Application Note

Technical Application Note

Collimation of extended light sources

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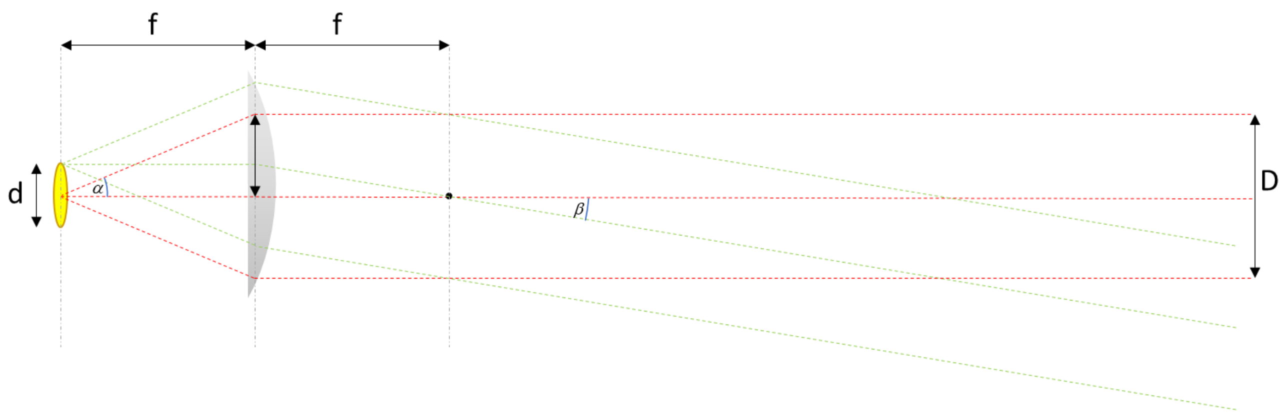
Lightsource.tech produces a range of fiber coupled light sources for small core diameter, multimode optical fibers (50 – 1000µm). The high brightness fiber output is sometimes termed as a “point light source”. This is merely colloquial usage by comparison with other daily life light sources, which are generally more extended (e.g., fluorescent tubes). However, for some technical applications it is necessary to recognize that such fiber coupled sources do have some geometrical extend that may not be neglected.

Often it is required to produce a collimated light beam, i.e., a light beam that does not diverge much and keeps its diameter over a certain distance. Usually, collimation is achieved by placing a lens at the focal distance. A common misunderstanding is that the diameter of the collimated beam simply may be reduced by using a lens of smaller focal length (f). This would be true only for an ideal point source with zero diameter. Practically, however, a radiating point of the optical fiber not on the optical axis will produce light rays that propagate under some angle (b) with respect to the optical axis. Travelling some distance z, such rays would increase the diameter of the light beam from its original value directly behind the collimating lens. Thus, the divergence angle b may be regarded as a measure of the quality of collimation.

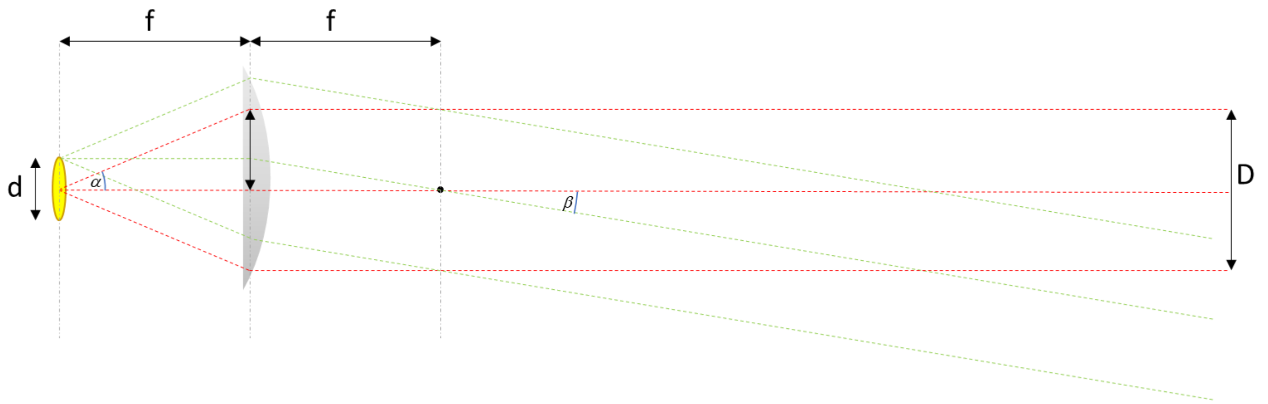
This is shown on the following drawing:

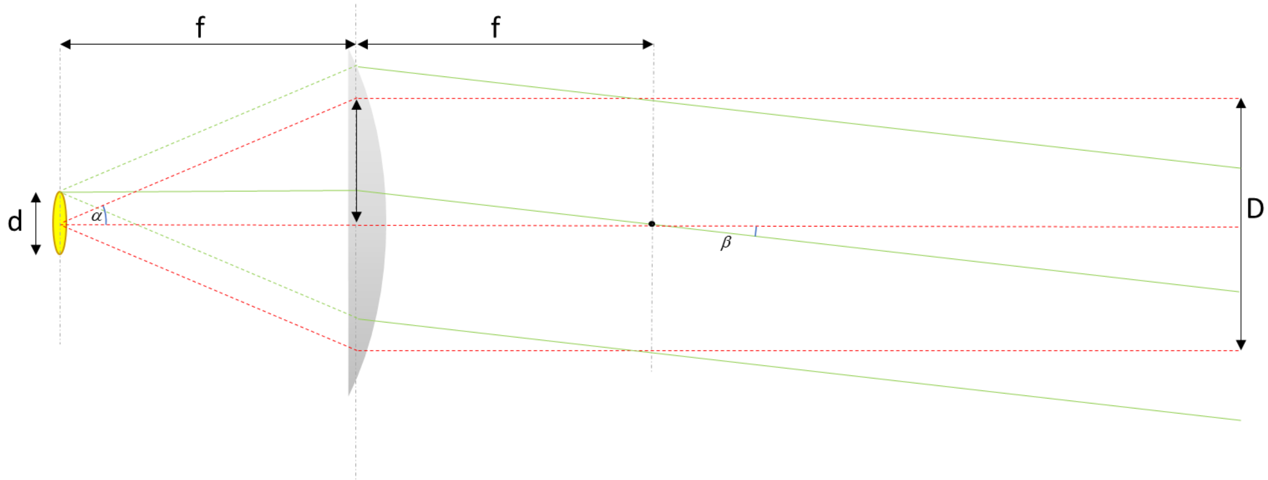


Here, the idea was to produce a well-collimated beam of diameter D (right-hand side). A lens with focal length f was selected such that the entire beam emitted from the fiber with an numerical aperture of NA = sin(a) (= 0.39 in the drawing) and placed at focal distance to the fiber with core diameter d (left-hand side). It can be seen how extreme points of the fiber give rise to rays (shown in green) that propagate under an significantly large angle b with respect to the optical axis.

If, for example, a beam diameter of D = 2mm is sought, and the fiber would be roughly to scale in the drawing, d » 1mm, a very poor collimation results: the green rays would increase the effective diameter of the light distribution roughly by a factor of 2 already after a few centimeters behind the lens.

For a given fiber diameter d and a given fiber NA, the only way to improve collimation, i.e., to reduce b (without loss of light) is to allow for a wider beam diameter D on the right-hand side.





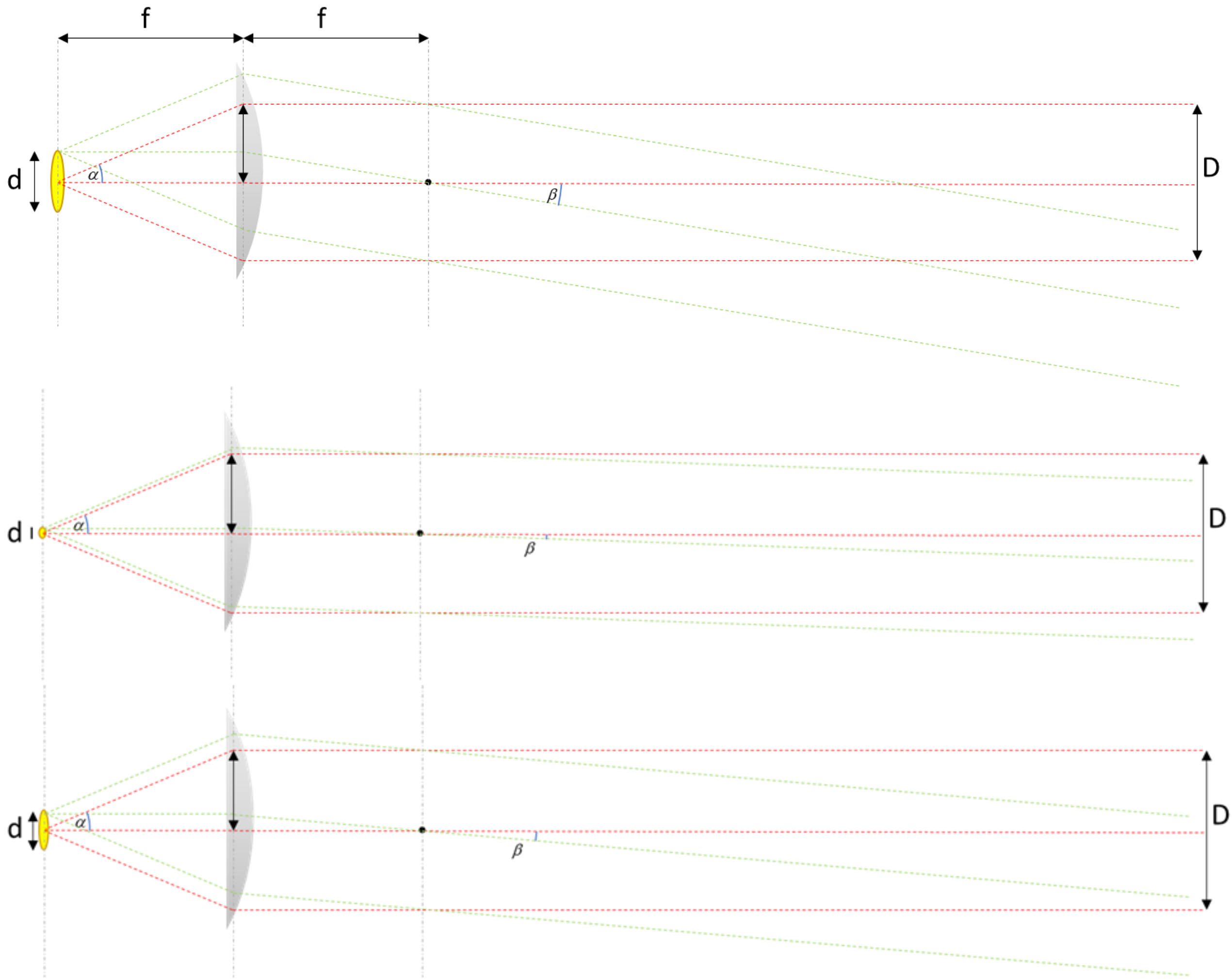
Consequently, larger lenses are required to collect all the light. With large enough lenses and unrestricted beam diameters, it is possible to obtain well-collimated beams for any wanted divergence.

The relation between the diameters and angles is simply given by:

$$D/\tan(\alpha) = D/ \tan(\arcsin(NA) = d/\tan(\beta)$$

NA (fiber)	Fiber d (µm)	Beam D (mm)	Divergence b (°)
0,39	1000	25	1,0
0,39	100	4	0,6
0,39	1000	4	6,0
0,39	1000	2	12,0
0,39	1000	1	23,0
0,39	400	10	1,0
0,39	100	4	0,6
0,22	1000	13	1,0
0,22	400	5	1,0
0,22	100	1,3	1,0

Similarly, one could reduce the fiber diameter right from the beginning. As this would usually also reduce the overall optical output, it may only be possible, if abundant light is available for the given application:



This example illustrates the importance of choosing the right fiber diameter to limit beam divergence. From the drawing it can be seen easily that mm-sized, very well collimated beams (laser-like divergence in the mrad range) would require very small, µm-sized fibers (or sources in general).

This is the case for single mode laser diodes, one familiar example being laser pointers. It is not the case for multimode fibers for transmission of incoherent, broadband light from sources like LEDs or similar. Here, with fiber core sizes in the range of hundreds of micrometers, we are talking about collimated beams of several centimeters in diameter.

If smaller beam diameters are required though, there is no way around using smaller fibers, aperture-limiting diaphragms or other means which unavoidably cut a significant amount of the light.