Spatial profile shaping for use in optical fibres

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Abstract

Controlling the spatial profile of light through optical fibres is extremely useful in being able to deliver tailored high-power beams directly to the point of contact, as well as in optical communication systems. Here, we compare various types of optical fibres, ranging from single mode, multi-mode step index and graded index fibres, as well as photonic crystal **fibres**. We first demonstrate spatial control by dynamically modifying the beam size of the fundamental mode with the use of a Digital Micro-mirror Device (DMD) and use it to verify the placement of the image planes when using an objective lens to couple into an optical **fibres**. Two methods are presented for generating and tailoring a Flattop profile with the use of a DMD. Ultimately, we plan to propagate the generated Flattop profile through a multimode fibres.

Fibers

Optical **fibres** have become a topic of interest in many research fields, this is because of their numerous applications in areas such as materials processing, optical communication, sensors, etc. Optical fibres are malleable, transparent polymer filaments that constitute a core as thin as the size of a human hair. The core is the inner part of the fibre that directs light, and the cladding surrounds it completely. There are different types of fibres which consist of single mode, multimode, step-index, graded-index fibres and photonic crystal fibres

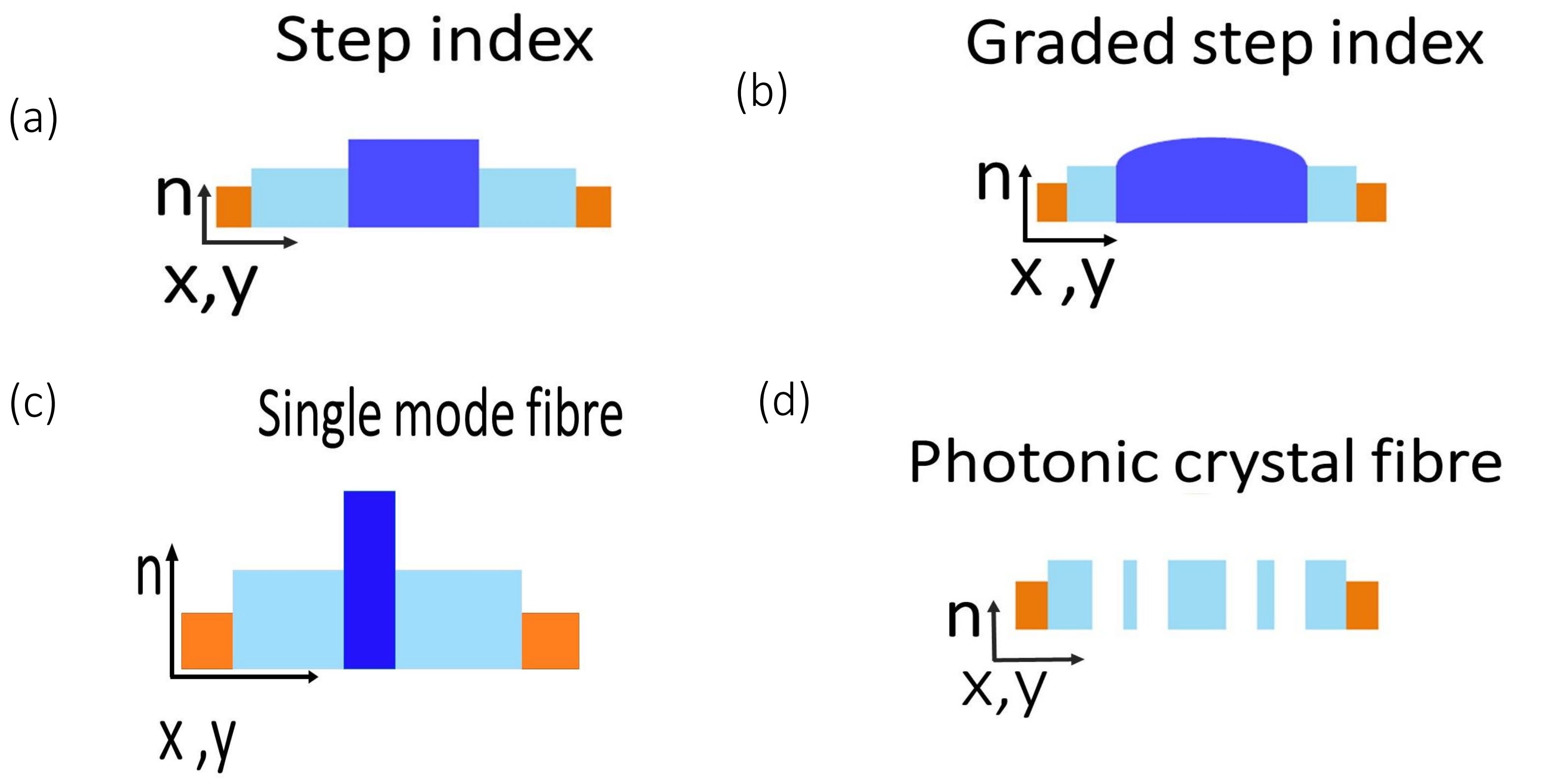

Figure 1: (a) The refractive index is uniform, and it undergoes an instantaneous change at the core-cladding interference. b) Graded index fibre the refractive index is maximum the centre of the core and decreases with an increase in the radial distance towards the core-cladding. (c. Single modes fibres only allow one mode of light to propagate through. (d) Photonic crystal fibres.

Coupling efficiency plot

Coupling efficiency is a measure of the beam can the fiber can absorb. This can be achieved using the integral. $\iint l$aserBeam x fibreMode x r dr.

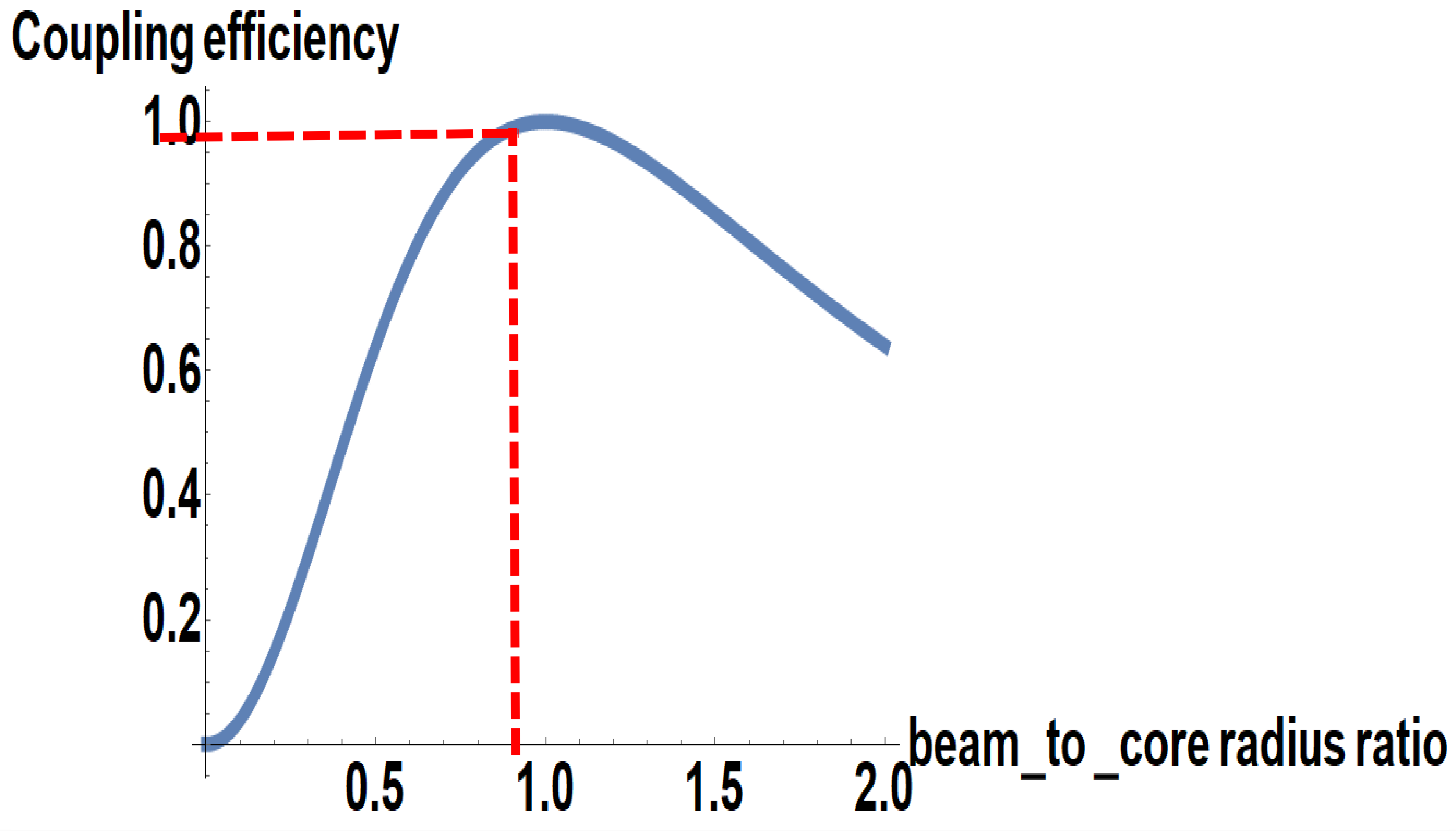

Figure 2: This graph shows the coupling efficiency as the beam size increases. The coupling efficiency is 100% when the size of the core and the be beam are equal.

Beam size magnification

In order to verify the placement and image planes when using an objective lens before the fibre, we used the objective lens to magnify various beam size and validated on at the correct magnification was achieved as presented in figure 4 .

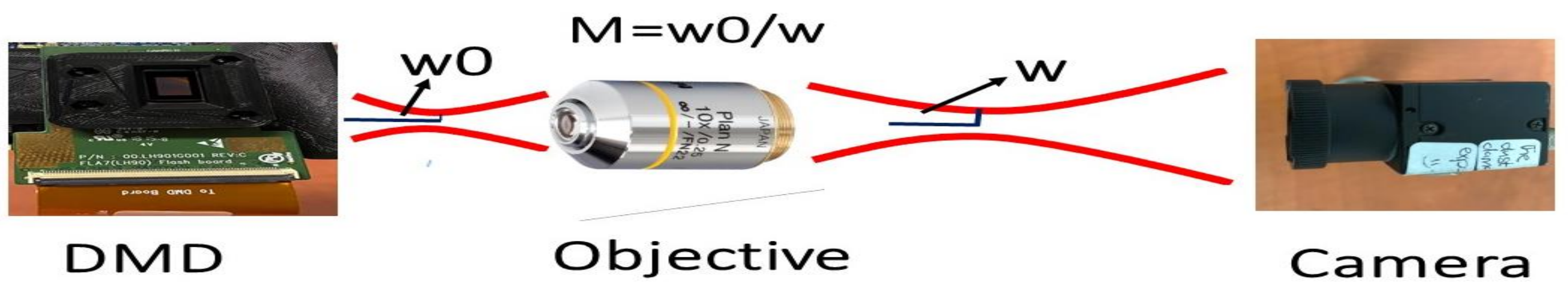

Figure 3: Schematic of the setup used to verify the objective lens placement

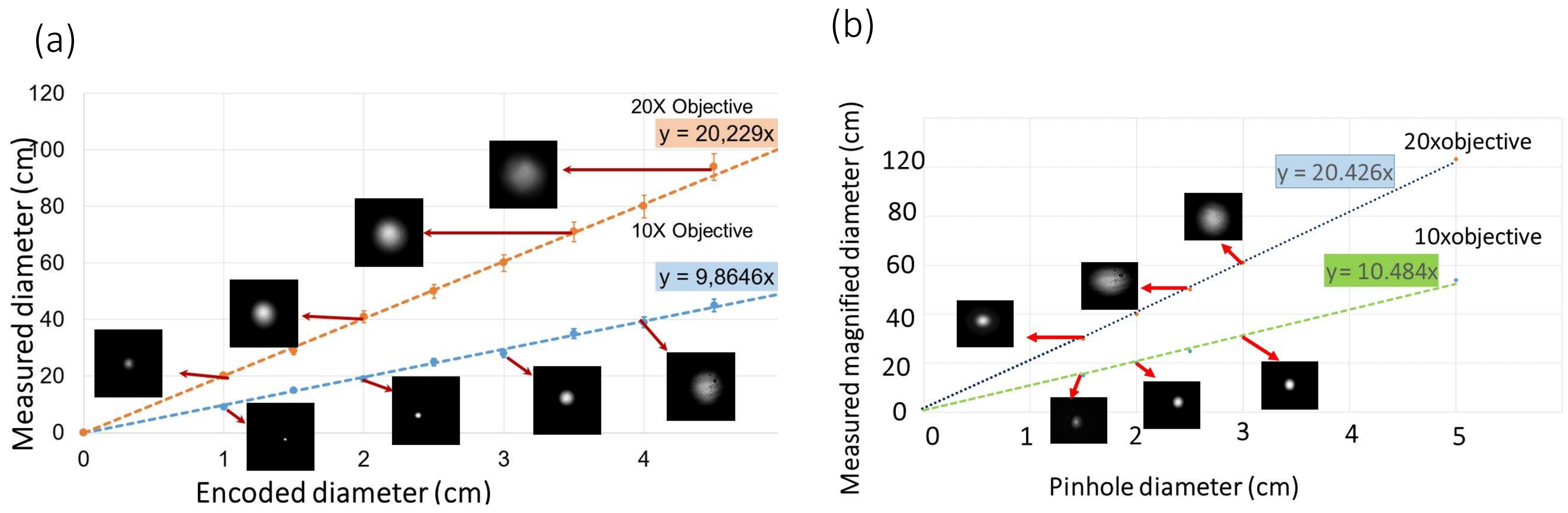

Figure 4: (a)Different beam sizes were encoded on the DMD to monitor their magnification. (b) Pinholes of different diameters were used as source to monitor magnification.

Generation of flat top beam

Flat top beams have a constant irradiance profile. This type of beams are useful for many applications such as, material processing. Below we have simulations of two methods for generating flat-top beams

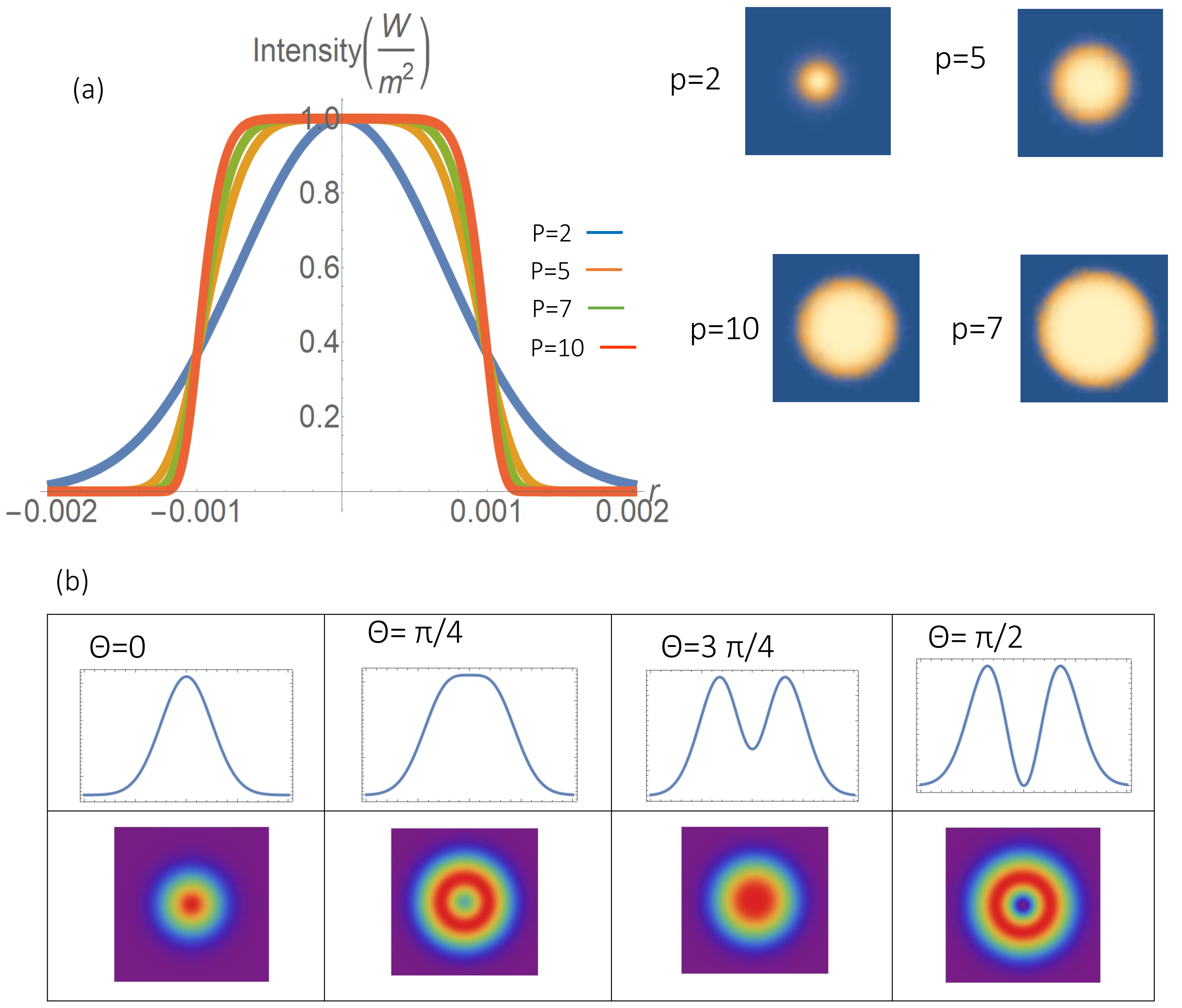

Figure 5: (a). U(r)=$\boldsymbol{exp}\left[-\left(\frac{r}{w}\right)^{p}\right]$, $\mathrm{p} = 2$ (Gaussian, $\mathrm{p} = \infty$ *is a* Flat top) [1]
(b) $I(r,\emptyset,z) = \cos(\theta)\,|LG_{01}(r,\emptyset,z)|^2 + \sin(\theta)\,|LG_{00}(r,\emptyset,z)|^2$
If Ɵ = 0 is a perfect Gaussian, Ɵ = π/2 is a perfect vortex and the Super-position of both gives a vector flat-top beam. [2]

Future work

We plan to use the digital micro-mirror device to construct a variety of spatial modes (one of these being the Flat-top), and monitor how their properties change as they propagate inside an optical fibre.

References

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[2] M. MacLare et. Al., "Optical trapping with Super-Gaussian beams. "Optics in the Life Science, (2013).