

OPTICAL DESIGN
of the
FIES fibre assemblies B and C

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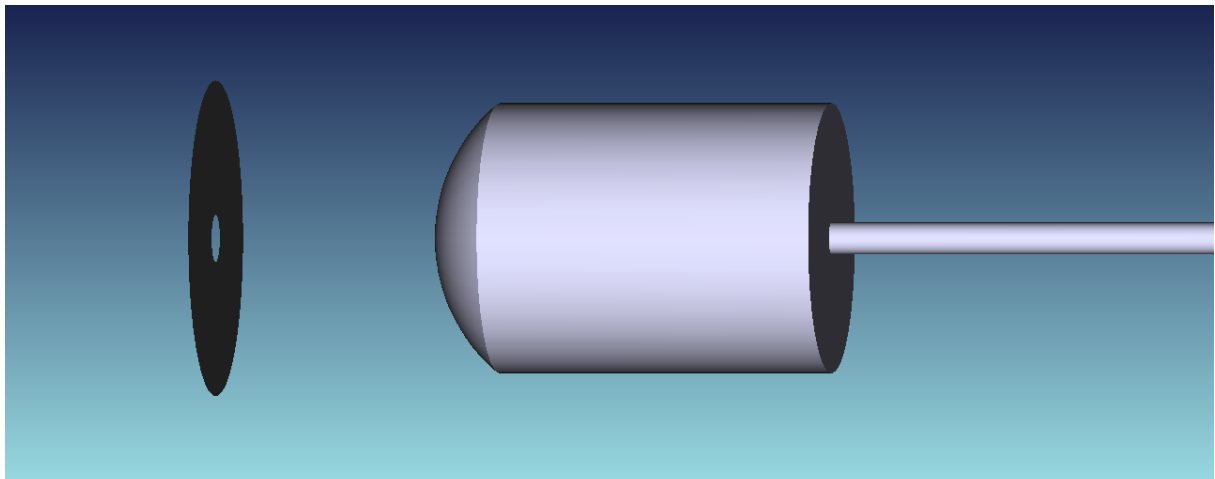
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Introduction

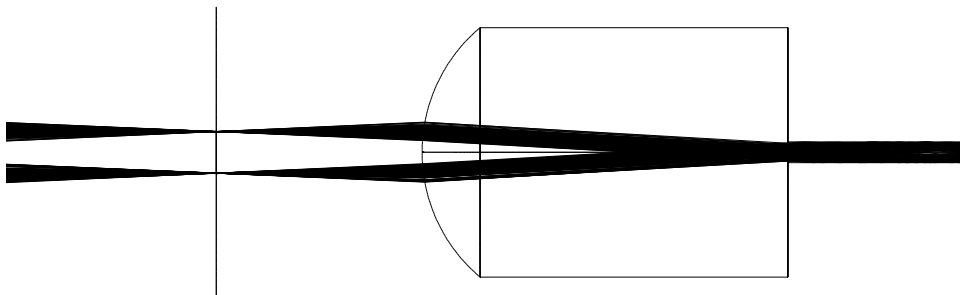
This report is a documentation of the optical design of the FIES fiber assemblies B and C. The mechanical design is not shown. It is shown in the assembly drawing made by Aarhus University.

Fibre entrance

The entrance handle of the fibres assembly has four separate fibres, one fibre with a 200 micron core, and three with a 100 micron core. Each fibre rests in a ferrule, with a micro lens glued directly on to the fibre end. In front of each fibre there is a micro mirror with a hole in the centre. The figure below shows how the optical components are arranged for one of the small fibres. No mechanical parts are shown.



The figure below shows a ray trace through the fibre entrance of the small fibre. The telescope is focused at the plane of the micro mirror. Two focal points are shown. Both at the edge of the micro mirror aperture. The focal length of the micro lens is selected such that the telescope pupil is imaged on to the fibre entrance, which is the plane where the fibre meets the rear surface of the lens. The micro mirror is close to the front focal point of the micro lens, so the light bundle from each point in the image is parallel inside the lens.



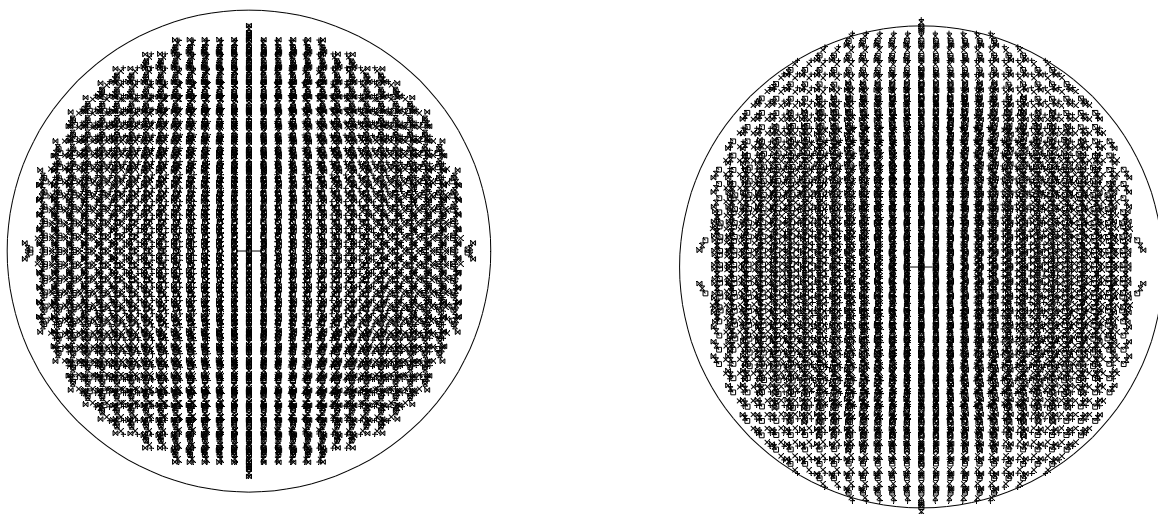
The table below shows the optical parameters of the small fibre entrance for fibre assembly C.

Optical parameters for small fibre entrance (assembly C)

Micro mirror position	In telescope focus
Micro mirror hole diameter	210 microns *
Micro mirror thickness	20 microns
Micro mirror outer diameter	4.5 mm
Axial distance between aperture and micro lens	0.993 mm
Micro lens length	1.777 mm \pm 0.05 mm
Micro lens diameter	1.2 mm
Micro lens front radius	0.78 mm \pm 1%
Micro lens material	Schott N-LAF34
Micro lens focal length (at 550 nm)	1.005 mm
Pupil position	At fibre entrance
Pupil diameter (Polychromatic)	92 microns
Fiber type	Polymicro FBP 100120140
Fiber diameter (Core)	100 microns

* For fibre assembly B, the hole diameter is 180 microns

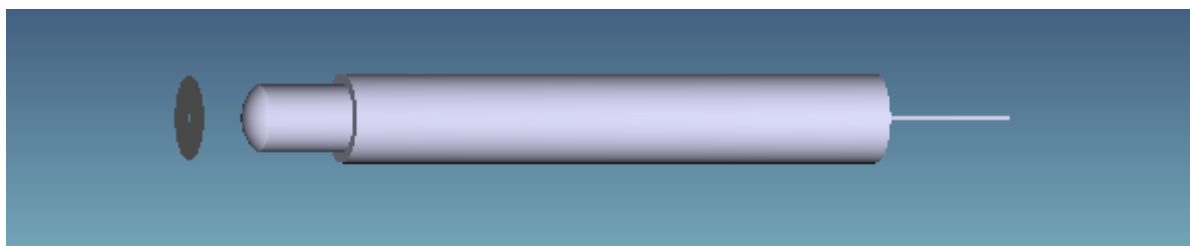
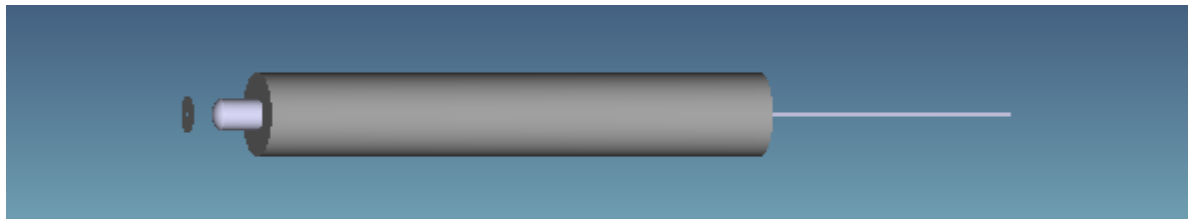
The leftmost image below shows the beam footprint on the fibre entrance for the nominal design (for the two image points used above, and full spectrum). The rightmost image shows the beam footprint if the lens radius and lens length has the most unfavourable positions in the tolerance interval (bad centering not shown).



Optical parameters for big fibre entrance (assembly C)

Micro mirror position	In telescope focus
Micro mirror hole diameter	350 microns
Micro mirror thickness	20 microns
Micro mirror outer diameter	4.5 mm
Axial distance between aperture and micro lens	2.04 mm
Micro lens length	3.66 mm \pm 0.05 mm
Micro lens diameter	2.4 mm
Micro lens front radius	1.6 mm \pm 1%
Micro lens material	Schott N-LAF34
Micro lens focal length (at 550 nm)	2.06 mm
Pupil position	At fibre entrance
Pupil diameter (Polychromatic)	0.193 mm
Fiber type	Polymicro FBP 200220240
Fiber diameter (Core)	200 microns

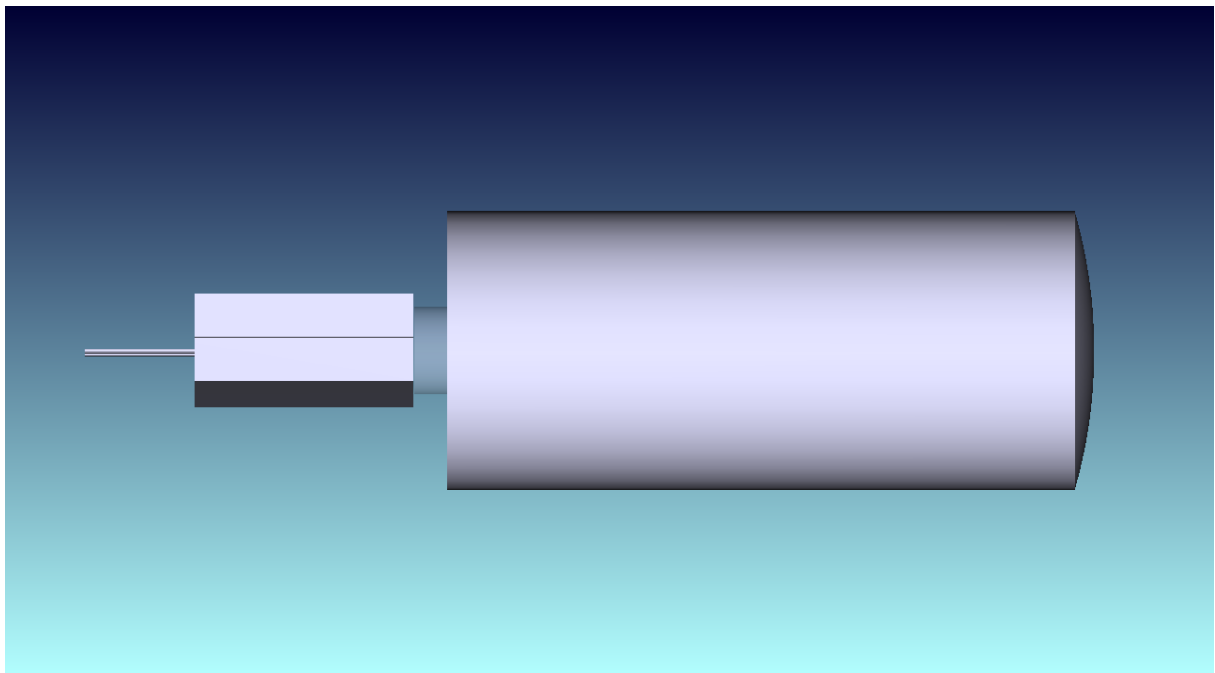
The images below shows how the fibre, micro lens, and ferule is assembled for the small and big fibre.



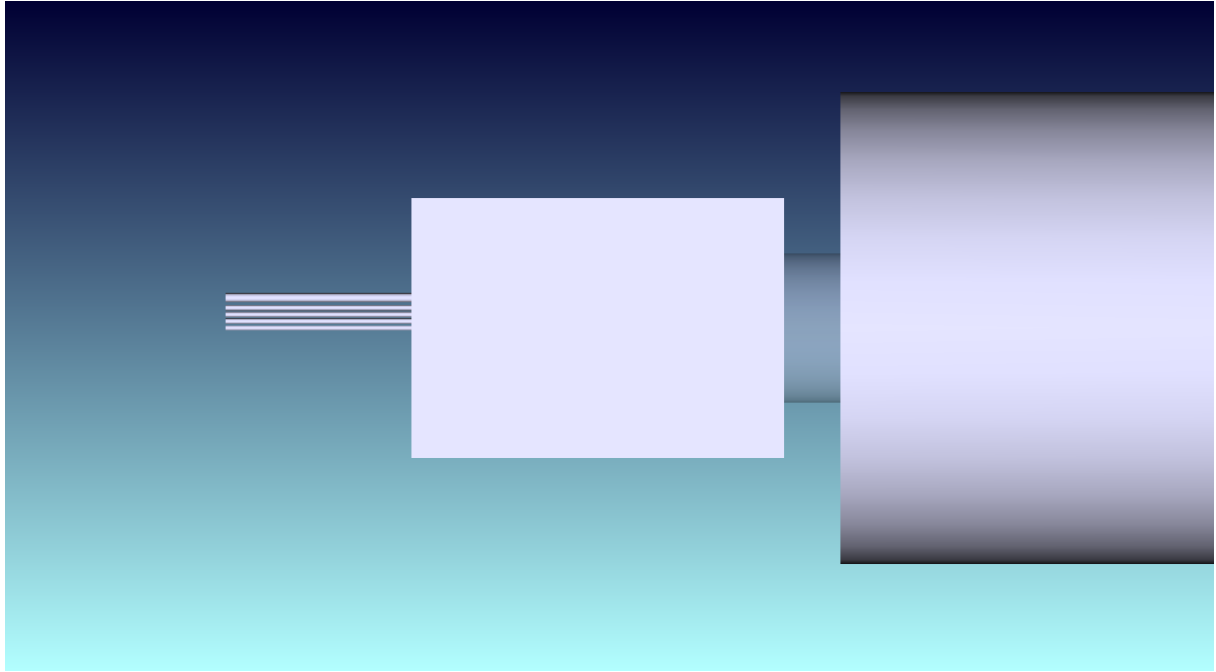
Ferule outer diameter	3.175 mm
Ferule length	20 mm
Ferule material	Metal

The output end

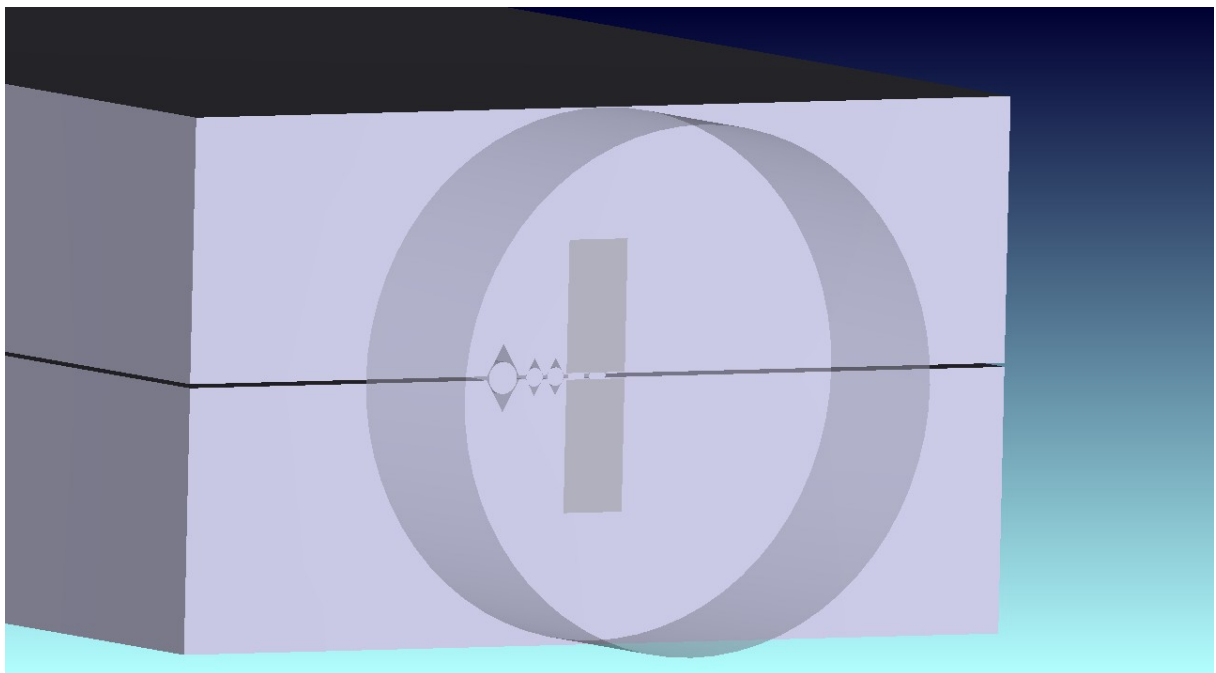
The optical parts that constitute the output end are shown in the four figures below. The five fibres rests in a micro V-block made of glass (the square part to the left in the image below), with a lid that consists of an identical V-block. The bottom, the lid and the fibres are cemented together, and the end of the package is polished. A slit plate (the small diameter part in the centre) is glued on top of the polished surface. The output lens that increases the F-number of the output beam (the large part to the right) is contacted to the slit plate with an index matching gel. All optical parts have mechanical holders, and the holders rest in a larger steel V-block. None of this is shown in the figures.



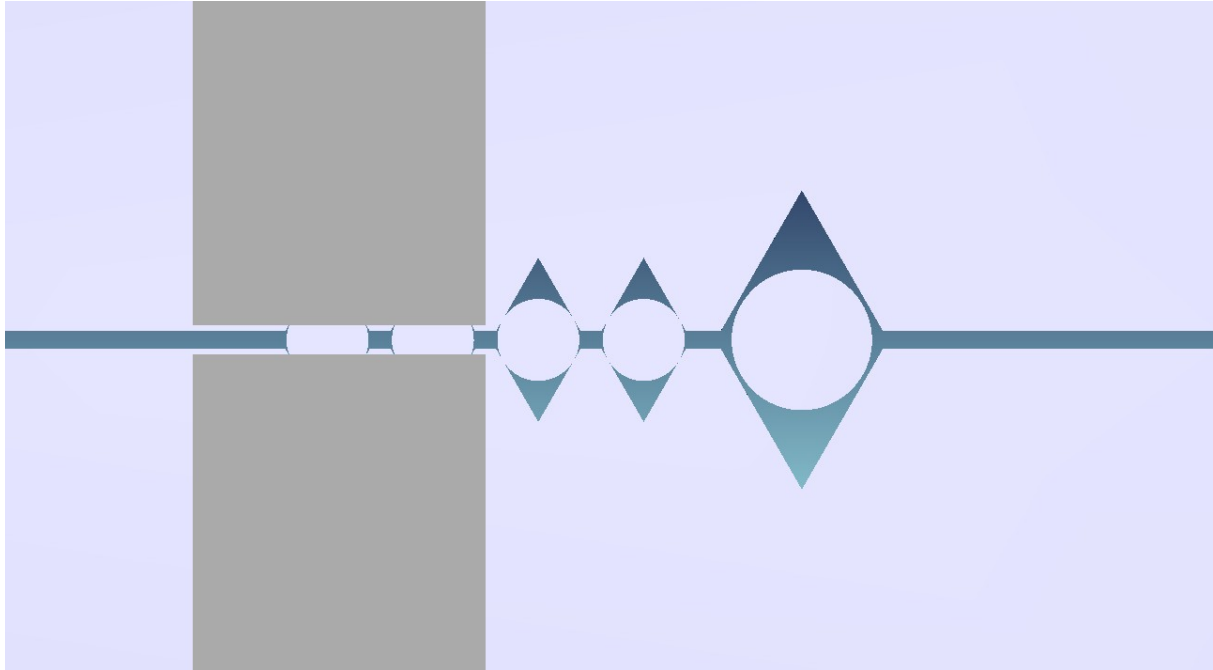
The output arrangement from the side and a bit below



The micro V-block and the fibres from above



The polished end of the micro V-blocks, with the slit plate



The micro V-block with the fibres and the slit

Micro V-block parameters

Grove angle	60 degrees
Pitch small fibres	180 microns
Distance small to big fibre	270 microns
Material	Fused silica
Length	10 mm
Height	2 mm (one part)
Width	7 mm

Ideally, the bottom part and the lid should meet exactly, and leave no play for the fibres, but as can be seen from the figure above the bottom and top micro V-block does not meet. There is a gap of 30 microns between them. The reason is that the V-blocks were ordered for a small fibre diameter of 125 microns, but the diameter of the current small fibre is 140 microns. This has the consequence that there are two stable positions of the lid when it is pressed down over the fibres.

In one position, the small fibres are hold in exact position and the large fibre can move within the 30 micron gap. If we assume that the fibre is straight within the V-block, the pointing error can be maximum 0.25 degrees.

In the other stable position, the rightmost small fibre is held in place, and the lid is rotated around it so the edge of the bottom and the lid meet to at the right edge of the V-block (se figure for right and left). The pointing error of the large fibre gets a bit smaller, and the pointing error of the leftmost small fibre is maximum 0.05 degrees, still assuming that the fibre is straight within the V-block. Our judgement is that this is not a problem.

In practice, there was a mechanical problem during the gluing process of the C fibre, so the lid position was worse than the worst case described above. For the B fibre no such problem were met.

The V-block can be produced with submicron accuracy, so it would be possible to achieve a higher accuracy.

Optical parameters of the output stage

Magnification of the fibre arrangement *	1.75 x
Change of F-number *	1.75 x
Lens focal length	48.75 mm (at 400 nm)
Lens material	Fused silica
Lens length	29.52**
Lens front radius	Plane
Lens rear radius	-22.92 mm
Lens diameter	12.7 mm
Slit plate length	1.5 mm
Slit plate material	Fused silica

* The lens magnifies the fibre arrangement so it seems to be 1.75 times bigger as seen from the spectrograph. At the same times the beam divergence angle is reduced 1.75 times, that is the F-number is increased 1.75 times.

** The lens is a standard catalogue lens with a thickness of 2.9 mm glued to a 26.62 mm long custom made fused silica glass rod (from Kire in China). The curved side of the lens has a custom broad band coating from Tafelmaier in Germany.

Difference between B fibre and C fibre

The only nominal difference between the B fibre and the C fibre is that the input aperture for the small fibres is 180 microns for the B fibre, and 210 microns for the C fibre.