



Queen Mary

University of London

Science and Engineering



SmartPhantom Improved Imaging Optics

Peter Hobson

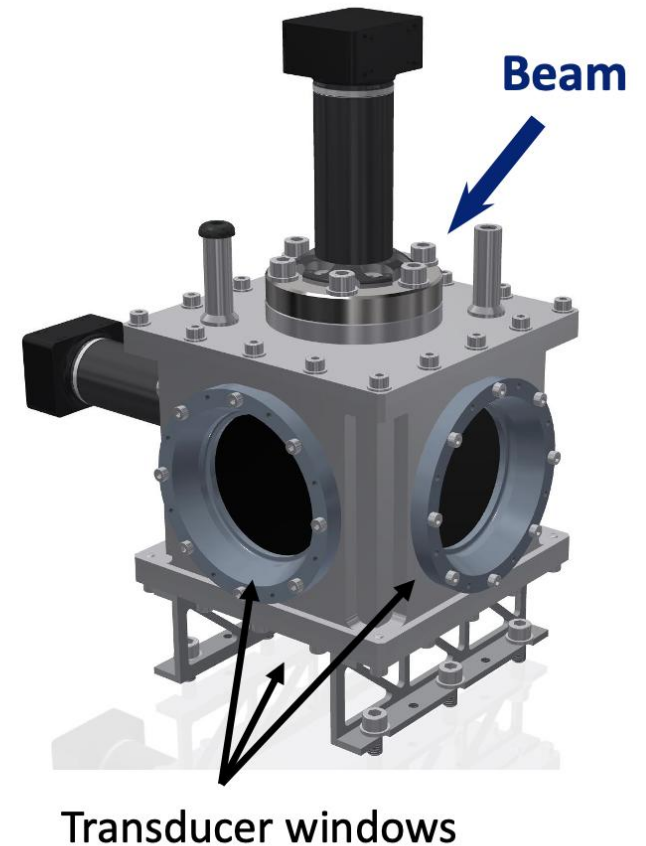
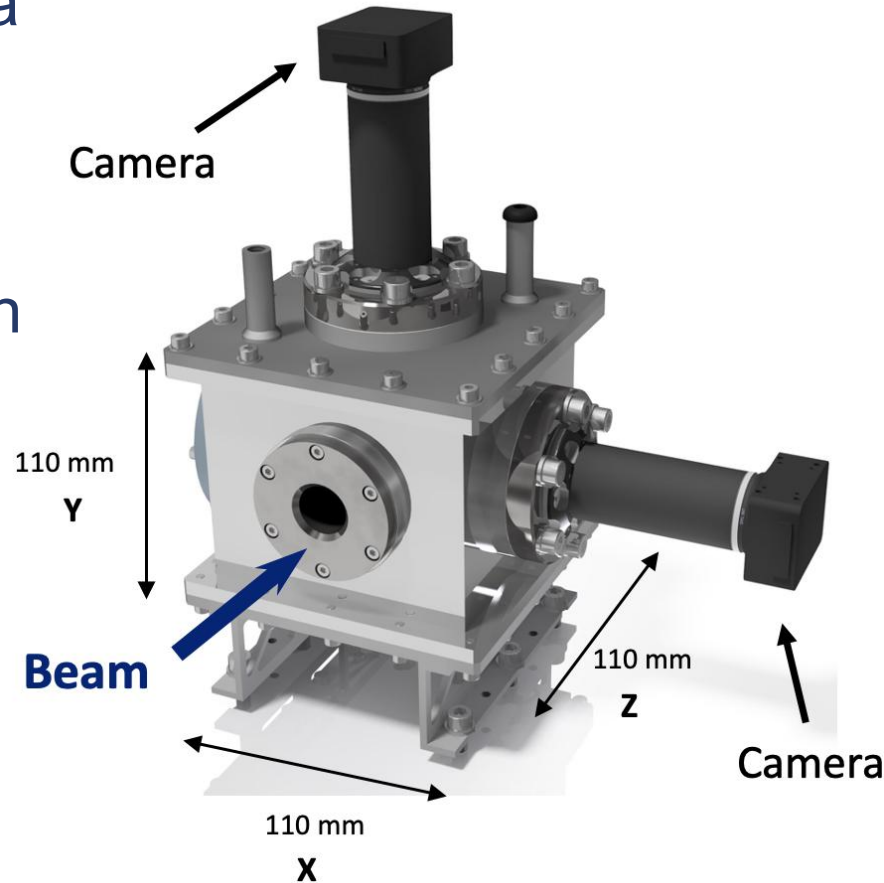
Queen Mary University of London, Department of Physics and Astronomy

Scintillator-based approach to dose mapping

Here we image the light arising from the proton beam, using a liquid scintillator contained within a 1000 mL volume, or using scintillating fibre planes in air.

This will be a cross-check on our ion-acoustic image and simulations.

The “Smart Phantom” with ports for optical cameras and external ultrasonic transducer arrays.

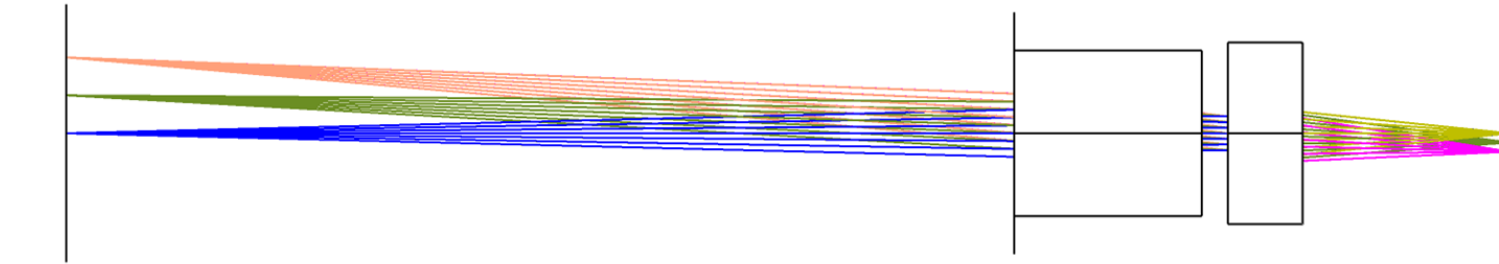


Simulating the new optics

1. SmartPhantom is assumed to contain air;
2. Sequential ray tracing is used; fields represent the dimensions of the scintillator planes;
3. Imaging optics are multi-element commercial lenses;
4. Lens descriptions are provided as “black-box” objects by Edmund Optics;
5. Simulations use **Ansys ZEMAX OpticStudio Pro** (PC is an i5 6/12 core @4.6 GHz peak with 32 Gbytes of 3200 MHz DDR4 memory);
6. Data shown for a wavelength of 486 nm (except where stated).
7. The lens purchased:

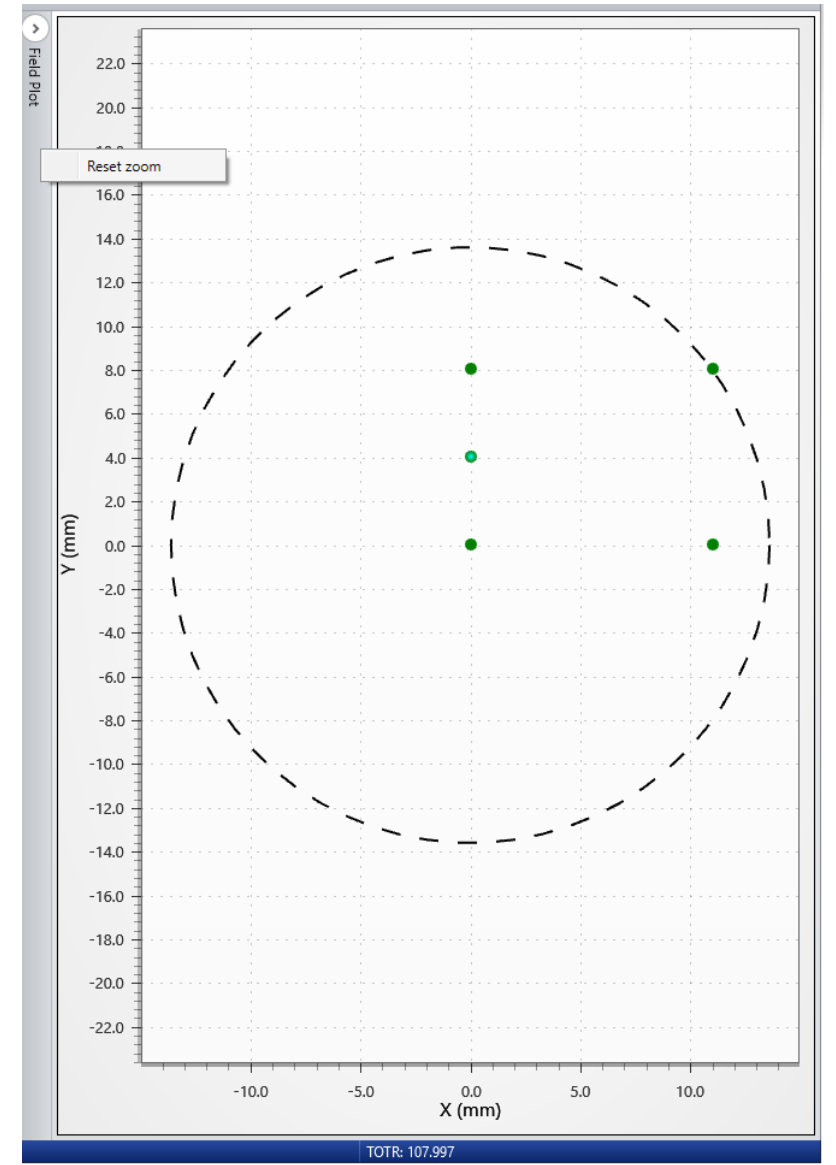
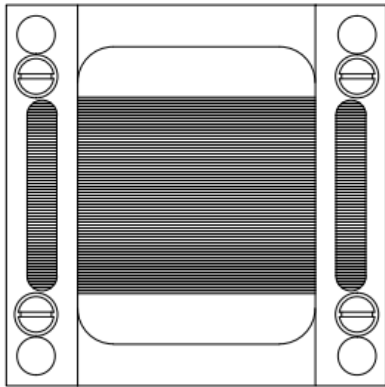
#59-871: 25 mm, F1.4, Primary WD: 100 – ∞ mm

Lens #59-871

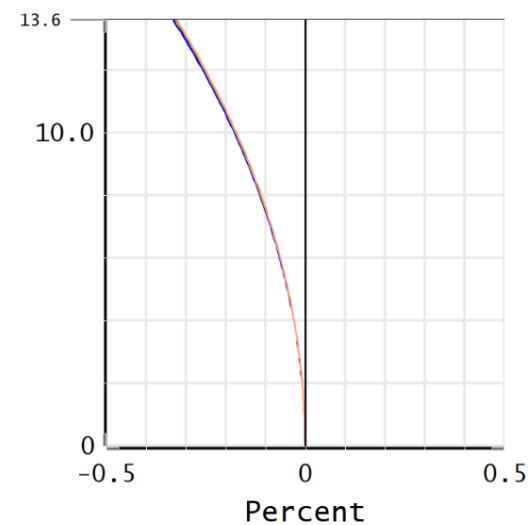
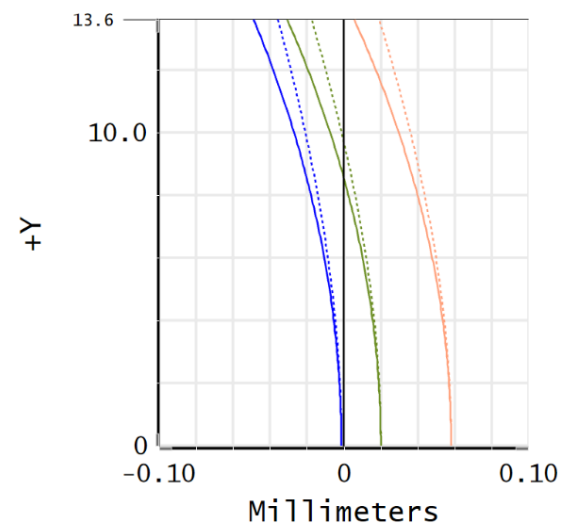


50 mm

32,0
MACHINE TO FINAL LENGTH ON ASSEMBLY



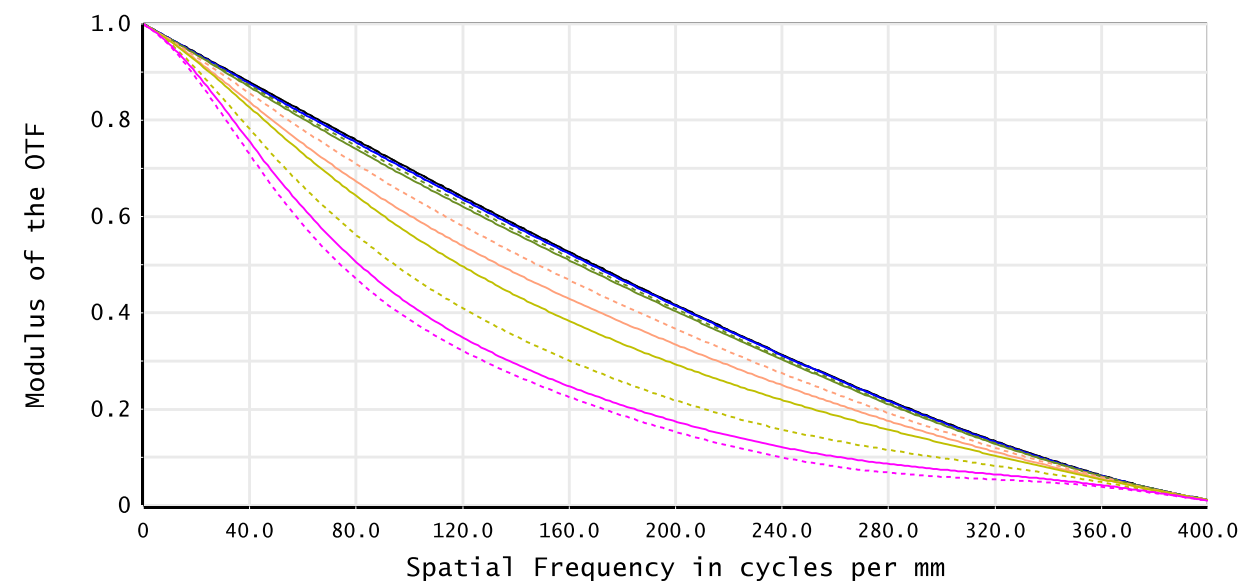
Lens #59-871 F4



0.4861-Tangential 0.4861-Sagittal
0.5876-Tangential 0.5876-Sagittal
0.6563-Tangential 0.6563-Sagittal

0.4861 0.5876 0.6563

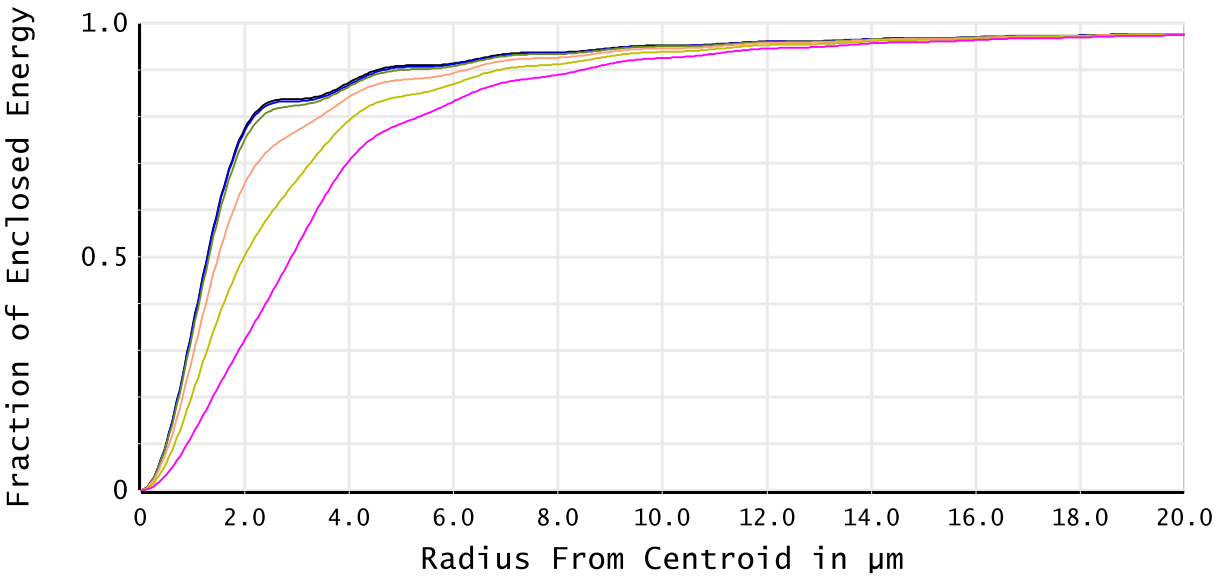
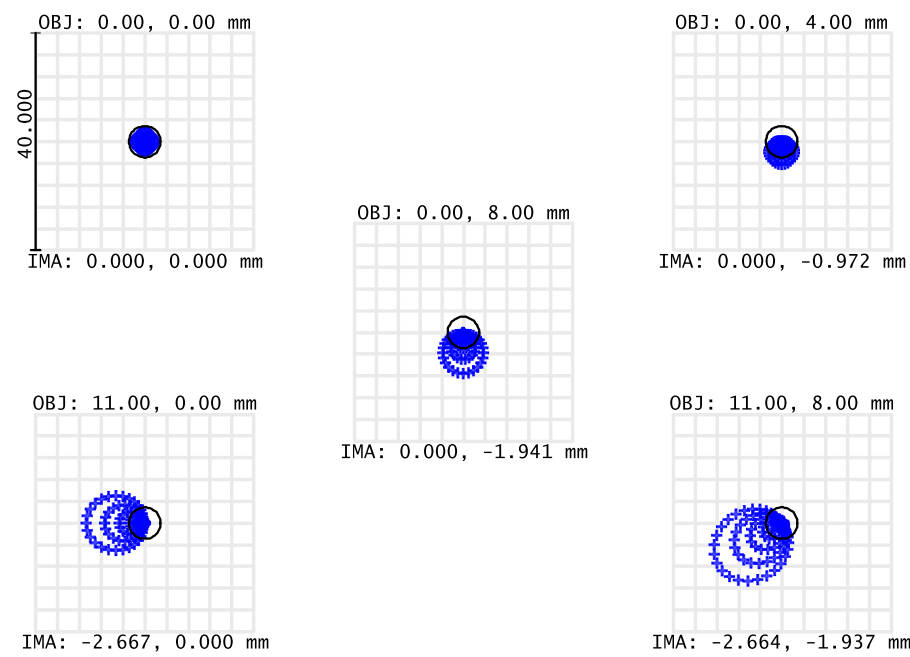
Field Curvature	F-Tan(Theta) Distortion	
59871 06/05/2025 Maximum Field is 13.601 Millimeters. Field Curvature Sagittal = 0.0375 Millimeters Field Curvature Tangential = 0.0507 Millimeters Legend items refer to Wavelengths	59871 06/05/2025 Maximum Field is 13.601 Millimeters. Maximum distortion = 0.3254%	Queen Mary University of London School of Physical and Chemical Sciences London, E1 4NS UK
		59871_03_BB.zmx Configuration 1 of 1



Diff. Limit-Tangential Diff. Limit-Sagittal 0.00, 0.00 mm-Tangential 0.00, 0.00 mm-Sagittal
0.00, 4.00 mm-Tangential 0.00, 4.00 mm-Sagittal 0.00, 8.00 mm-Tangential 0.00, 8.00 mm-Sagittal
11.00, 0.00 mm-Tangential 11.00, 0.00 mm-Sagittal 11.00, 8.00 mm-Tangential 11.00, 8.00 mm-Sagittal

Diffraction MTF

Lens #59-871 F4

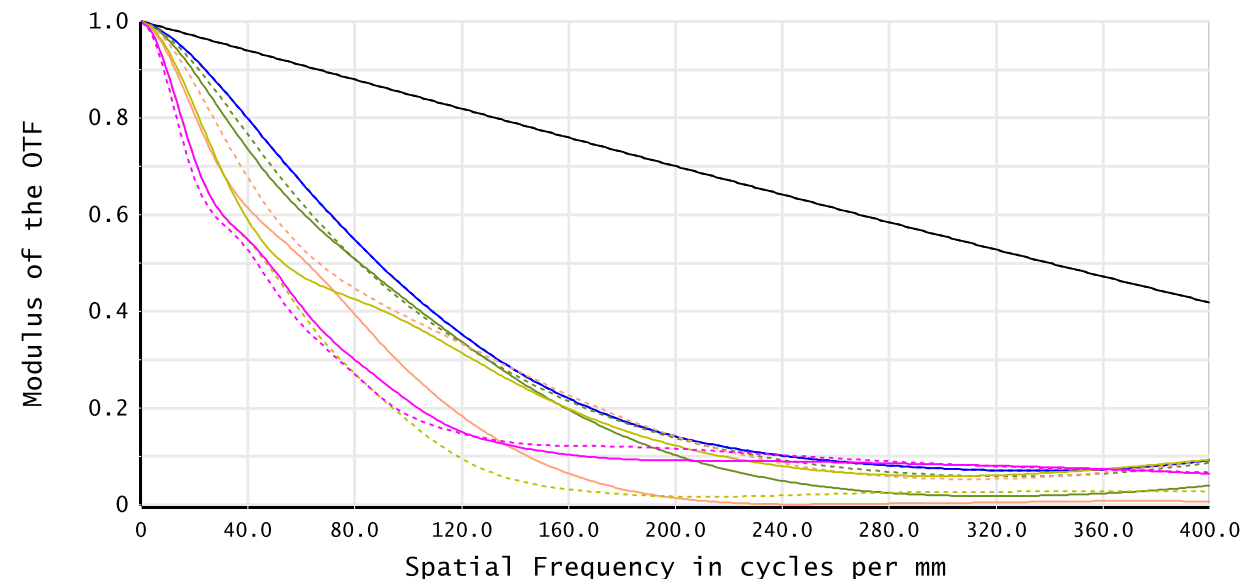
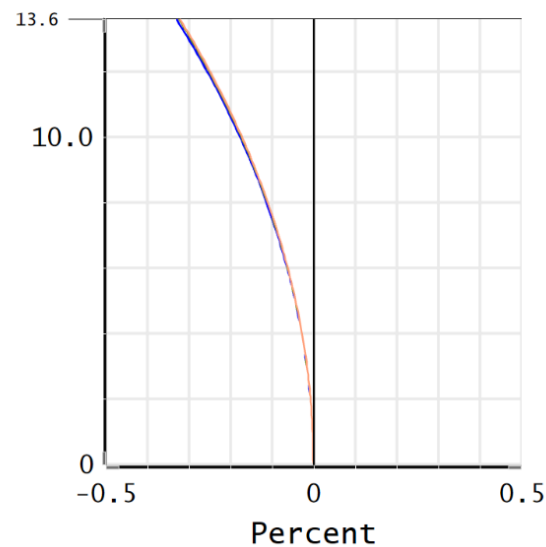
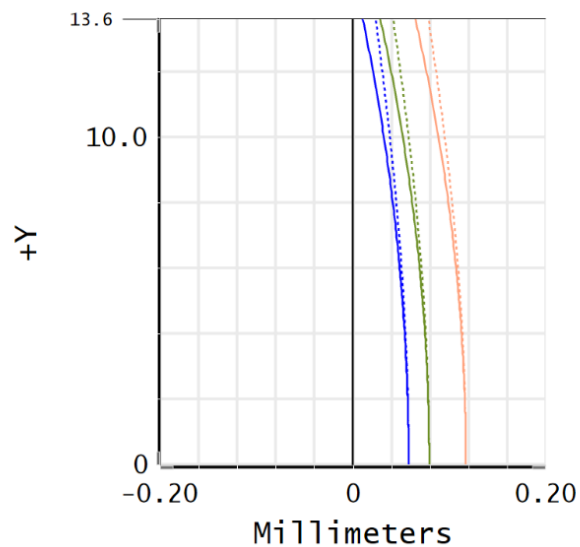


Surface IMA: Front Metal

Spot Diagram						Qu School
59871, 23/05/2025						
Units are μm . Airy Radius: 2.910 μm . Legend items refer to Wavelengths						
Field	:	1	2	3	4	5
RMS radius	:	0.984	1.586	2.859	4.101	5.375
GEO radius	:	1.718	4.199	7.587	10.779	14.013
Scale bar	:	40.000	Reference : Chief Ray			

FFT Diffraction Encircled Energy

Lens #59-871 F2



0.4861-Tangential 0.4861-Sagittal
0.5876-Tangential 0.5876-Sagittal
0.6563-Tangential 0.6563-Sagittal

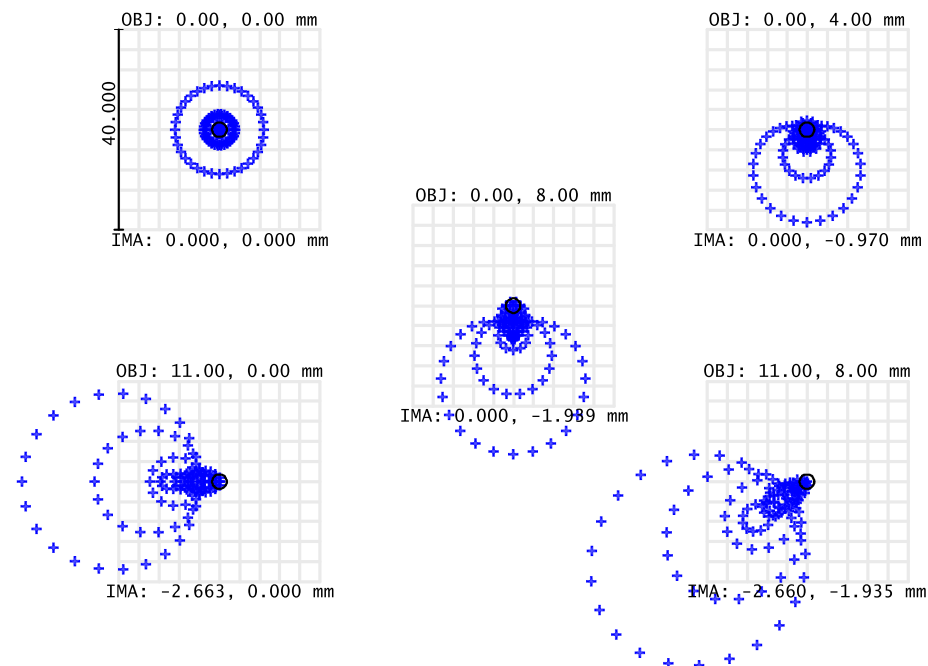
0.4861 0.5876 0.6563

Diff. Limit-Tangential Diff. Limit-Sagittal 0.00, 0.00 mm-Tangential 0.00, 0.00 mm-Sagittal
0.00, 4.00 mm-Tangential 0.00, 4.00 mm-Sagittal 0.00, 8.00 mm-Tangential 0.00, 8.00 mm-Sagittal
11.00, 0.00 mm-Tangential 11.00, 0.00 mm-Sagittal 11.00, 8.00 mm-Tangential 11.00, 8.00 mm-Sagittal

Field Curvature	F-Tan(Theta) Distortion
59871 16/06/2025 Maximum Field is 13.601 Millimeters. Field Curvature Sagittal = 0.0375 Millimeters Field Curvature Tangential = 0.0508 Millimeters Legend items refer to Wavelengths	59871 16/06/2025 Maximum Field is 13.601 Millimeters. Maximum distortion = 0.3237% <div>Queen Mary University of London School of Physical and Chemical Sciences London, E1 4NS UK</div> <div>59871_03_BB.zmx Configuration 1 of 1</div>

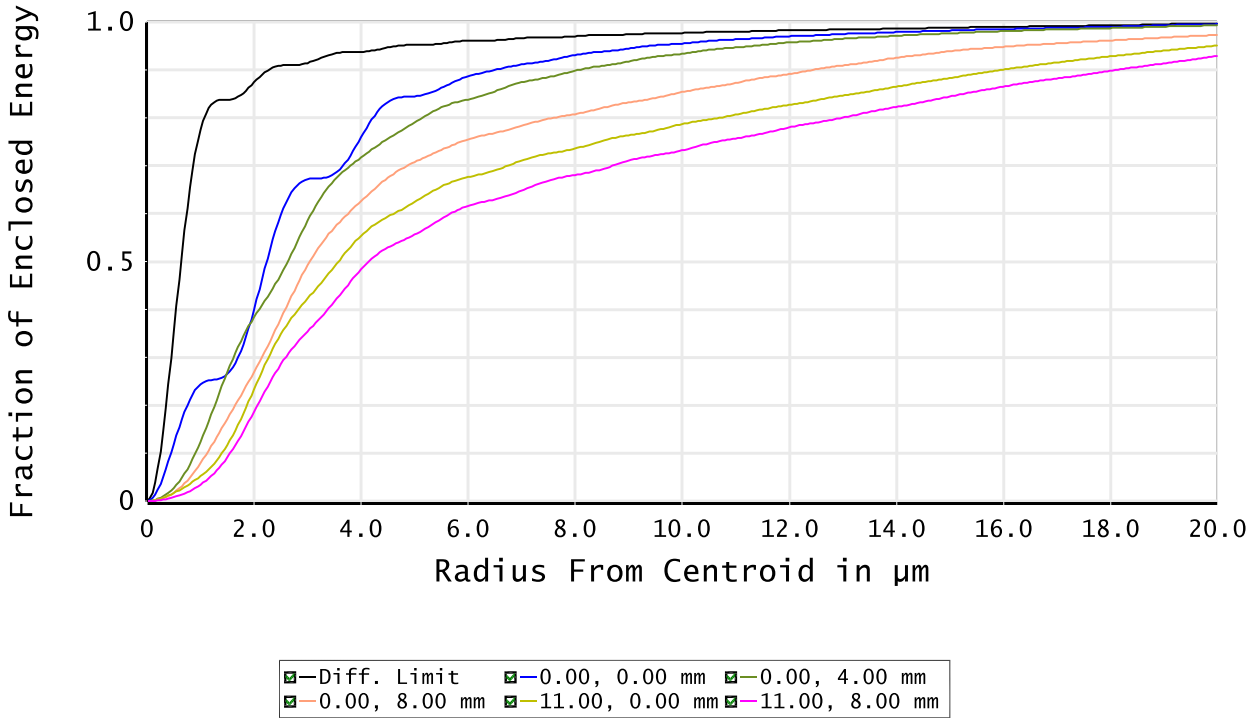
Diffraction MTF

Lens #59-871 F2



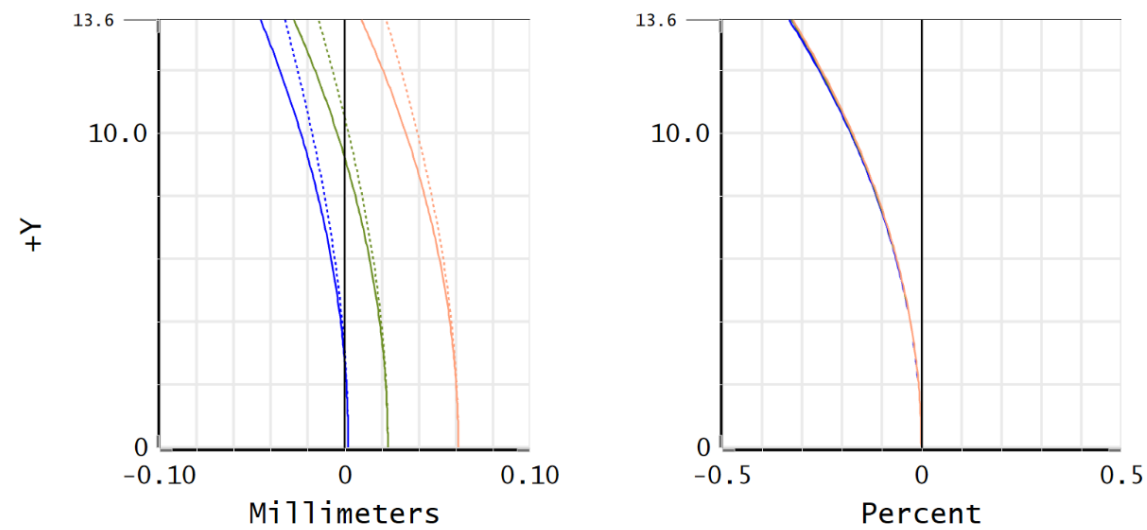
Surface IMA: Front Metal

Spot Diagram					School
59871, 16/06/2025					
Units are μm . Airy Radius: 1.450 μm . Legend items refer to Wavelengths					
Field :	1	2	3	4	
RMS radius :	5.169	6.986	10.926	14.542	
GEO radius :	8.837	18.464	29.648	39.328	
Scale bar :	40.000	Reference : Chief Ray			



FFT Diffraction Encircled Energy

Lens #59-871 F8



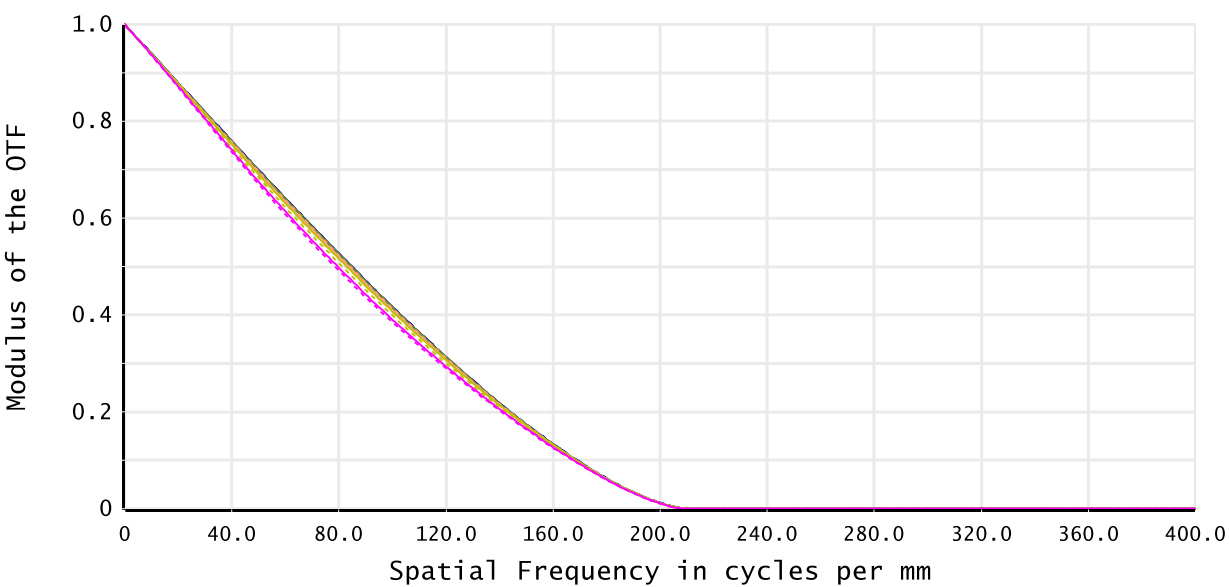
0.4861-Tangential 0.4861-Sagittal
0.5876-Tangential 0.5876-Sagittal
0.6563-Tangential 0.6563-Sagittal

0.4861 0.5876 0.6563

Field Curvature	F-Tan(Theta) Distortion
59871 16/06/2025 Maximum Field is 13.601 Millimeters. Field Curvature Sagittal = 0.0375 Millimeters Field Curvature Tangential = 0.0507 Millimeters Legend items refer to Wavelengths	59871 16/06/2025 Maximum Field is 13.601 Millimeters. Maximum distortion = 0.3253%

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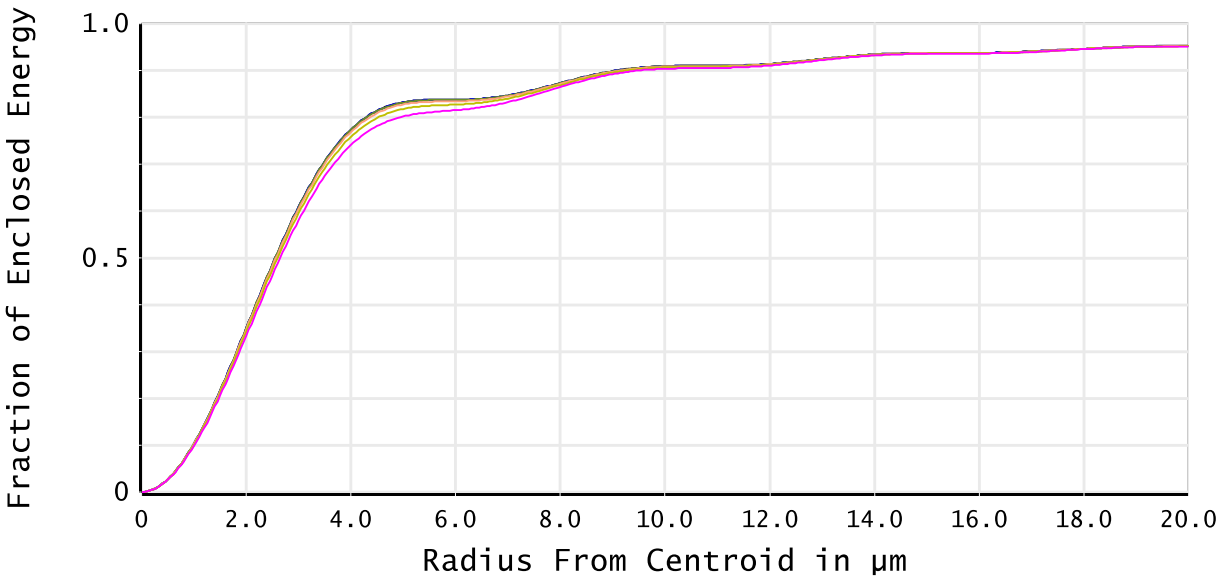
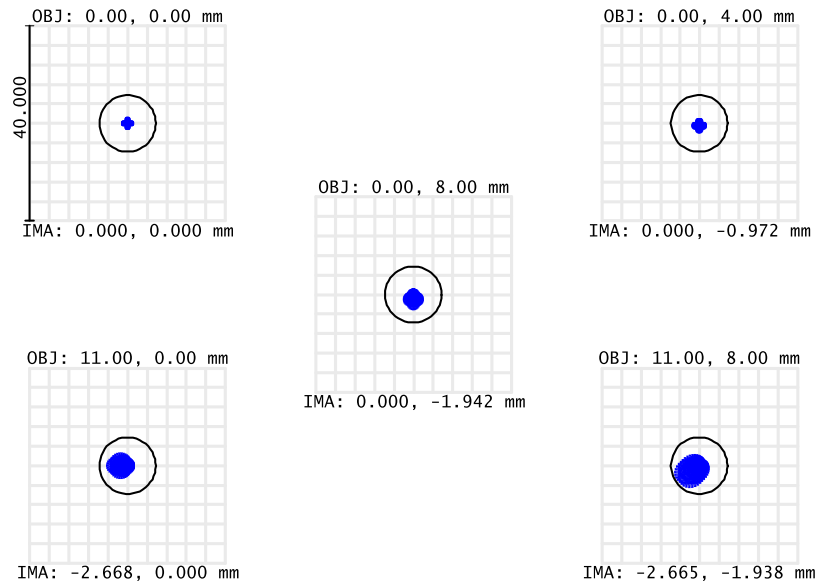
59871_03_BB.zmx
Configuration 1 of 1



Diff. Limit-Tangential Diff. Limit-Sagittal 0.00, 0.00 mm-Tangential 0.00, 0.00 mm-Sagittal
0.00, 4.00 mm-Tangential 0.00, 4.00 mm-Sagittal 0.00, 8.00 mm-Tangential 0.00, 8.00 mm-Sagittal
11.00, 0.00 mm-Tangential 11.00, 0.00 mm-Sagittal 11.00, 8.00 mm-Tangential 11.00, 8.00 mm-Sagittal

Diffraction MTF

Lens #59-871 F8



Surface IMA: Front Metal

Spot Diagram					
59871, 16/06/2025					
Units are μm . Airy Radius: 5.824 μm . Legend items refer to Wavelengths					
Field	1	2	3	4	5
RMS radius	0.185	0.409	0.902	1.430	1.997
GEO radius	0.313	1.037	2.201	3.376	4.608
Scale bar	40.000	Reference : Chief Ray			

FFT Diffraction Encircled Energy

Lens #59-871 Geometric Image on camera F4

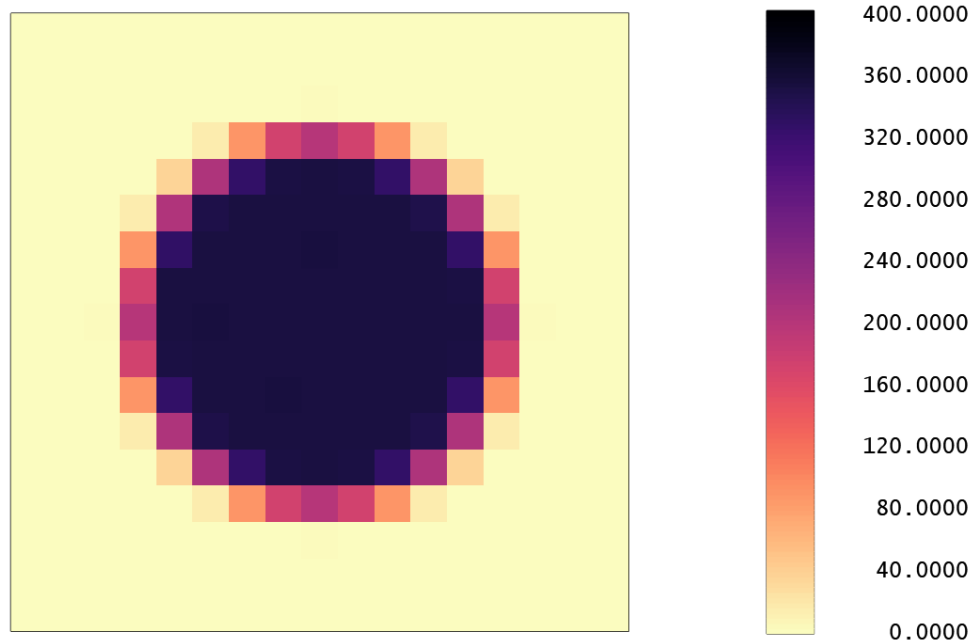


Image Diagram

59871
23/05/2025
Image Width = 0.1000 Millimeters, 17 x 17 pixels
Field position: 0.00, 0.00 mm
Percent efficiency: 100.000%, 1.000E+00 Watts
Surface: 8. Units are watts per Millimeters squared.

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Configuration 1 of 1

On axis image

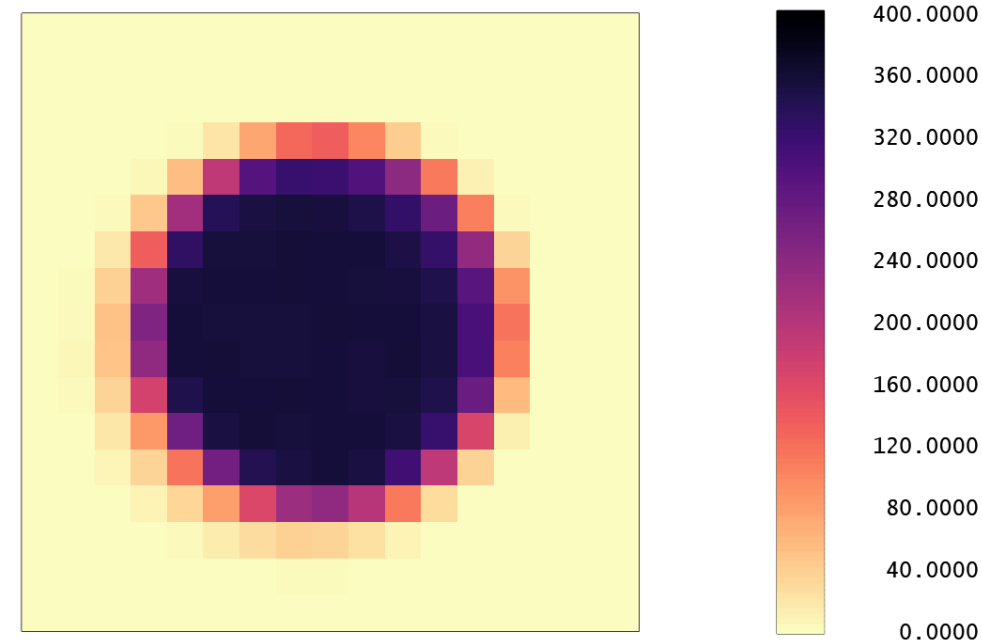


Image Diagram

59871
23/05/2025
Image Width = 0.1000 Millimeters, 17 x 17 pixels
Field position: 11.00, 8.00 mm
Percent efficiency: 100.000%, 1.000E+00 Watts
Surface: 8. Units are watts per Millimeters squared.

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59871_03_BB.zmx
Configuration 1 of 1

X = 11 mm by Y = 8 mm off axis

Teledyne BFLY-U3-23S6M-C Camera

Physical & Mechanical Properties

Dimensions (mm): 29 x 29 x 30 (excludes connectors and lens mount)

Weight (g): 36

Housing: Full

Sensor

Image Buffer: 16MB

Imaging Sensor: Sony IMX249

Type of Sensor: Progressive Scan CMOS

Type of Shutter: Global

Camera Sensor Format: 1/1.2"

Resolution (MegaPixels): 2.30

Pixels (H x V): 1,920 x 1,200

Pixel Size, H x V (μm): 5.86 x 5.86

Sensing Area, H x V (mm): 11.25 x 7.03

Frame Rate (fps): 41.00

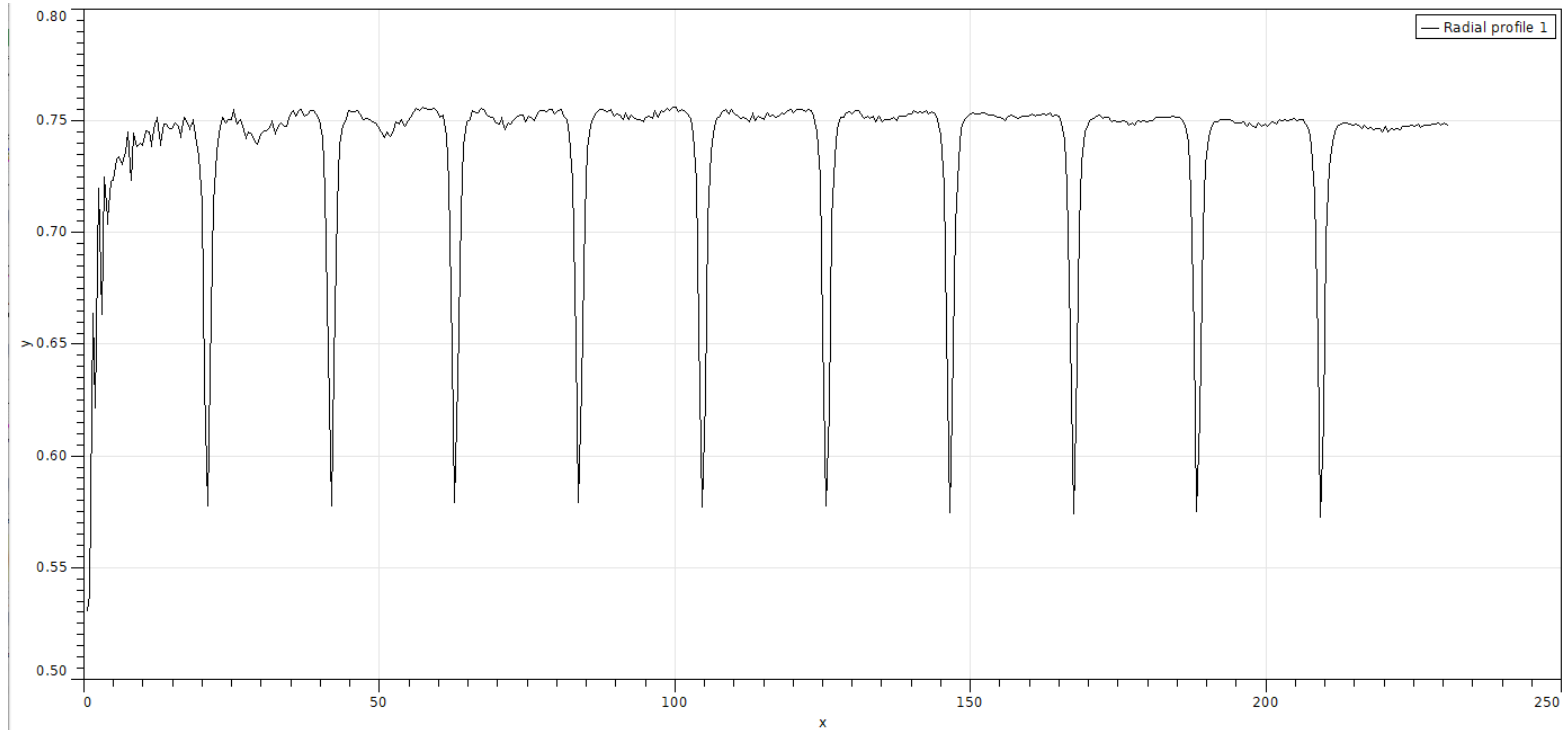
Pixel Depth: 10/12 bit

Exposure Time: 19μs – 3.9s

Dynamic Range (dB): 67.12 (Mode 0) / 73.08 (Mode 7)

Machine Vision Standard: USB3 Vision v1.0

Teledyne BFLY-U3-23S6M-C Camera



Test target at ~ 120 mm from focal plane.

Rings are $10\text{ }\mu\text{m}$ thick and spaced at 1 mm intervals.

Plot above shows radial profile using Gwyddion. X-axis scale is in pixels ($5.86\text{ }\mu\text{m}$)

Where next with the SmartPhantom Optics?

Two lenses purchased cost (two—off cost, exc VAT) from QMUL STFC grant:

#59-871: 25 mm, F1.4. £440 ✓

Two FLIR BFS-U3-23S6M-C USB 3.1 Blackfly® S, Monochrome Camera purchased (£506 exc VAT each). Two 4m GPIO cables to camera 6 pin connector also purchased. ✓

Bought adapter from lens front filter thread to Thorlab SM1 thread. ✓

Quick test of one lens and one camera ✓

To do: Fully test and quantify both cameras in 12-bit mode

Software to drive cameras using the Spinnaker SDK (Python, C++)