Science & Technology Facilities Council

UK Research and Innovation

Additive manufacture of mirrors for astronomy

Carolyn Atkins

UK Astronomy Technology Centre

Science & Technology Facilities Council

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Additive manufacture of mirrors for astronomy

metal

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UK Astronomy Technology Centre

Collaborators and funding

Collaborators

Science & Technology Facilities Council

diamond

UCL

The University Of Sheffield.

UNIVERSITY OF LEICESTER

NPL National Physical Laboratory

Durham University

CfAI Centre for Advanced Instrumentation

LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

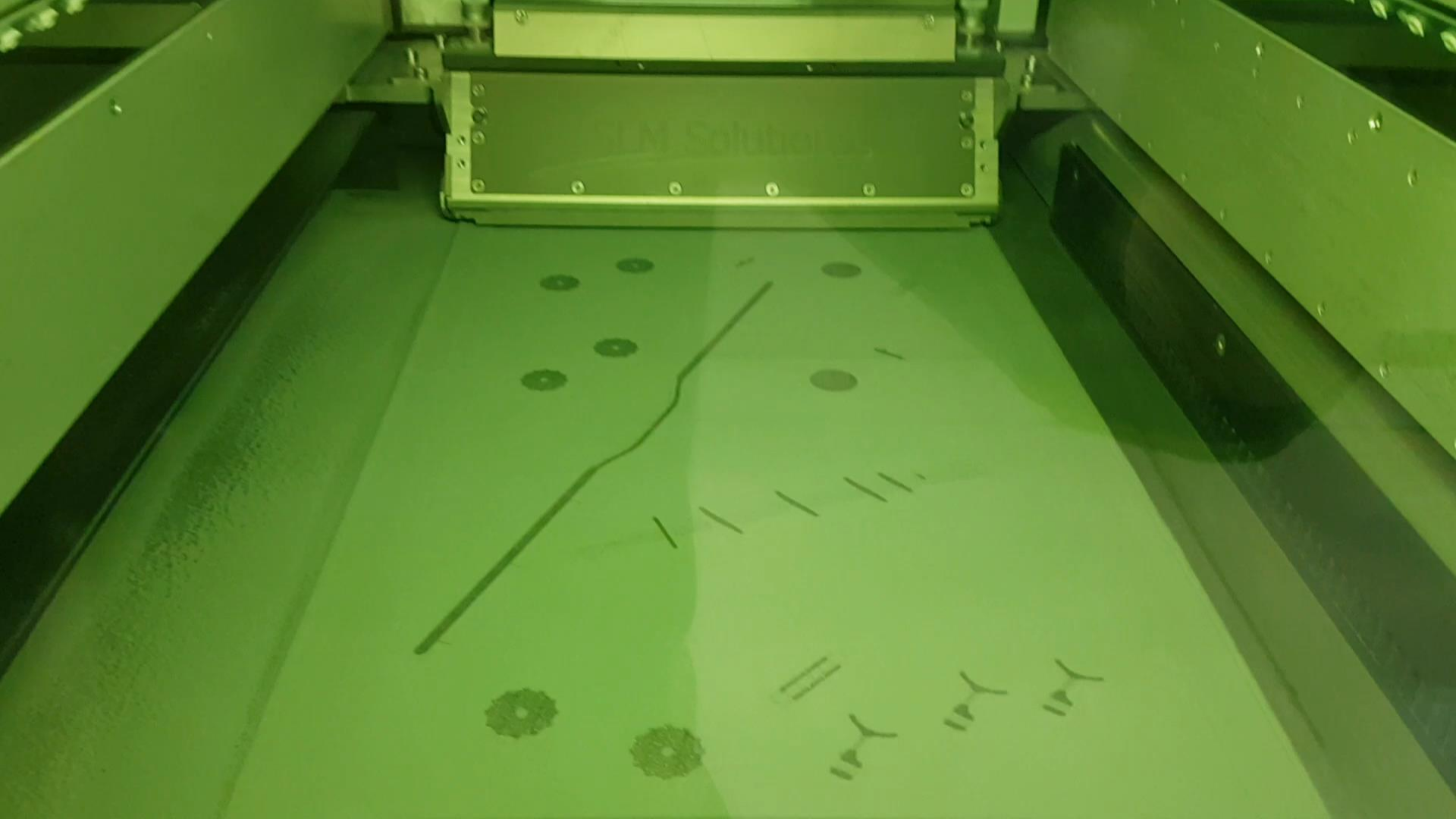
ESRF The European Synchrotron

Funding

UK SPACE AGENCY — National Space Technology programme.

Science & Technology Facilities Council — Internal funding + fellowship

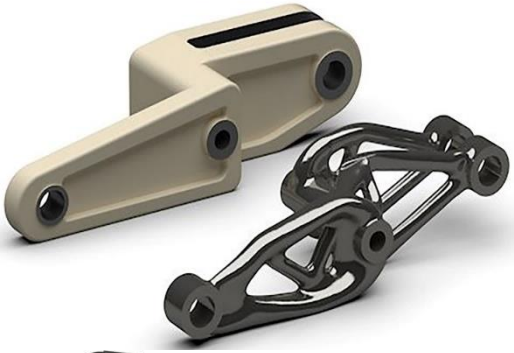
European Commission | Horizon 2020 European Union funding for Research & Innovation — Fellowship + OPTICON



Additive manufacture: design

Additive manufacture (AM) = 3D printing

To utilise the design freedom of AM to create bespoke hardware that is more tailored to function than tailored to manufacturability.



Additive manufacture of mirrors

Additive manufacture (AM) = 3D printing

Why use additive manufacture?

- Lightweighting
- Part consolidation
- Optimised functionality

Additive manufacture of mirrors

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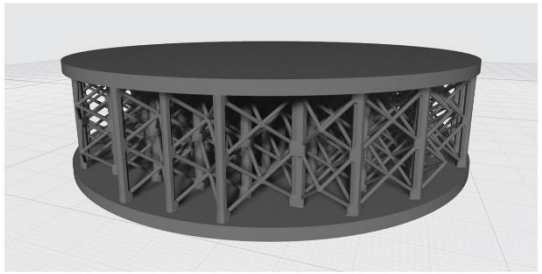

Optimised Star lattice mirror structure (x, y, z)

Additive manufacture of mirrors

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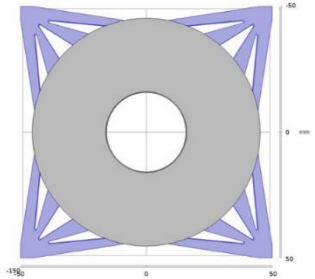
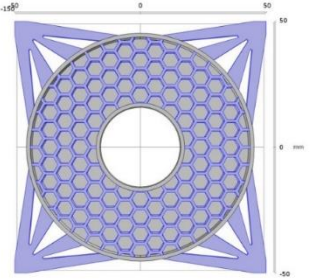
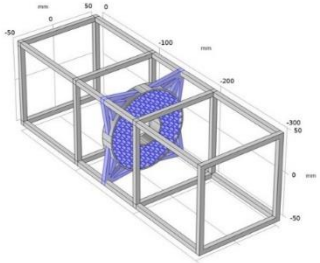

a)


b)


c)

Additive manufacture of mirrors

Additive manufacture (AM) = 3D printing

Why use additive manufacture?

- Lightweighting
- Part consolidation
- Optimised functionality

UKSA NSTP3 PF2 008: Additive manufacturing of CubeSat mirrors

Case study

- Design mentality
- Fabrication
- Metrology
  - XCT
  - Surface form
  - Surface roughness

Requirements capture

↓

Concept design

↓

Design for AM

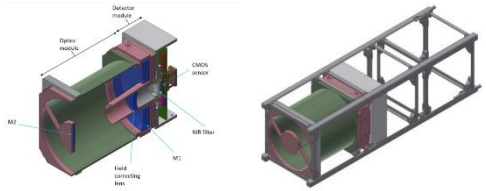
↓

Design for manufacture

↓

Final design

1)

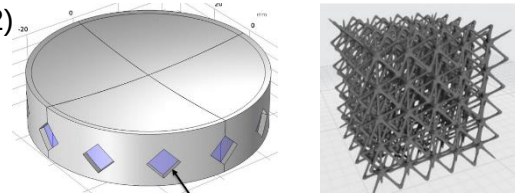


- Dimensions
- Optical prescription
- Mounting fixtures
- Lightweighting
- Surfaces for machining

Is the part suitable for AM?

Yes No

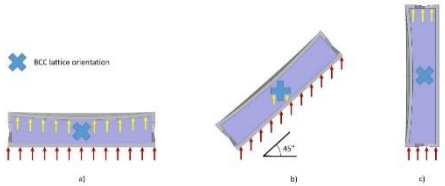
2)



Implement dimensions, optical prescription and mounting fixtures.

Apply AM specific design tools like lattice generation or optimisation routes

3)



- Material
- Orientation during print
- Powder removal
- Support material

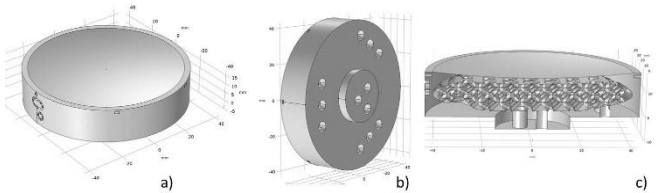
There is **a lot** of iteration between the concept, design for AM and design for manufacture

4)

How is the part held in machining, diamond turning and polishing?

Consider how an AM part is referenced for machining.

5)



Let’s go printing!

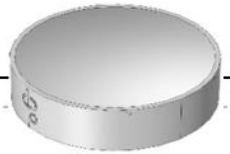
One mirror design

Additive manufacture: printing

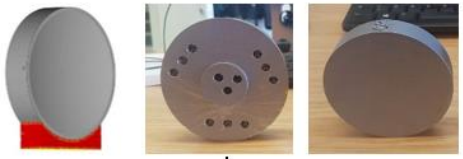
Subtractive machining: lathe, drill

Surface preparation and NiP coating

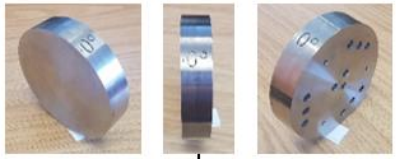
Polishing and diamond turning



4 substrates printed in $AlSi_{10}Mg$

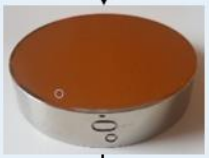


1 substrate printed in Ti64



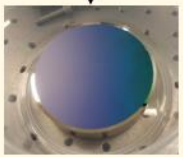
Diamond turning
Uni. of Durham

Polishing
Uni. College London



DT RSA Al

DT $AlSi_{10}Mg$

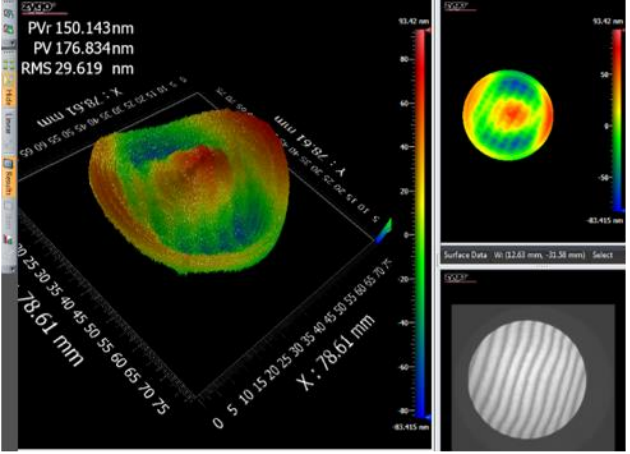


DT $AlSi_{10}Mg$ + NiP

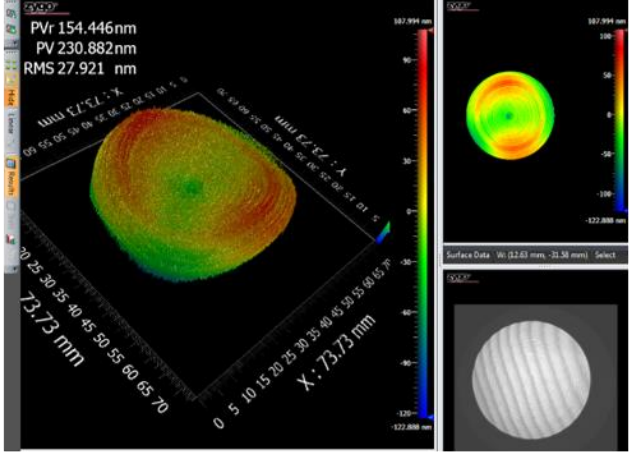
Pol. $AlSi_{10}Mg$ + NiP

Pol. $AlSi_{10}Mg$

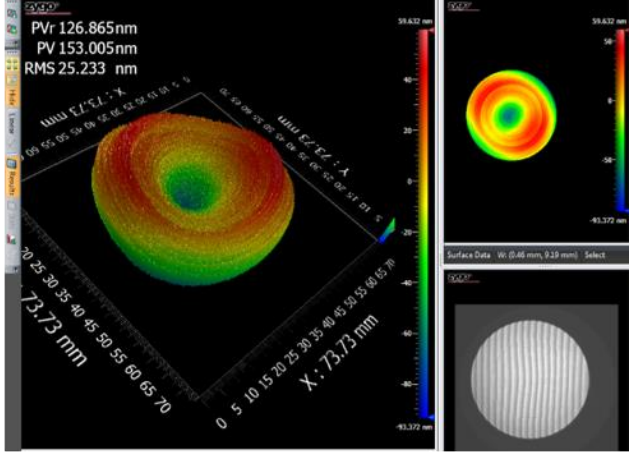
Pol. Ti64



Diamond turned: Al + NiP

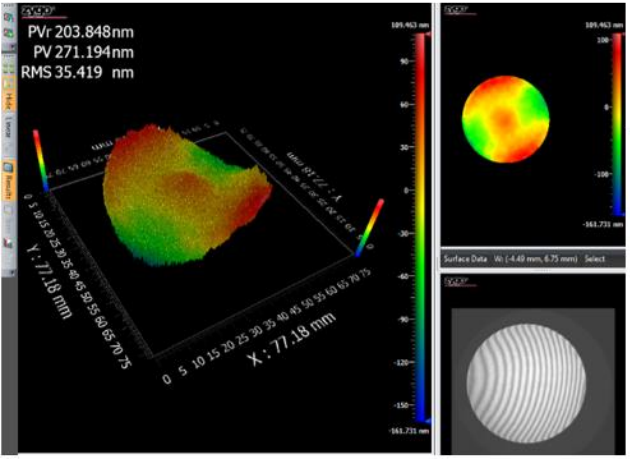


Diamond turned: Al

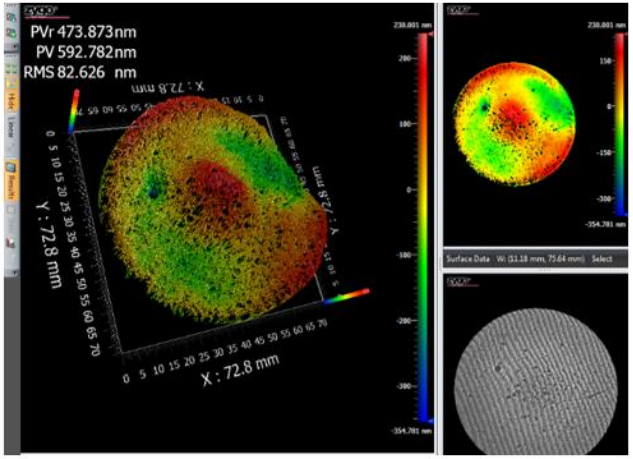


Diamond turned: RSA Al

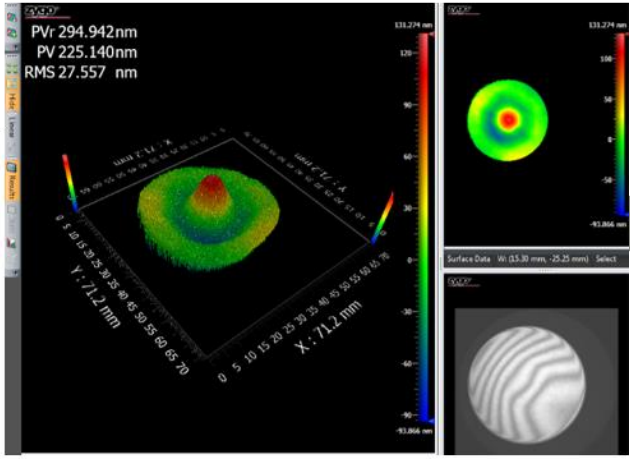
Polished: Al + NiP

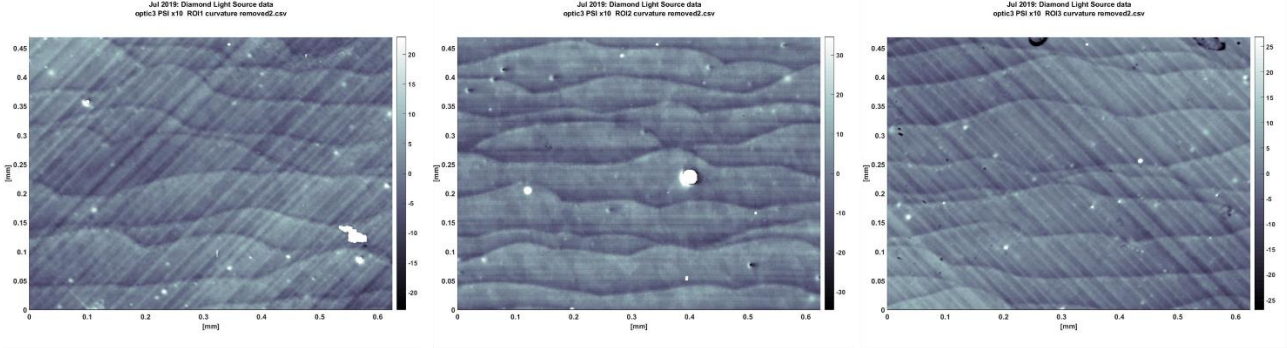


Polished: Al



Polished: Ti

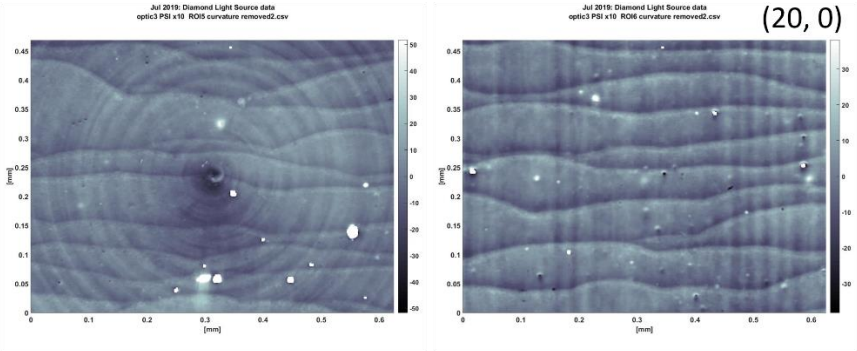




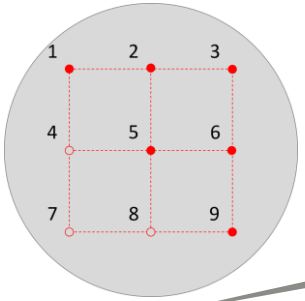
Optic 3: AM Al
Diamond turned

10x magnification

Measurement area:
~0.6 x ~0.45 mm^2

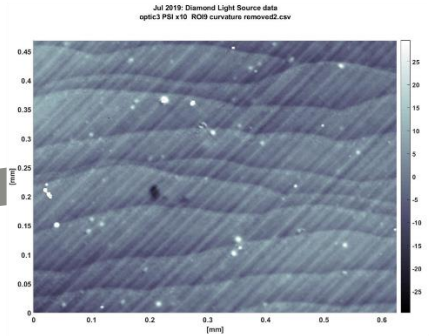


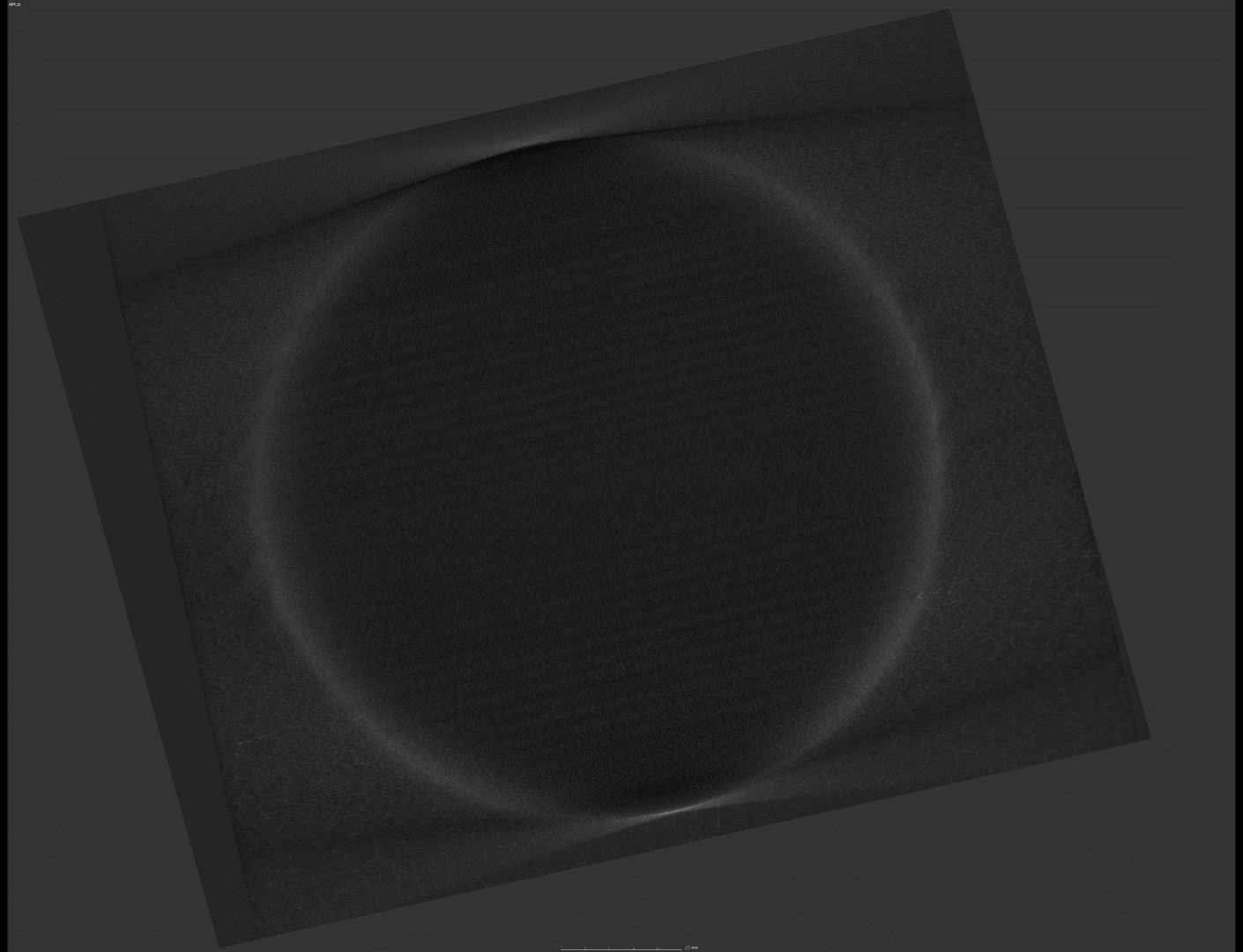
(20, 0)



optic3 PSI ROI# curvature removed2

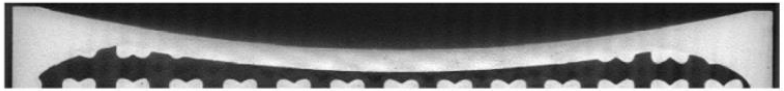
	Sa [nm]	Sq [nm]	Sp [nm]	Sv [nm]	Sz [nm]
ROI1	2.47	3.27	98.75	-78.34	177.09
ROI2	3.72	4.94	105.71	-57.37	163.08
ROI3	2.79	3.84	76.12	-87.53	163.65
ROI5	5.04	7.37	213.90	-57.52	271.43
ROI6	4.29	5.44	93.00	-117.60	210.59
ROI9	3.20	4.23	149.99	-21.55	171.54
Average	**3.59**	**4.85**	**122.91**	**-69.99**	**192.90**





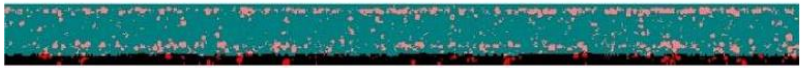
Porosity: XCT data

Concave optical surface

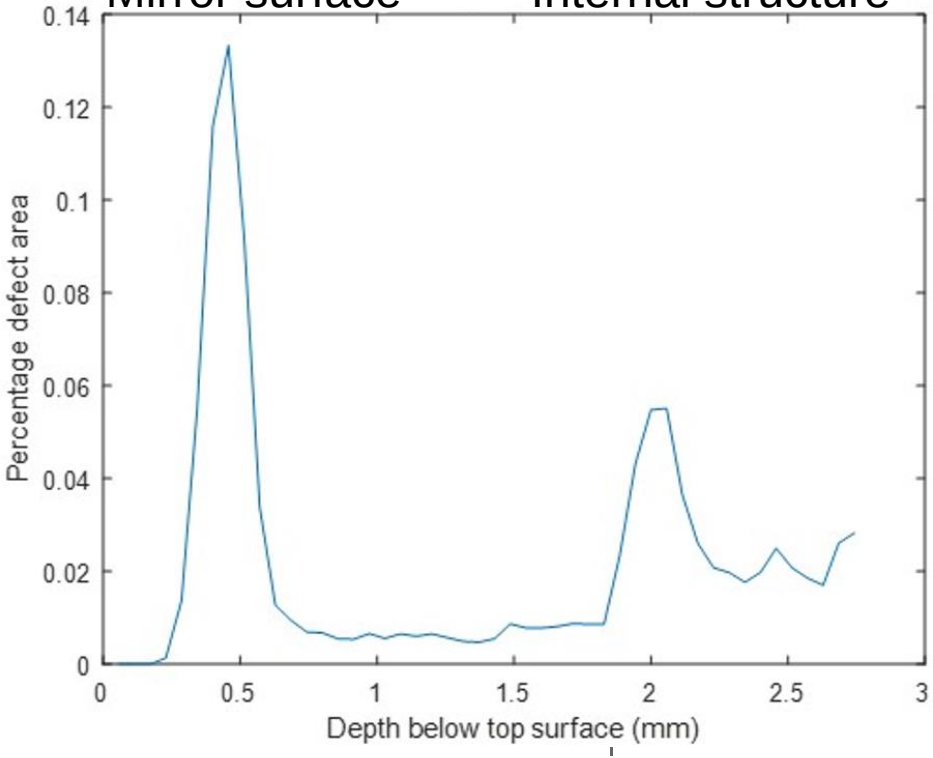


Curvature removed

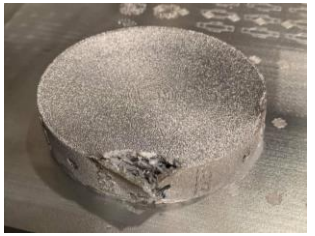
Cumulative porosity density

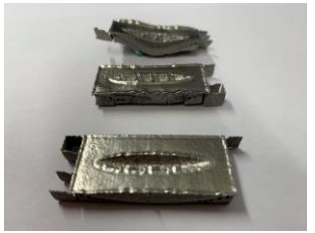


Mirror surface → Internal structure



Future work





- Design optimisation and functionality
  - Part consolidation/ mirrors + mounts
  - Lightweighting design
- AM material properties and suitability for optical fabrication.
  - Porosity/ AM materials available/ stress
- Raising the TRL of AM mirrors towards space qualification.

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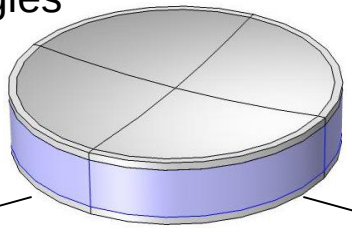
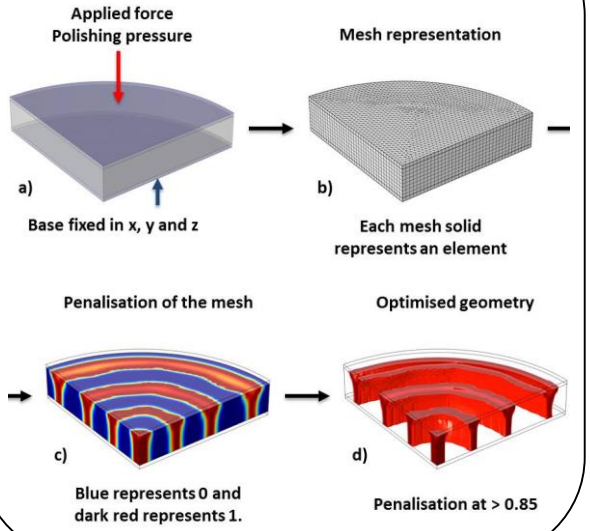
Examples of three lightweighting strategies that have been investigated so far…

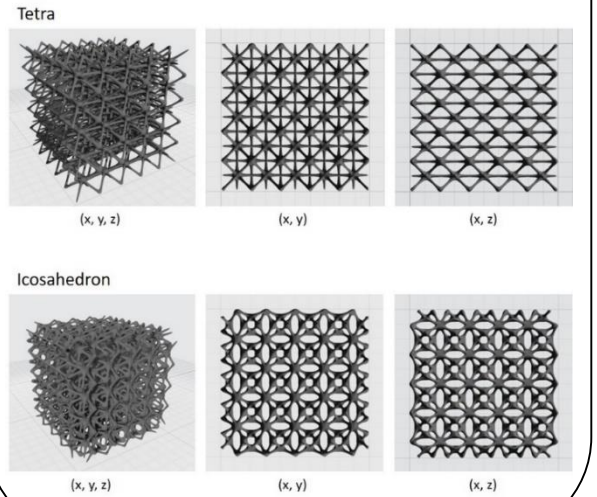


… there are many more to consider.

Topology optimisation



Lattice generation



Structures in nature