MDT Element for Beam Shaping

How does it work ?

Unpolarized or circular polarized monochromatic radiation with Gaussian intensity distribution can be transformed into different beam profiles, for example into a flat-top, a hollow cylinder and some more.
Beam shaping with MDT is based on the phenomenal effect of internal conical refraction, where the resulting beam profile always depends on the diameter and wavelength of the incoming beam and the length of the MDT element.
It means that for each diameter and wavelength of the incoming beam only one well defined MDT length will lead to the desired beam profile.
The MDT's are highly transmissive from the near IR down to approximately 350 nm and therefore suitable for laser beam shaping in a broad range.
The setup for beam shaping at minimum consists of an unpolarized laser source and one MDT element, which is oriented for the effect of internal conical refraction.
In case of a polarized laser beam a λ/4-plate has to be used in order to generate circular polarized radiation.

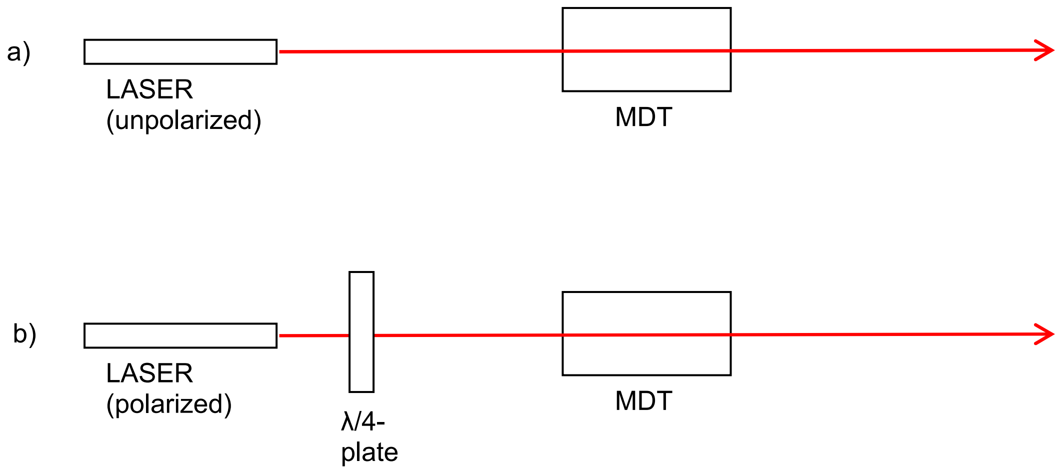

Fig. 1: Realization of Beam Shaping with a) an unpolarized und b) polarized laser beam

Beam shaping with MDT means, that only one and almost quite small MDT element is required, which is quite cheap in comparison to beam shapers, consisting of several micro lenses or diffractive optics.
Additionally the MDT element is able to generate a large number of different beam profiles, beginning with a hollow light cylinder and finishing with the well known "flat-top".
Figure 2 shows possible beam profiles, which result from different diameters of an incoming Gaussian beam at constant crystal length. In some cases also the length of the MDT has influence to the resulting beam profile. Therefore for each desired beam profile, under consideration of the diameter and wavelength of the incoming Gaussian laser beam, the required crystal length has to be calculated with help of complex algorithms and a pc.

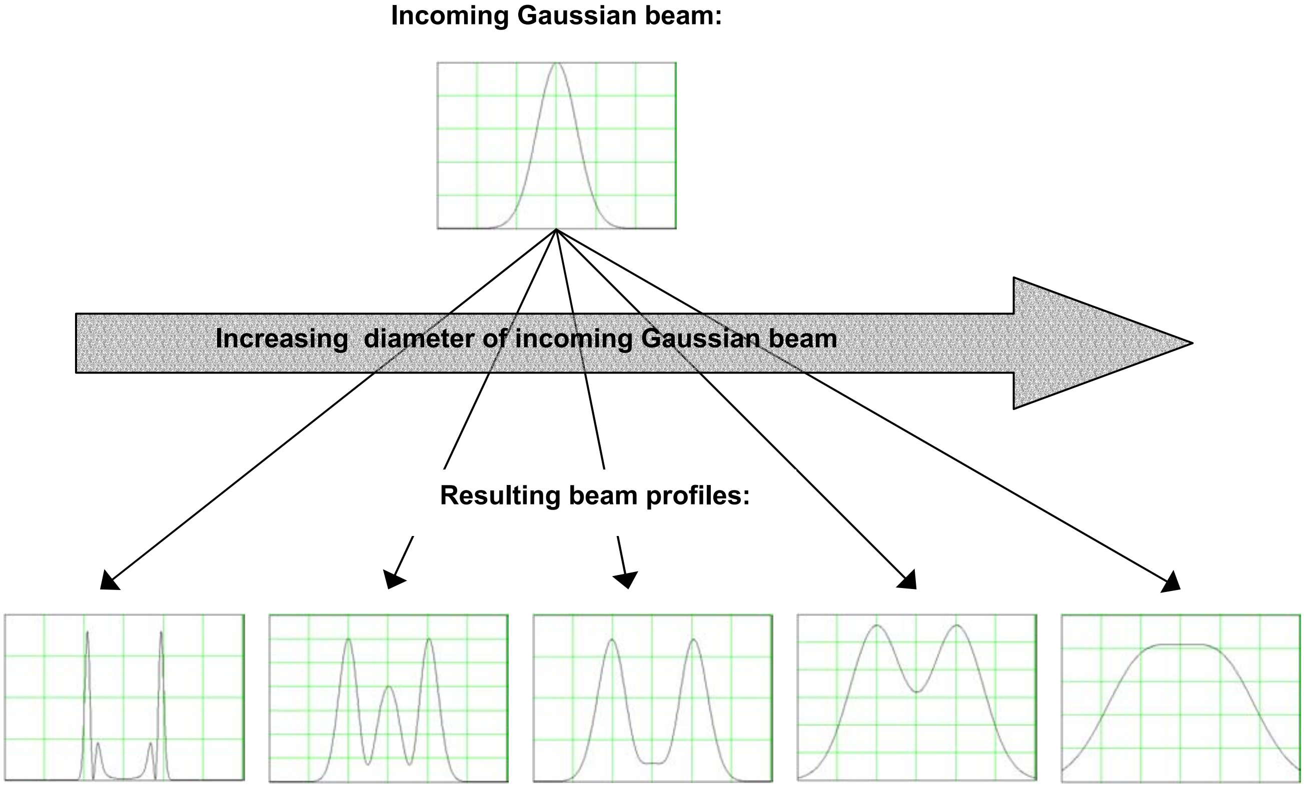

Fig. 2: Beam profiles as result of different diameters of the incoming Gaussian beam at constant MDT length

Adjustment of an MDT element as Beam Shaper

Pre-Adjustment

First it has to be ensured that the MDT element can be fine adjusted with micrometer screws in the vertical and horizontal plane.
The beam shaping MDT element has to be pre-adjusted with an input beam of small diameter with help of the effect of internal conical refraction.
This means that for pre-adjustment the input beam diameter should be smaller than 200 µm and its divergence should be as small as possible. Also the M2-value should be as small as possible and in best case smaller than 10.
For adjustment and also beam shaping the input beam must be depolarized or circular depolarized (i.e. with help of a λ/4-plate).

To get a small input beam diameter you can use a pinhole or also a lens.
Using a lens you must ensure that the Rayleigh length of the focussed beam is at minimum (recommended) two times bigger than the crystal length. Also a combination of pinhole and lens may lead to good results.

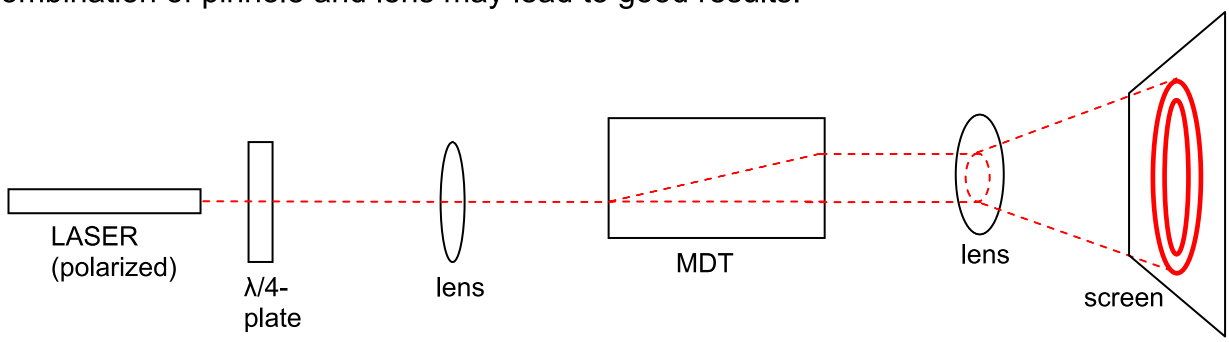

Fig. 3: Example of pre-adjustment for beam shaping in case of visible laser radiation

Placing a lens of small focal length behind the exit facet of the MDT these cylinders can be projected onto a screen and seen as two light rings, where the inner ring is of lower intensity than the outer one. Also a CCD camera is suitable to see the rings.
If the crystal is not adjusted you will see two small spots onto the screen or exit facet.
Rotate the λ/4-plate as long as both spots seem to have the same intensity.
Now rotate the MDT horizontally as long as both spots are vertical aligned to each other.
In the last step you have to tilt the crystal vertically as long as the spots transform (quite quickly) into the mentioned light rings, known as “Poggendorff rings”, resulting from internal conical refraction within the MDT element.
To achieve the Poggendorff rings the precision of adjustment has to be about 0.2 °.

Final Adjustment for Flat-Top Generation

After the pre-adjustment all additional optical components in front and behind of the MDT have to be removed, except the λ/4-plate if you are working with a polarized laser beam. Up to here don't change the position of the MDT !
Behind the MDT you have to place a CCD camera to watch the beam profile.
Now tilt carefully the MDT only with help of micrometer screws in the horizontal and vertical position as long as your CCD cam quite suddenly sees a homogeneous flat-top beam profile.
The required precision of adjustment is approximately 0.2 °.

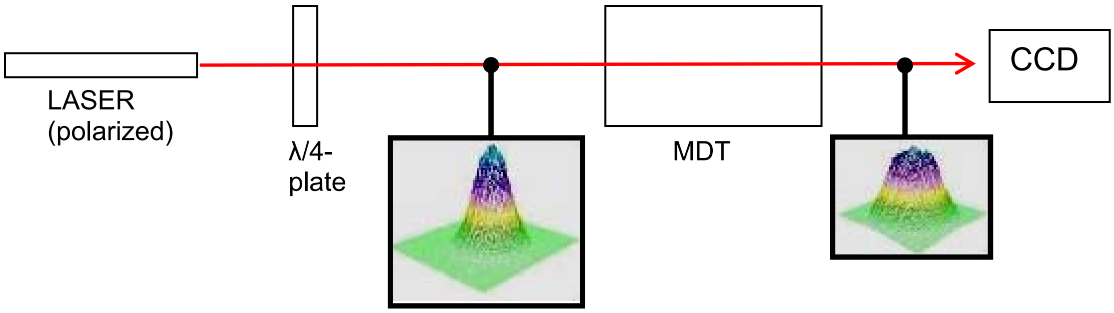

Fig. 4: Typical setup to receive a flat-top beam profile with one MDT element

Note:

- ***Beam shaping (and also conical refraction) only works well with depolarized or circular polarized monochromatic radiation.***

- ***For each wavelength and diameter of the incoming beam a well defined length of the MDT element is required to achieve a flat-top. Therefore you cannot use one MDT for different wavelengths or diameters of the input beam.***