



SuperHero League Webinar: Photonics for Space Communications

Predicting Operational Performance from Alignment Measurements

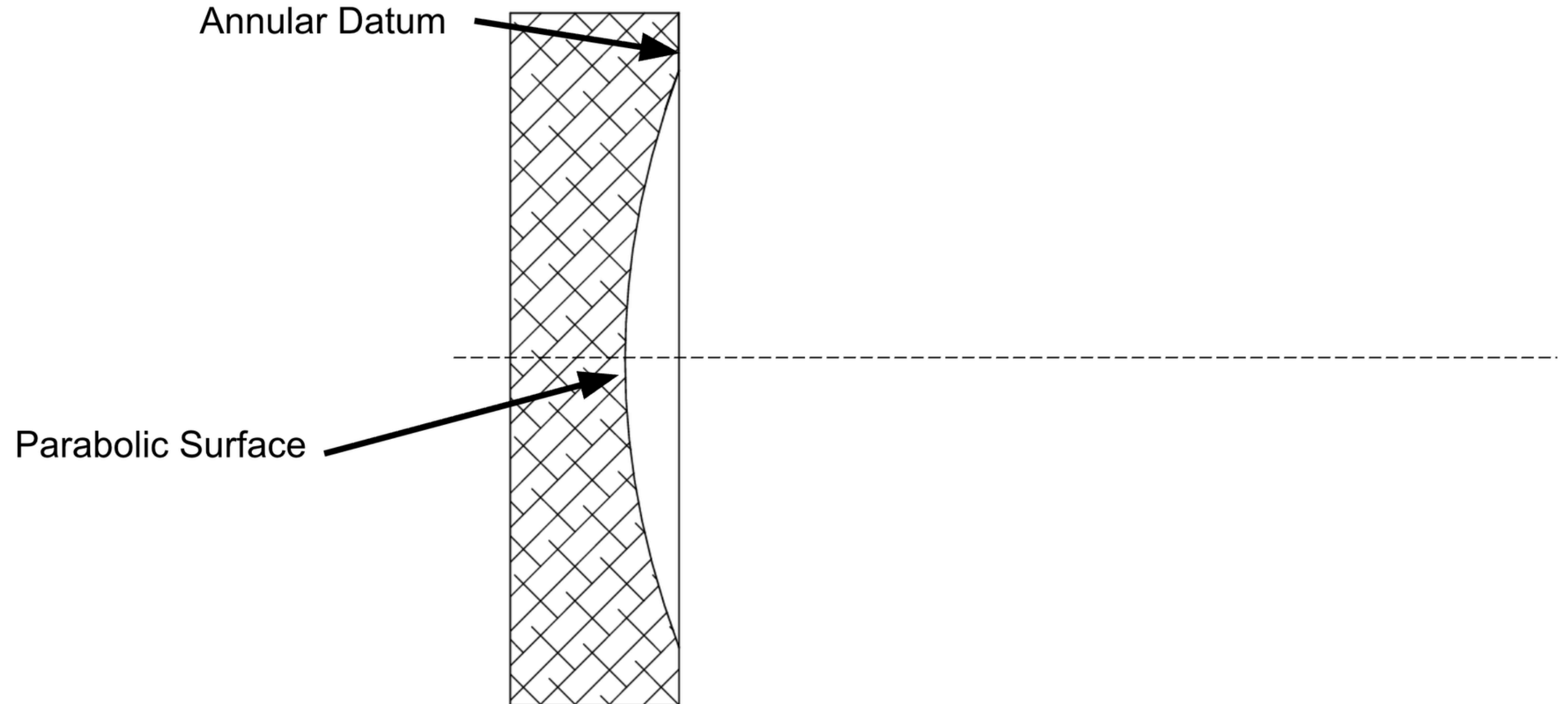
Richard Pultar
Zygo

Measurement to Model

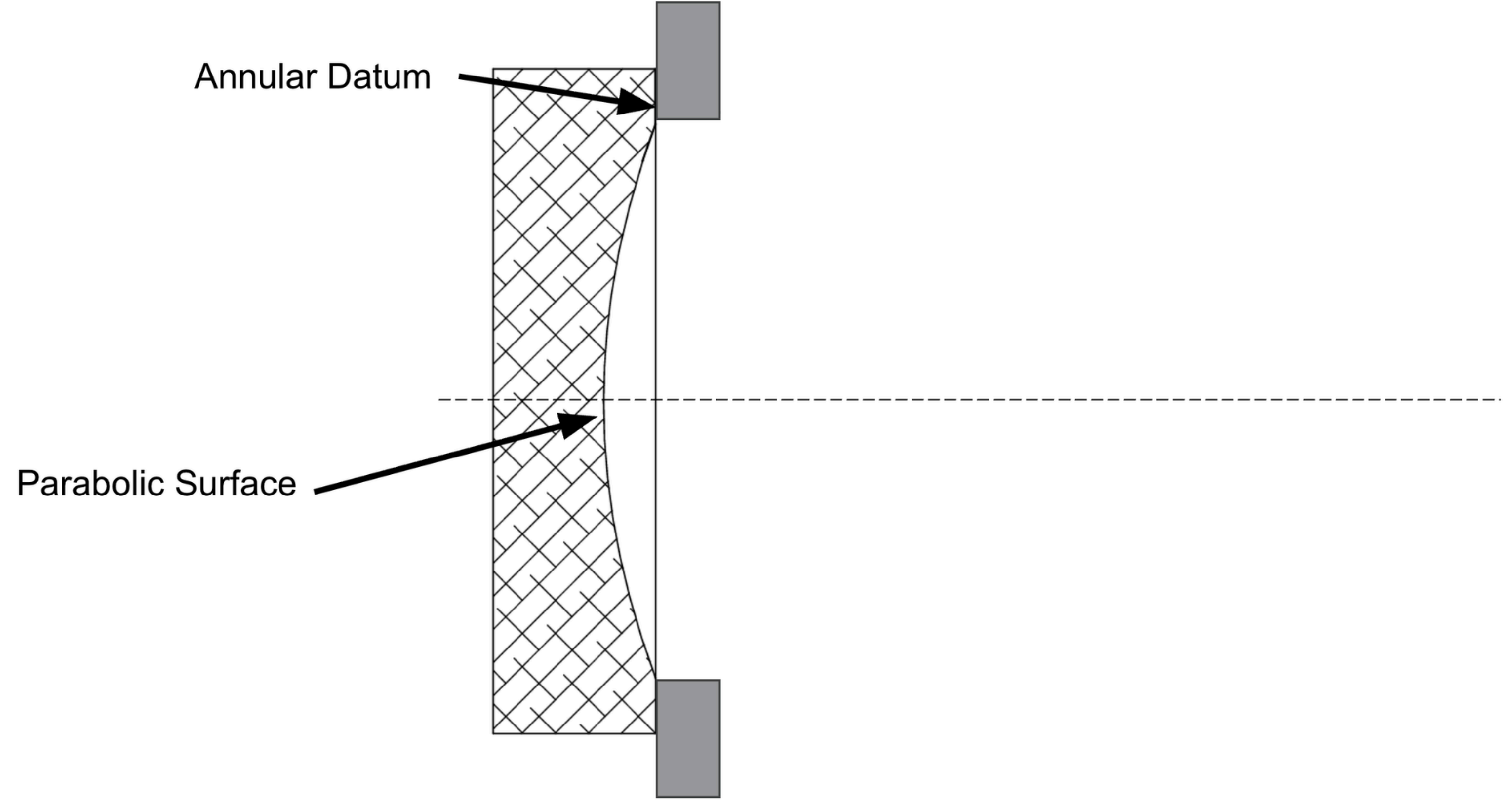


- Measuring a mirror using alignment datums
- Analyzing measured data PSF, MTF in Mx
- Data export and modeling

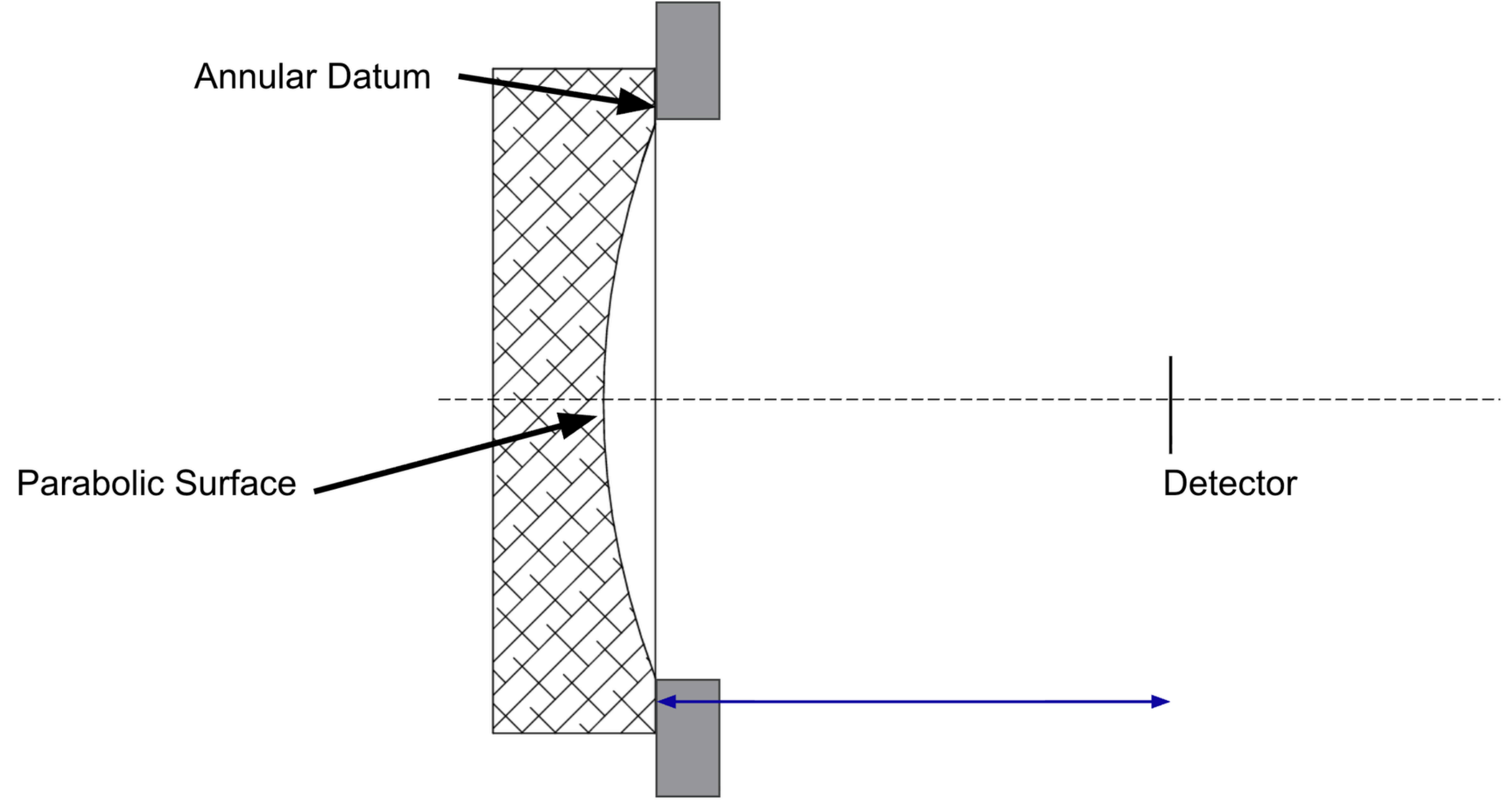
Mirror Under Test



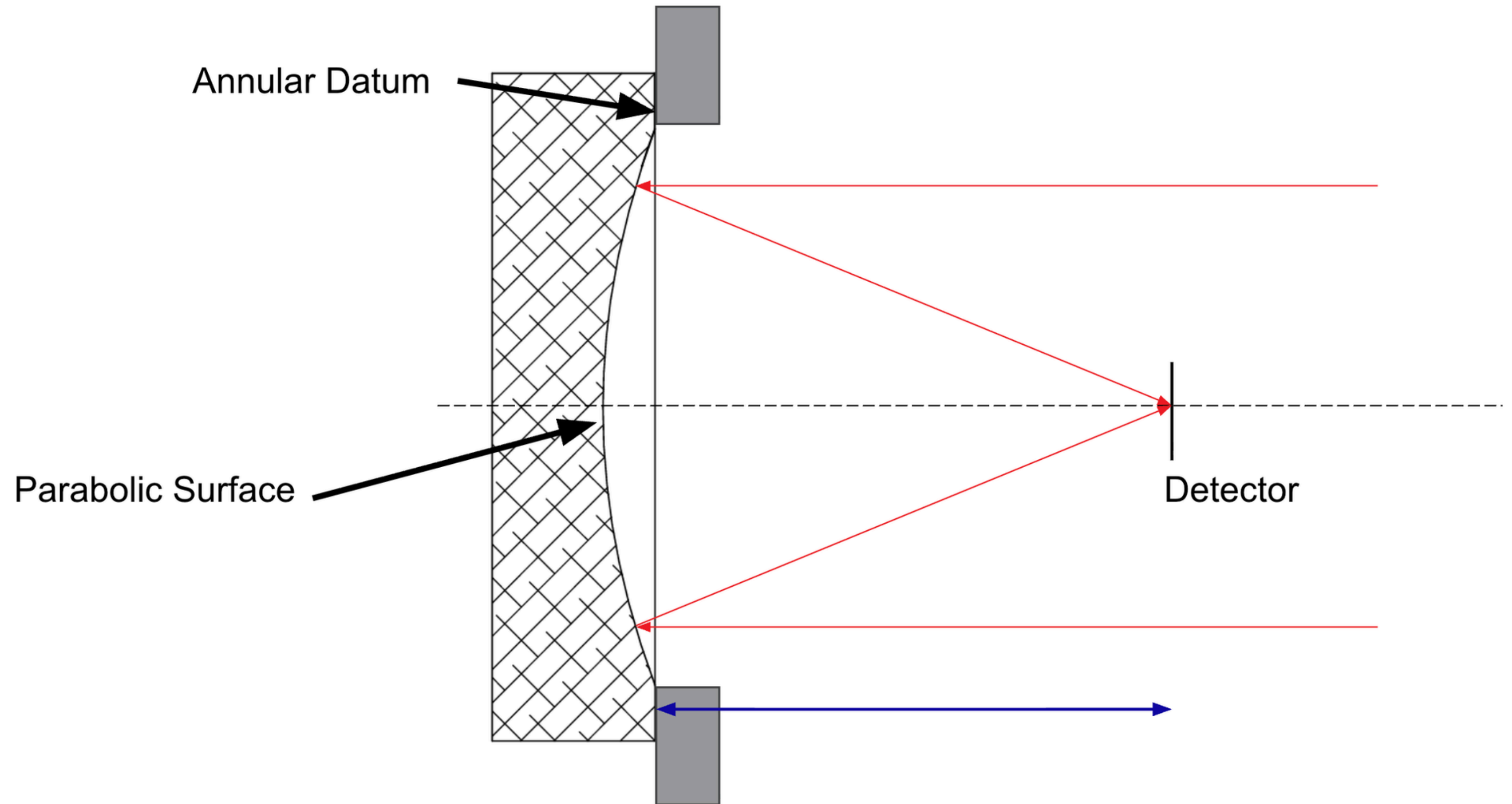
Mirror Under Test



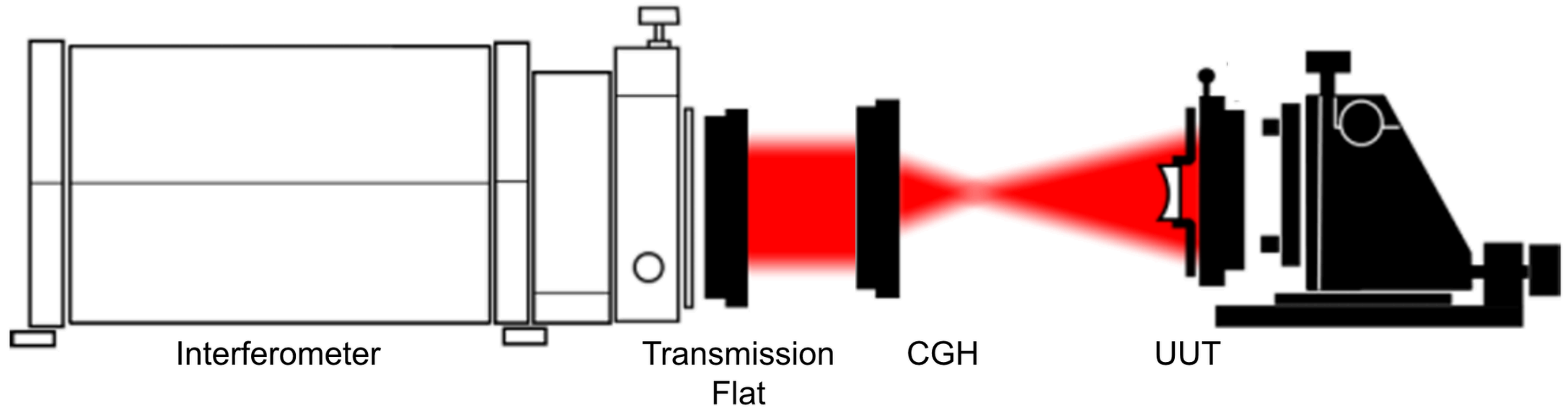
Mirror Under Test



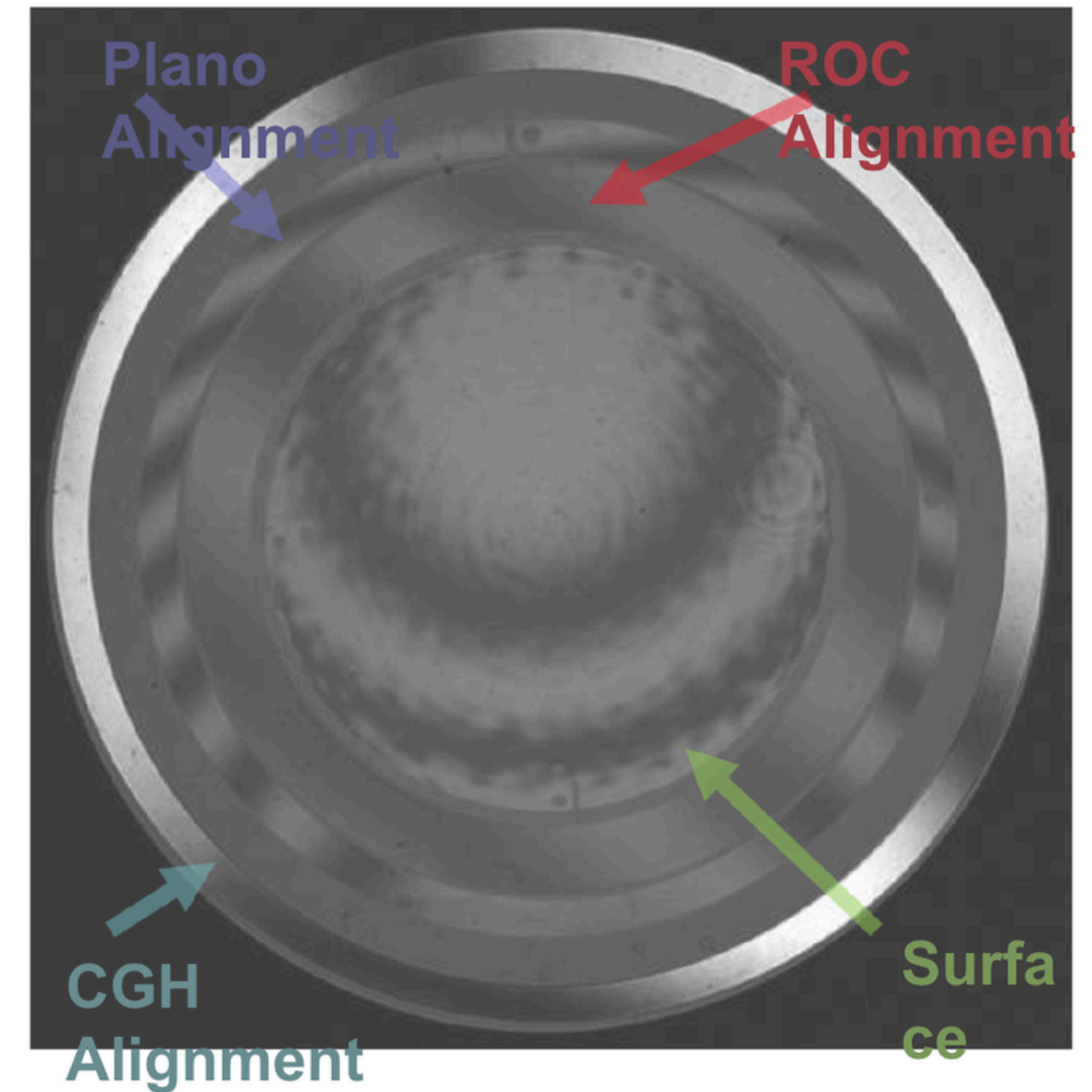
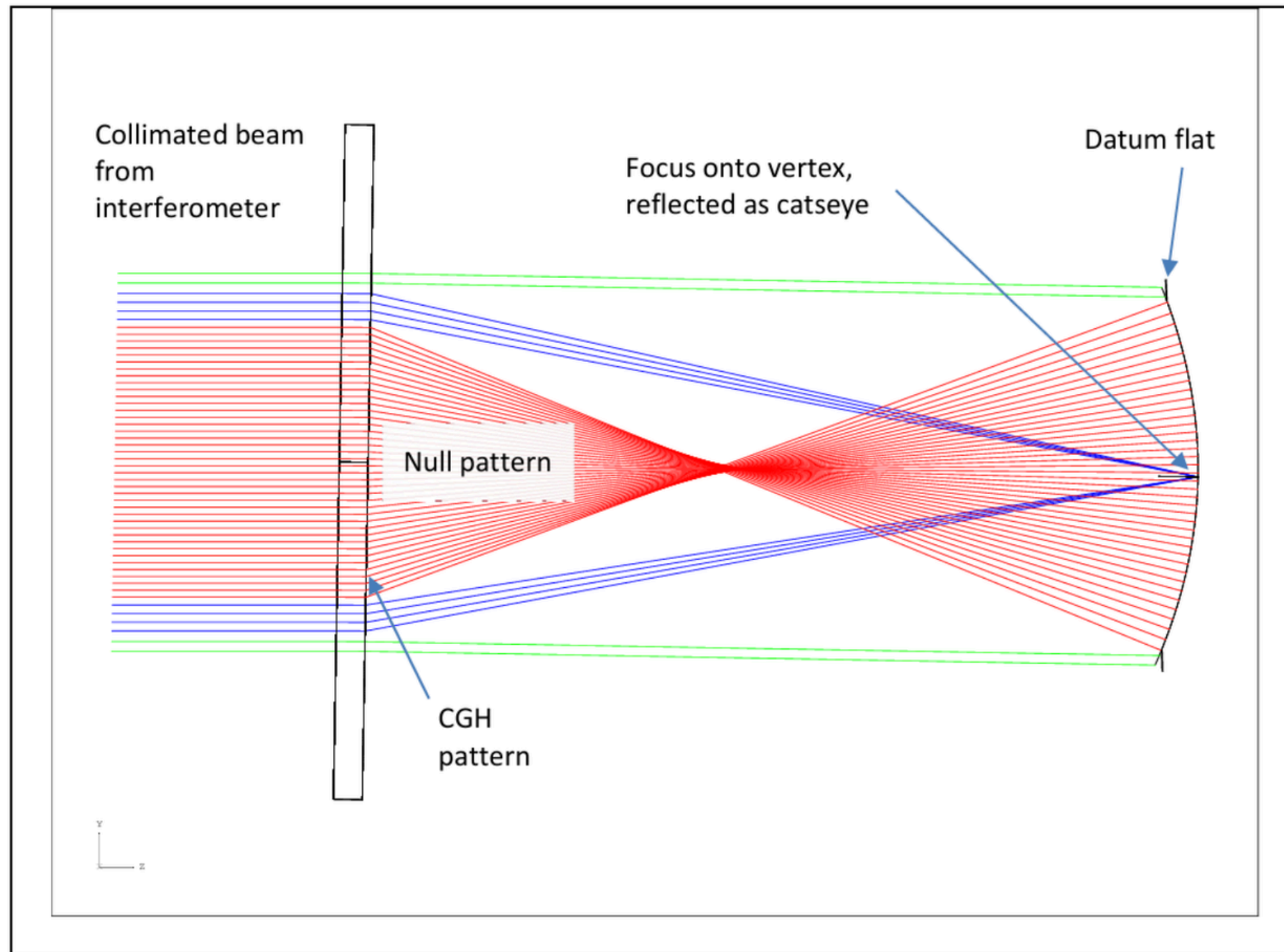
Mirror Under Test



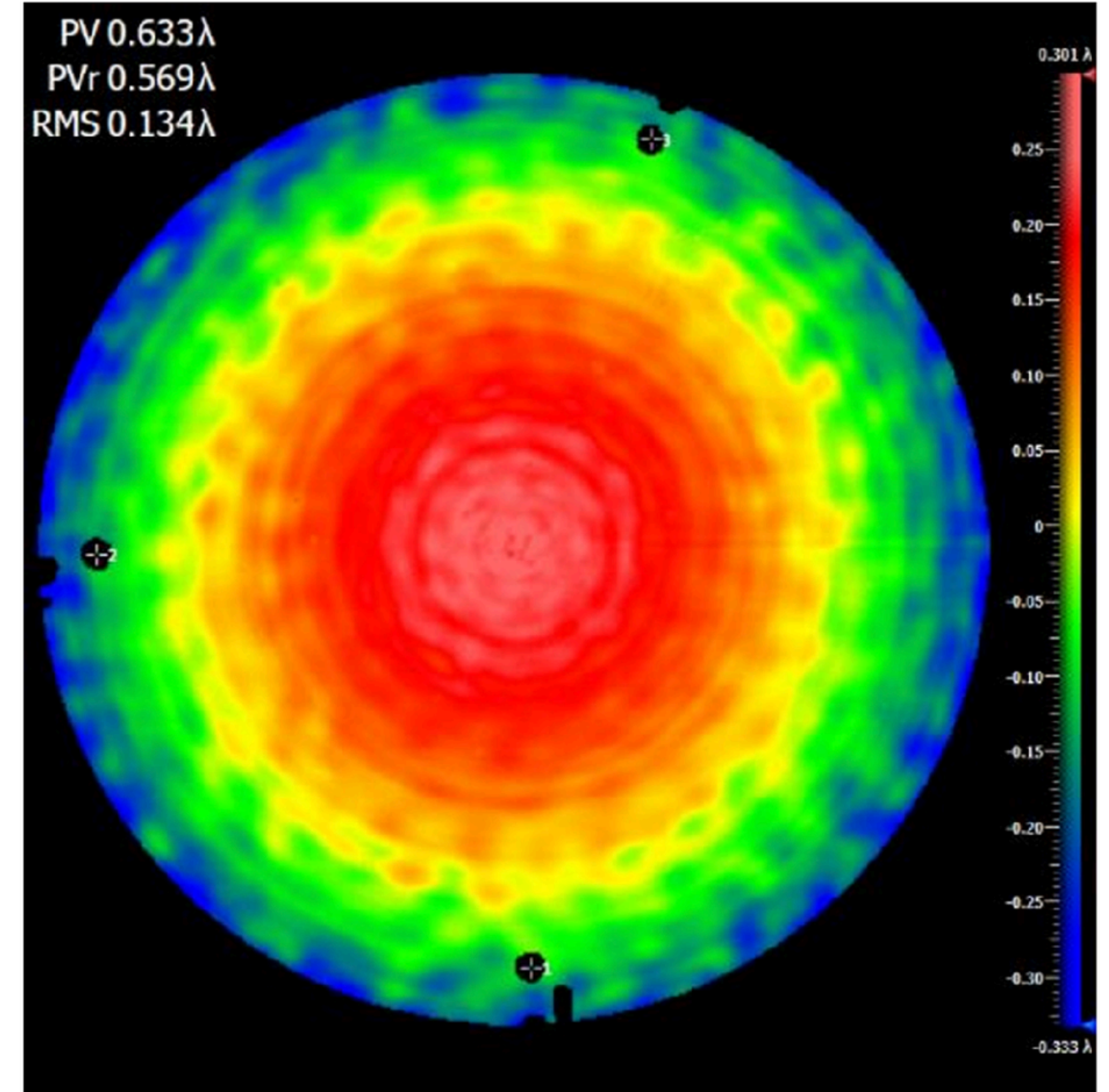
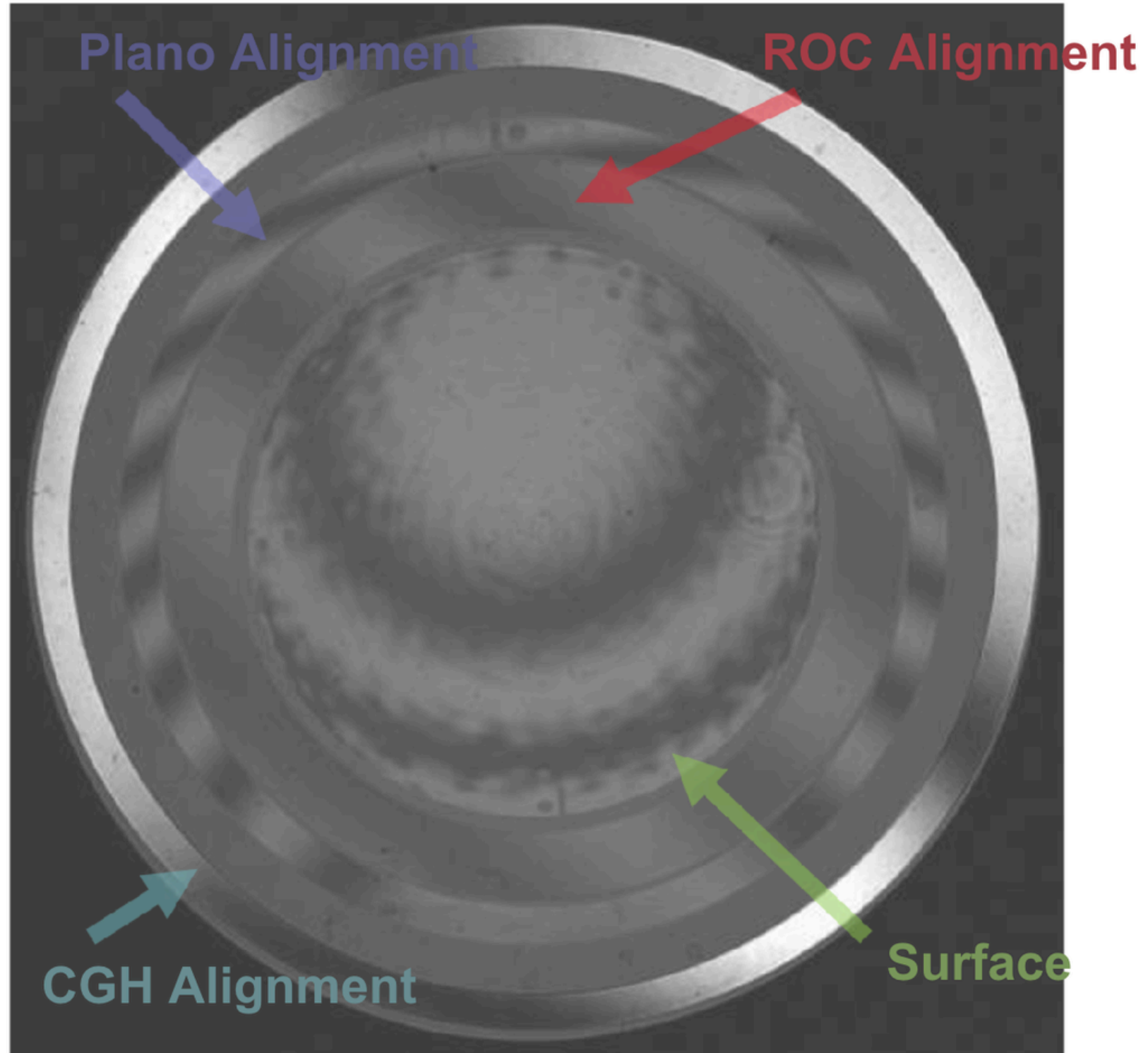
Measurement Setup



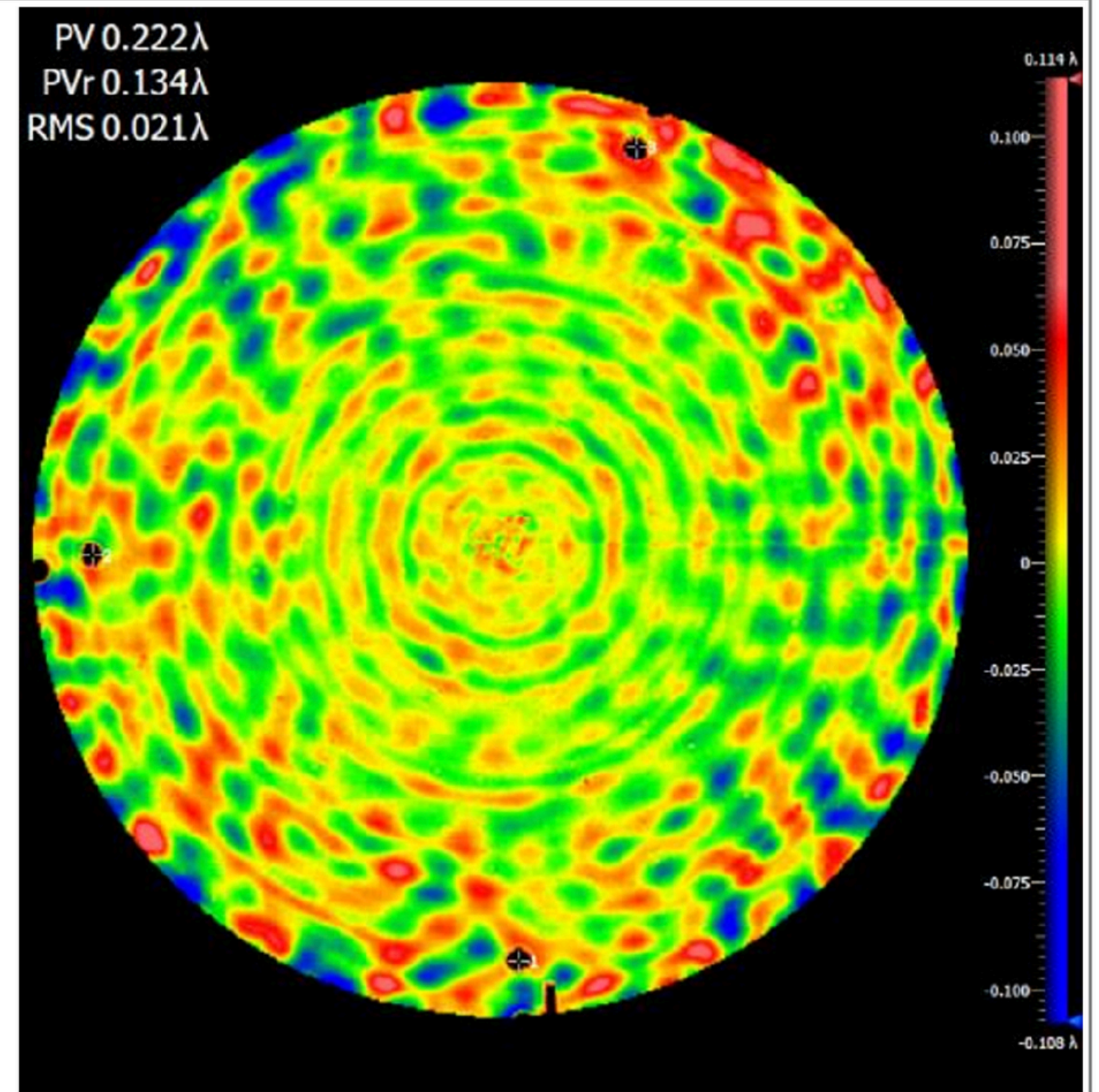
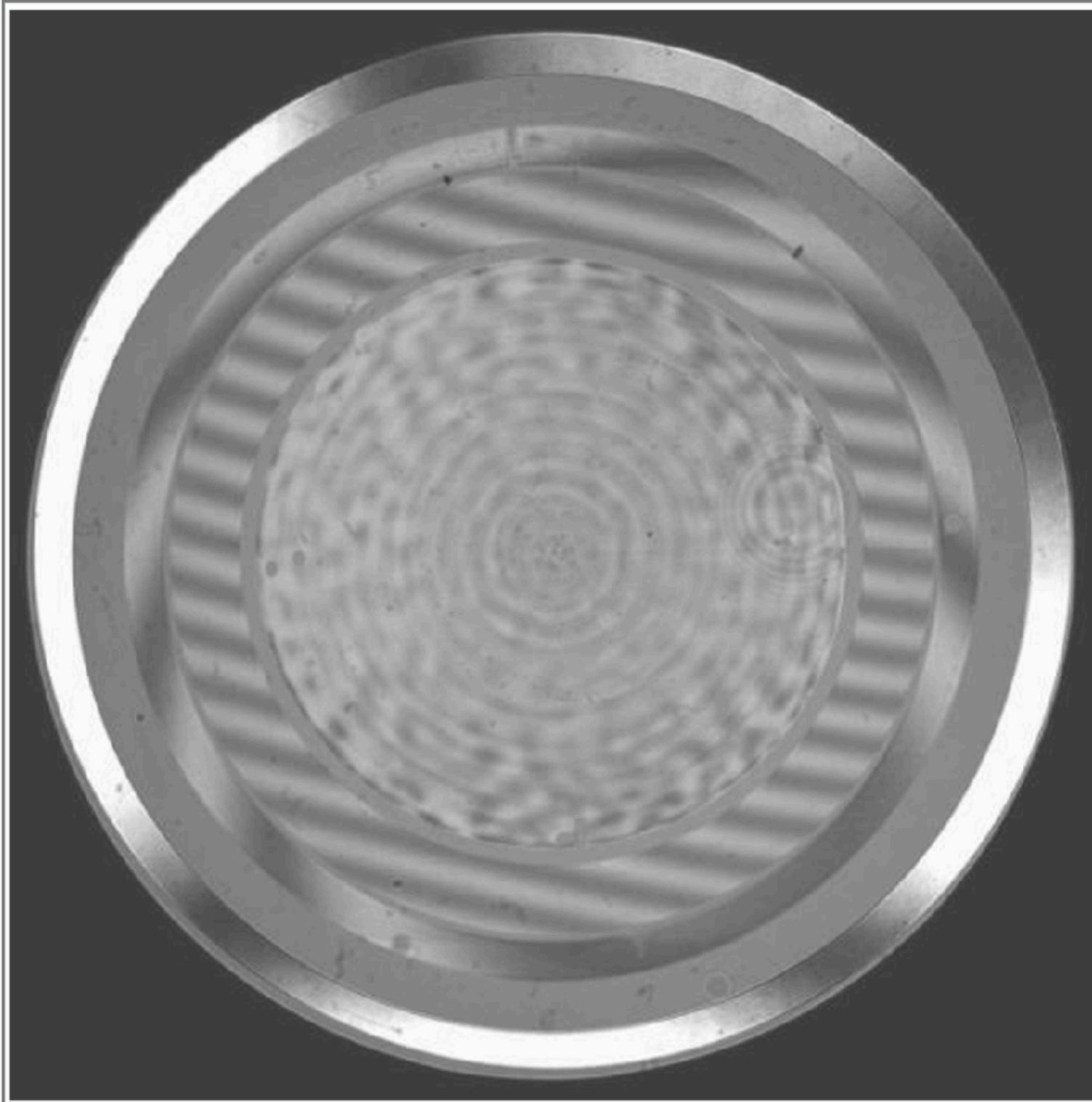
CGH Alignment Pattern



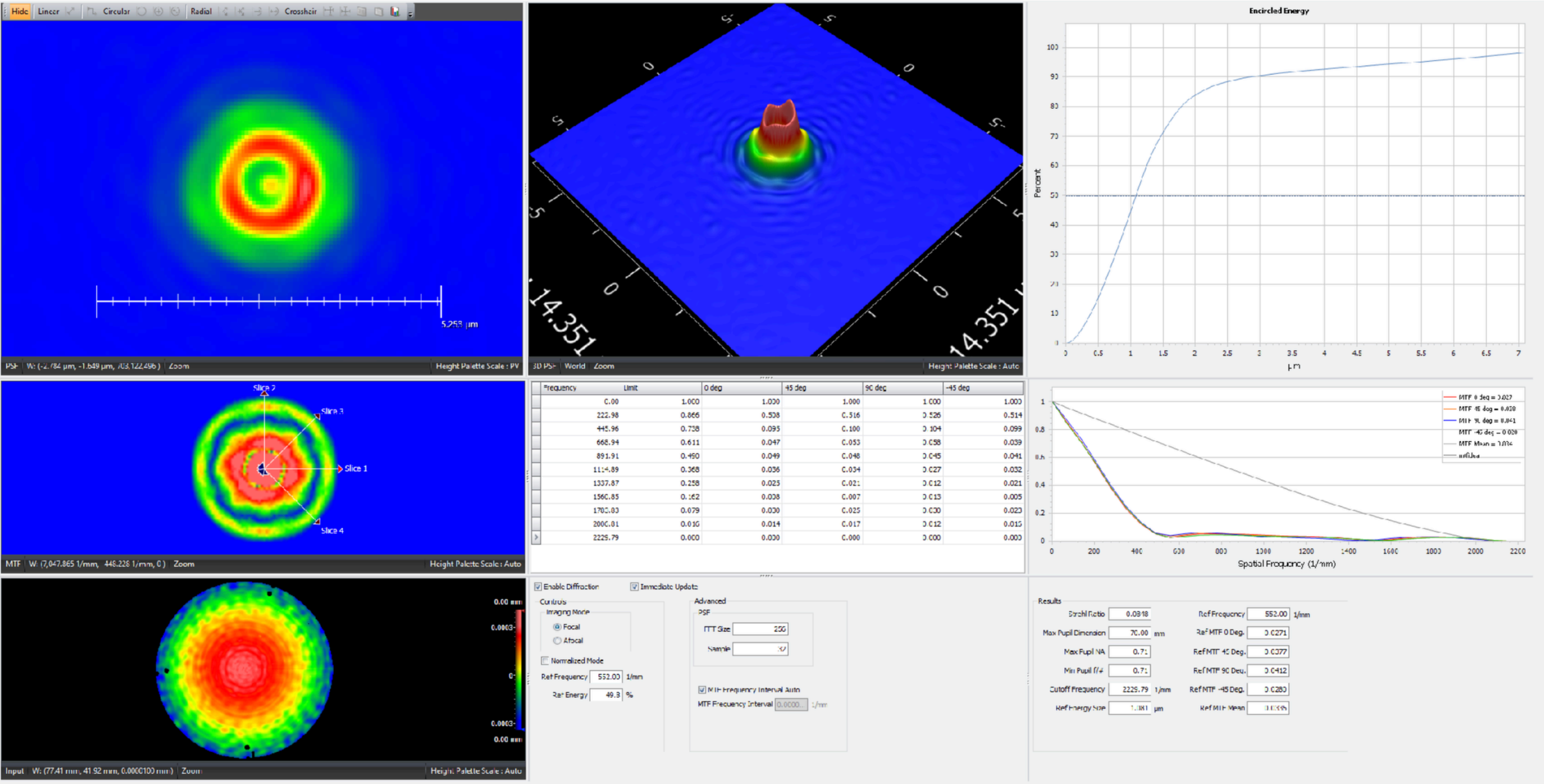
CGH Measurement Data



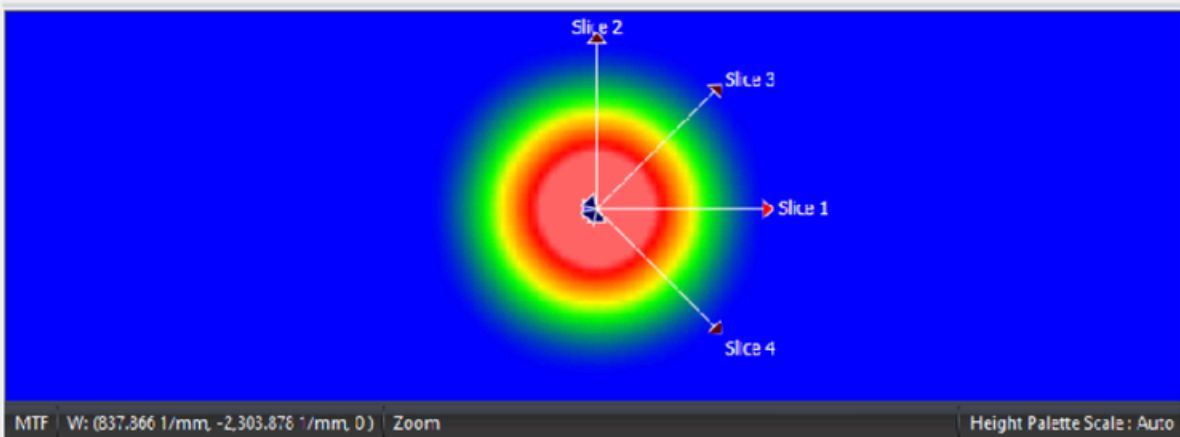
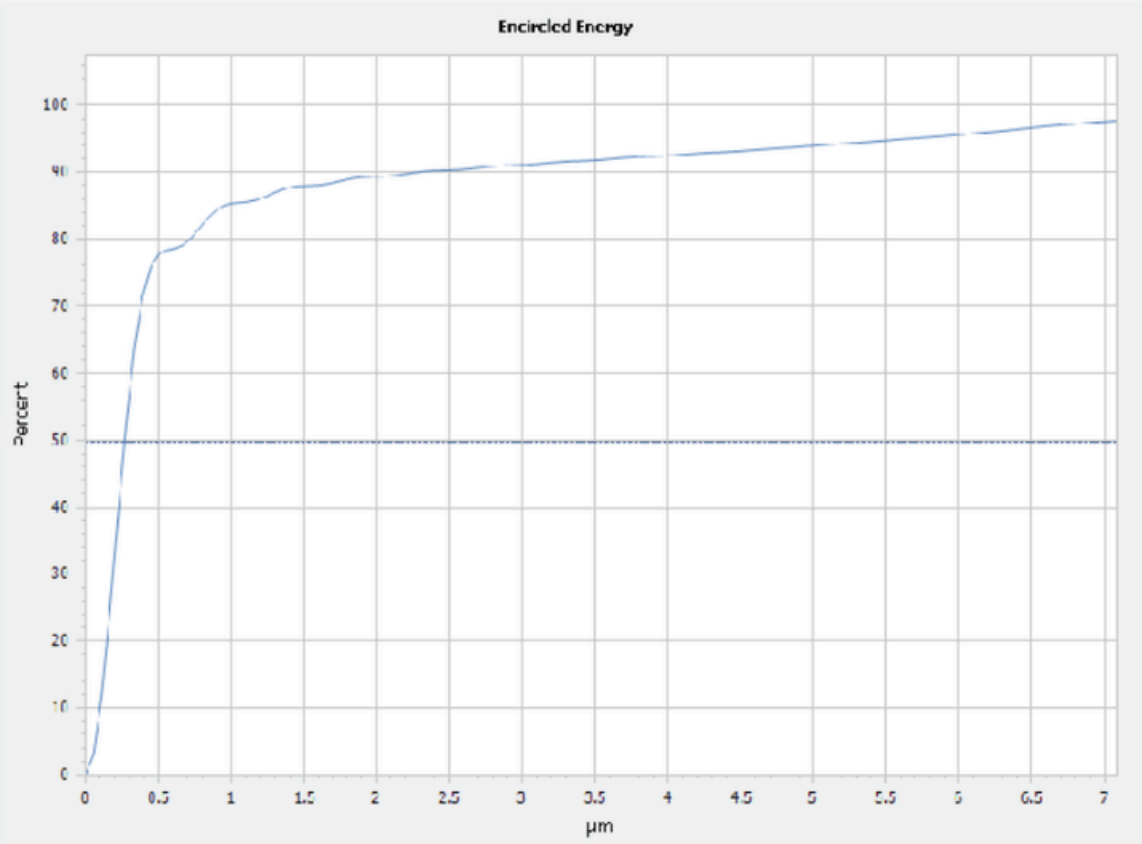
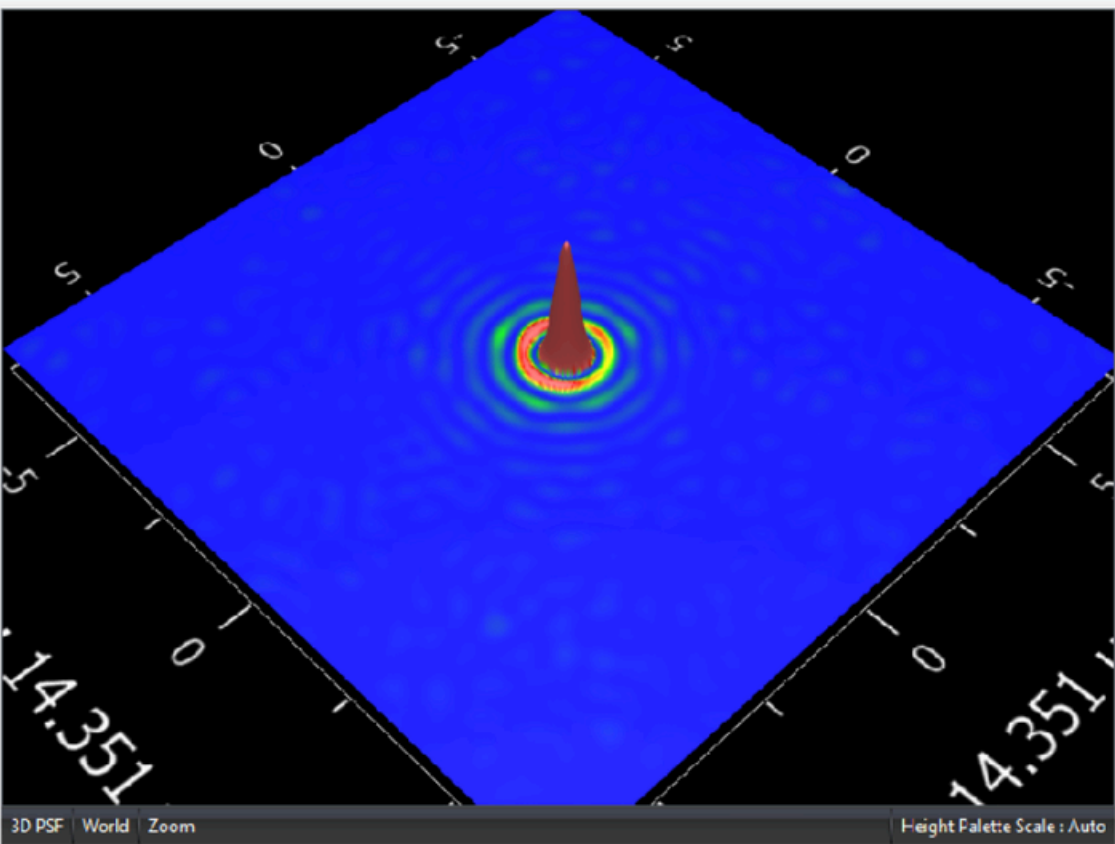
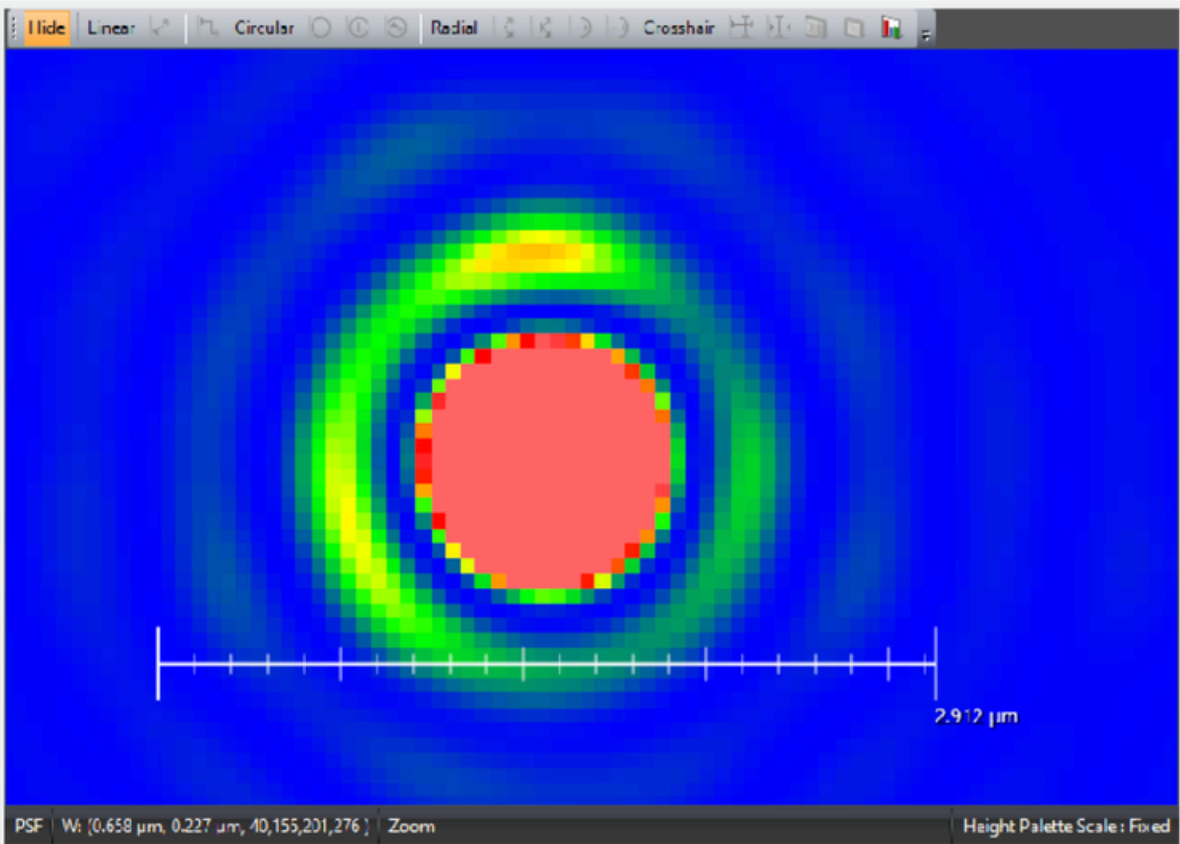
CGH Measurement Data



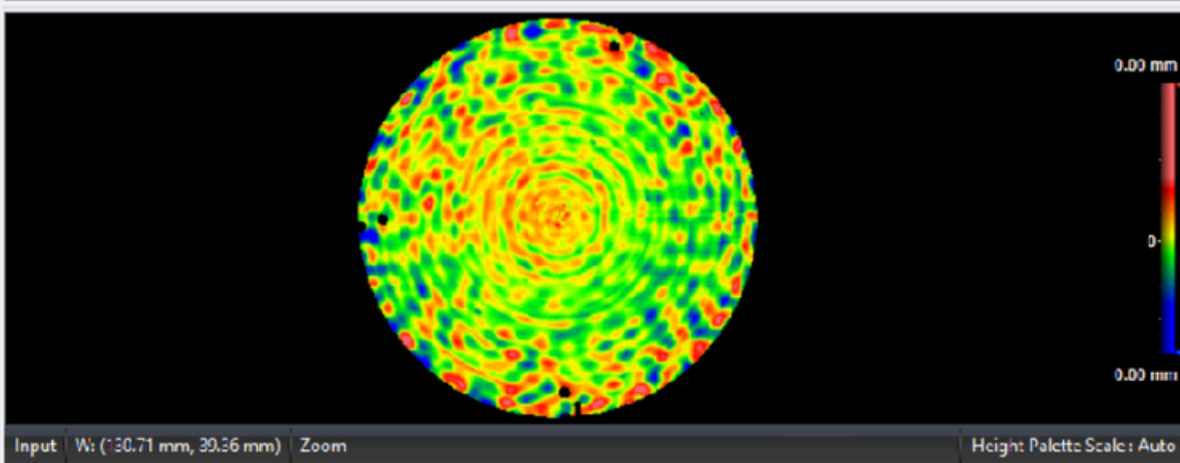
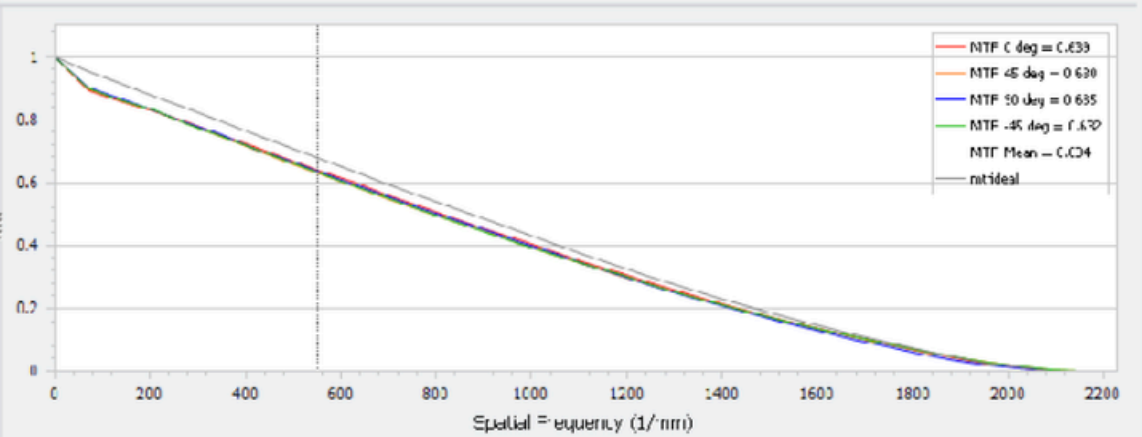
Mx Diffraction Results with Power



Mx Diffraction Results Power Removed



Frequency	Limit	0 deg	45 deg	90 deg	-45 deg
0.00	1.000	1.000	1.000	1.000	1.000
222.98	0.866	0.820	0.820	0.821	0.821
445.96	0.738	0.698	0.698	0.693	0.693
668.94	0.611	0.577	0.555	0.572	0.557
891.91	0.490	0.457	0.450	0.455	0.448
1114.89	0.368	0.344	0.338	0.339	0.339
1337.87	0.258	0.241	0.236	0.234	0.236
1560.85	0.162	0.150	0.149	0.144	0.149
1783.83	0.079	0.075	0.074	0.056	0.076
2006.81	0.016	0.015	0.019	0.012	0.019
2229.79	0.000	0.000	0.000	0.000	0.000



Enable Diffraction

Immediate Update

Controls

Imaging Mode

Focal

Affocal

Normalized Mode

Ref Frequency 552.00 1/mm

Ref Energy 10.8 %

Advanced

PSF

TT Size 256

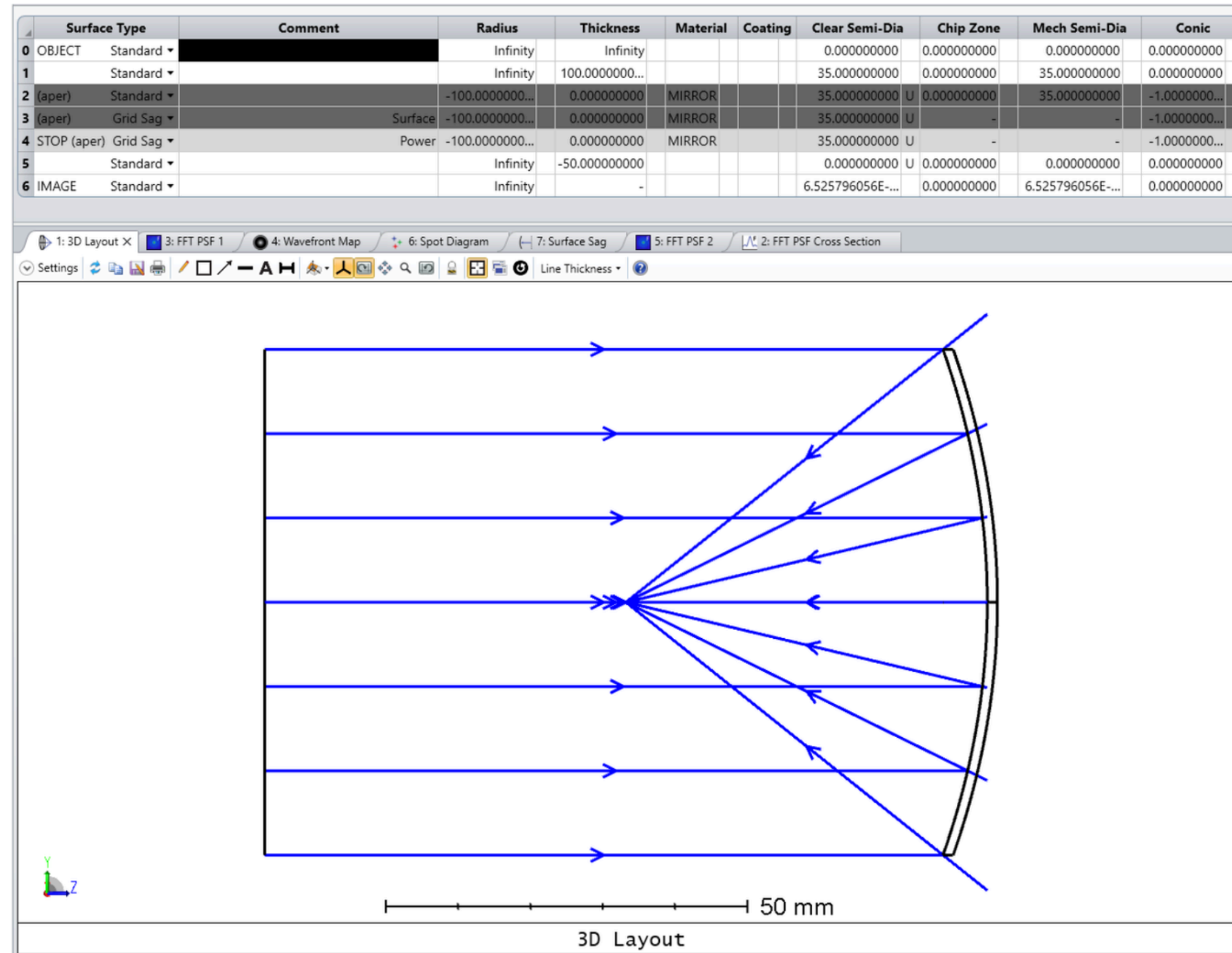
Sample 32

MTF Frequency Interval Auto

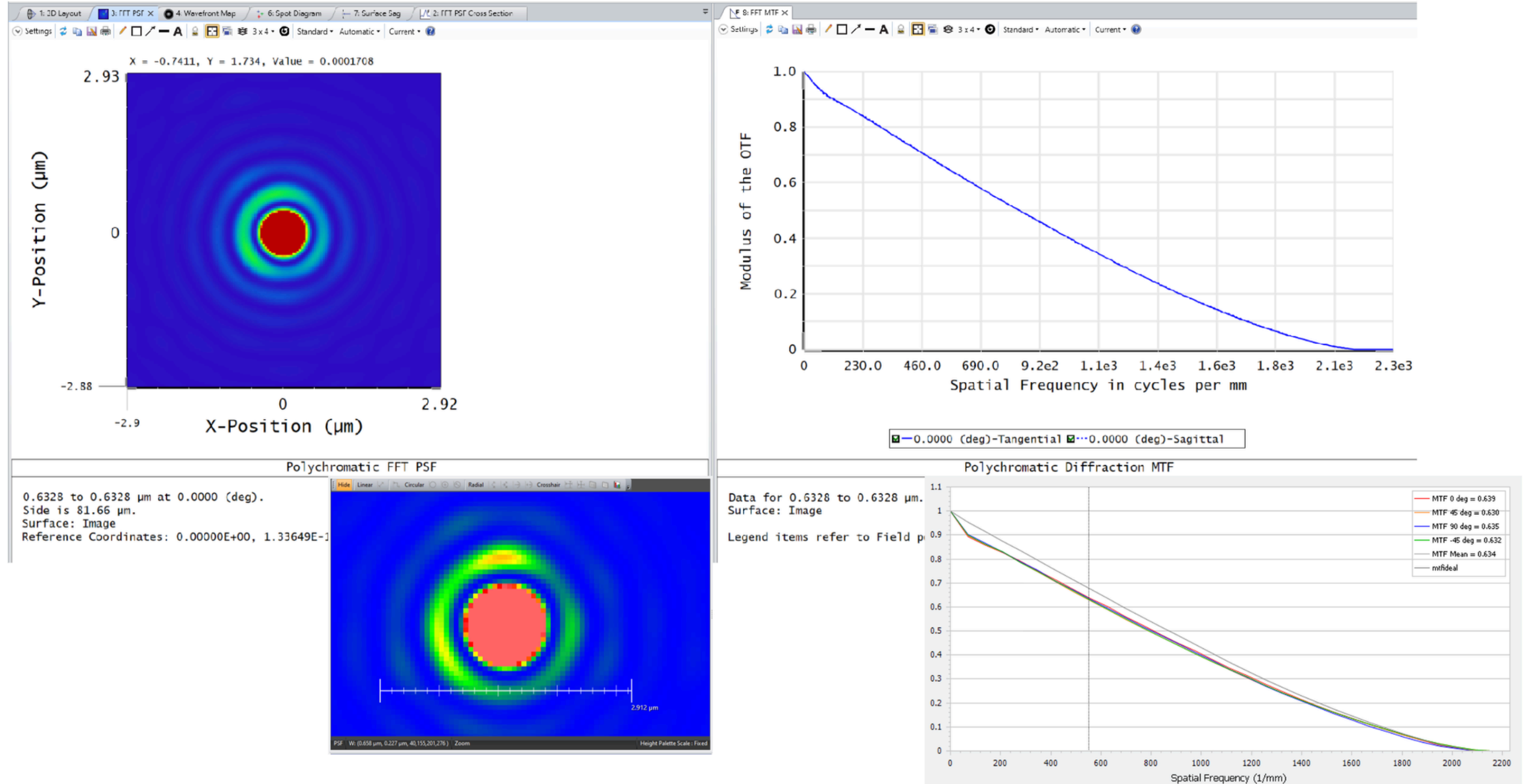
MTF Frequency Interval 0.0000... 1/mm

Results	
Stretch Ratio	0.3305
Max Pupil Dimension	70.00 mm
Max Pupil NA	0.71
Min Pupil f/#	0.71
Cutoff Frequency	2229.79 1/mm
Ref Energy Size	0.269 μm
Ref Frequency	552.00 1/mm
Ref MTF 0 Deg.	0.5387
Ref MTF 45 Deg.	0.5296
Ref MTF 90 Deg.	0.5354
Ref MTF -45 Deg.	0.5318
Ra* MTF Mean	0.5339

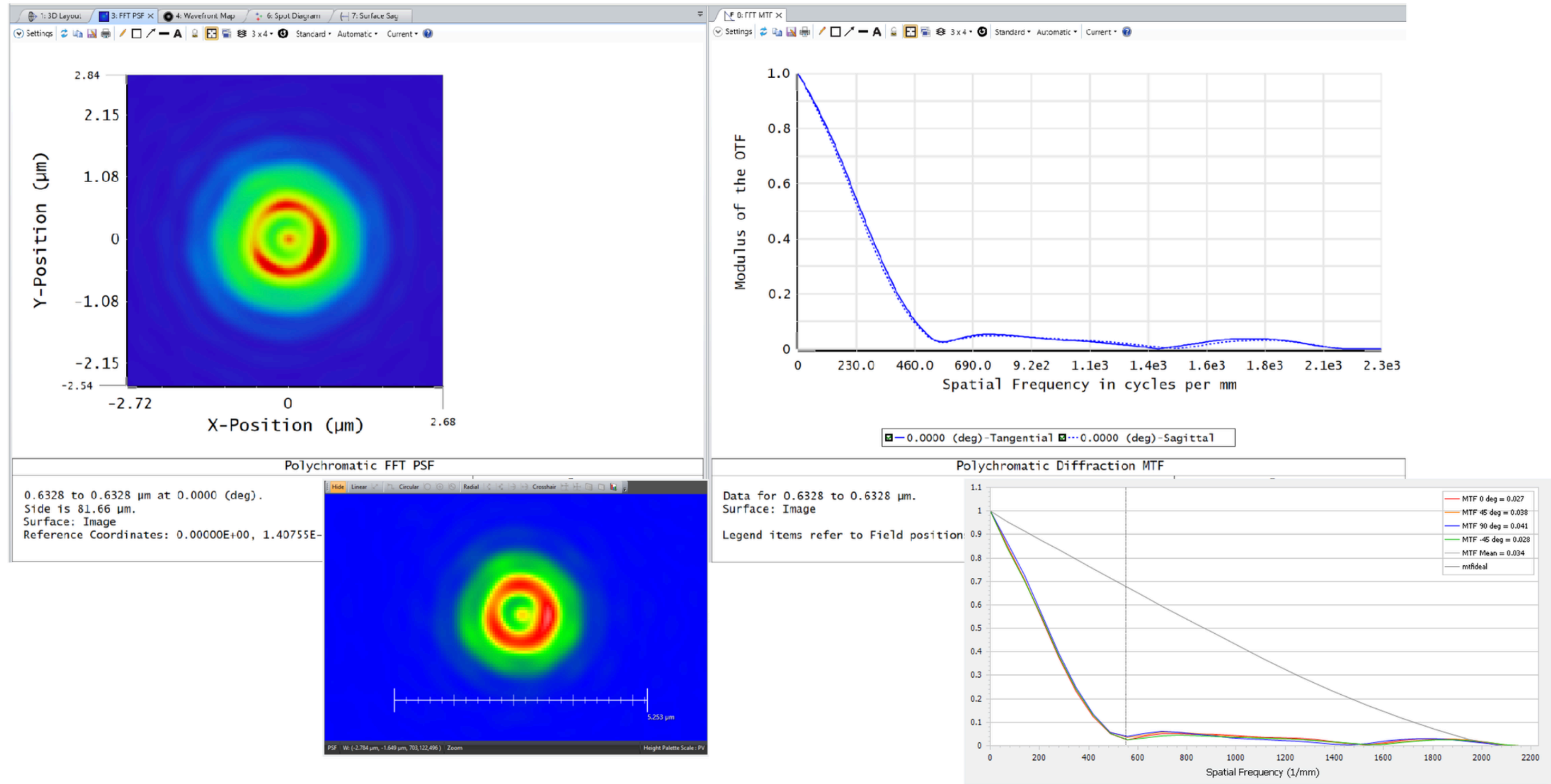
Zemax Model



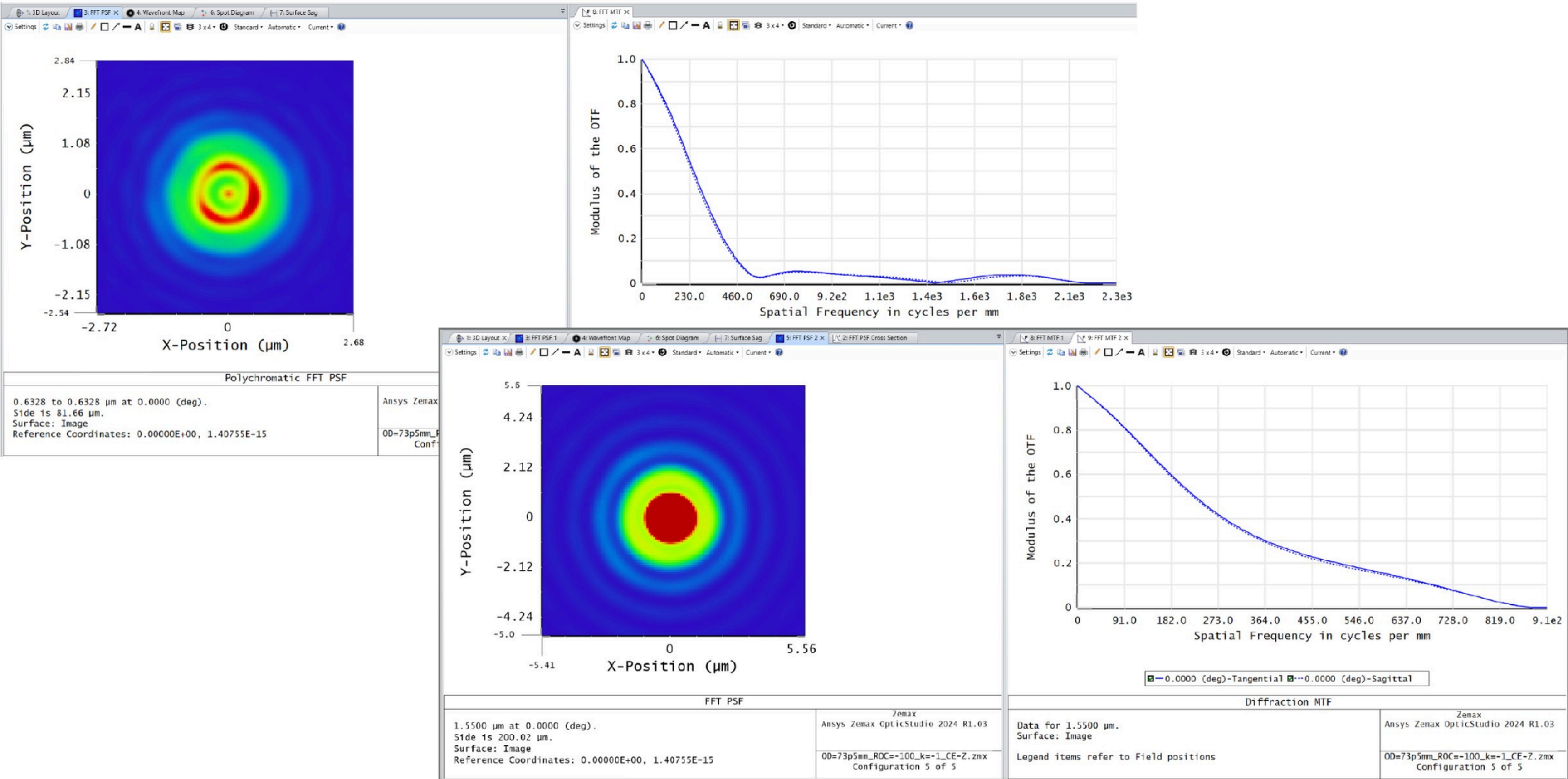
Zemax PSF and MTF Power Removed



Zemax PSF and MTF with Power

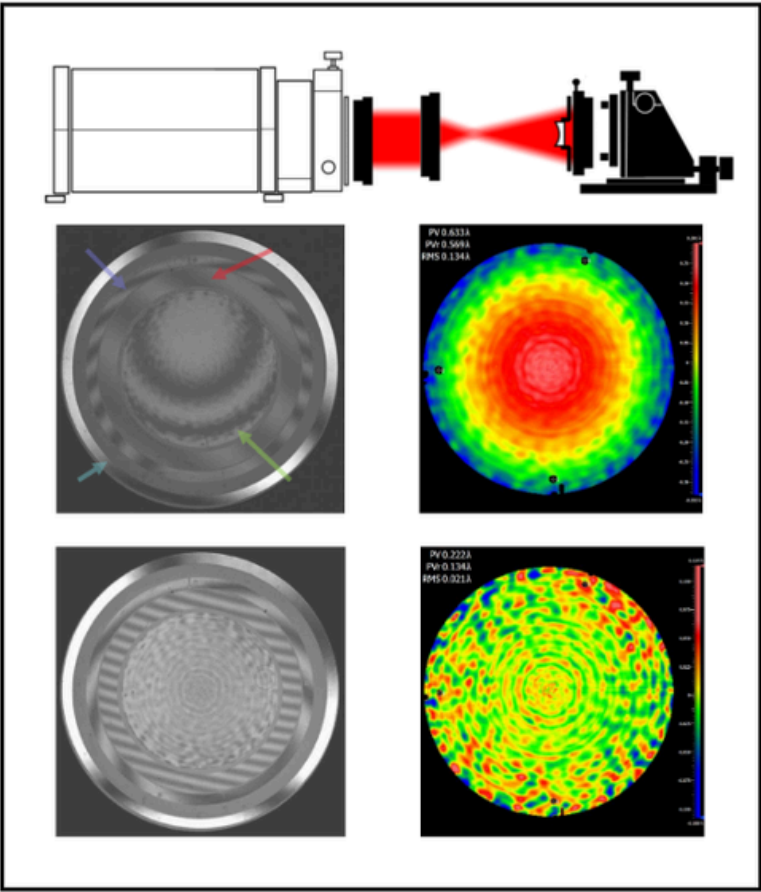


From 633nm to 1550nm

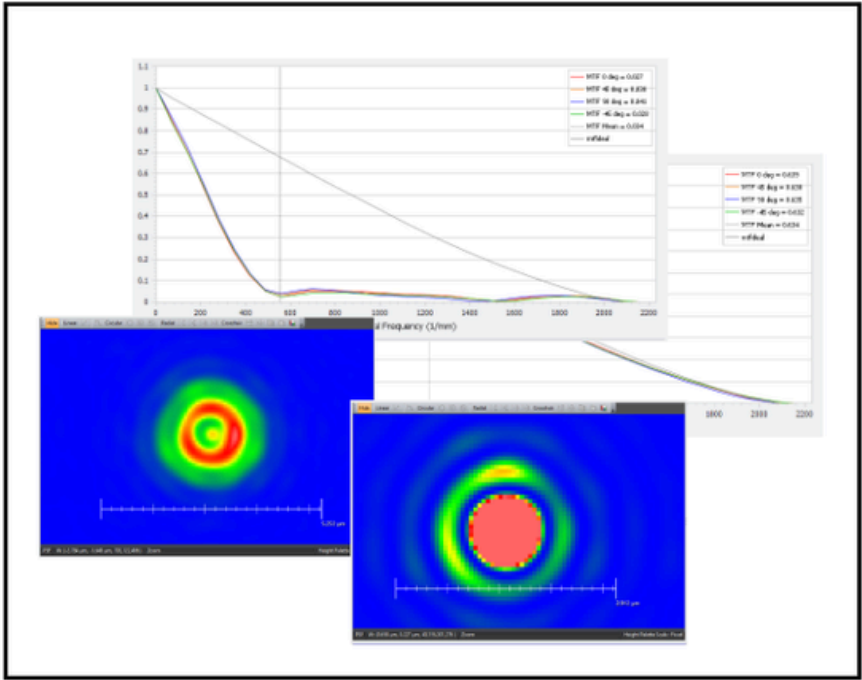


Summary Workflow

Measurement



Mx Analysis





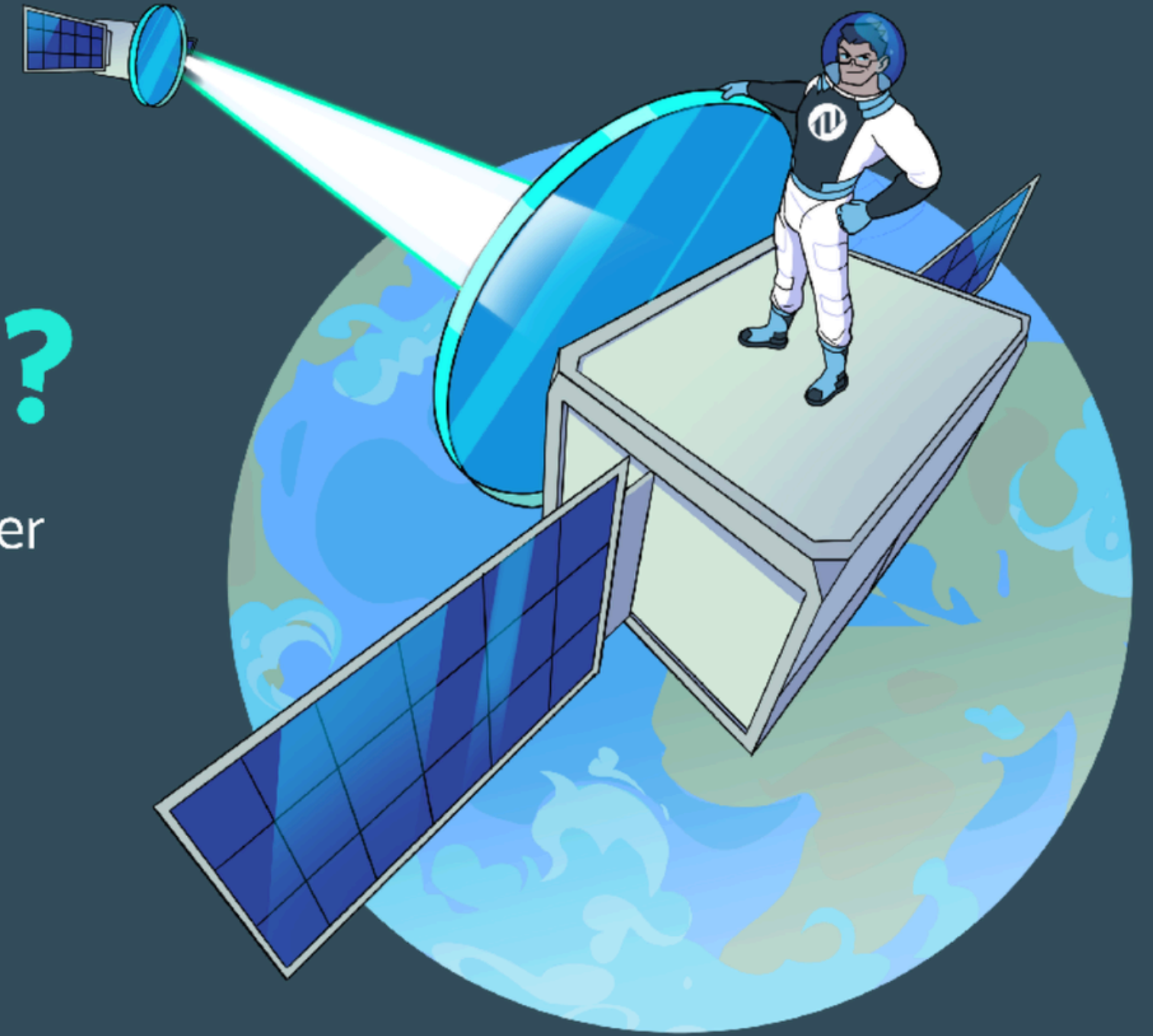
YOUR HERO FOR HIGH POWER LASER OPTICS

LIDT or Absorption?

Which number actually predicts coating performance in laser power transfer and space communications?

Martynas Adomaitis

Market Development Manager, Defence & Space



Two specs. Two different questions.

THE TWO NUMBERS ON EVERY COATING DATASHEET

THE HEADLINE SPEC

LIDT

“Will it survive the worst single shot?”

- A threshold - pass or fail, with a damage probability
 - Measured in μm -scale spots, over seconds of exposure
 - Says nothing about hour 10 000 of the mission
-

Predicts catastrophic failure

WHAT THE MISSION ASKS

Absorption

“Will it still point straight in year fifteen?”

- A rate - every ppm becomes heat, continuously
 - Thermal load, gradient, figure change, pointing drift
 - Measured in ppm - and it changes with power
-

Predicts degradation, misalignment and lifetime

Neither number is wrong. But a space terminal asks **the second one - and the market buys against the first.**

What a space comms link actually asks of a coating

THREE LINKS, THREE OPERATING POINTS

LEO / GEO CROSSLINK

2 - 5 W average

1064 / 1550 nm, BPSK or OOK

Continuous, 15 years on orbit

Absorption + lifetime

DEEP-SPACE DOWNLINK

4 W average

1550 nm PPM, MHz rep rate

Heat never clears between pulses

Absorption sets the rep-rate limit

GROUND UPLINK

5 kW average

1030 nm, continuous kW-class

Thermal design is the whole job

Absorption + stack conductivity

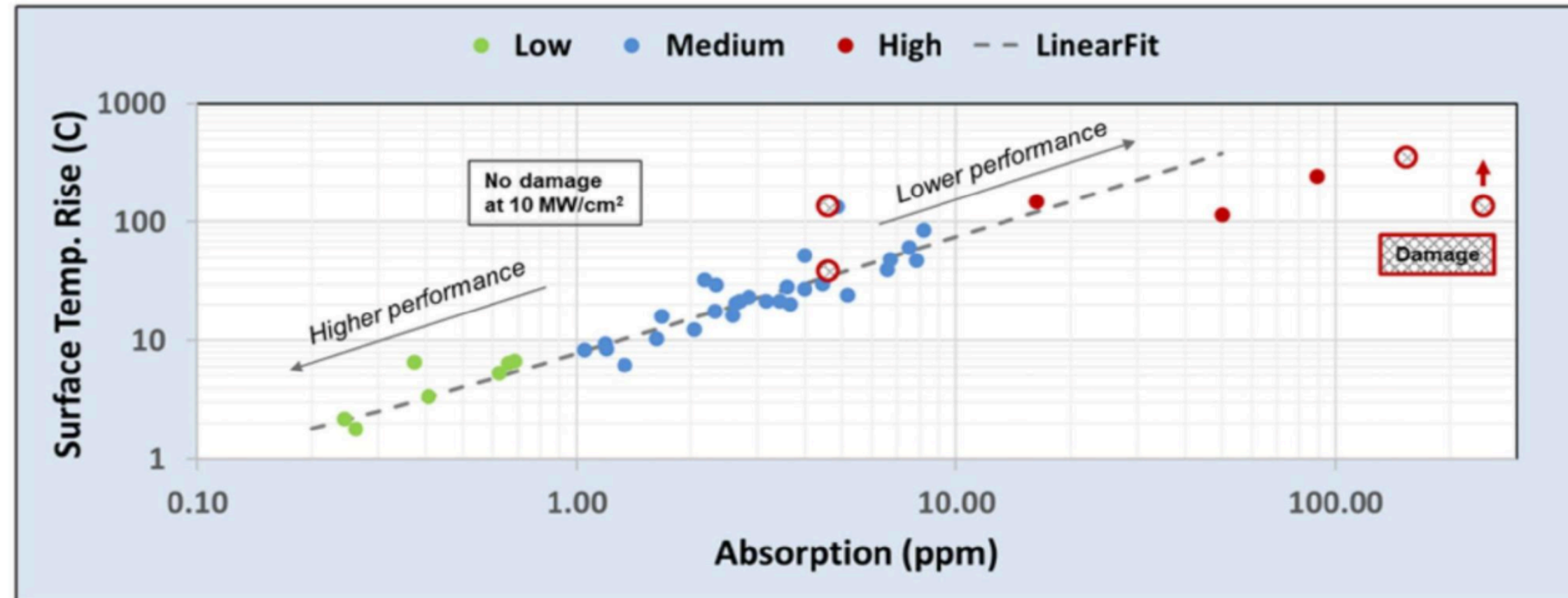
Every one of these is an **average-power** problem. Including the pulsed one.

LIDT is still the floor - but a number without its conditions is not a spec: λ , pulse width, rep rate, spot, AOI, protocol.

Operating points from published figures - Tesat LCT135 and SCOT80; NASA DSOC flight and ground laser transmitters.

In CW, absorption is the temperature

1077 NM CW MIRROR THIN-FILM DAMAGE COMPETITION, 2022



Surface temperature rise (in °C) measured by thermal camera during CW laser irradiation (at 10 MW/cm² if no damage was observed vs. absorption (in ppm) of coating samples measured by PCI. Data is sorted by average absorption values in three bins as Low, Medium and High (solid data points), respectively. Samples with damage are singled out by hashed data points.

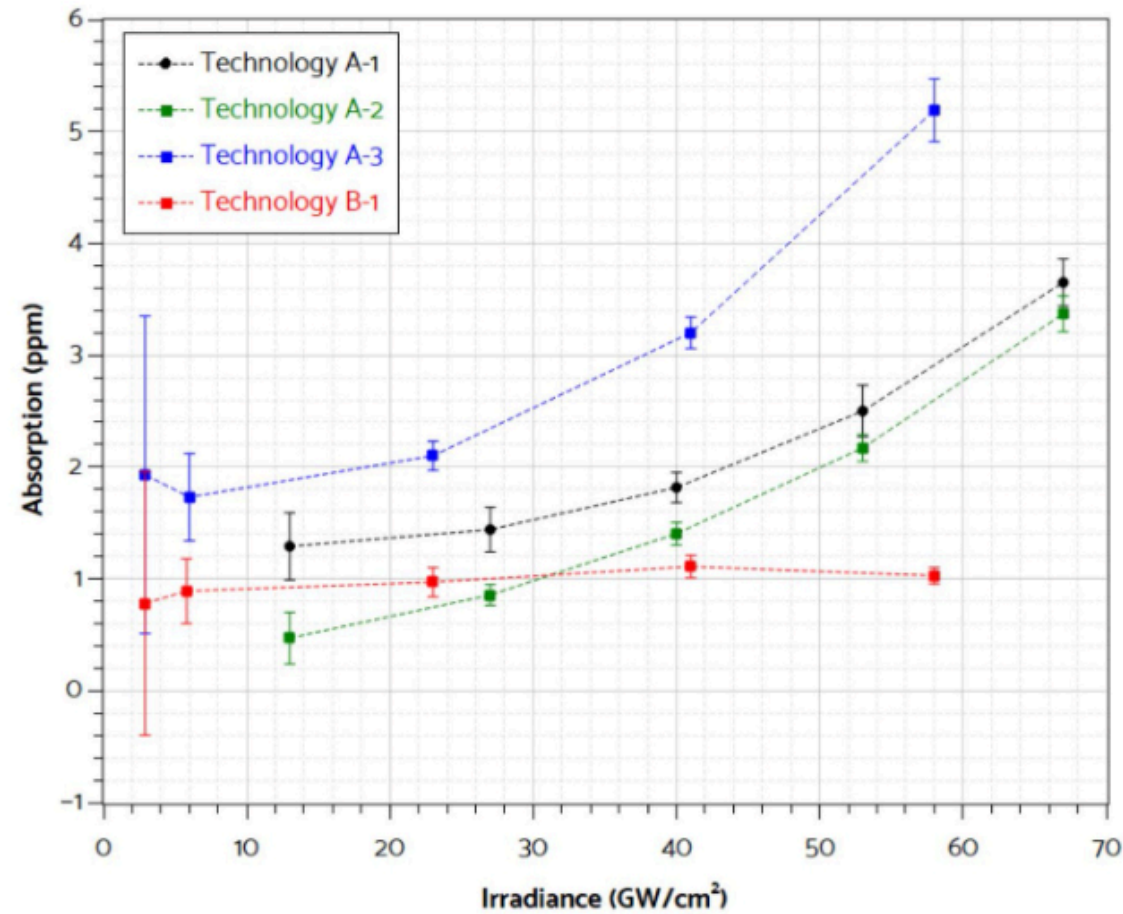
The measurement

- HR > 99.5% @ 1070 nm, AOI = 0°
- 17 kW CW laser at 1077 nm, 500 μm beam, 5 spots per sample
- Peak irradiance up to 10 MW/cm²
- Surface temperature by thermal camera; absorption by PCI

Across two decades of absorption, temperature rise tracks it almost one-for-one - and every damaged sample sits at the high-absorption end.

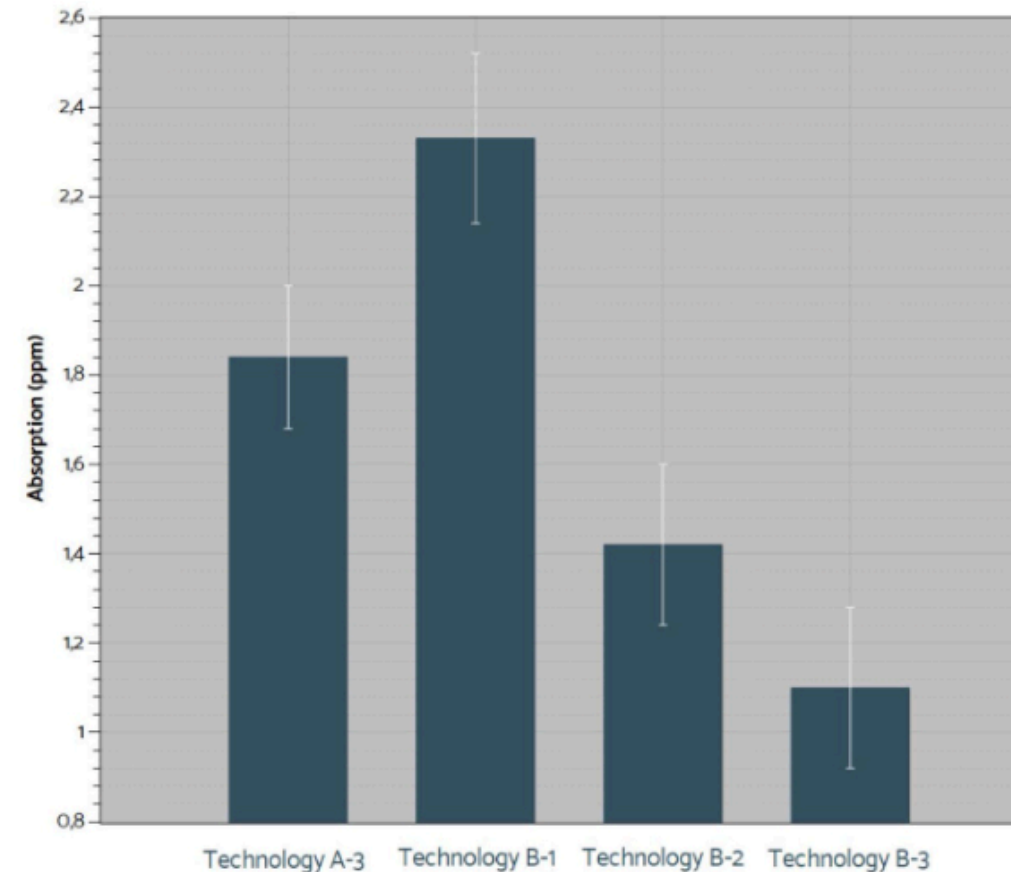
Nothing here is an LIDT number. In continuous wave, absorption is the performance spec.

Tantala or hafnia? The label does not decide it



A-1 Ta₂O₅ / SiO₂ (0 deg)
A-2 Ta₂O₅ / SiO₂ (0 deg)
A-3 Ta₂O₅ / SiO₂ coating annealed (45 deg)
B-1 HfO₂ / SiO₂ coating annealed (45 deg)

Nonlinear absorption · 1064 nm, linear P



A-3 Ta₂O₅/SiO₂ coating
B-1 HfO₂/SiO₂ coating
B-3 Also HfO₂/SiO₂ coating
B-2 Also HfO₂/SiO₂ coating ☺

Linear absorption · 1070 nm, T-scan

The ranking inverts

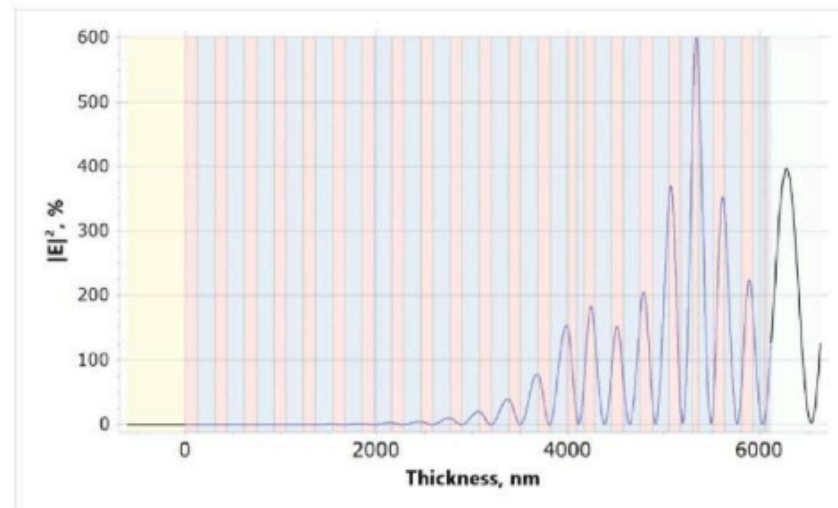
- At low power B-1 hafnia is the worst of the four - 2.3 ppm against 1.8 for A-3 tantala
- Under irradiance B-1 stays flat near 1 ppm while A-3 climbs past 5
- Three hafnia coatings span 1.1 to 2.3 ppm. Same material, twofold spread

Measure at probe power and you would pick the wrong coating. Absorption has to be measured where you operate.

Design moves absorption more than material does

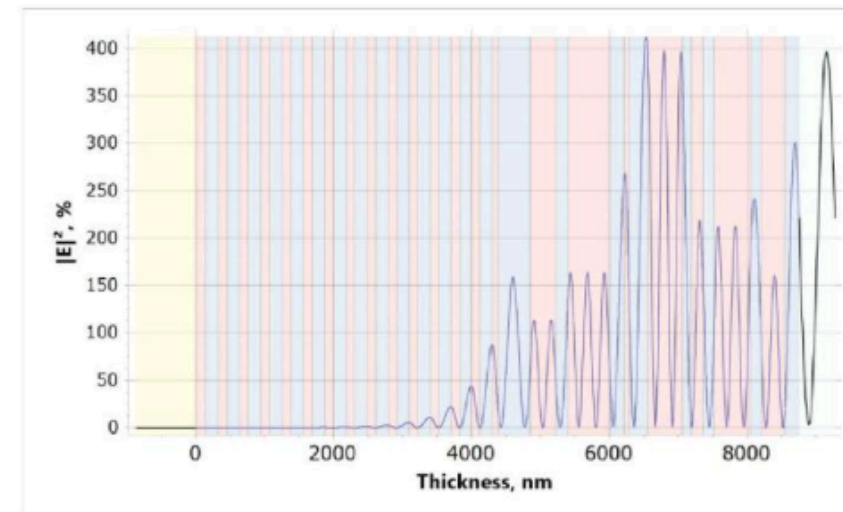
E-FIELD OPTIMISATION IN DISPERSIVE MIRRORS

Standard Design

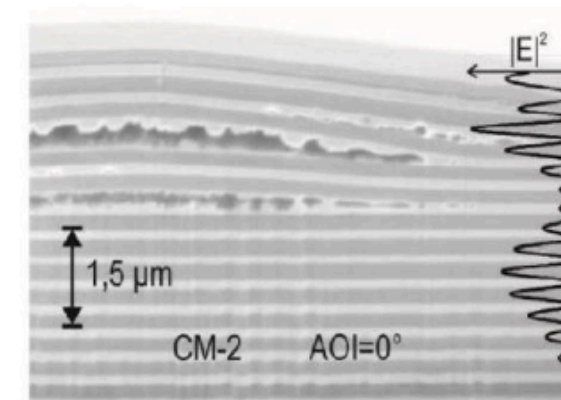
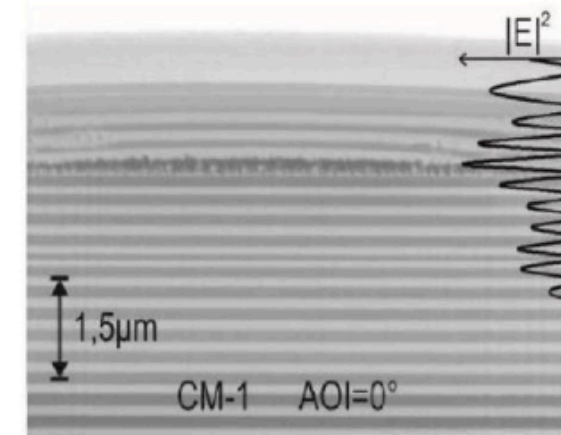


Absorption: 80 ppm
LIDT: 0.052 J/cm²

E-field Optimized



Absorption: 10 ppm
LIDT: 0.077 J/cm²



Take-away

- Interfaces between layers are the weak link - move the standing-wave peak off them
- Same materials: absorption fell 8x, LIDT rose about 1.5x
- Absorption is far more sensitive to design than LIDT is

So “which material” is the wrong first question. “Optimised for which operating point” is the right one.

Which number should drive your coating selection

Ultrafast pulsed

fs / ps, low duty

LIDT + lifetime

with full test conditions

Nanosecond pulsed

high energy per pulse

LIDT + defect statistics

beam size scaling matters

CW power beaming

kW-class, vacuum

Absorption

plus stack thermal conductivity

Space comm terminal

modest power, 10+ years

Absorption + lifetime

plus laser-induced contamination

Use LIDT as the floor. Use absorption as the limit.

Five things to ask your coating vendor

HOW HARD IT IS TO GET		
1	Give me LIDT with its conditions	Already in the test report
2	Give me absorption at my wavelength	Routine PCI at standard lines
3	Show me the power dependence	High-power pump series
4	Show me endurance, not a threshold	Hours to days of laser time
5	Tell me how it behaves in vacuum	Vacuum chamber and a long run

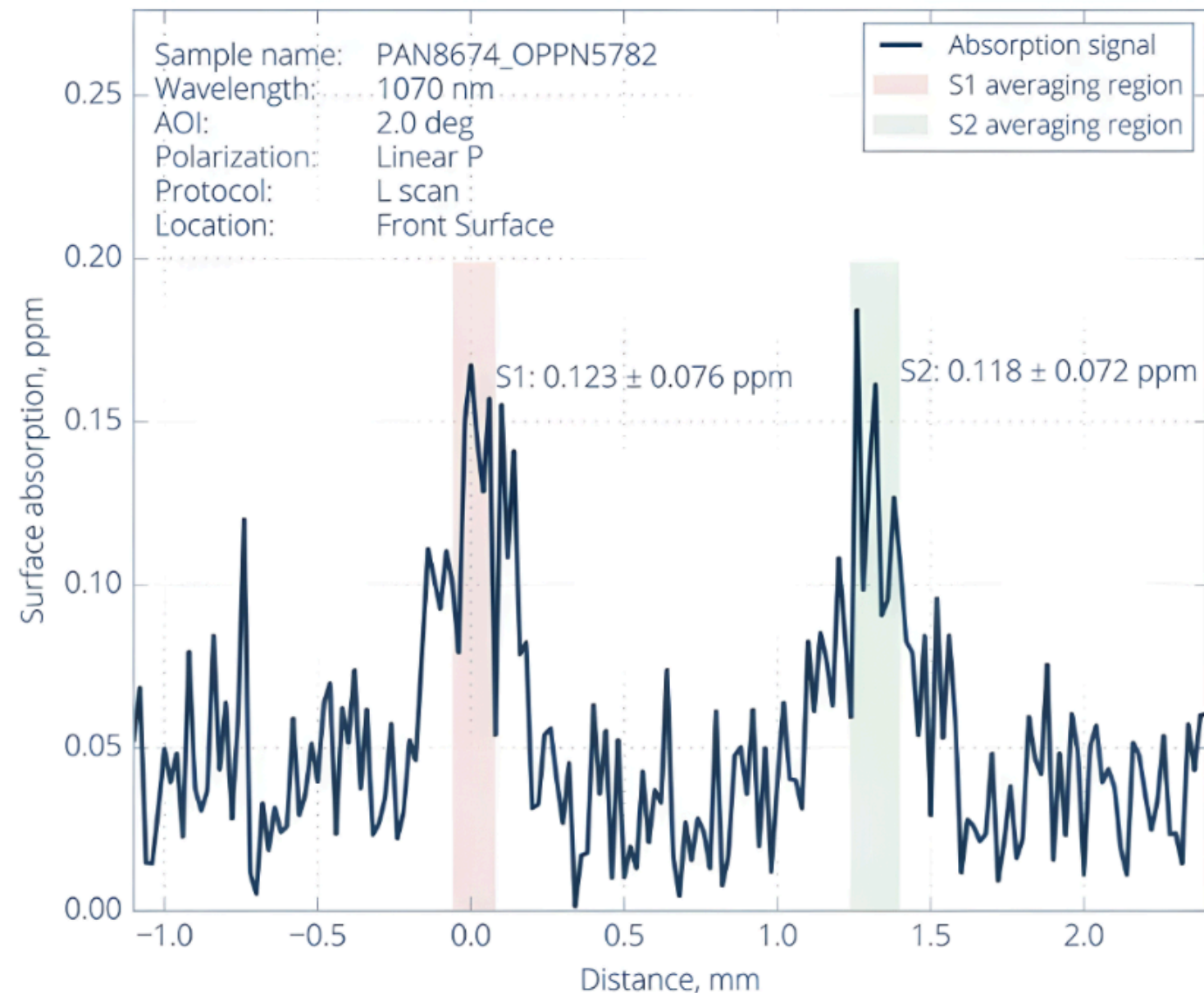
They get more expensive as they get more useful.

But if a supplier can only answer the first one, you are buying a pulsed-laser optic for a continuous-wave job.

Where OPTOMAN sits on this



PCI ABSORPTION REPORT · AR-COATED 1070 NM



0.123 ppm on S1, 0.118 ppm on S2 - and every test condition printed on the face of it.

< 1 ppm

absorption on IBS
low-loss coatings

> 168 J/cm²

1064 nm, 10 ns,
100 Hz, 224 μ m

> 426 kW/cm²

CW at 1070 nm,
137 μ m spot

CW · ns · ps · fs

LIDT, lifetime and PCI
metrology

*If your system runs in space, bring us your
operating point - not just a damage number.*

Martynas Adomaitis

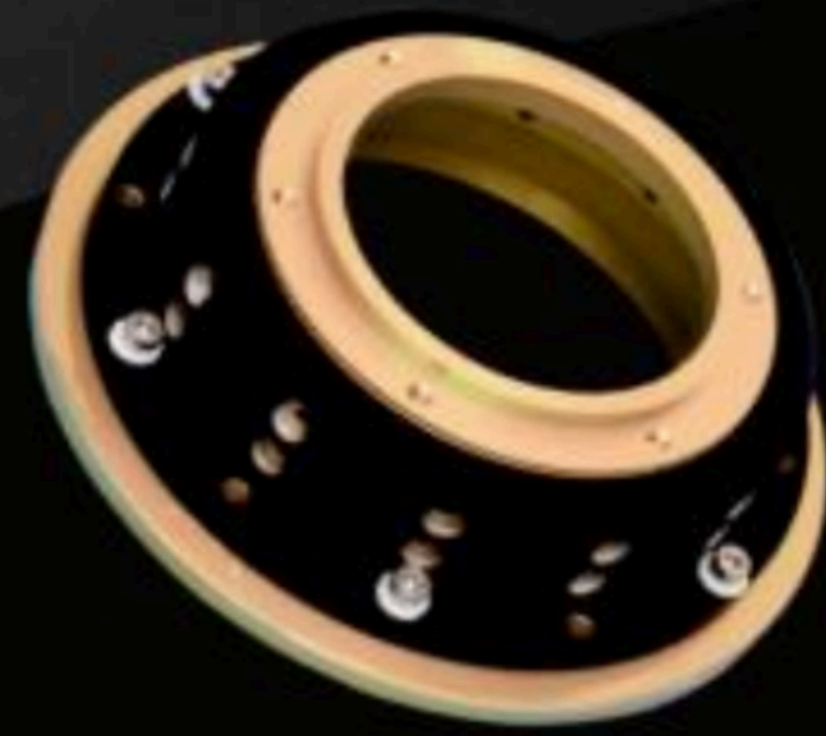
optoman.com · IBS coatings 193–5000 nm · 3–600 mm

ITAR-free EU supply chain · ISO 9001:2015 · JOSCAR registered

Acktar

Advanced Coatings

- Suppress stray light
- Absorb laser power
- Create high emissivity



ACKTAR

Ultra-black coatings & foils

SuperHero League Webinar, 8 September 2026

Advanced Coatings for Straylight Suppression and Passive Thermal Management in Space Applications

SUPRESS STRAY LIGHT, ABSORB LASER POWER, CREATE HIGH EMISSIVITY

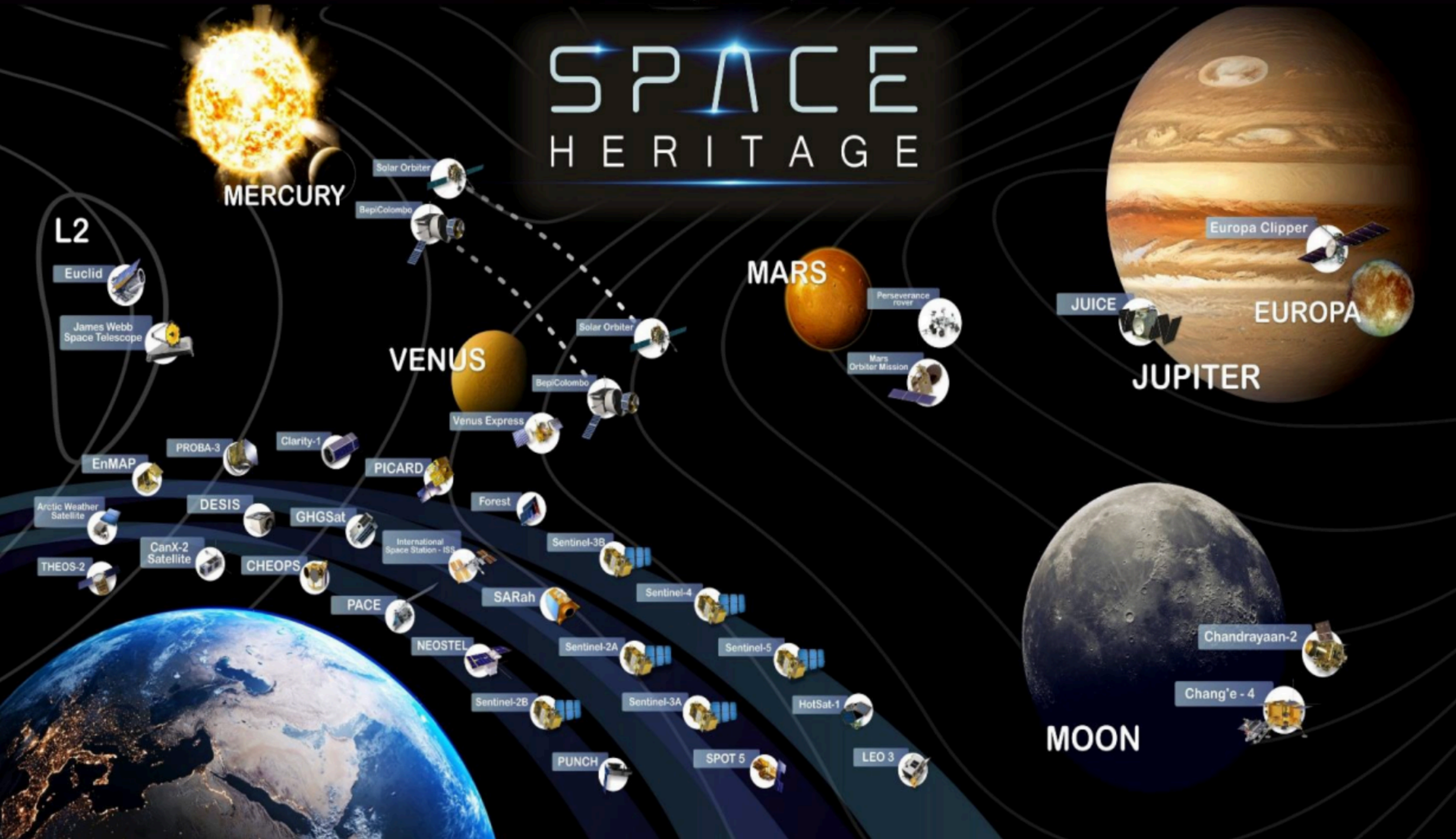
Alexander Telle

CEO ACM Coatings GmbH – subsidiary of Acktar Ltd.

PROVEN IN ORBIT

Built across decades, missions, and constellations

SPACE HERITAGE



Acktar
Advanced Coatings

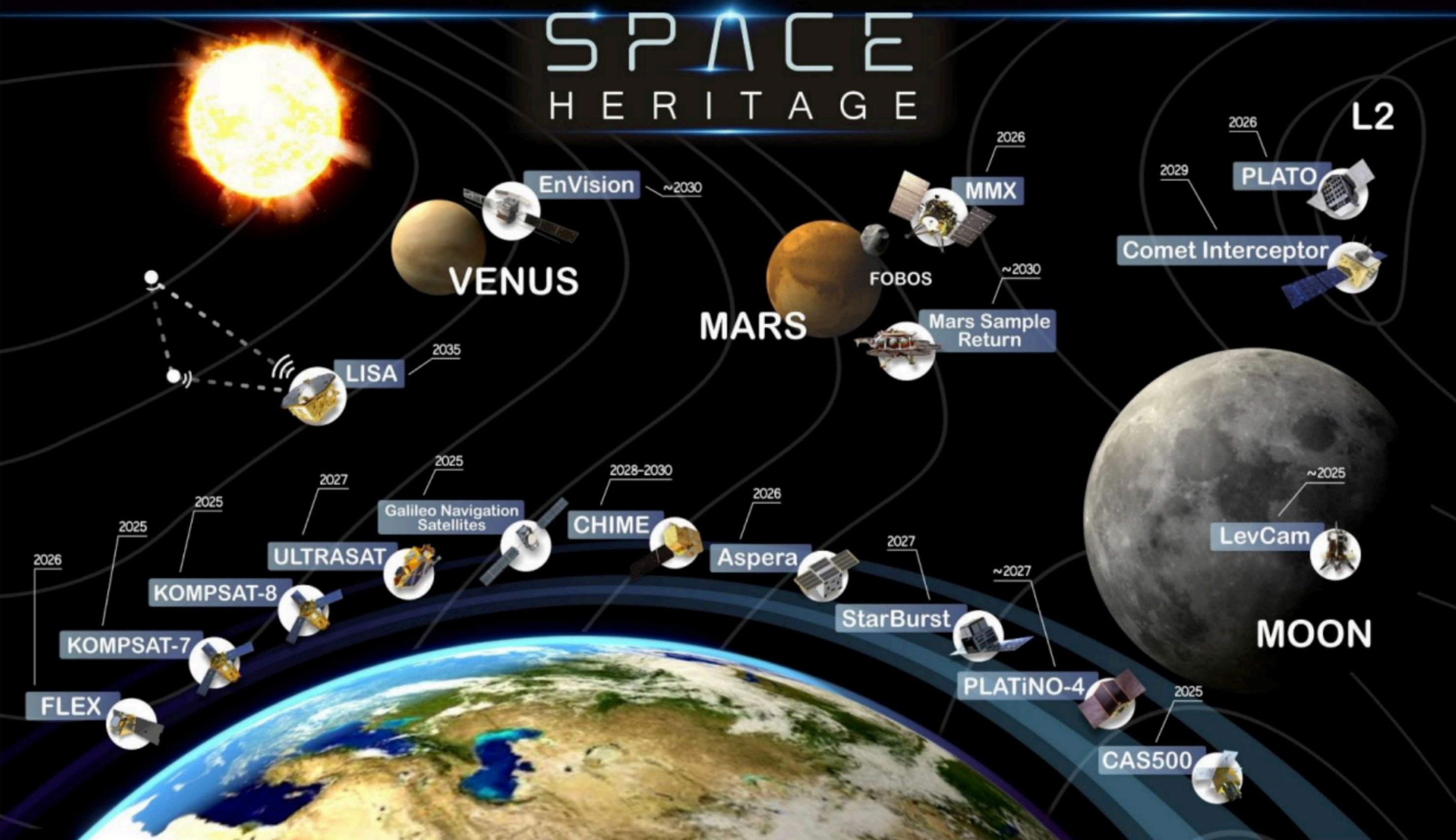
SPEAKER: Alexander Telle, CEO – ACM Coatings GmbH – subsidiary of Acktar Ltd.
EVENT: SHL Webinar "Photonics for Space Communications", 08/09/2026

MEMBER OF
EPIC
EUROPEAN PHOTONICS
INDUSTRY CONSORTIUM

optonet
Photonics Network Thuringia

COUNTDOWN TO ORBIT

SPACE HERITAGE



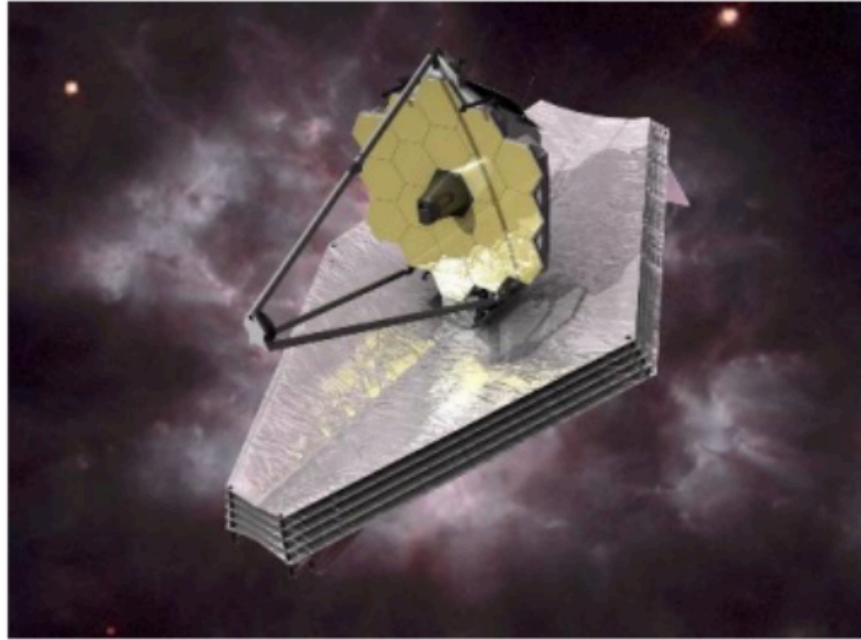
Acktar
Advanced Coatings

SPEAKER: Alexander Telle, CEO – ACM Coatings GmbH – subsidiary of Acktar Ltd.
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MEMBER OF
EPIC
EUROPEAN PHOTONICS
INDUSTRY CONSORTIUM

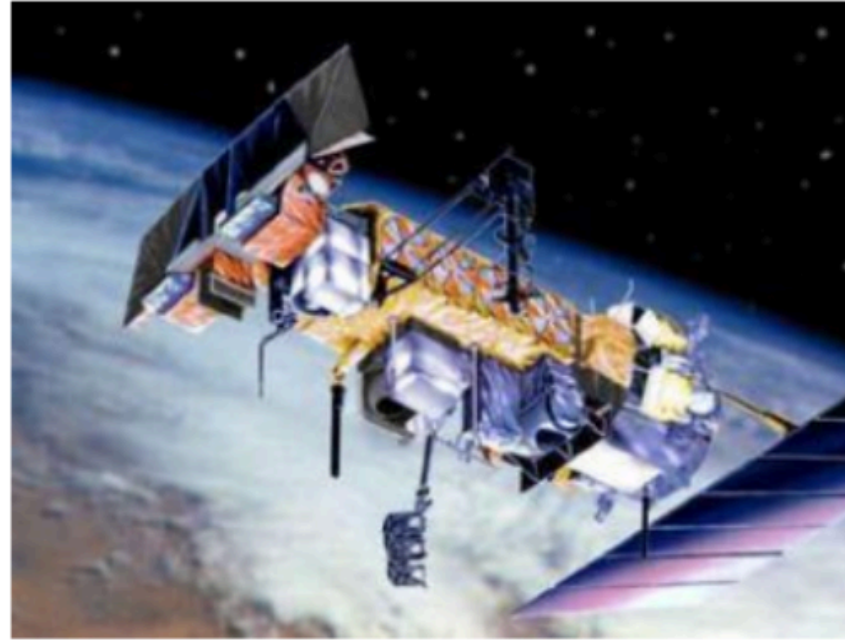
optonet
Photonics Network Thuringia

Acktar's Coating Solutions for Space Triple Functionality



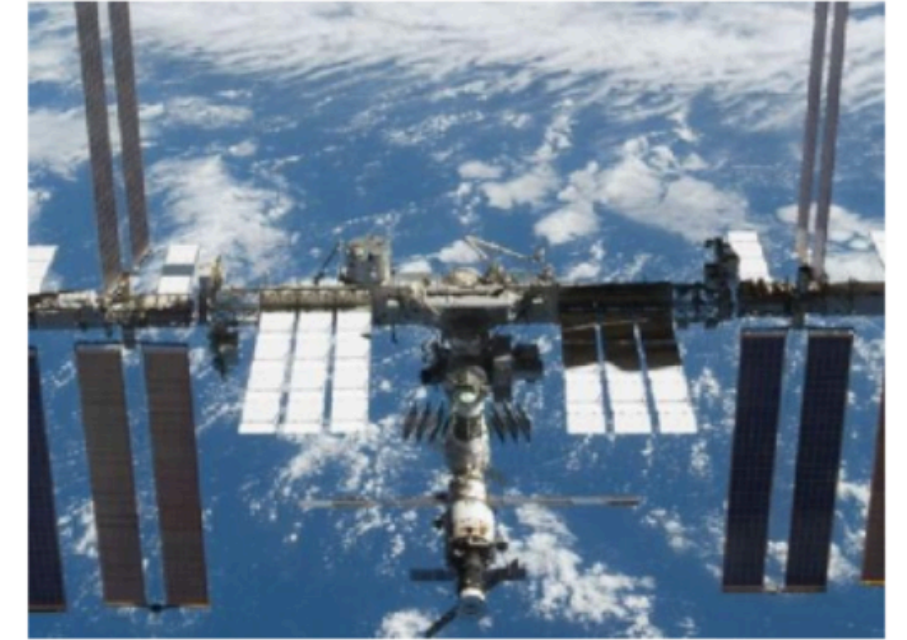
Straylight Suppression

Ultra-black, highly absorbing coatings for UV-VIS-IR



Passive Thermal Management

Coatings with controllable solar absorbance and emissivity



Light Pollution Mitigation

With highly diffusive black & white coatings

Acktar's Coating Solutions for Space Technology Highlights



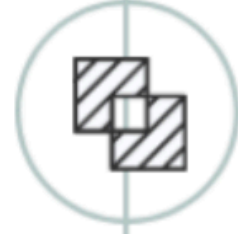
99% Absorptance



Extremely low outgassing



Thermal stability:
-269°C to 450°C (4K to 723K)



Adhesion to metals, glass,
ceramics & polymers



Only few microns thick



Negligible particulation & high vibration
stability



Abrasion resistant & high
resistance to solvents



REACH/RoHS compliant, ecologically
clean



Electrically conductive or non-
conductive options



100% reworkable

Acktar's Coating Solutions Designed for Space



ATOX RESISTANCE



RADIATION



OUTGASSING



CONTAMINATION



THERMAL VACUUM
CYCLING



CRYOGENIC
TEMPERATURES



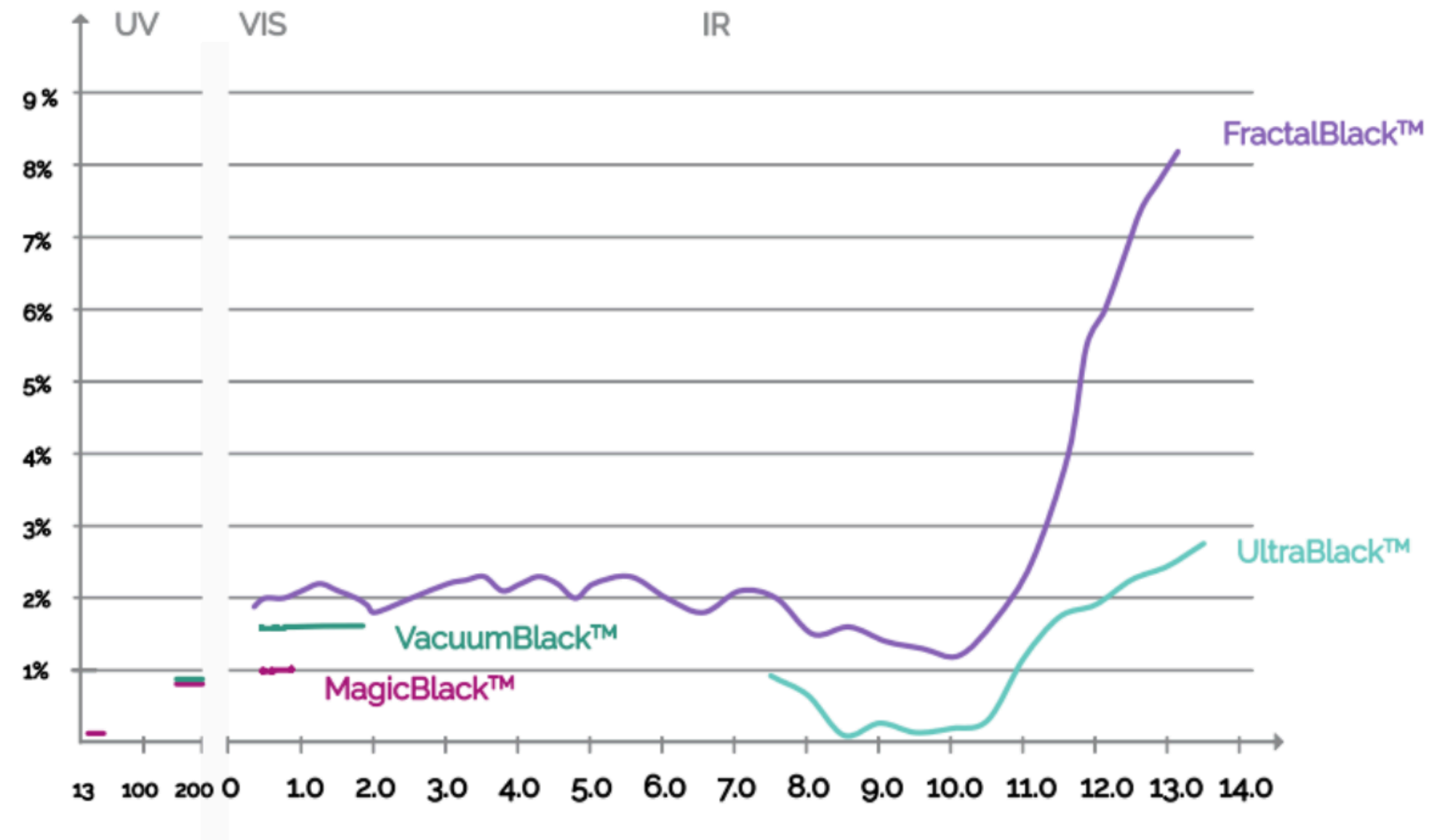
ADHESION



SURFACE
RESISTIVITY

Optical performance – Hemispherical Reflectance of ultra-black direct coatings

-  Magic Black
-  Vacuum Black
-  Ultra Black
-  Fractal Black



Acktar's ultra-black product portfolio



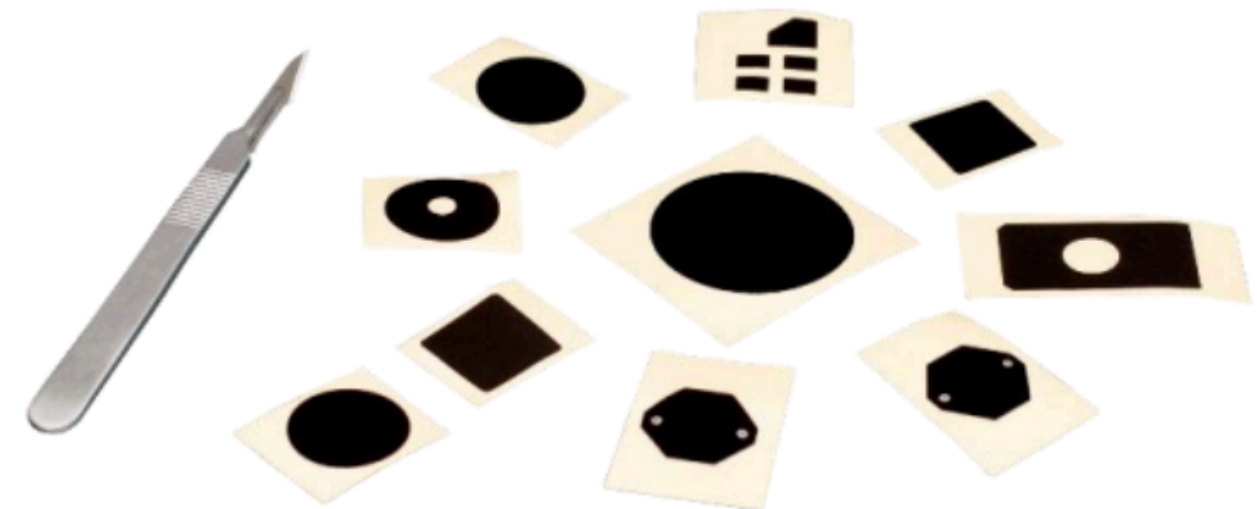
— ULTRA-BLACK DIRECT COATINGS

- On your optical and mechanical components

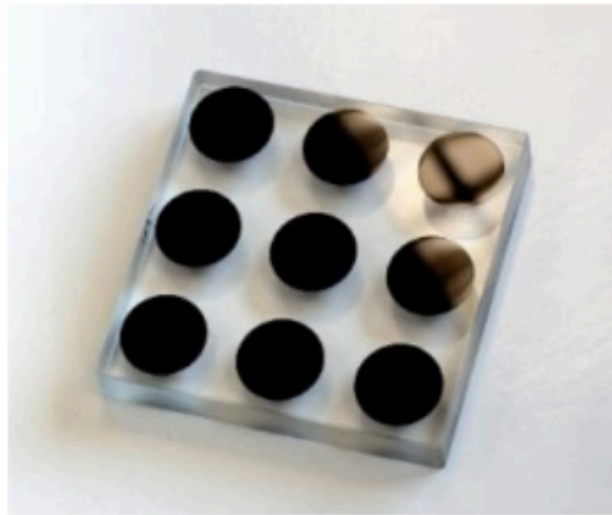


— ULTRA-BLACK COATED FOILS

- For assembling to your components



Space Application Examples:



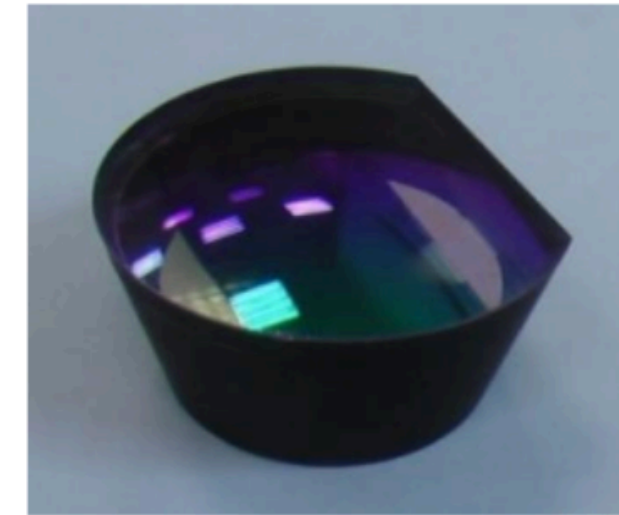
- Coating on glass
- Calibration target



- Black body radiator



- Spectrometer telescope housing

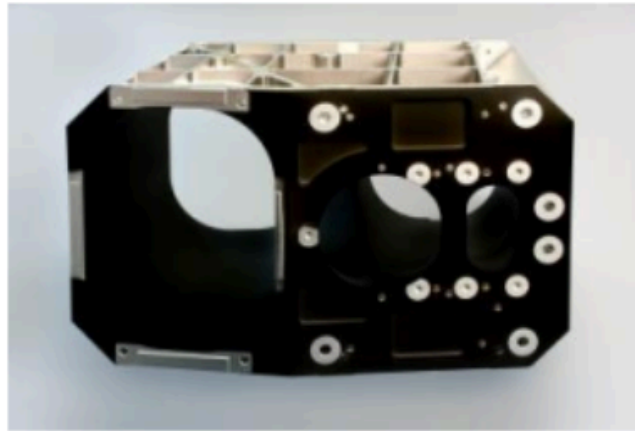


- Lens housing



- Aperture unit

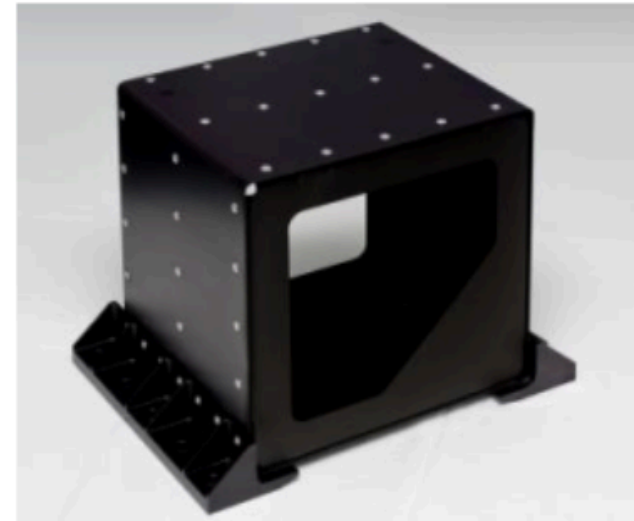
Space Application examples



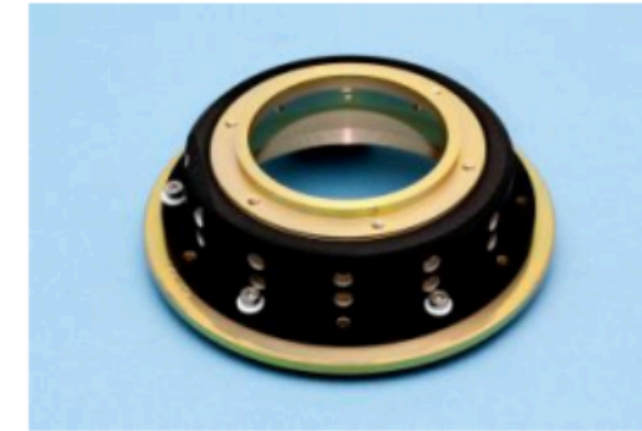
- DESIS instrument housing (AlSi42)



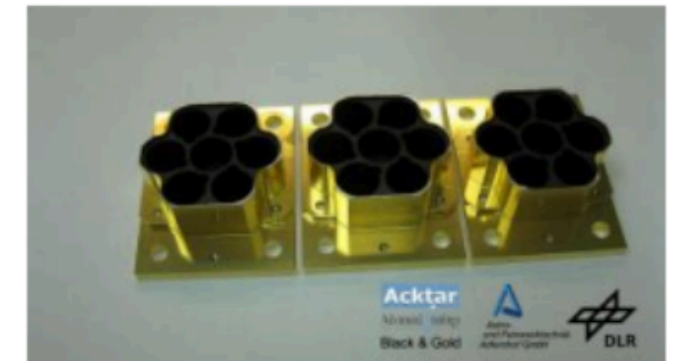
- Sentinel 4 stop aperture (AA 4032)



- METimage SCAD tunnel (AA 6061) (coating sample)



- Lens barrel (Titanium)



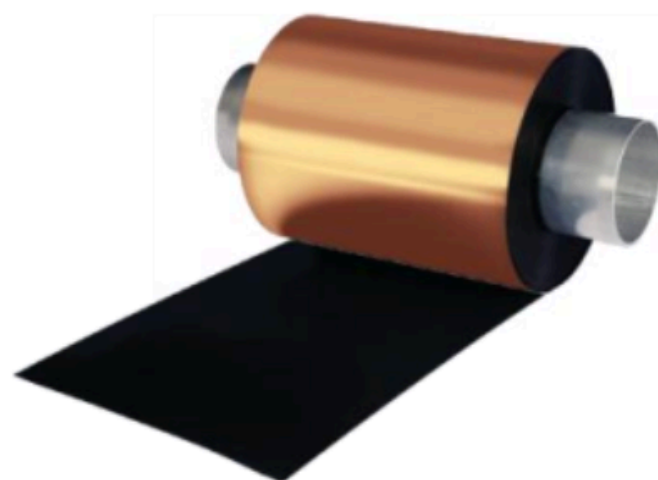
- Aperture plate (gold plating + Acktar black)

New Product Line: Acktar Thermal Management for Space



COOLING

α ↓ Low
 ϵ ↑ High



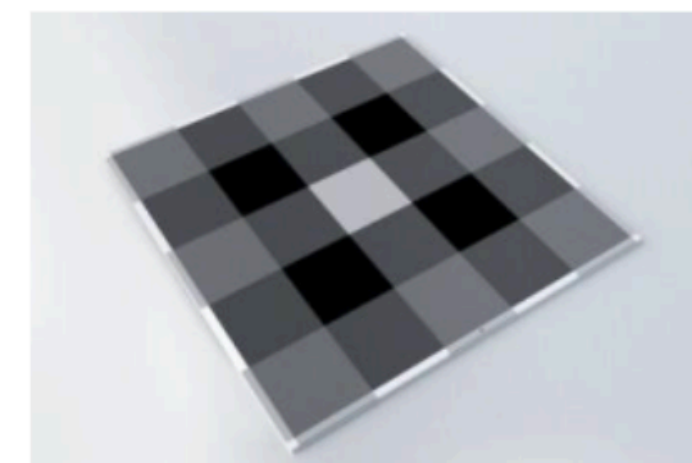
HEATING

α ↑ High
 ϵ ↓ Low



BLACK BODY

α ↑ High
 ϵ ↑ High



CUSTOMIZED

Tailored α/ϵ ratio

Contact us



Earth observation image taken by ESA Sentinel 2 with Acktar Black coatings aboard.

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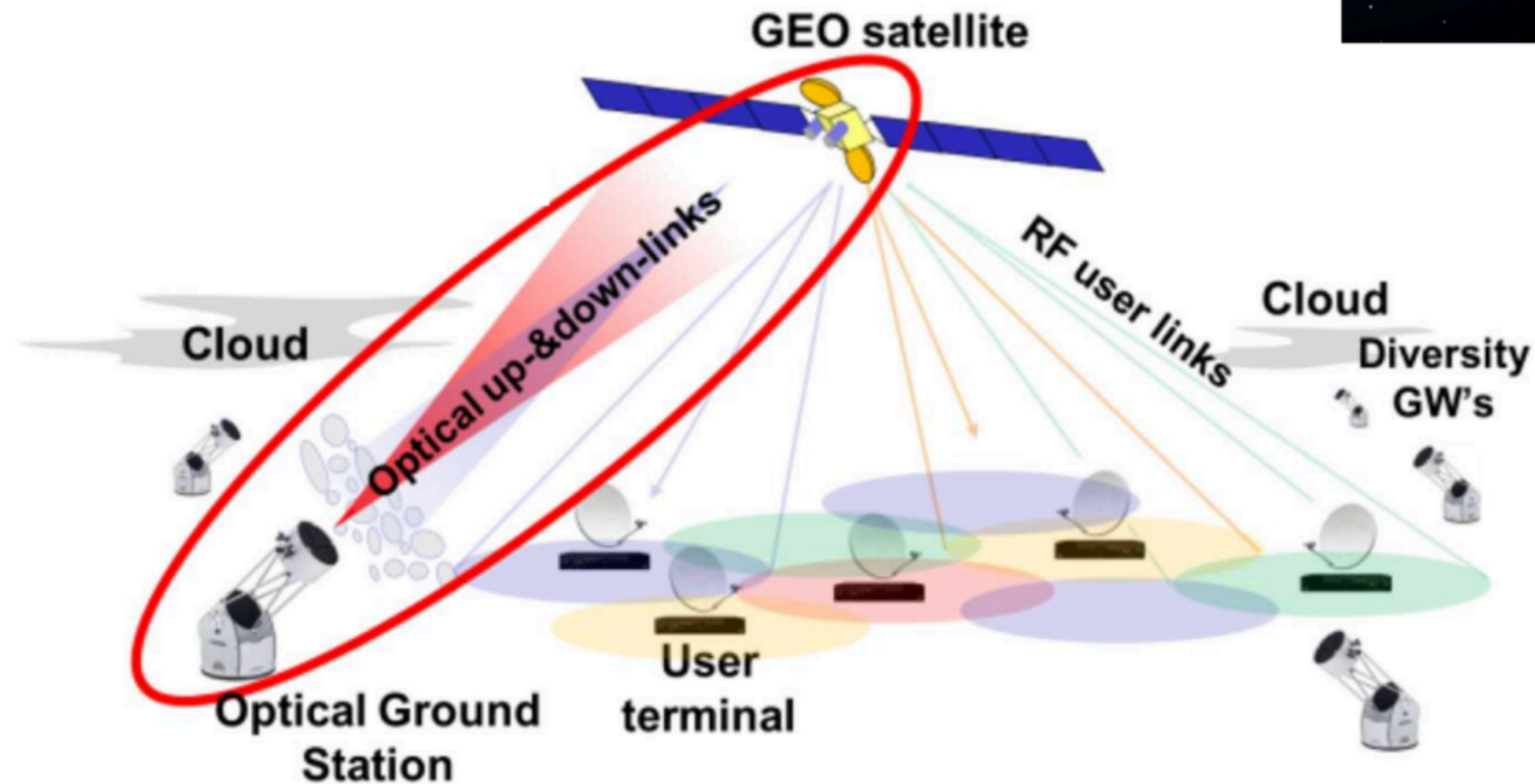
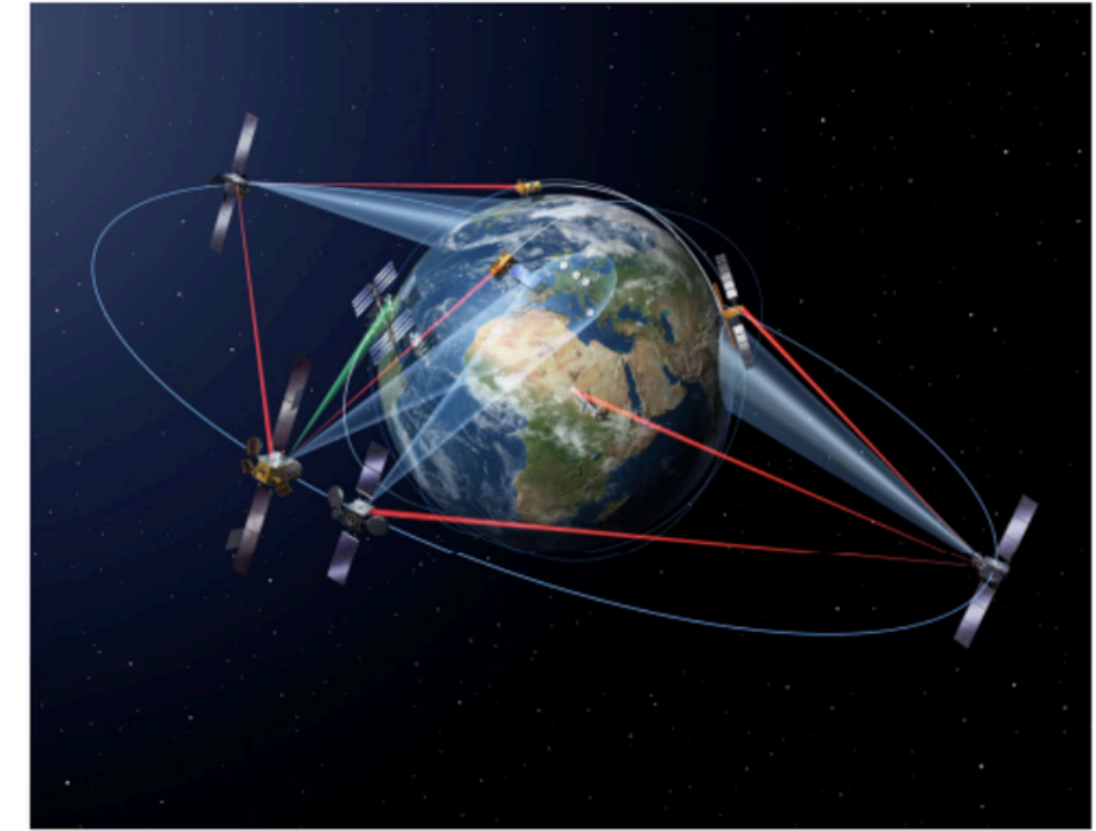
High-Power Fiber Amplifiers for Terabit-Class Space Communications

Dr Pete Kean



Satellite Laser Communications

- Laser communications enable a huge increase in data-rate, into Tb/s
- Feeder links / Uplinks: Ground to Space
- Downlinks: Space to Ground
- Inter-satellite links (ISL)



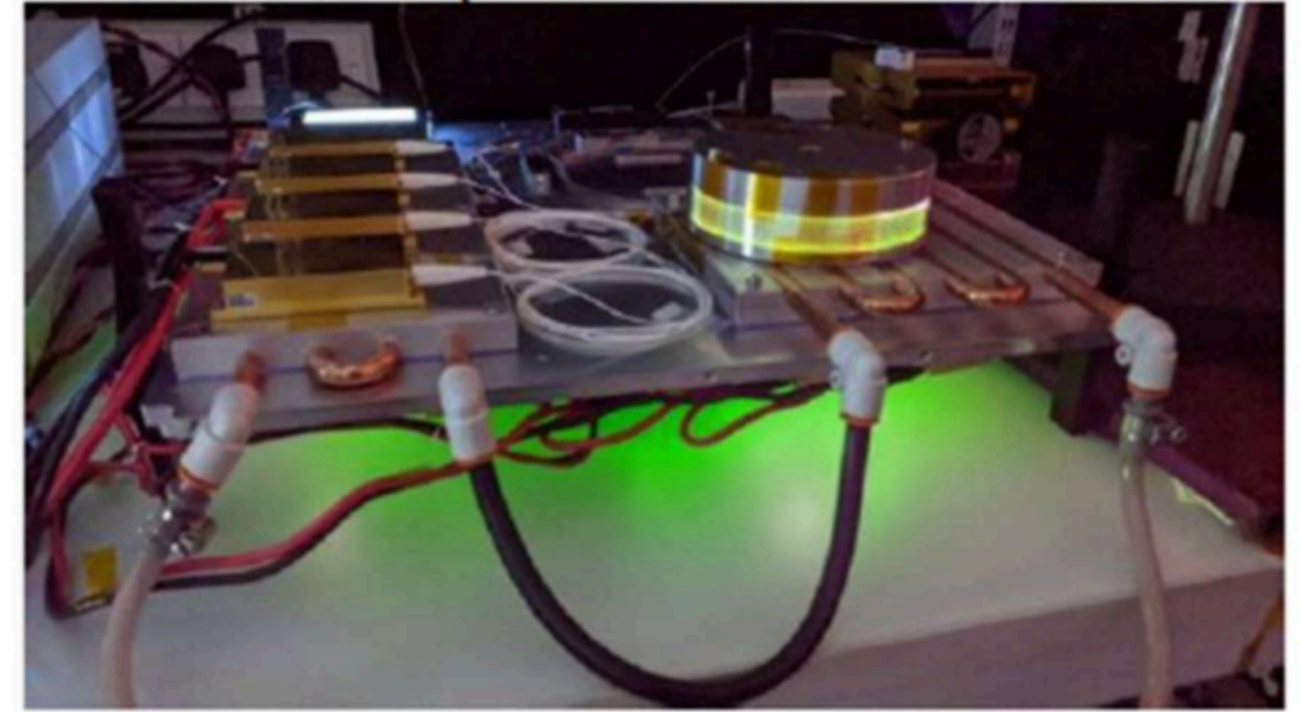
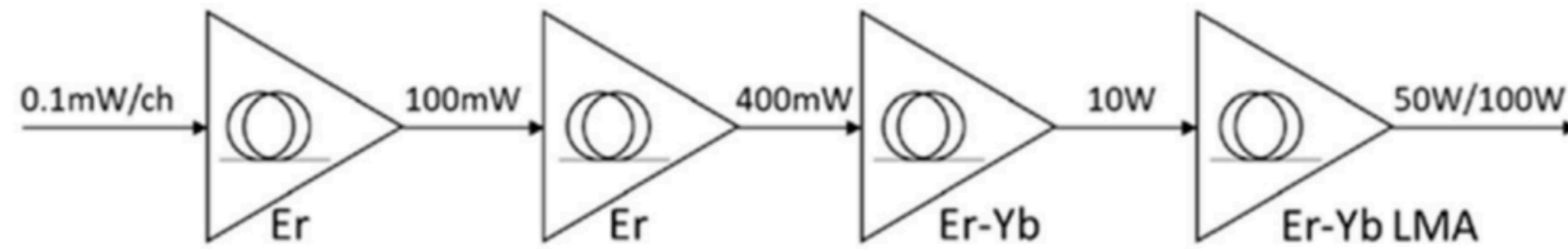
High Power Optical Amplifier



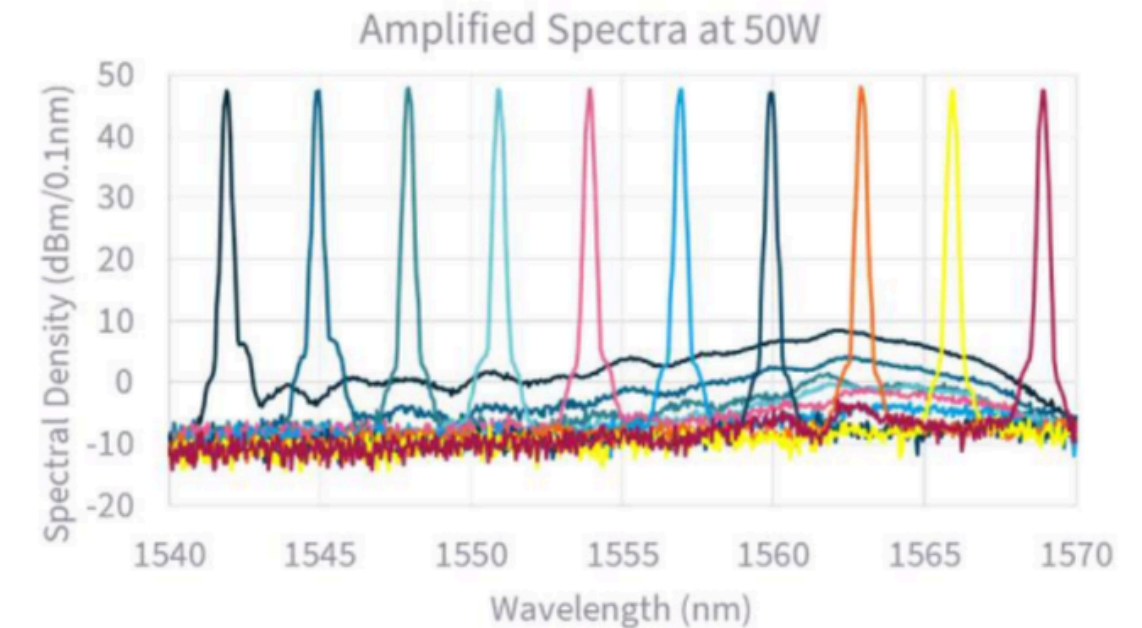
HPA Key Required Specifications

- 100W output
 - 1536.61nm – 1552.62nm (terrestrial uplink)
 - 1553.33 nm – 1569.59nm (space downlink)
 - For WDM system: 10 channels, 0.1 – 10mW input power/channel
 - Dual polarisation DPSK/QPSK 100Gbps/channel; OOK
 - Gain flatness $< \sim 1$ dB (for WDM system)
 - Cross talk < -30 dB
 - Target $M^2 < 1.05$
- Defined by the ESA Specification for Terabit/sec Optical Link (ESTOL) standard

Amplifier Architecture

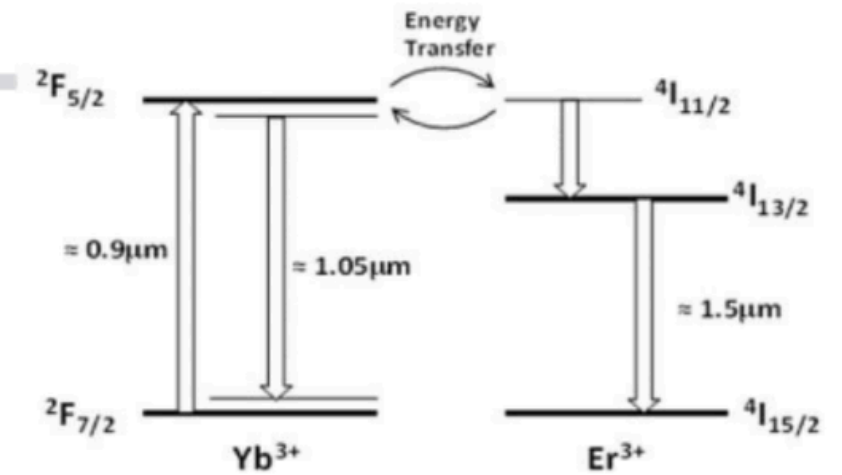


- 4 stage 100W high power amplifier design for $\sim 0\text{dBm}$ input
 - Stage 1: Core pumped;
 - Stage 2: Core pumped;
 - Stage 3: Cladding pumped;
 - Stage 4: LMA cladding pumped;
- Efficient thermal management essential

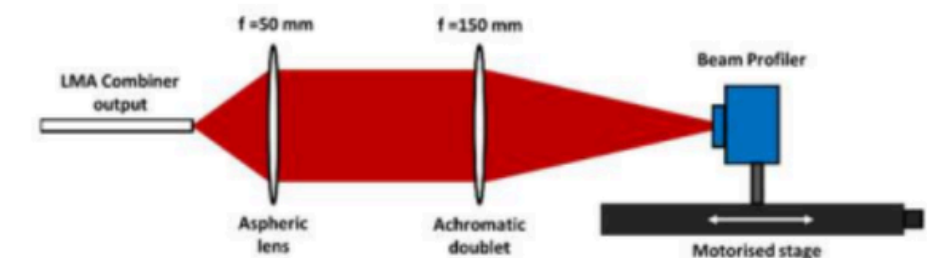
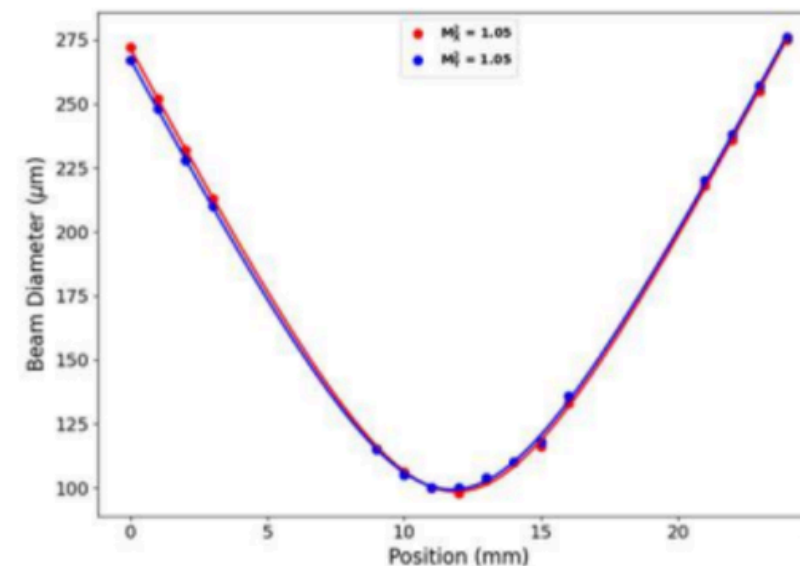
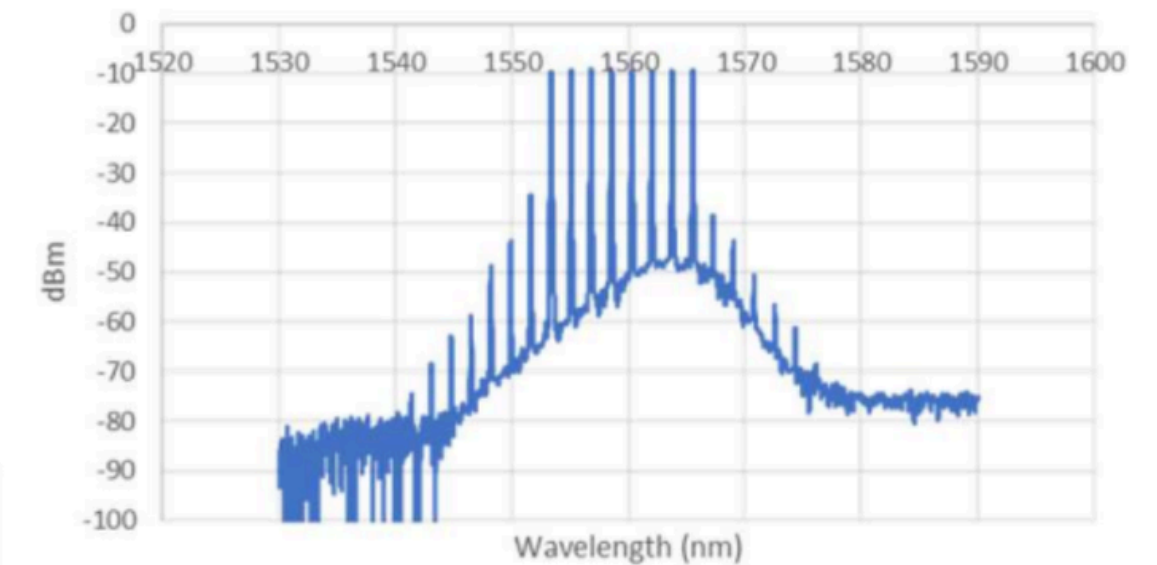


Optical Challenges

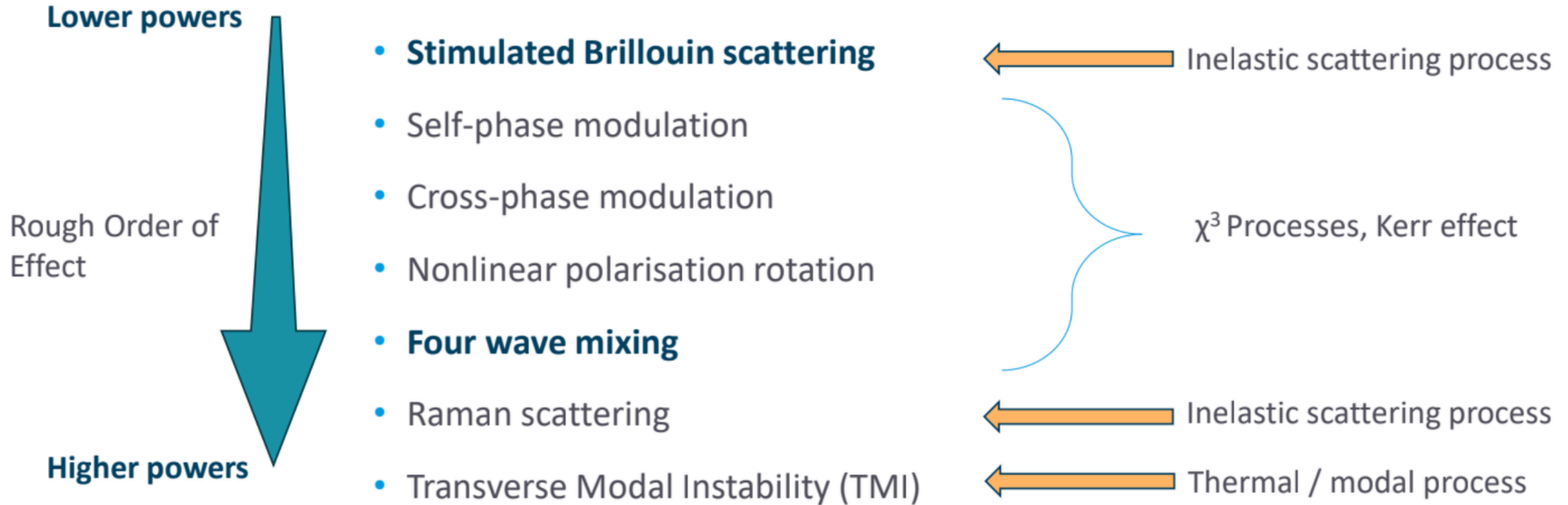
- Parasitic 1 μ m emission:
 - Bottlenecking in the transfer of energy Yb $\Rightarrow$ Er ions leading to emission at 1 μ m
 - Limits achievable C-band power.
 - Large core fibres reduce bottlenecking, allowing higher C-band powers to be achieved
- Gain Flatness
 - Large core (ErYb) amplifier designs typically have a gain peak in the 1560 – 1565nm window
 - Gain flattening filter to provide attenuation across band
- Beam Quality
 - LMA fibers used in final stage of amplifier
 - $M^2 < 1.09$ obtained at 100 W output power
 - S^2 measurements on LMA components in final stage



Stg4 Output (54.2W)

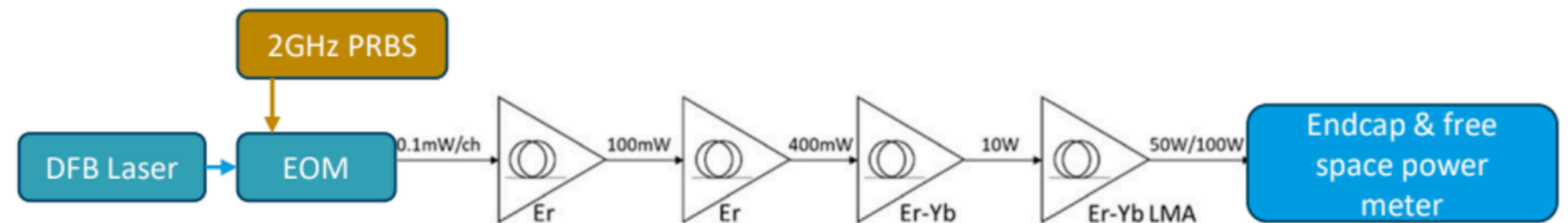
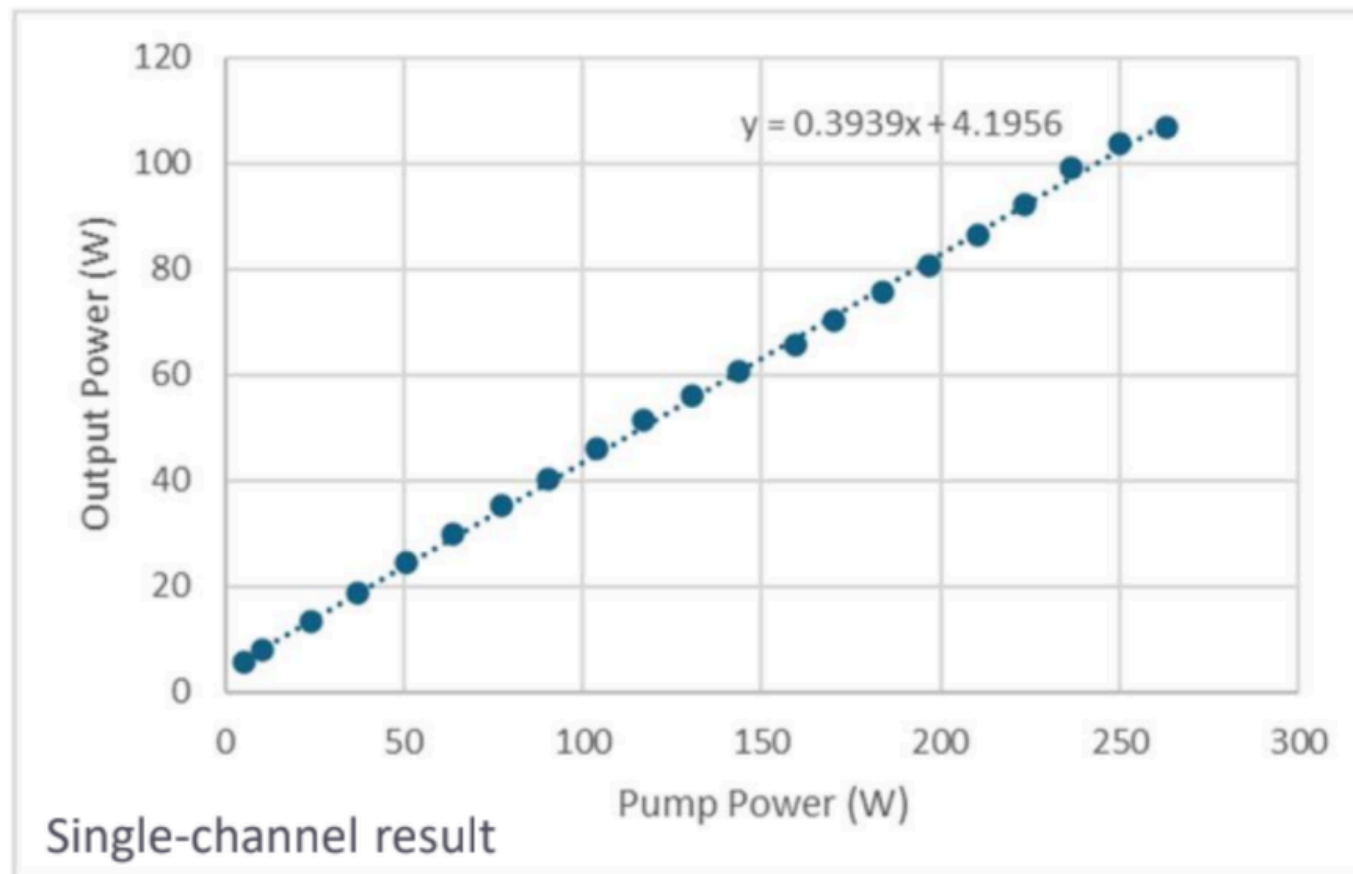


Nonlinear Effects in Optical Fibres



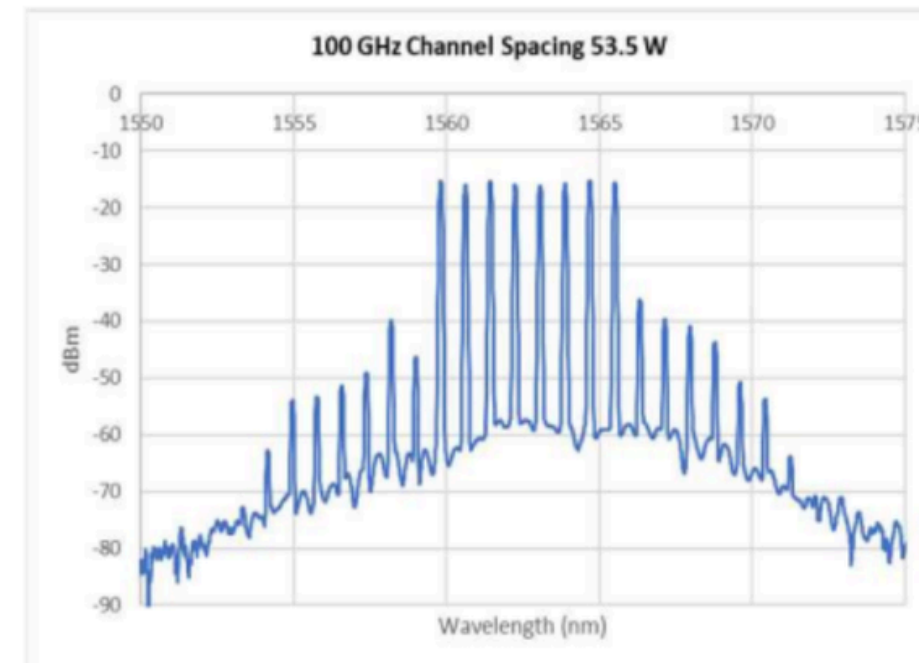
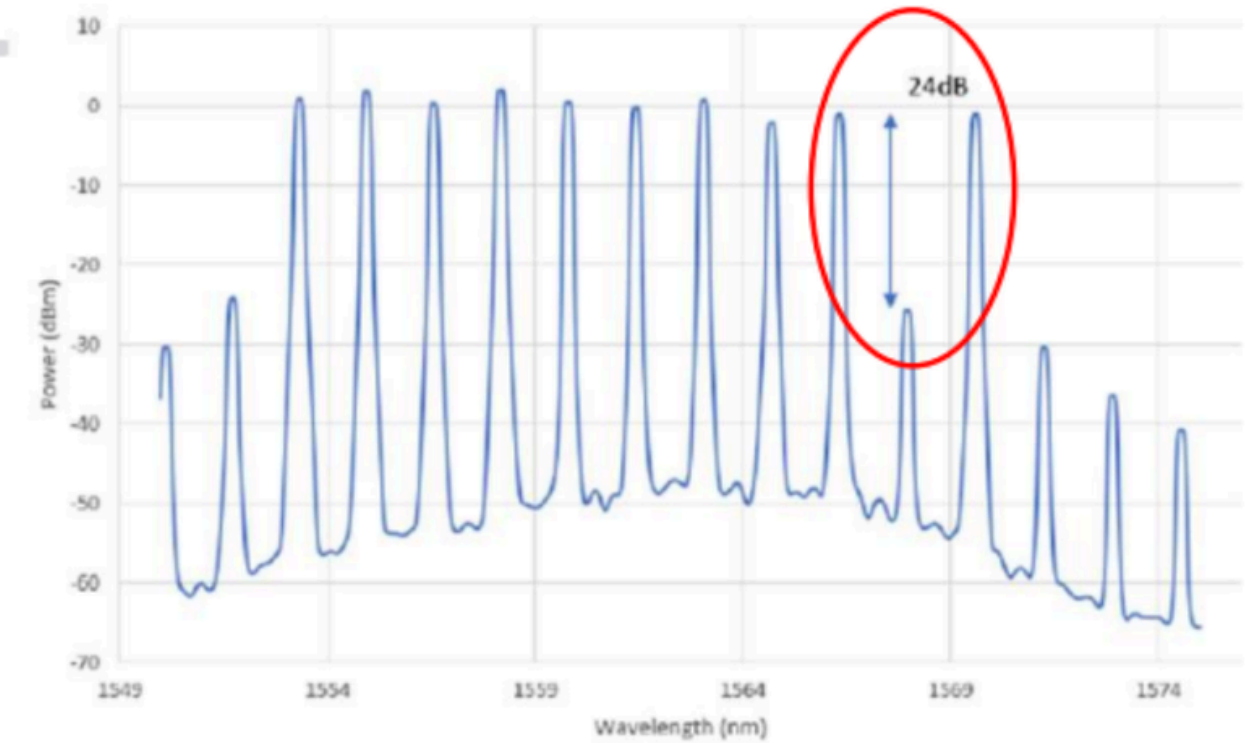
Nonlinear effect: Stimulated Brillouin Scattering (SBS)

- First nonlinear effect: Stimulated Brillouin Scattering (SBS)
 - Results in a rapid increase of backscattered power & instability and loss of main output
 - Linewidth dependent, length dependent
- I/P signals phase modulated (EOM) using a PRBS data stream -> **broadens the linewidth**
- Output power >100 W with 39.4% slope efficiency (Single channel active: 1550nm, 0dBm i/p)

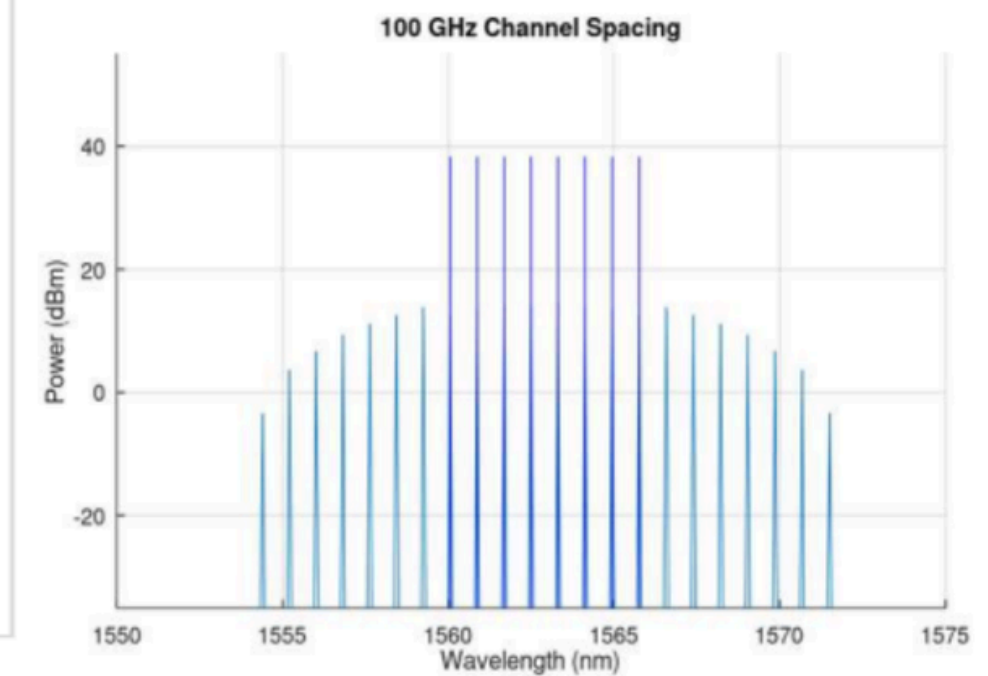


Nonlinear Effect: Four-Wave Mixing (FWM)

- FWM generates signal sidebands for each channel
 - $f_{new} = f_1 + f_2 - f_3$
 - Power- and fibre length- dependent
 - Degrades system performance
 - Reduces OSNR
- Reducing FWM:
 - LMA fibre
 - Keep fibre lengths short
 - Increase channel spacing or uneven channel spacing
 - Hollow core fibre!



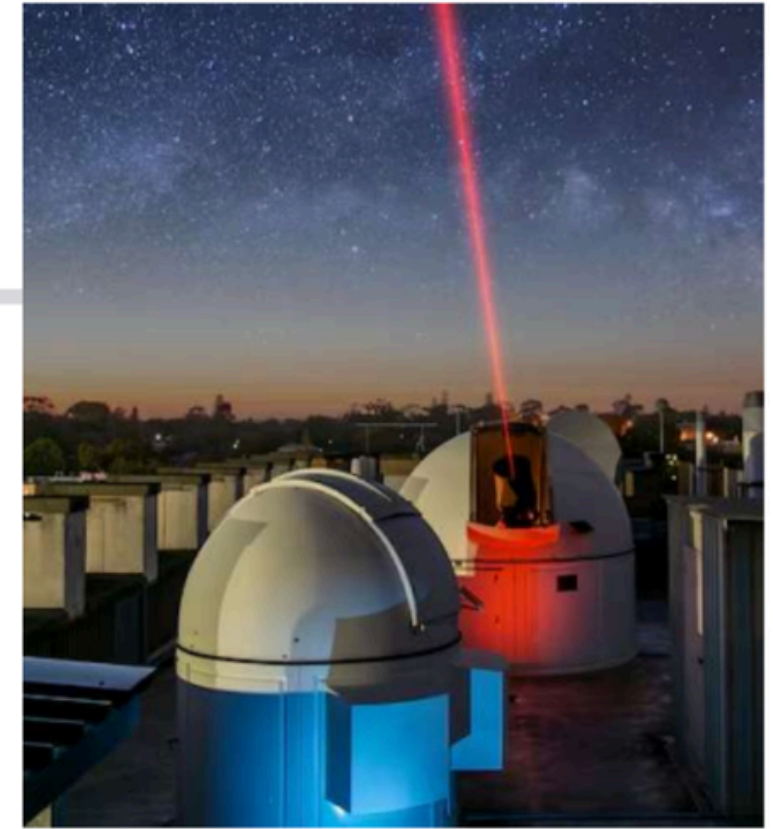
Experimental



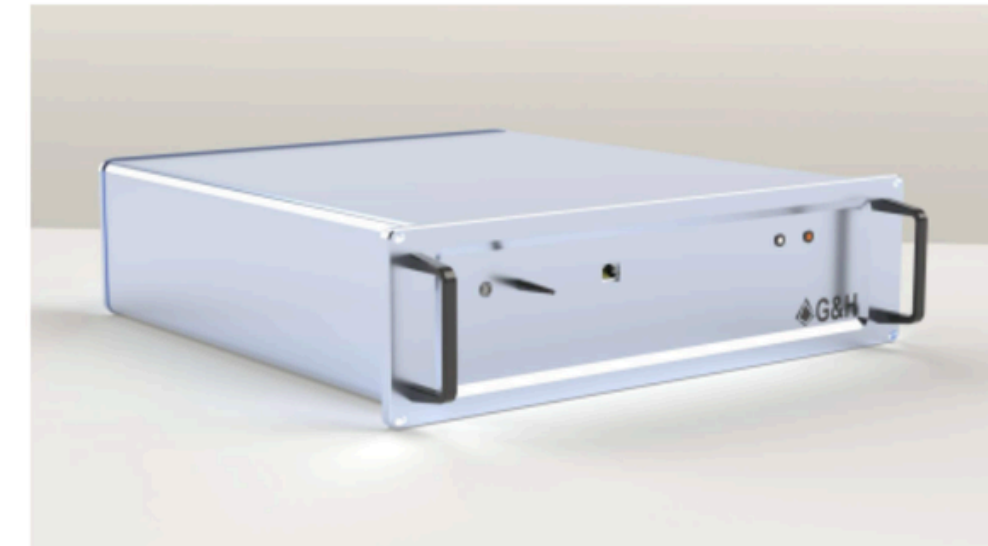
Simulated

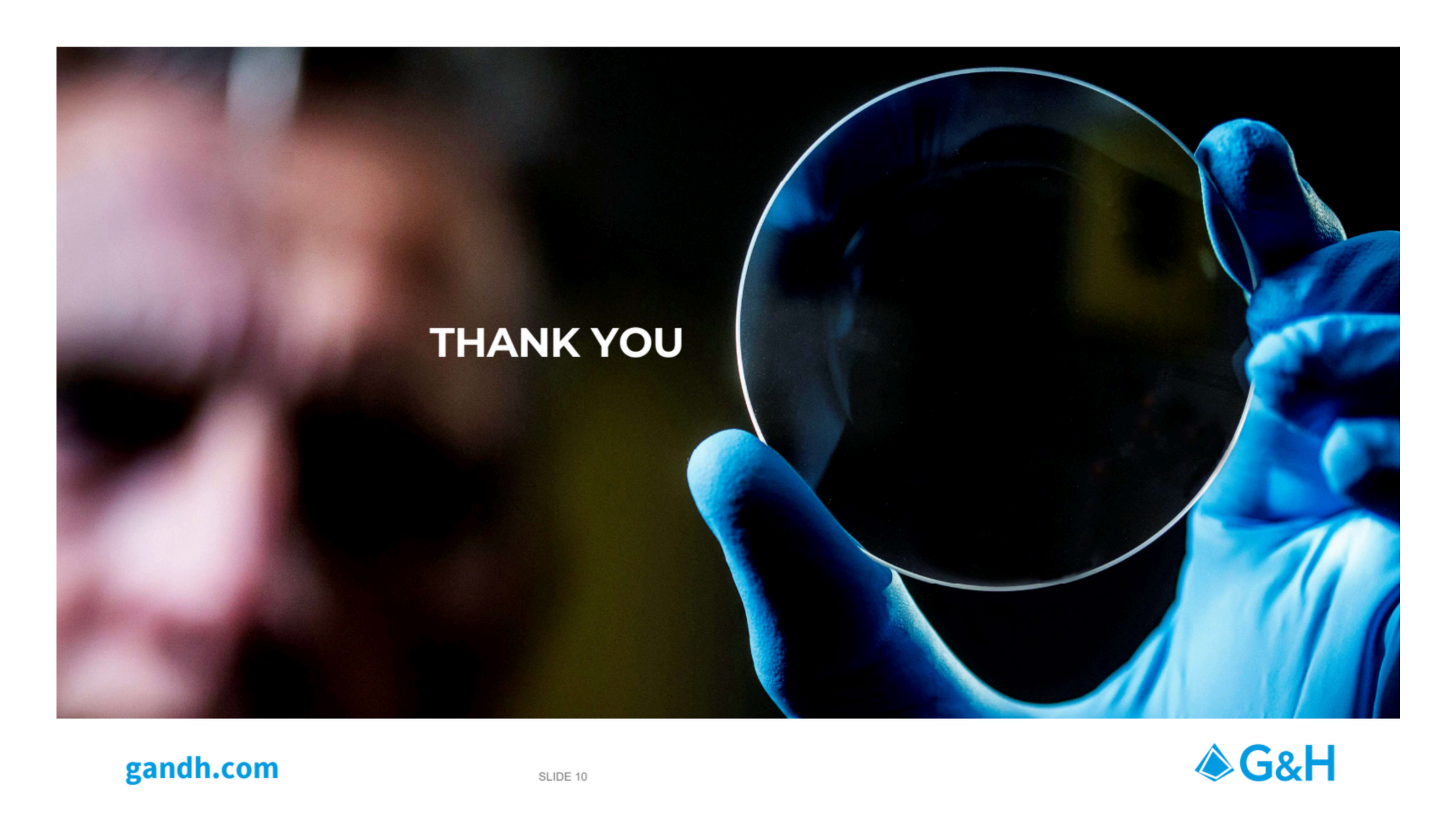
Summary

- High-power optical amplifiers can achieve ~ 100 W output across the C-band
- Key design considerations are:
 - Thermal management
 - 1 μ m ASE emission
 - Beam quality
 - Gain flatness for a WDM system
- Nonlinear impairments can significantly affect data quality
 - Keep fibre lengths short
 - For WDM systems – uneven channel spacing
 - Hollow core fibre may be a promising solution



Ref: Australian Optical Ground Station Network



A hand holding a magnifying glass over a globe, with a blurred crowd in the background.

THANK YOU