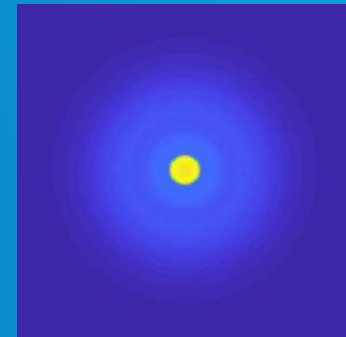
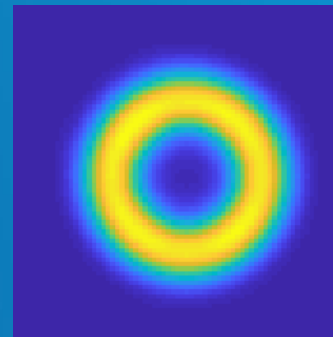
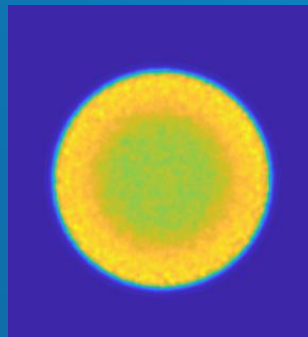
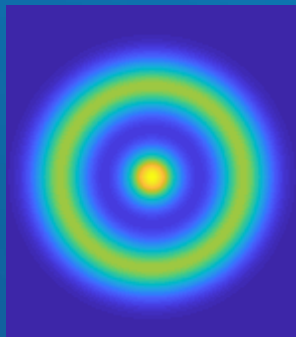
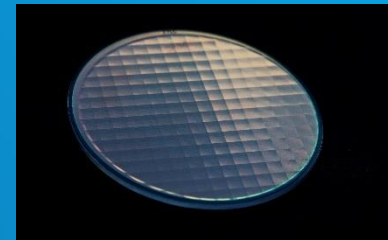
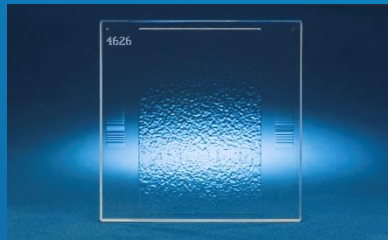




PowerPhotonic

Design and Wafer-Scale Manufacture of Advanced Freeform Micro-Optics for Laser Applications

Dr. Natalia Trela-McDonald



N. Trela-McDonald, PowerPhotonic Ltd

EPIC Meeting on Advanced Microoptics: Simulation, Fabrication & Characterization at Nanoscribe



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About PowerPhotonic

Freeform micro-optics manufacturer:

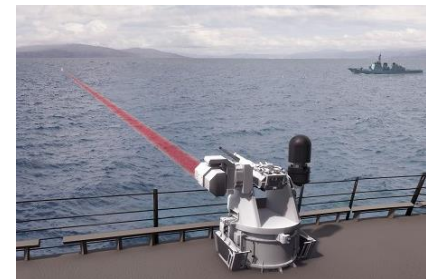
- Design and wafer-scale manufacture of precision fused silica micro-optics.
- Shipping freeform micro-optics since 2006 to industrial, imaging, defence, scientific and medical application.

Technology Leadership

- Proprietary patented laser direct-write process.
- One process from prototype to volume.
- 24/7 lights-out automated production/class 1000 cleanroom.

A proud member of

Phabulous

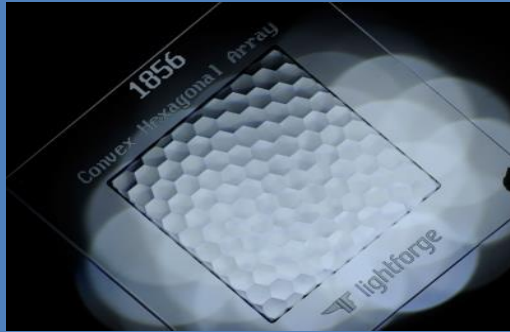




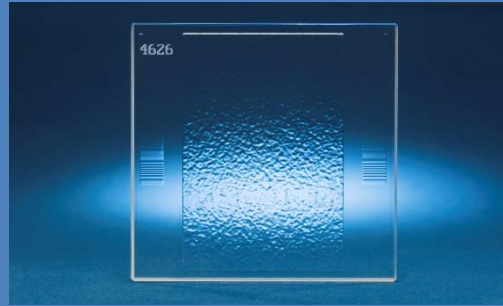
Optical components to shape laser beams

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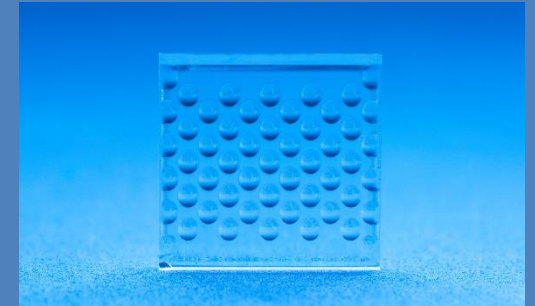
Lens Arrays



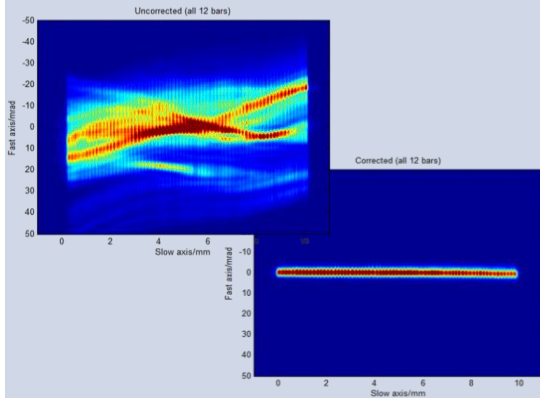
Homogenisers and Diffusers



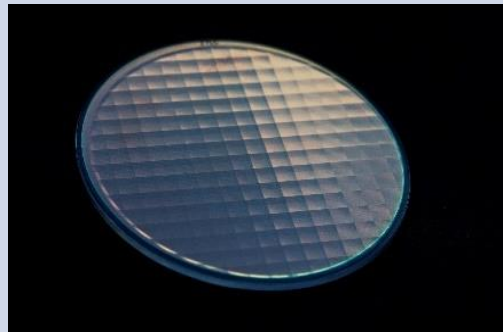
Fibre Coupling Lens Arrays



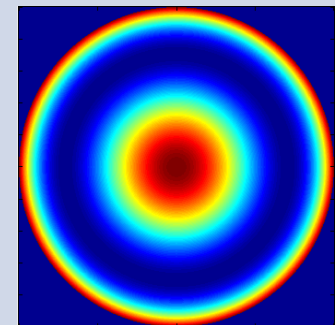
High Power LDA optics



Beam shapers



Aberration Compensators





Laser Machining Process

Cutting:

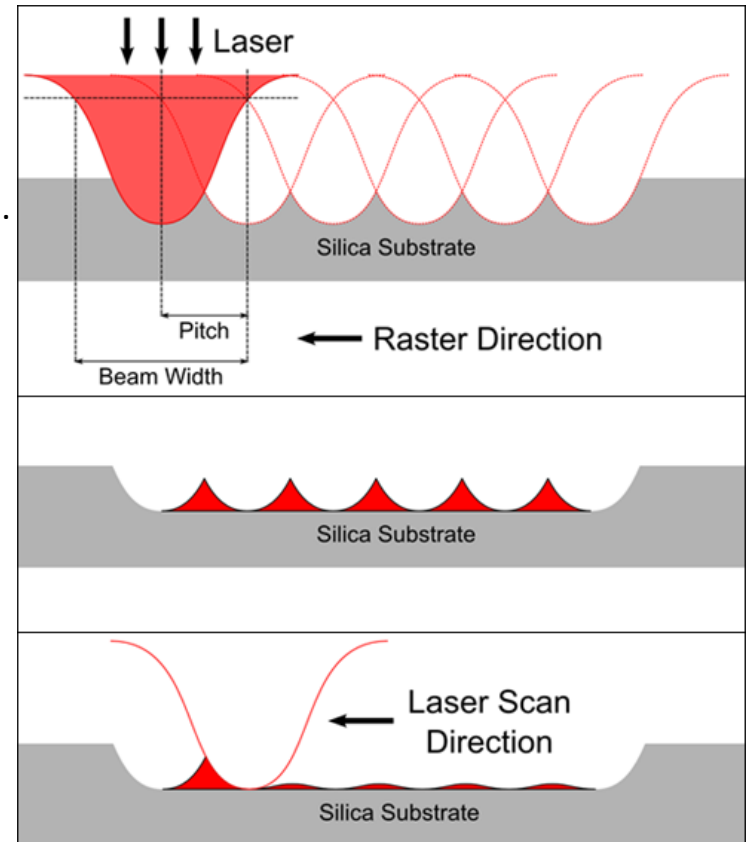
- Laser ablation process.
- Creates gross optic shape.
- Allows for arbitrary freeform silica surfaces of high depth.

Smoothing:

- Laser melting process creates refractive optics.
- Reflow effect creates ultra-smooth surface.
- Very low roughness ~1nm (@0.08mm Gaussian filter)
 - very low scatter = very high efficiency, up to 99.8%
- Maintains very high LIDT of bulk fused silica.

Parameters	Laser Induced Damage Threshold	
	MW/cm ²	J/cm ²
20 Hz 20 ns	5152	103.04

(example test on uncoated optic at 1064nm)



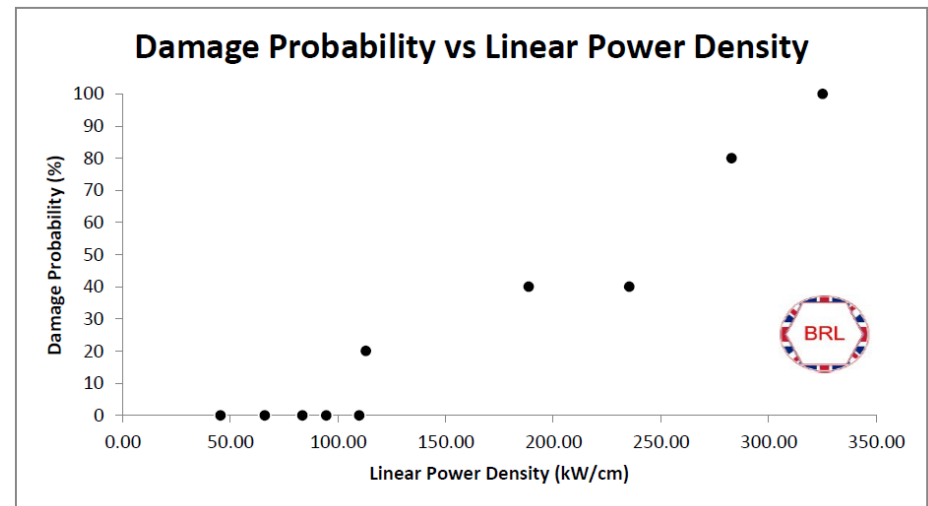
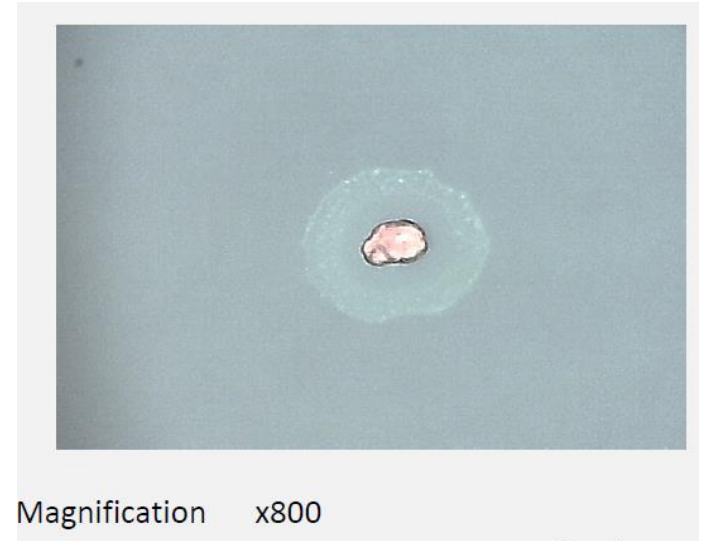


CW LIDT on AR coated optic

- Tested @1070nm (linear polarisation, input beam spot DIA >100um 1/e2, TEM00)
- >109kW/cm recorded.

Ready Reckoner			
Your Beam Size	Your Beam Size in cm	Your sample's LIDT value (kW/cm)	Max average power your sample can take (kW)
25 microns	0.0025	109.89	0.27
50	0.005	109.89	0.55
100	0.01	109.89	1.10
200	0.02	109.89	2.20
400	0.04	109.89	4.40
800	0.08	109.89	8.79
1 mm	0.1	109.89	10.99
2	0.2	109.89	21.98
4	0.4	109.89	43.96
8	0.8	109.89	87.91
1 cm	1	109.89	109.89
2	2	109.89	219.78
4	4	109.89	439.56
8	8	109.89	879.12
10	10	109.89	1098.90

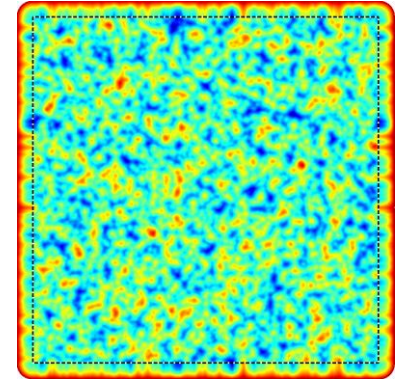
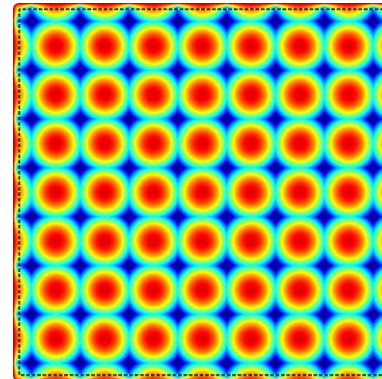
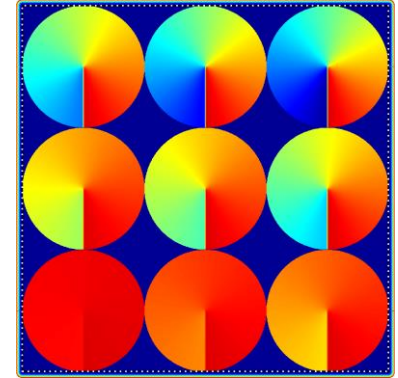
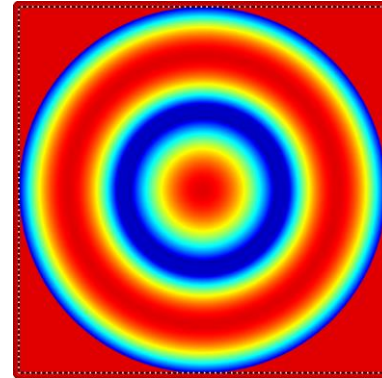
Max. av. power your sample can take (kW)= 109.89 x Your Beam Size in cm





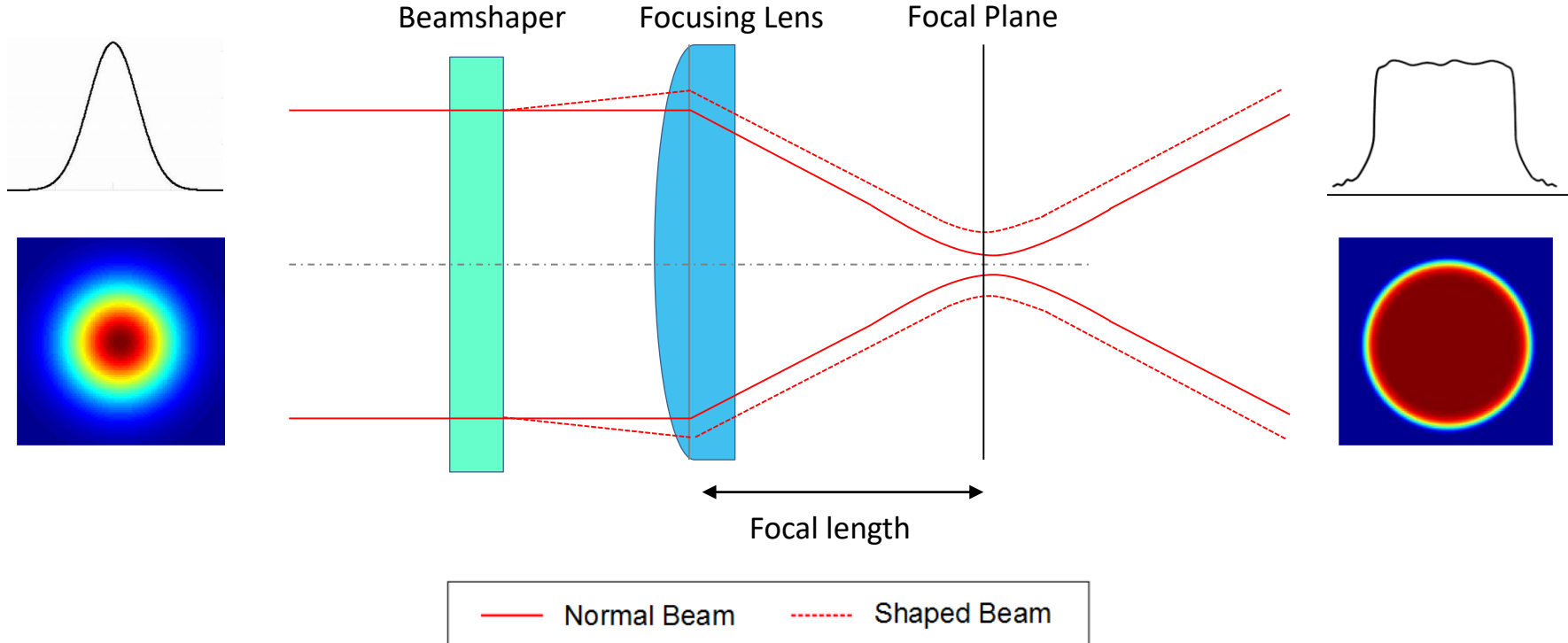
Freeform, direct-write optical fabrication

- **Freeform = design freedom**
 - Free from symmetry constraints
 - Realise complex optical designs
 - Wide range of functionality
- **Direct-write = flexibility**
 - No masks, no moulds
 - Trial, iterate and optimise design
 - Prototype to volume in one process
- **Process capability**
 - Max. sag 200um
 - Max. surface slope 30deg
 - Max. clear aperture area 100mm
 - UV-fused silica (all grades, incl. low-OH)
 - Design wavelength 190nm – 2um



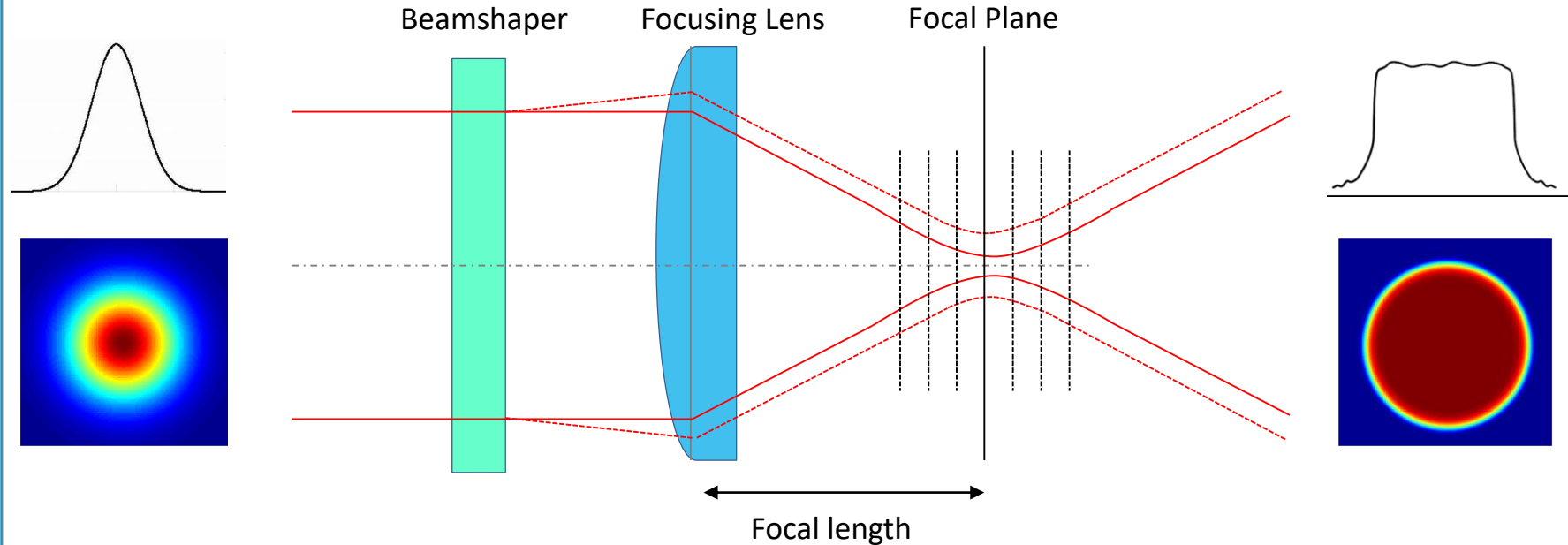


Beam shaping for laser processing



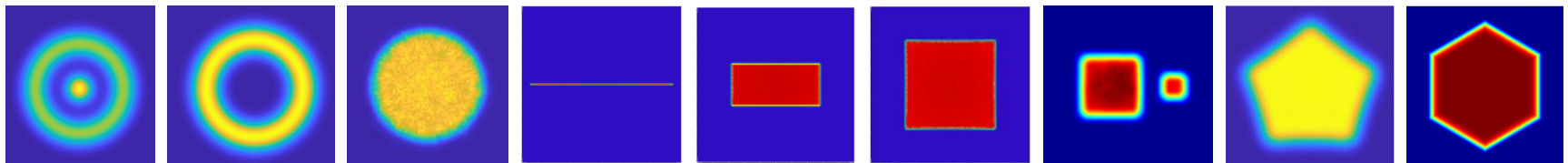
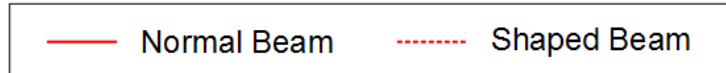


Beam shaping for laser processing



- Single-mode
- Multi-mode
- Non-Gaussian

- Wide range of output distributions
- Controlled through focus behaviours



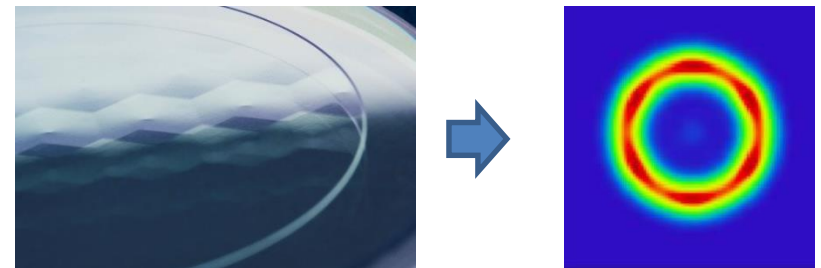
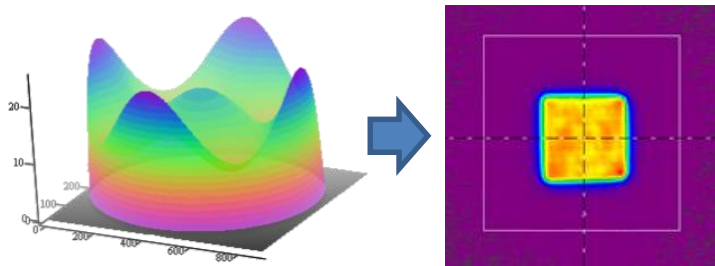
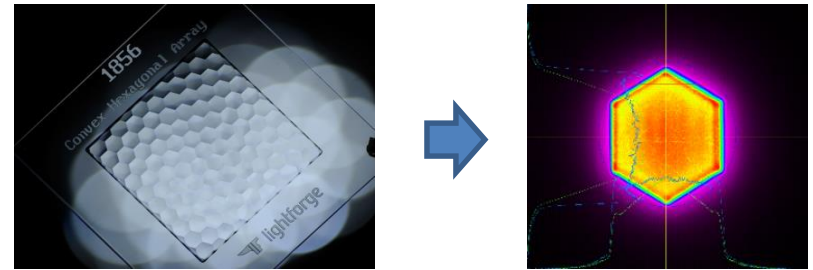
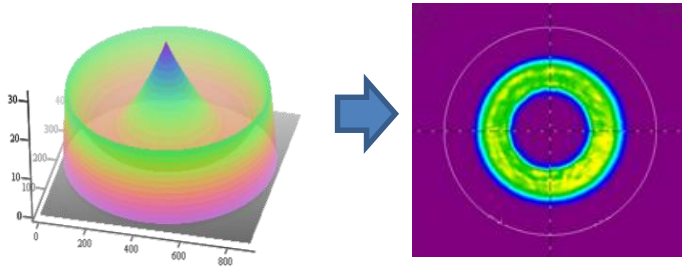
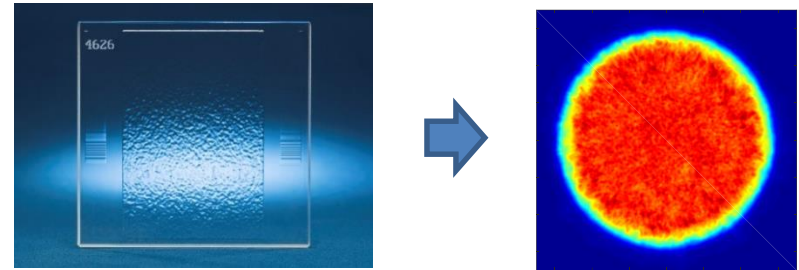
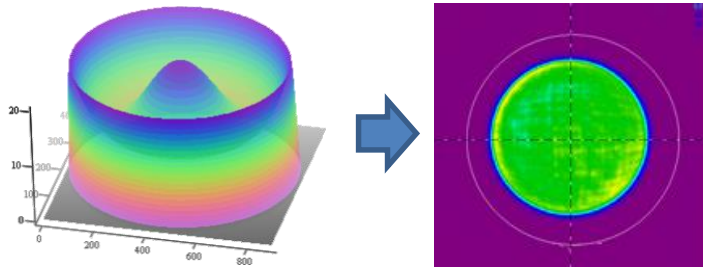


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SM and MM beamshaping

Single mode / few mode: field mapper

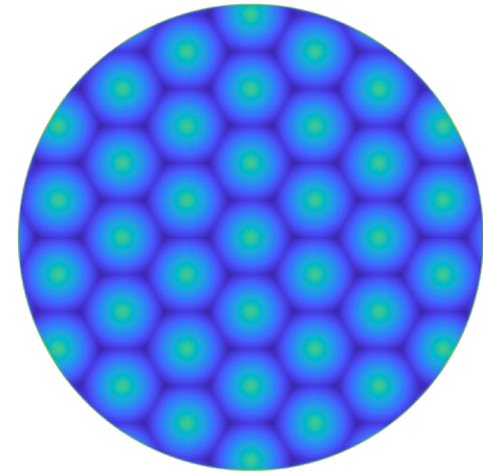
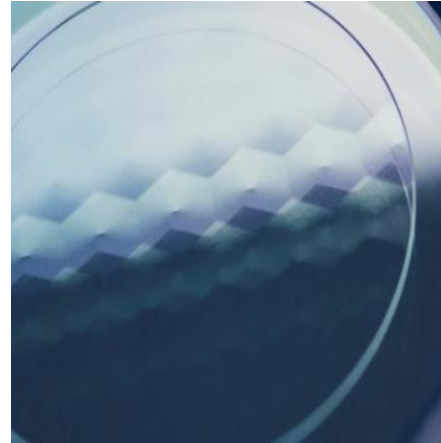
Multi-mode: homogeniser



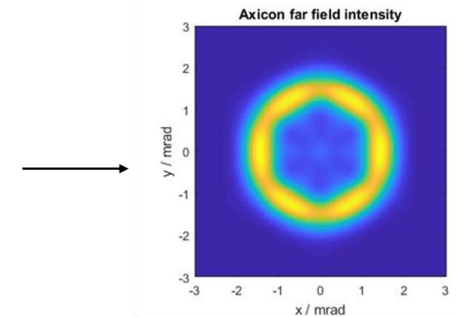
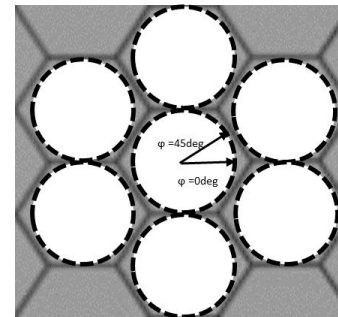
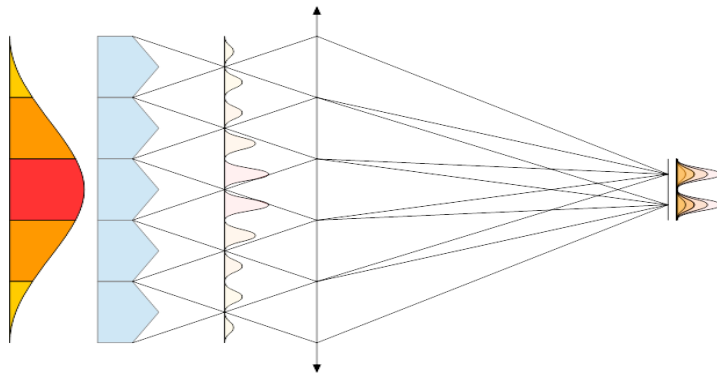


Axicon Array to Generate a Ring

- Use in multi-mode laser systems.
- Homogeniser behaviour =
 - No alignment sensitivity
 - Low sensitivity to input beam



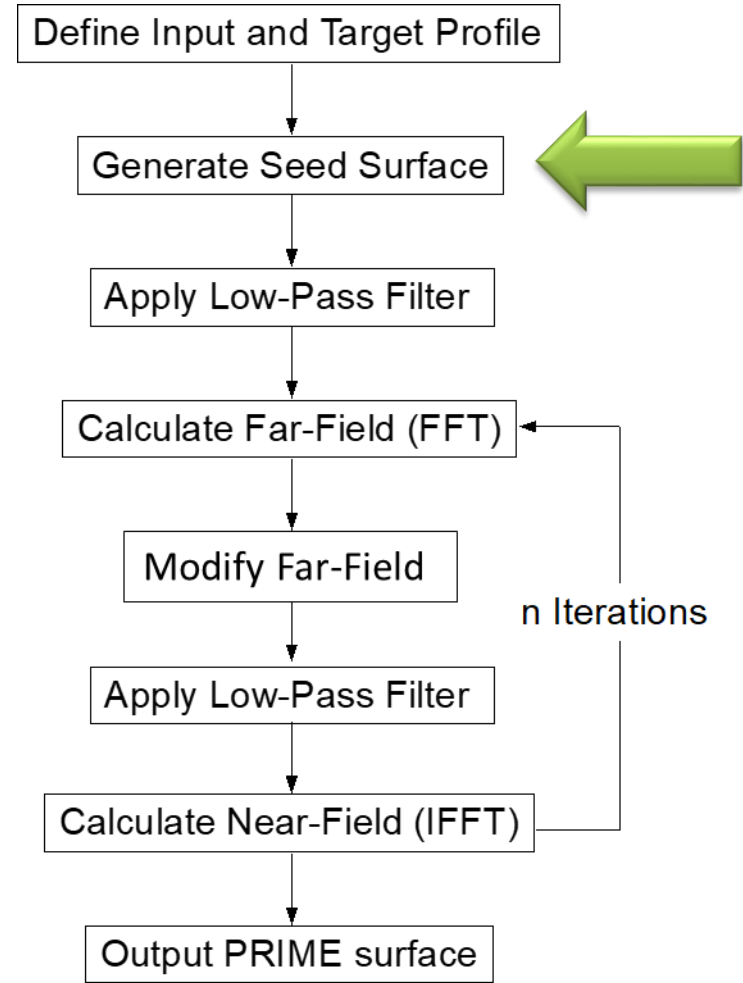
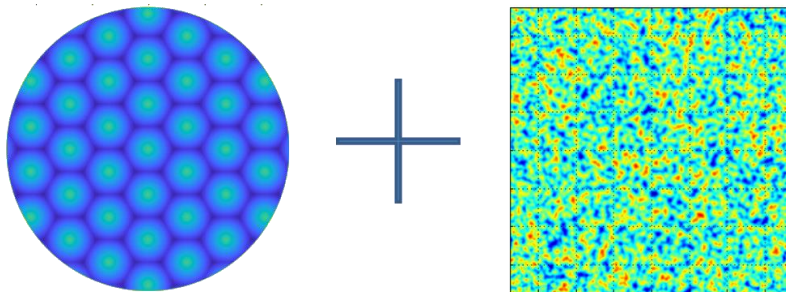
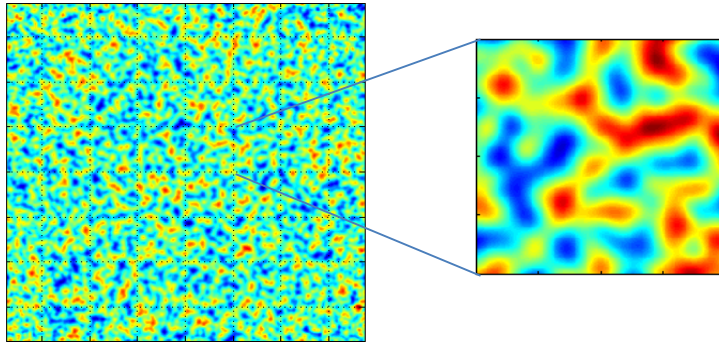
Width of ring and extinction in the middle determined by axicon angle and tip radius





Pseudorandom Refractive Intensity Mapping Element (PRIME)

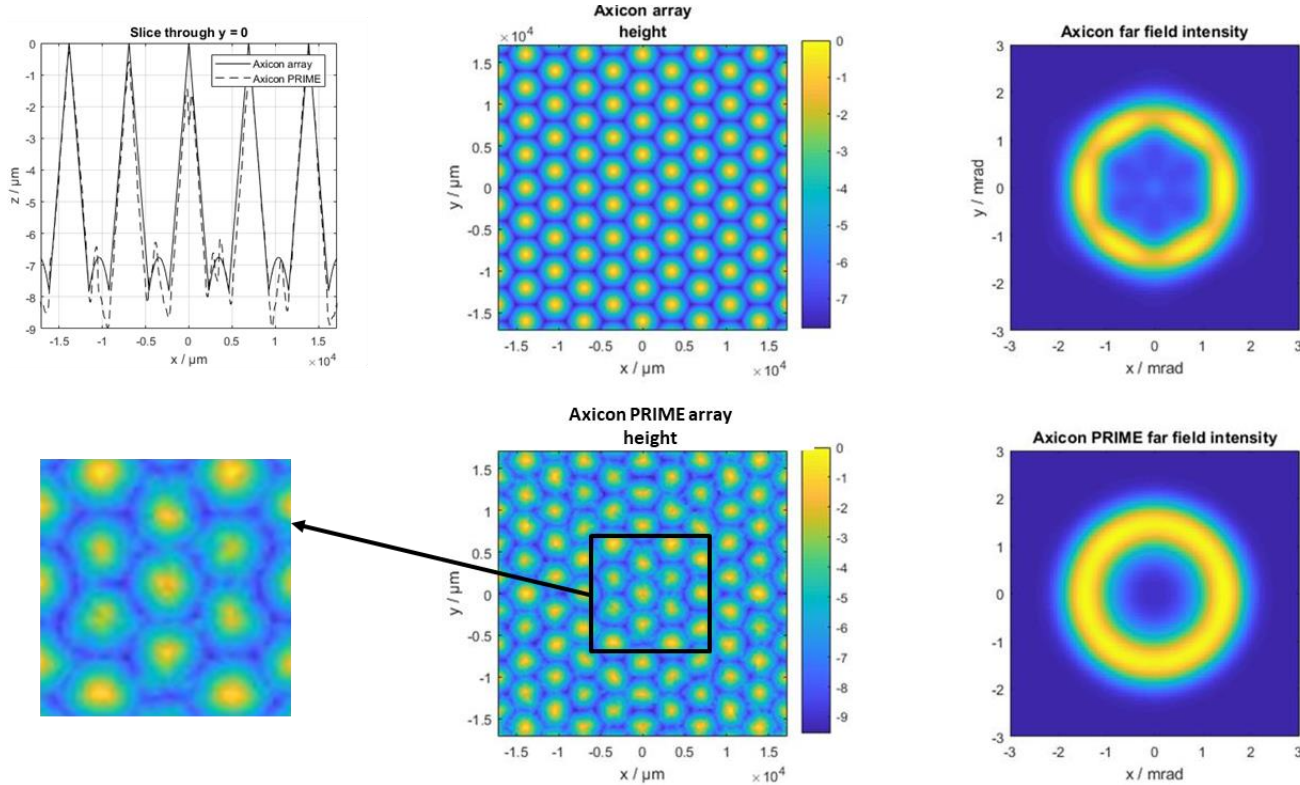
- Designed using Iterative Fourier Transform (IFT) algorithm
- Completely smooth, freeform surface.



Dixit et al. "Designing fully continuous phase screens for tailoring focal-plane irradiance profiles"



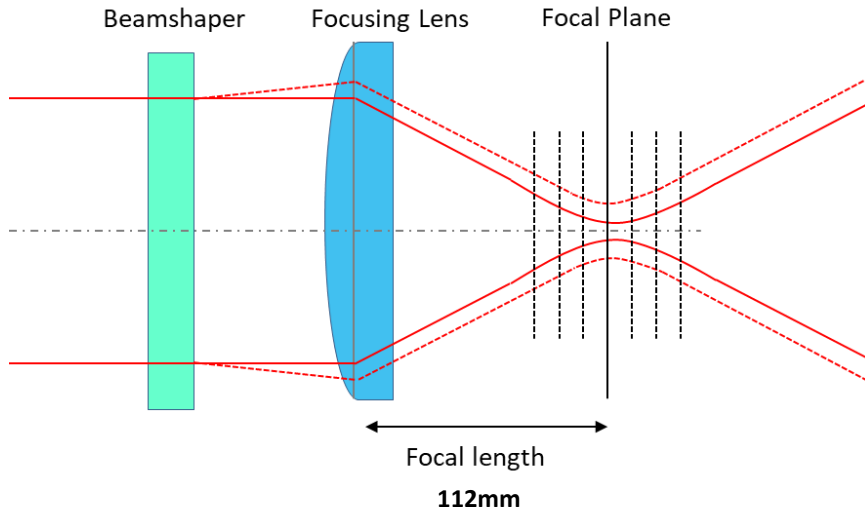
Pseudo-random axicon array



- Hot spots removed.
- Highly smooth optical surface.
- Refractive mode of operation.
- Insensitive to input beam and alignment



Through focus beam shaping



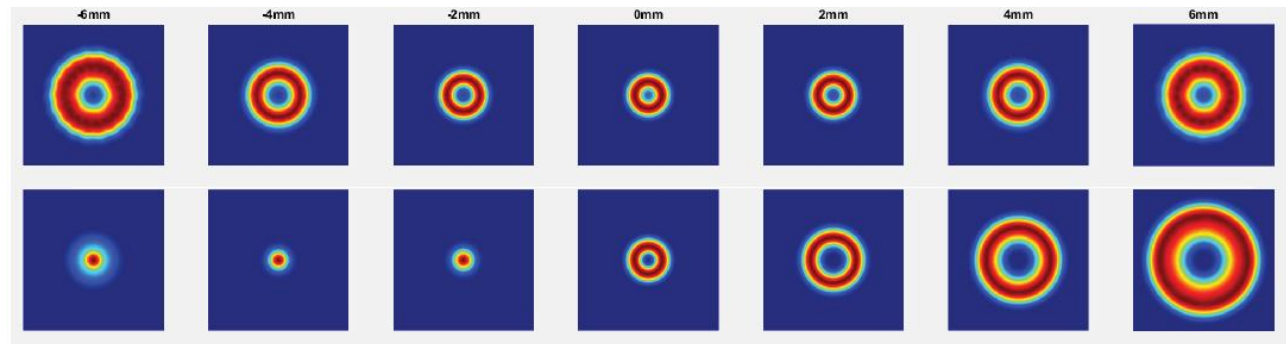
Light Tunnel Generation

Numerical design, optical simulation and functional validation demonstrate:

- Uniform ring
- Symmetric profile pre- and post-focus

Light Tunnel Generator
PP-LTG-400
profile at Z (axial) planes

Equivalent Axicon -
profile at Z (axial) planes





PowerPhotonic

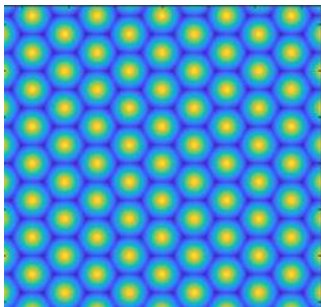
We offer:

- Truly freeform fabrication capability with high LIDT performance
- Computational solutions for freeform designs.
- Flexibility to address a wide range of laser applications.

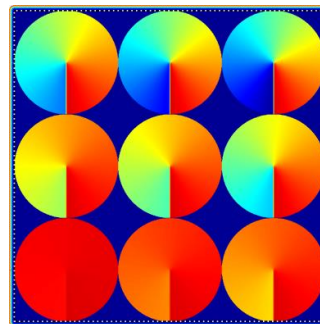
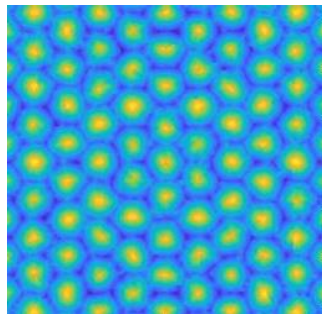
Looking for:

- New applications for our freeform solutions.
- Collaboration on application case studies.
- Surface metrology solution for high slope freeform surfaces.
- Complimenting technologies: coating, assembly and testing.

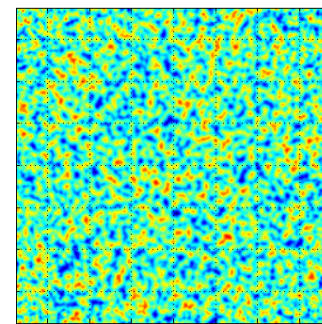
Thank you!



Enhancing Beam Performance



N. Trela-McDonald, EPIC



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