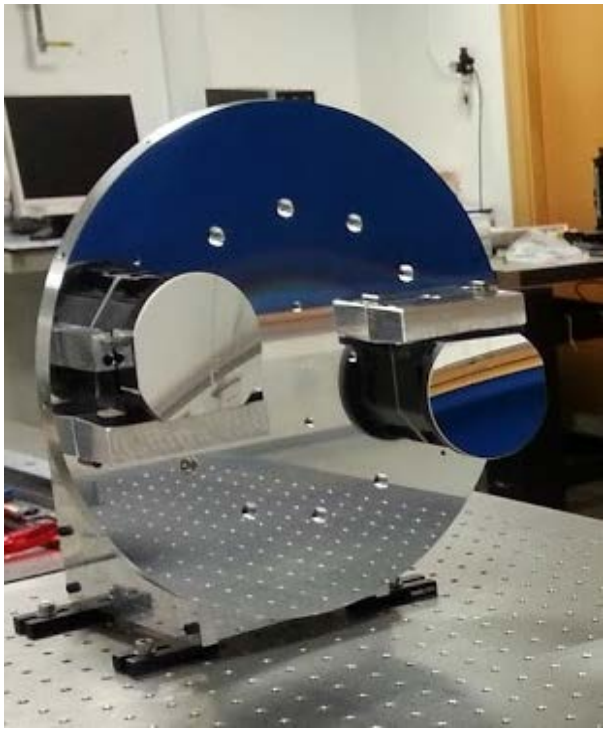
None



Form Error – 100mm Aperture

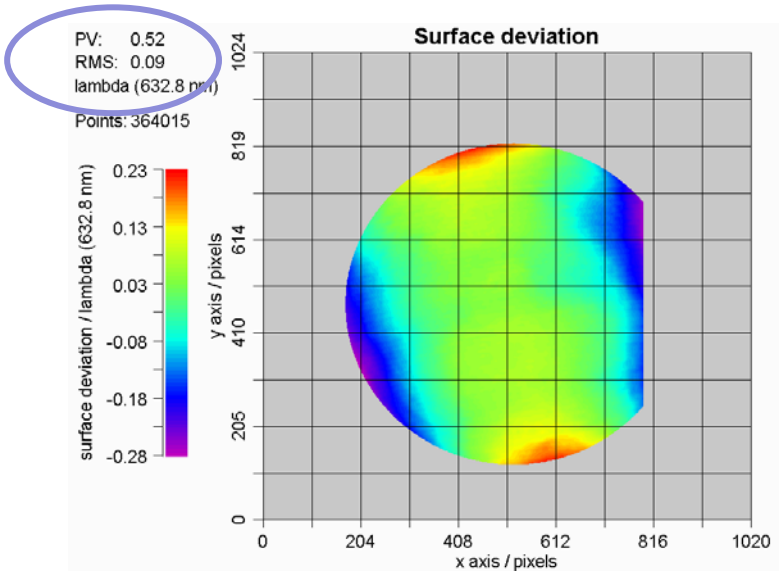
Off-Axis Parabola

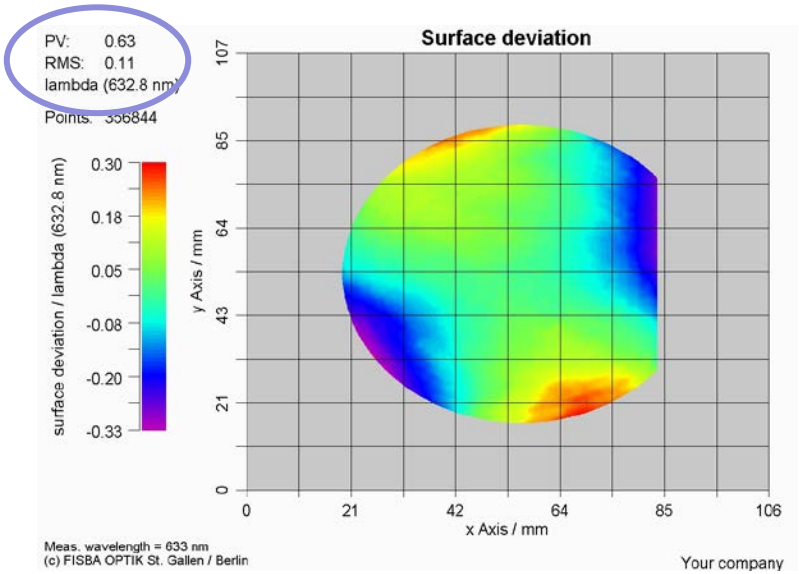




Mounted on Machining Fixture

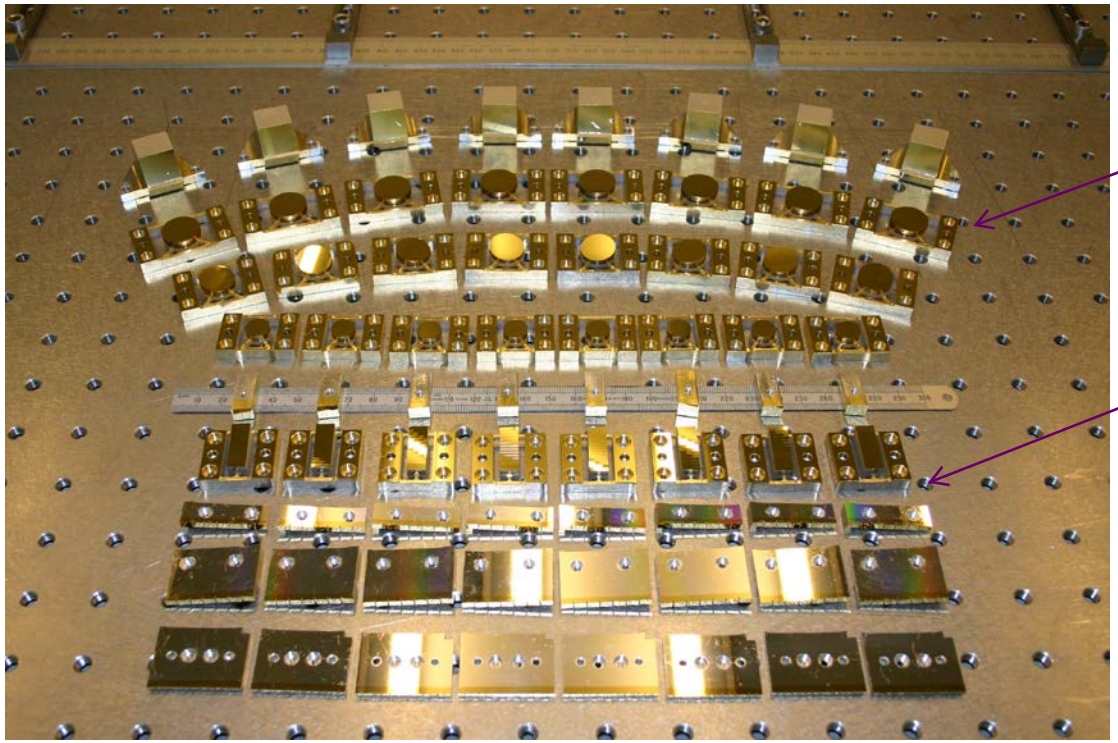
Form Error – 100mm Aperture





Specification 1 Fringe @ 633nm (p-v)

Form Error – Micro-optics



Freeform Optics

Multi-Faceted Optics

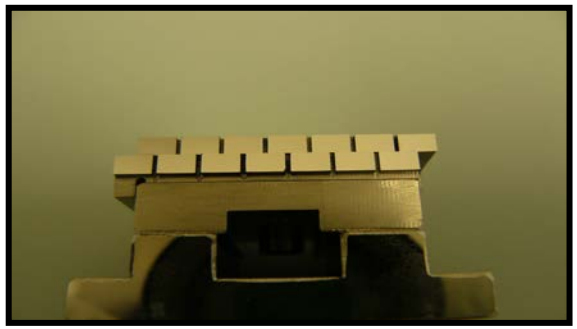
48 Flats

96 Freeform Surfaces

1008 Multi-faceted Surfaces on 96 substrates

1152 Optical Surfaces – 216 components

Form Error – Micro-optics



	Requirement RMS (nm)	Achieved Performance RMS (nm)
Surface Form Error ≤Z4	40nm	<20nm
Surface Form Error >Z4	20nm	<15nm
Surface Roughness Rastered Components	<10nm	3-4nm
Surface Roughness Freeform/Flat Components	<10nm	<2nm

Summary

- Metal (Diamond Machined) Optics perform well
- Significant incremental improvement in performance
- Provide a homogenous (mechanical and thermal) solution for optics mounting
- Lightweight, relatively straightforward and cost effective solution
- Implementation of Freeform and Multi-facet Optics is possible
- Produces Compact, High Performance Optical Systems

Thank You For Your Time