Adjusting the focus position of fiber collimators

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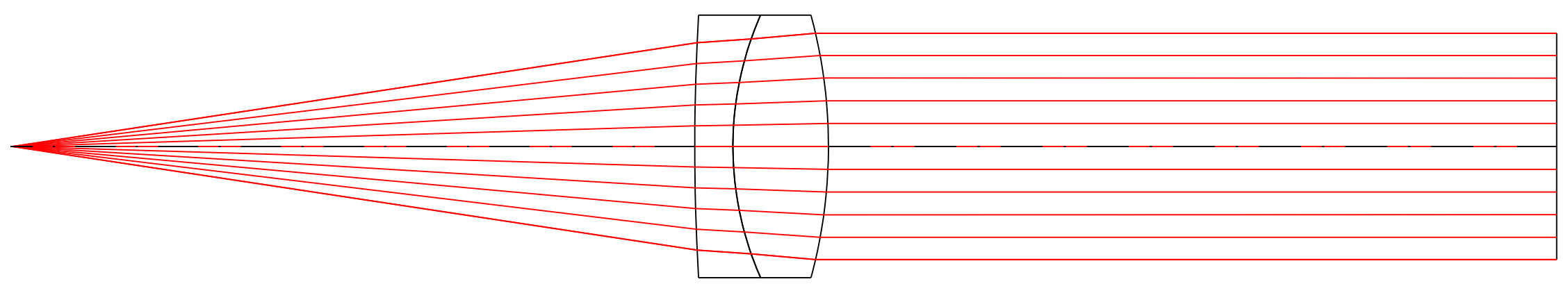
Overview

This poster describes simple methods to adjust the focus position of fiber collimators, that are also applicable e. g. in the infrared, where only limited test equipment might be available.

Target

The focusing procedure shall adjust the fiber exit position to the entrance focal plane of the collimator optics. At the collimator exit

- in geometrical optics all rays emitted by the fiber core are parallel to each other,
- in physical optics a beam waist is generated at the exit focal plane of the collimator.



The waist radius of the Gaussian beam is given by

$$w_0 = f \cdot \varphi_f$$

where f is the collimator's focal length, and φ_f is the aperture angle of the fiber. The beam radius $w(z)$ is a function of the axial distance z to the waist position

$$w(z) = w_0 \cdot \sqrt{1 + \left(\frac{z}{z_0}\right)^2}$$

and the far field divergence angle is

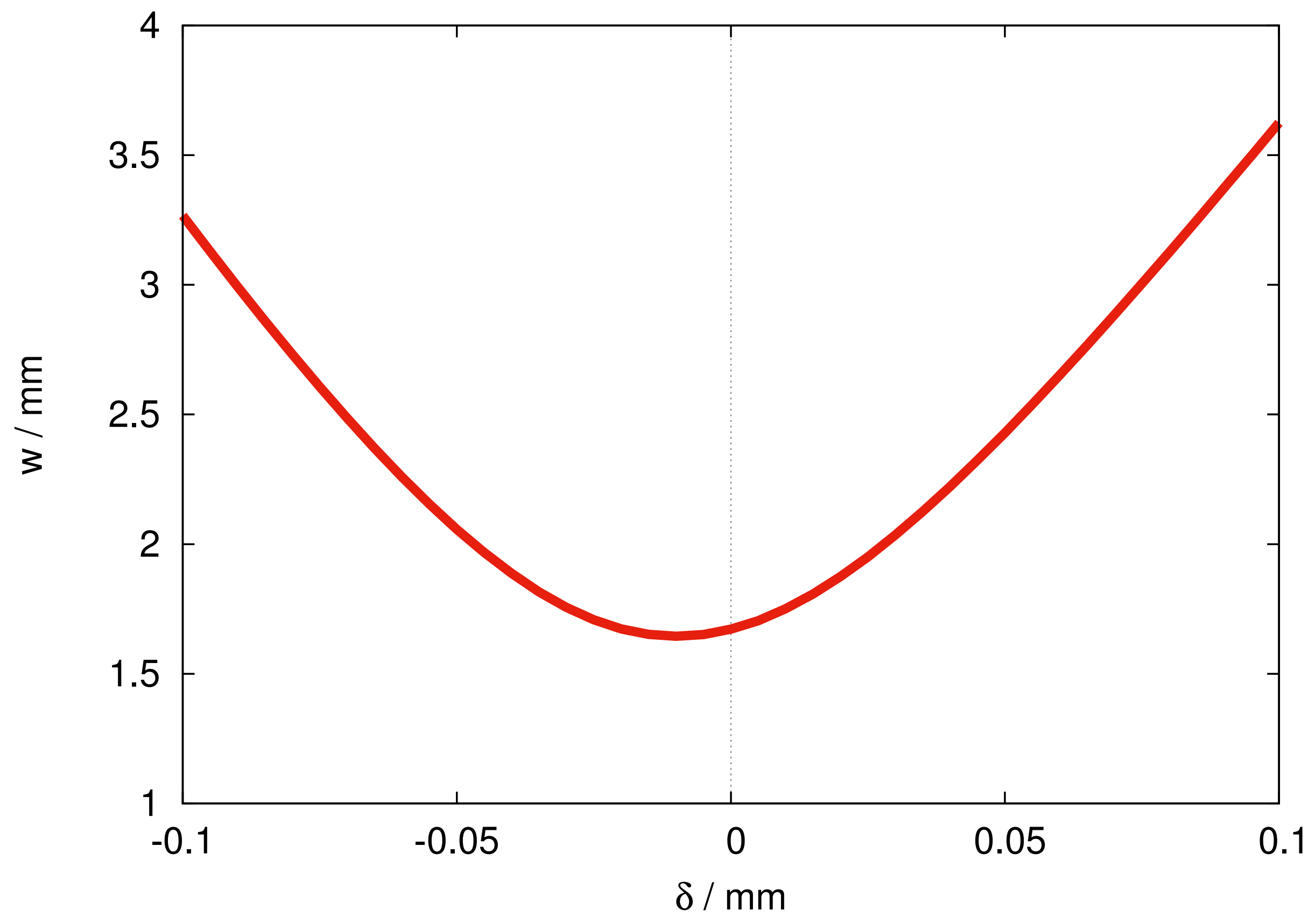
$$\varphi = \frac{\lambda}{\pi \cdot w_0}$$

where λ is the wavelength of the beam. The Rayleigh length is given by

$$z_0 = \frac{\pi \cdot w_0^2}{\lambda}$$

Small Collimators

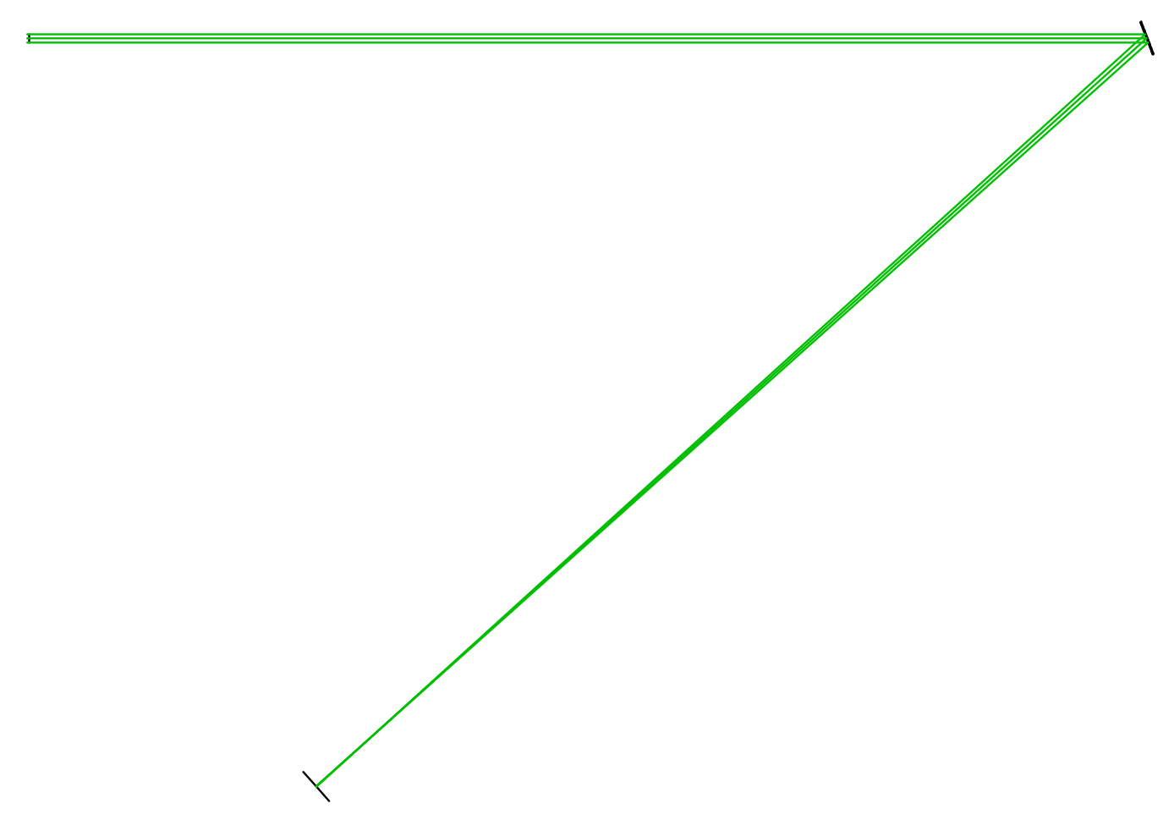
Collimators having a short focal length generate Gaussian beams with small waist radii and short Rayleigh lengths z_0, and the beams can easily be observed at a distance $z \gg z_0$. A paraxial analysis using ABCD matrices shows, that the beam radius $w(\delta)$ is minimal at $\delta \approx 0$, where δ is the focus error of the fiber position. The following graph describes this situation for a collimator $f = 3.16$ mm and a beam with wavelength $\lambda = 1550$ nm and $z_0 = 182$ mm:



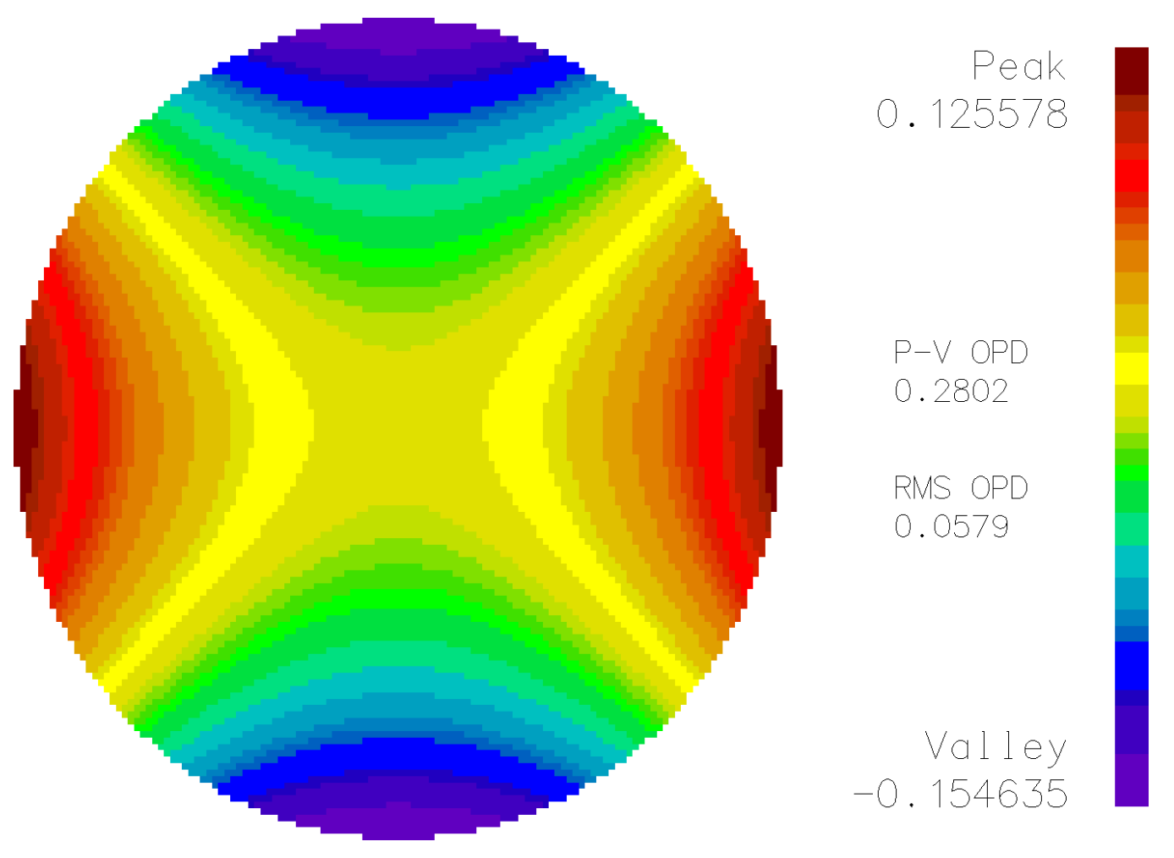
Larger Collimators

For larger collimators the Rayleigh length increases $z_0 \sim w_0^2$ resp. $z_0 \sim f^2$, and z_0 becomes larger than typical optical benches. Then $w(\delta)$ is a monotone function for $\delta \approx 0$, and the estimation of the correct w is difficult to do with normal cameras. A comparison of w at different distances is rather complicated, and therefore an alternative setup has been used: With an additional $2f$ optical system the collimator's exit beam waist is re-imaged to a much smaller secondary waist, and the complete system behaves like a small collimator with a minimum waist radius close to the optimum focus position.

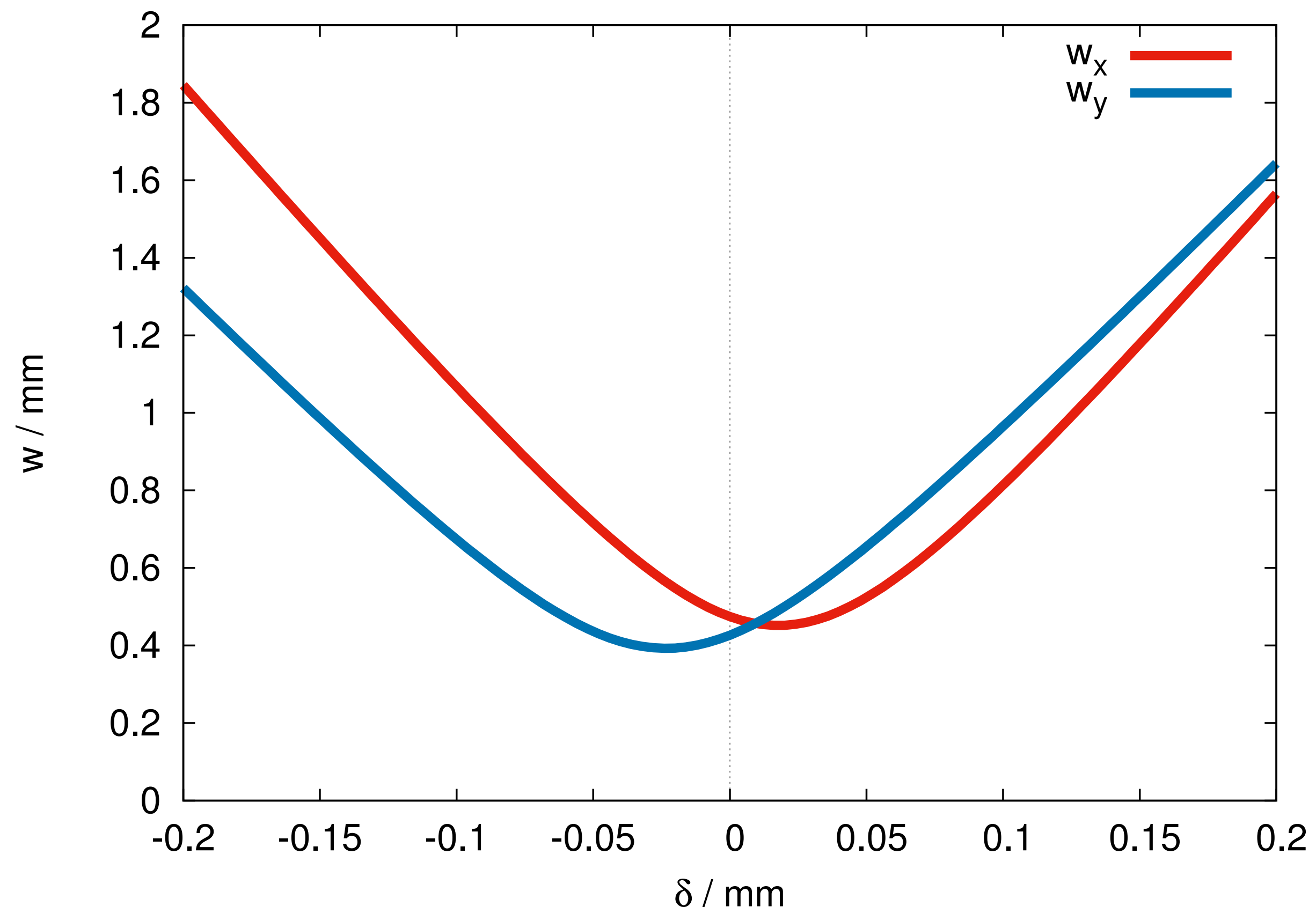
For the focusing of a collimator with $f \approx 23.6$ mm the $2f$ optics consists of a concave spherical mirror with radius $R = 3868$ mm and $f_2 = 1934$ mm, which is used at 21° incident angle:



Due to the off-axis use the mirror introduces significant astigmatism:



This astigmatism splits the axial horizontal and vertical waist positions and generates an elliptical beam profile. Very close to the best focus position the orientation of the ellipse changes from horizontal to vertical, and the beam profile becomes circular:



The small deviation of the position with the most circular beam profile from the best focus position can be corrected subsequently. The visual detection of this circular beam profile is even more sensitive than the search of the minimum waist radius.

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