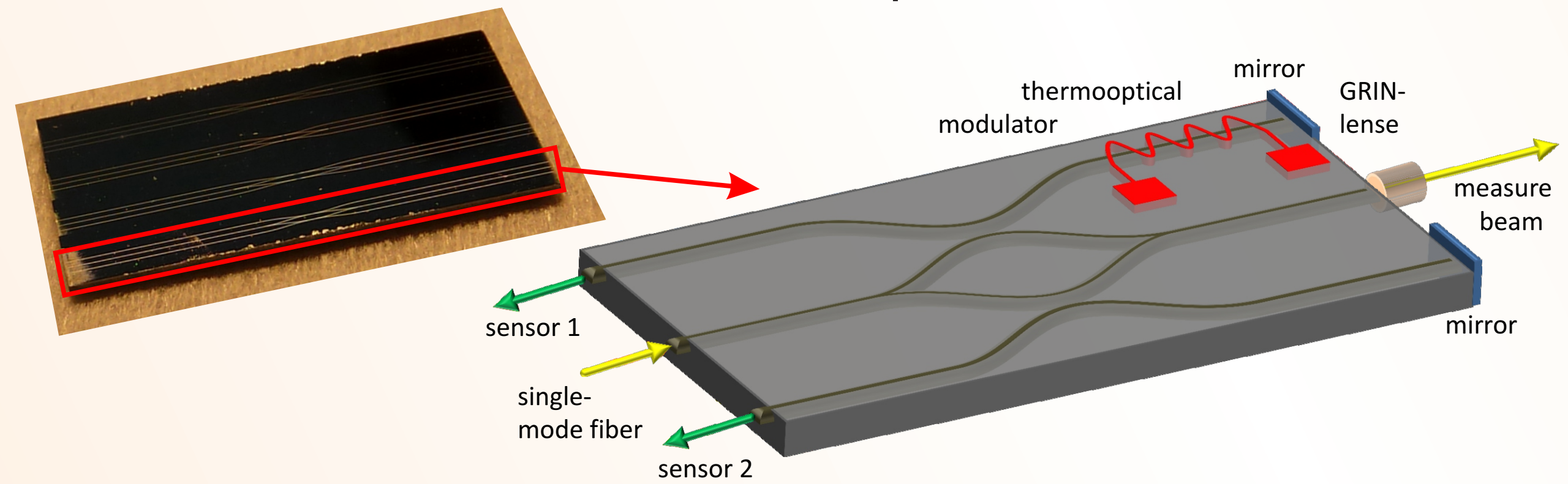


Integrated Hybrid GRIN Lenses

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Wafer-level optics



Concept and prototype of a wafer-level interferometer for displacement measurements

Advantages

- low cost by mass production (semiconductor technologies)
- high reliability
- high precision in geometric dimensions and positions (defined by lithography mask)
- can be combined with integrated photonic elements on the same substrate
- high refractive index range

Exemplary applications

- efficient coupling structures between integrated optics and free space
- beam shaping for integrated laser diodes

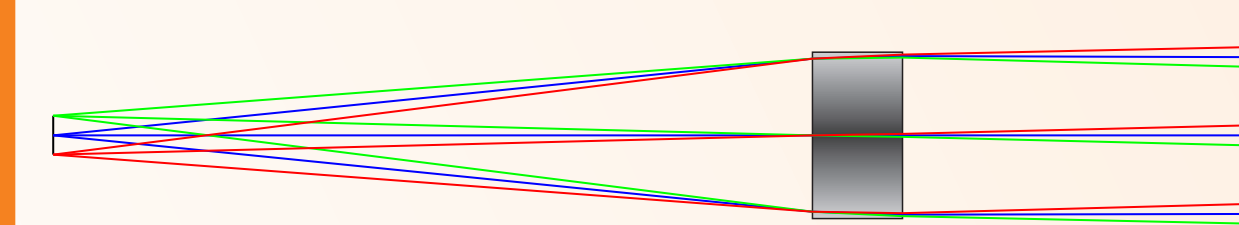
Challenges

- 2D structuring for 3D functionality
- High transmittance

Design

Design Principle: Independent wavefront control in two perpendicular directions

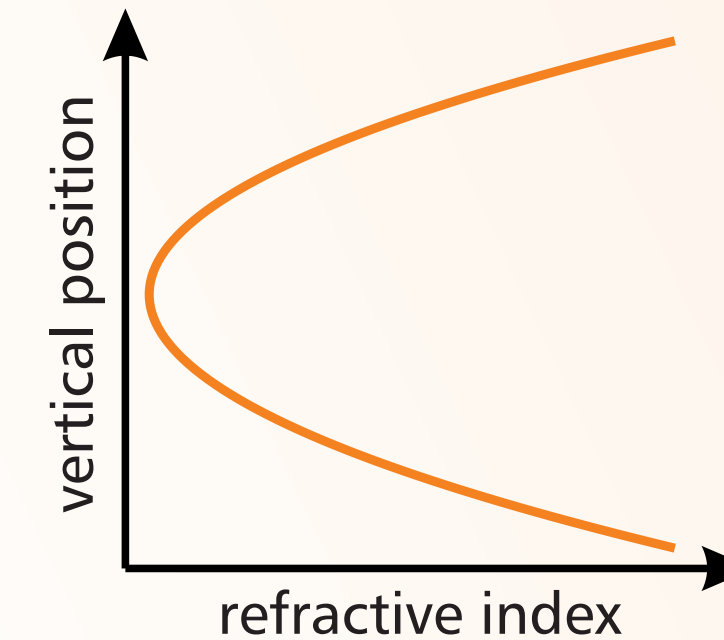
Direction 1: Perpendicular to the substrate



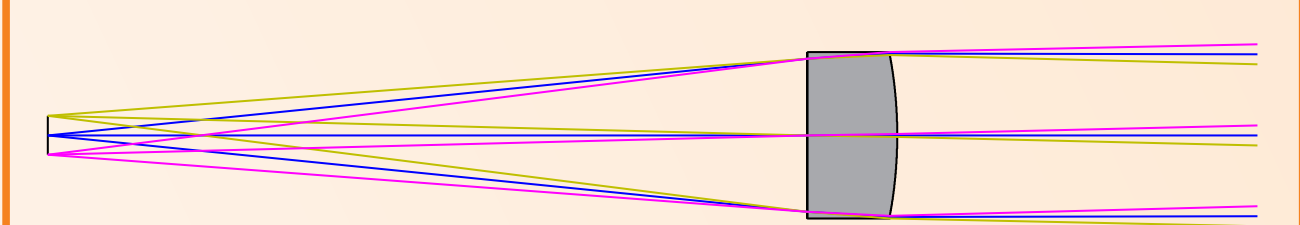
- GRIN element, variation of the refractive index during the layer deposition process

- Description of the refractive index profile:

$$n(y) = n_0 + n_1|y| + n_2|y|^2 + n_3|y|^3 + \dots$$

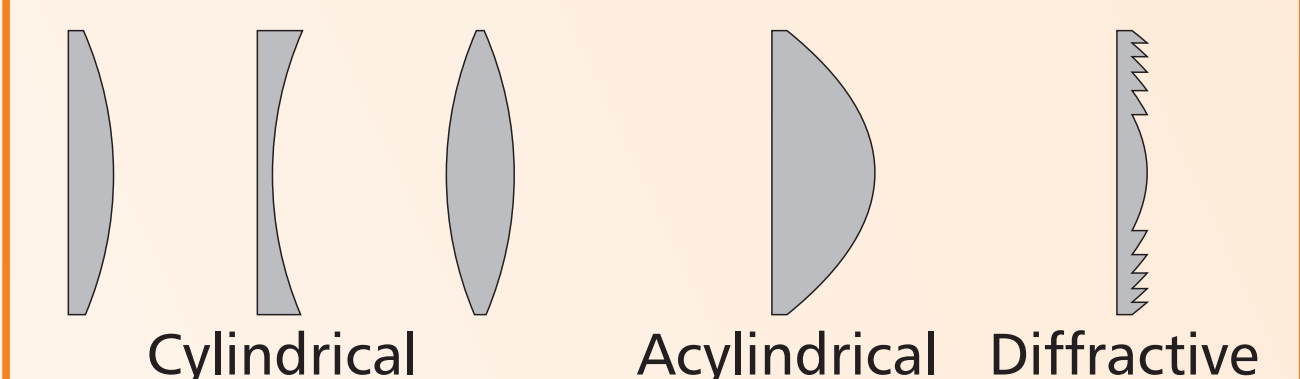


Direction 2: Parallel to the substrate



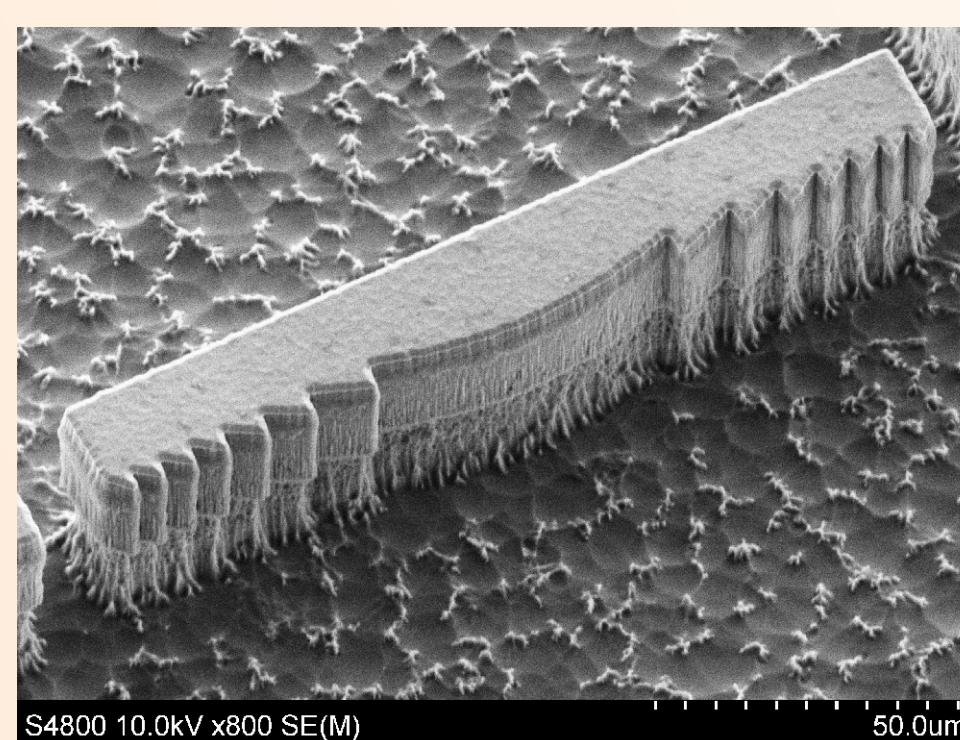
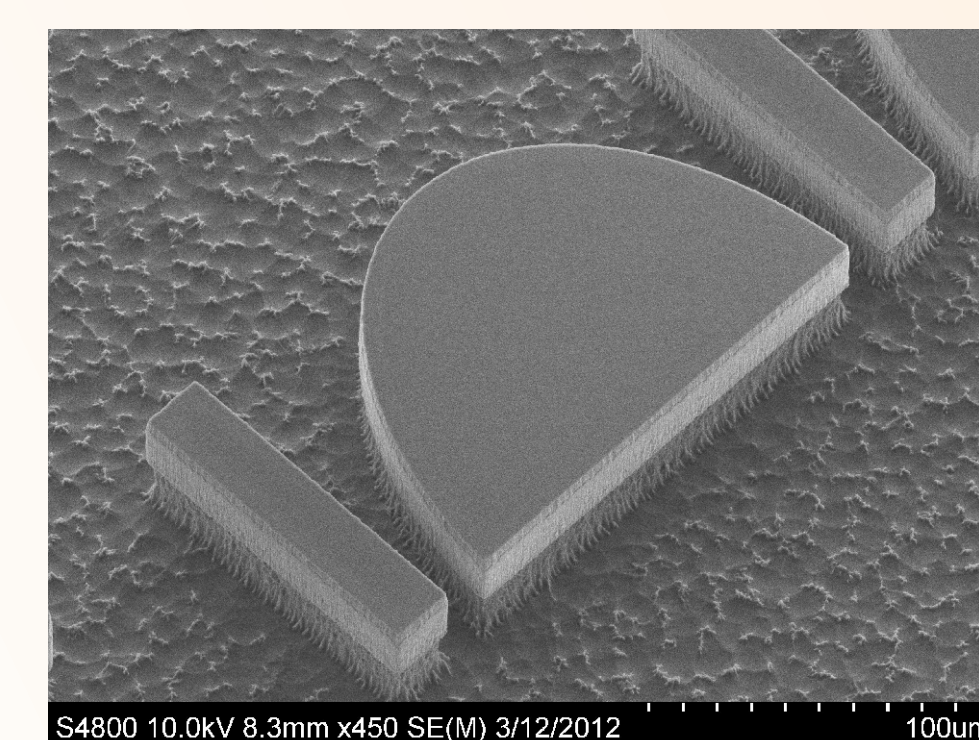
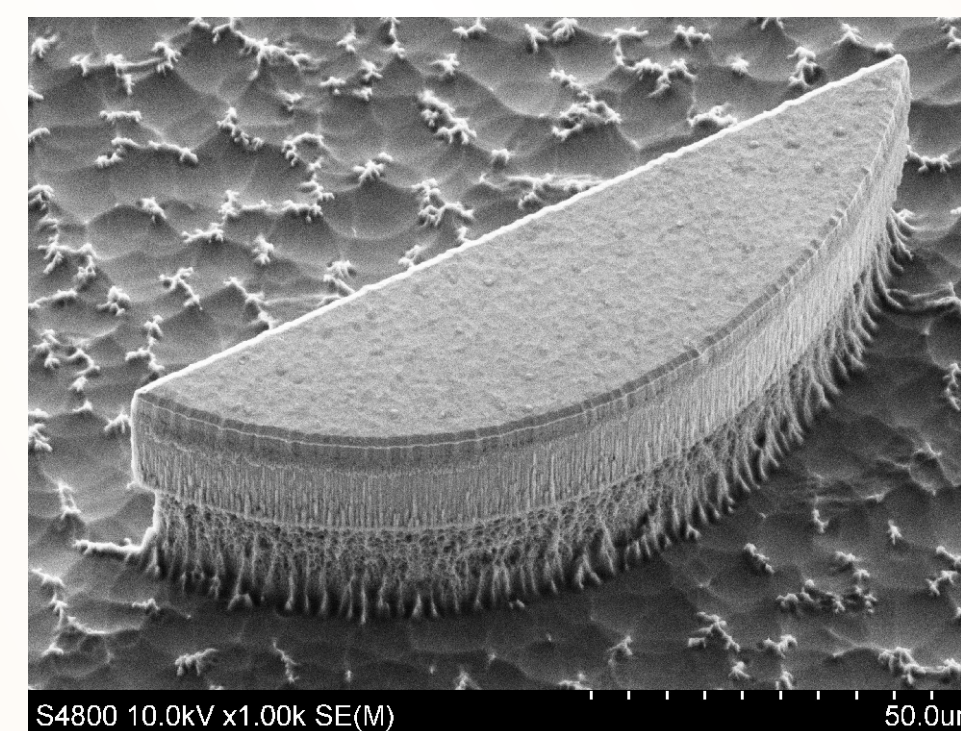
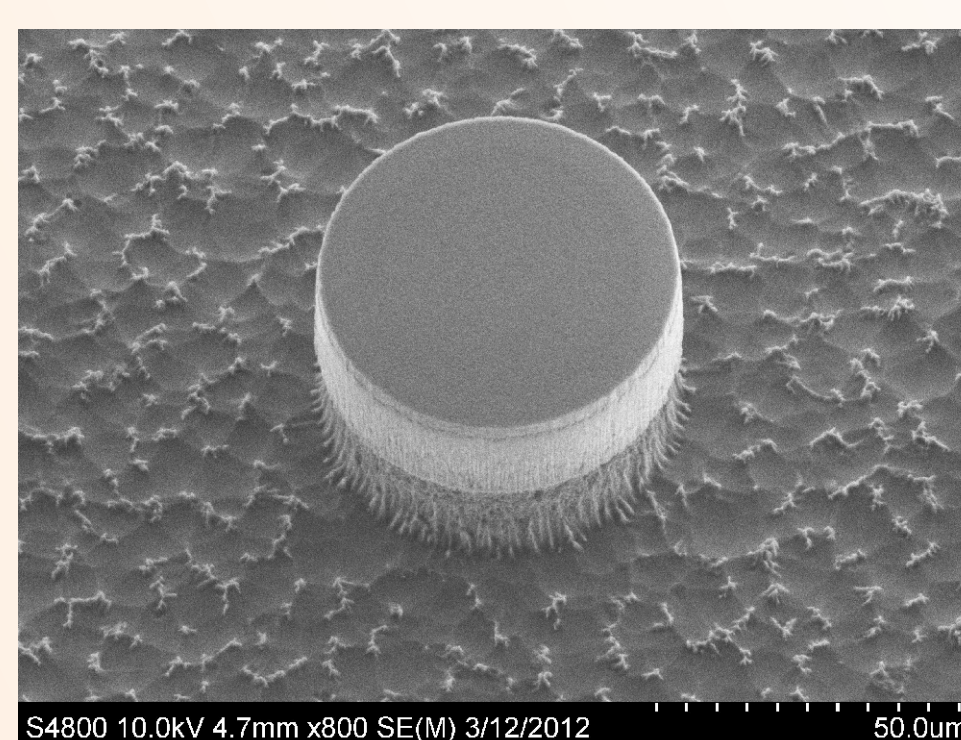
- Etching process with perpendicular, optical quality side walls

- Element shape determined by 2D-profile of the lithographic mask



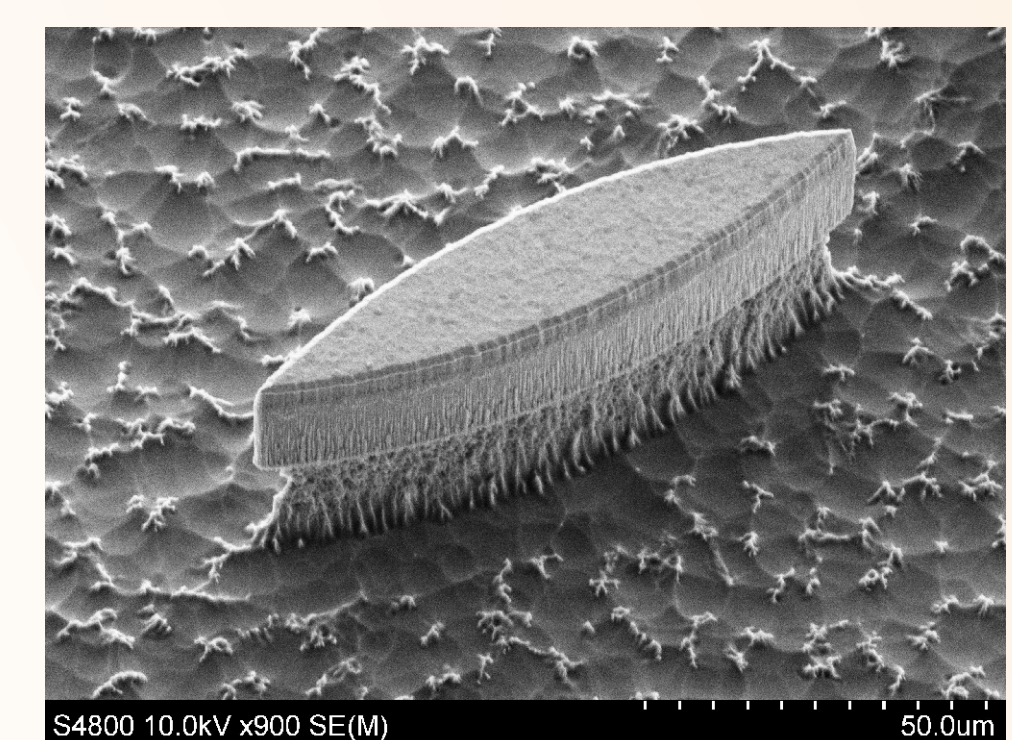
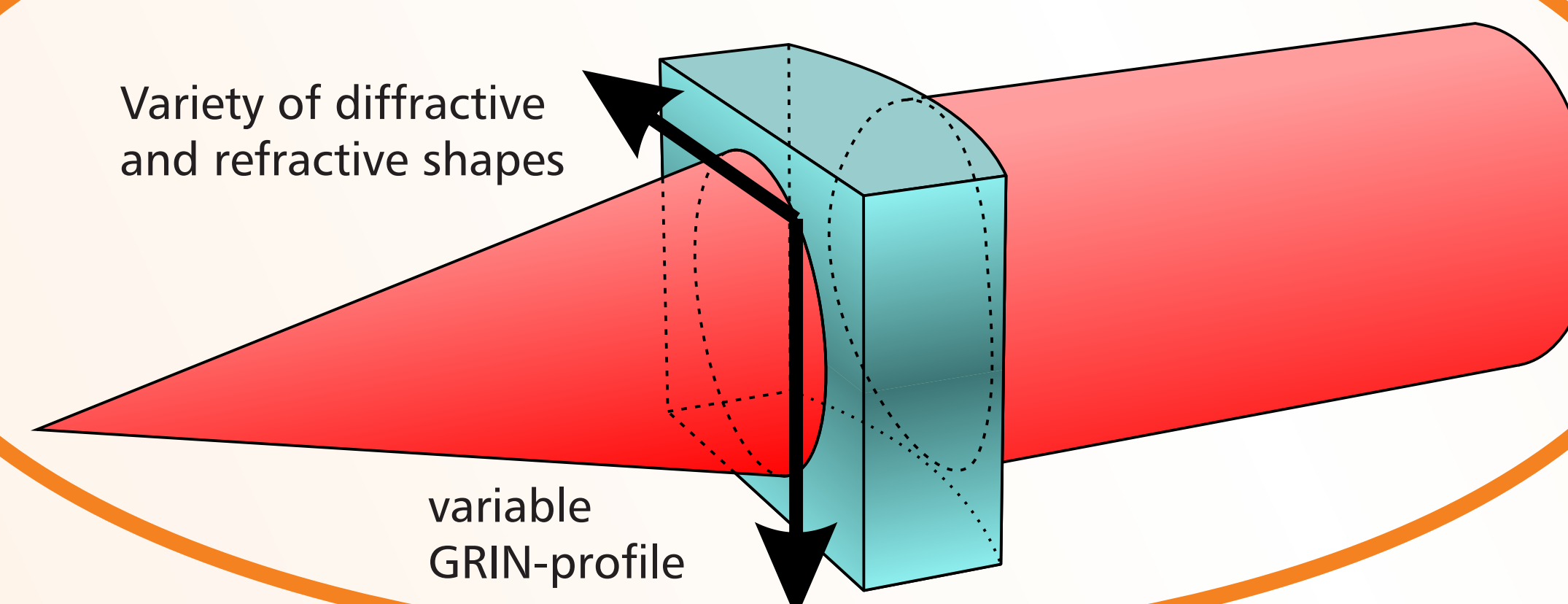
Design process

- Raytracing-based optimisation
- Simultaneous variation of the refractive or diffractive shape and the GRIN-profile
- Merit function based on the wavefront aberration of the output beam



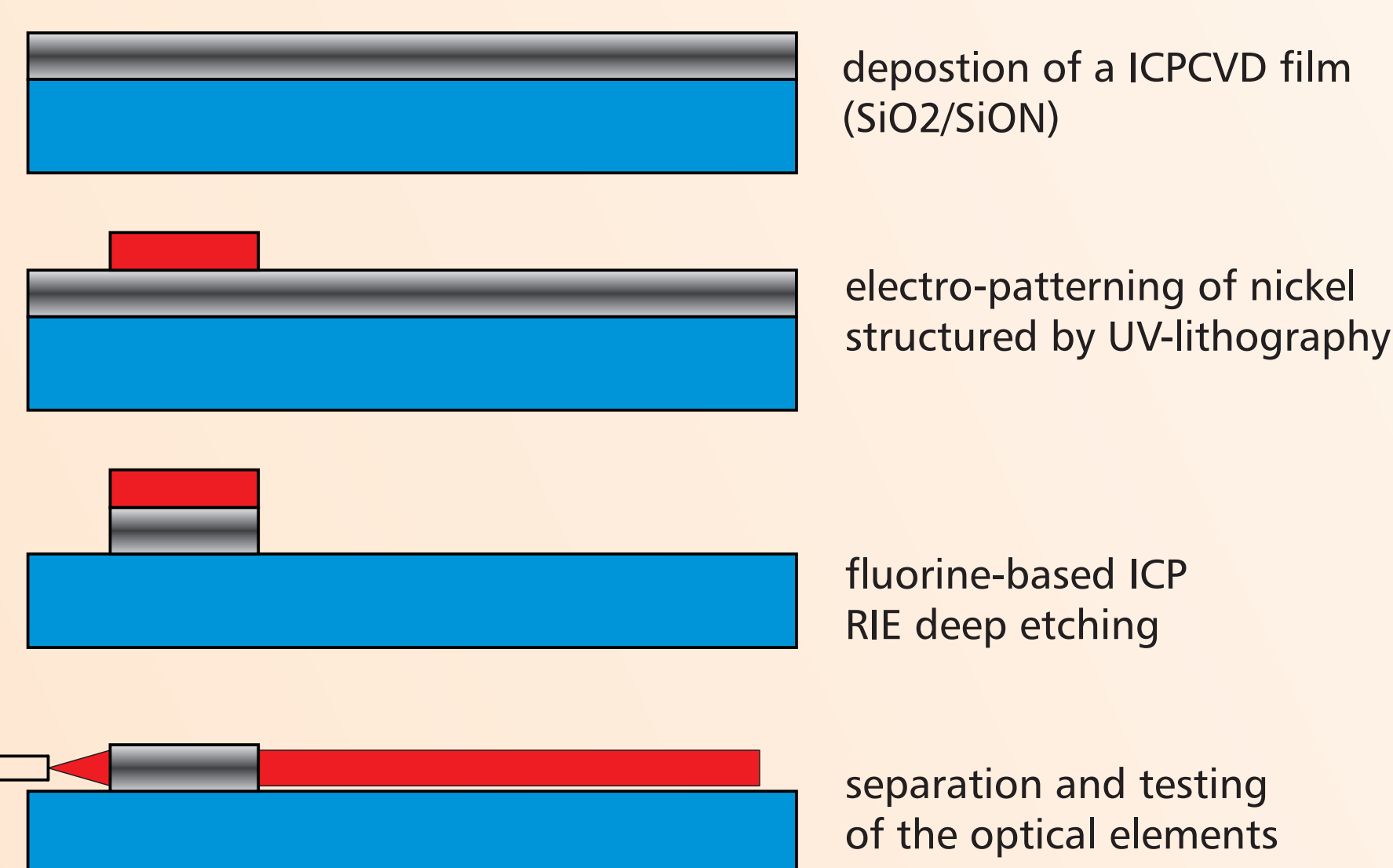
Wafer-level optics with a huge variety of shapes

Variety of diffractive and refractive shapes



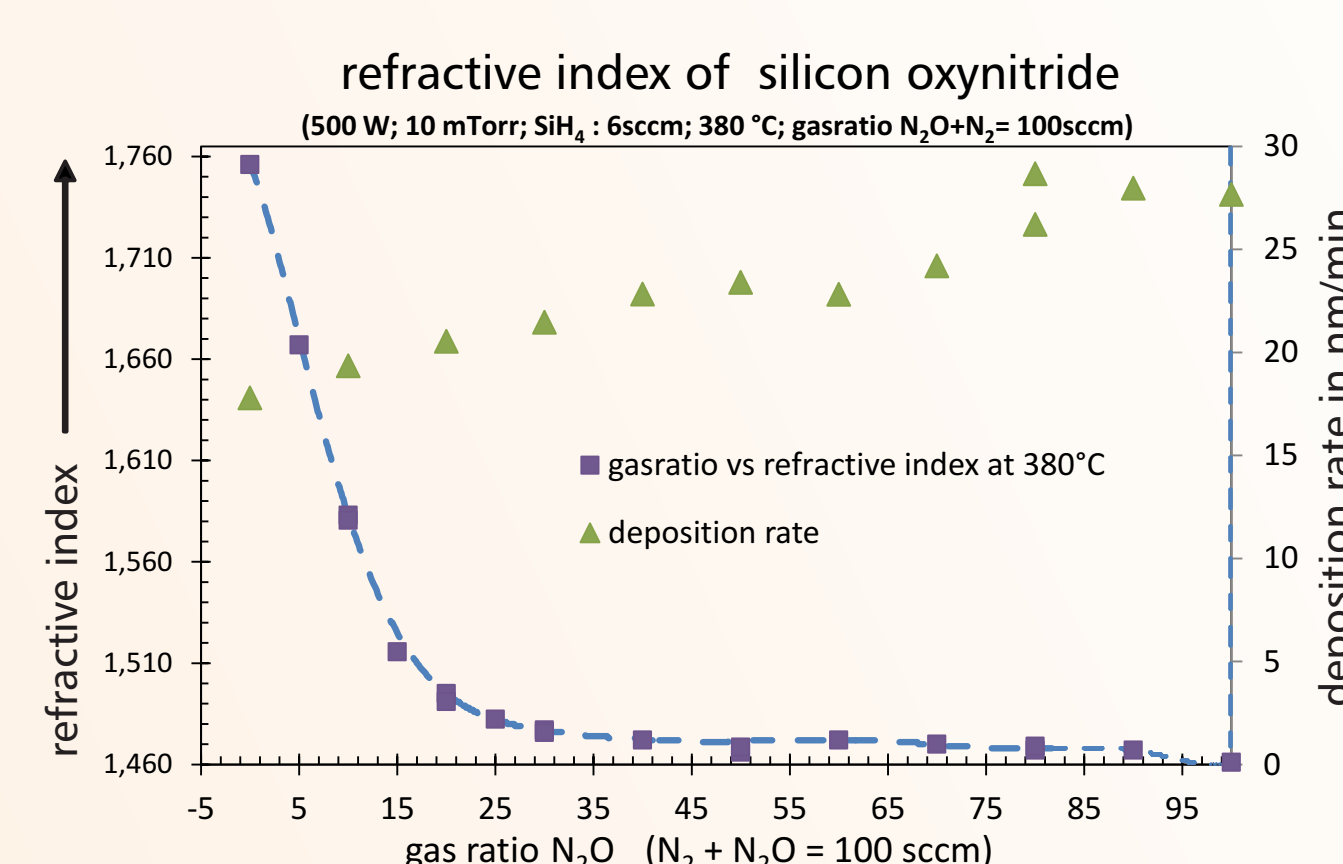
Technology and experimental results

Fabrication using semiconductor technologies

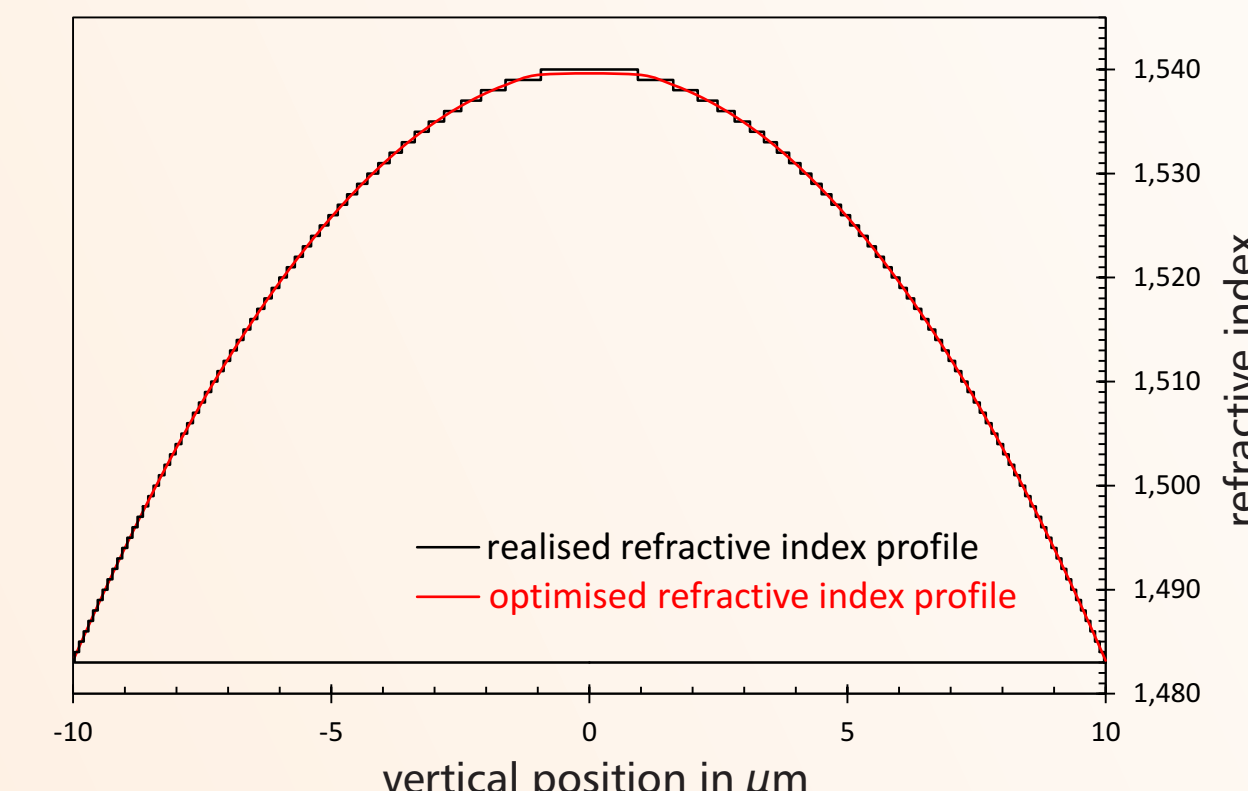


Achievable parameters

- Maximum height of the structures dependent on deposition time; structures with 30µm GRIN layer height realized
- Realized minimum feature size: 2 µm (DOE period)
- Possible refractive index range: 1,47-1,85



stepped index profile of the produced elements

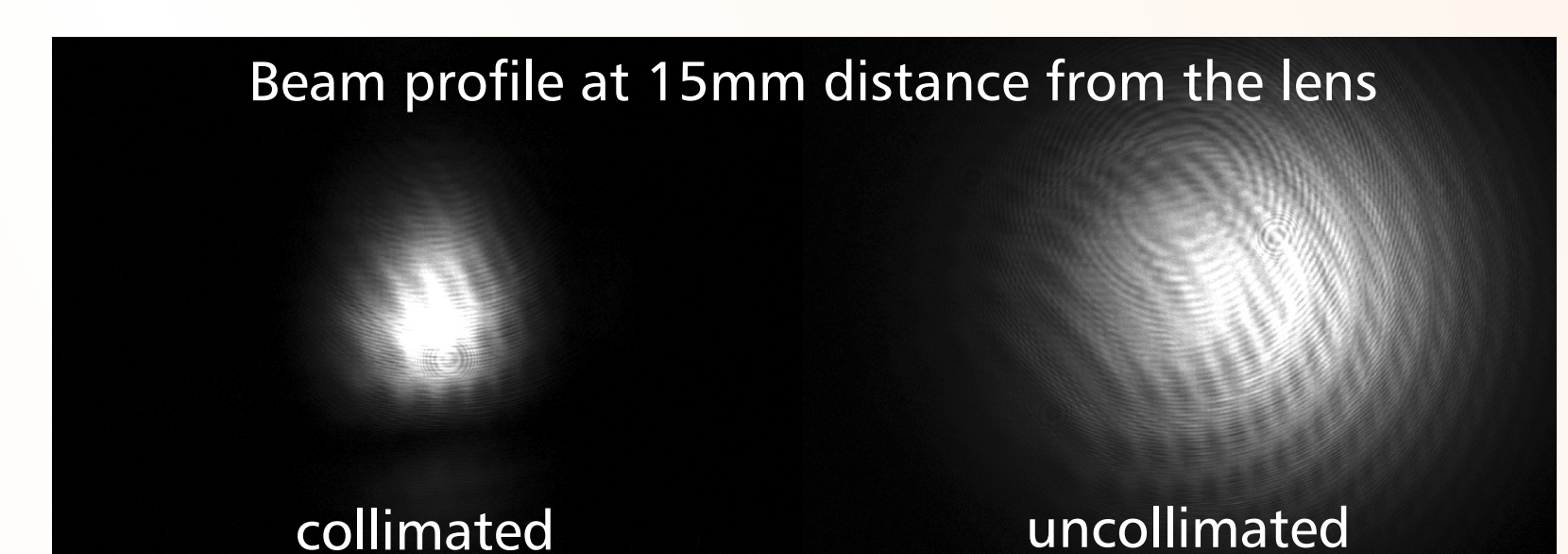


Experimental setup for laser beam collimation

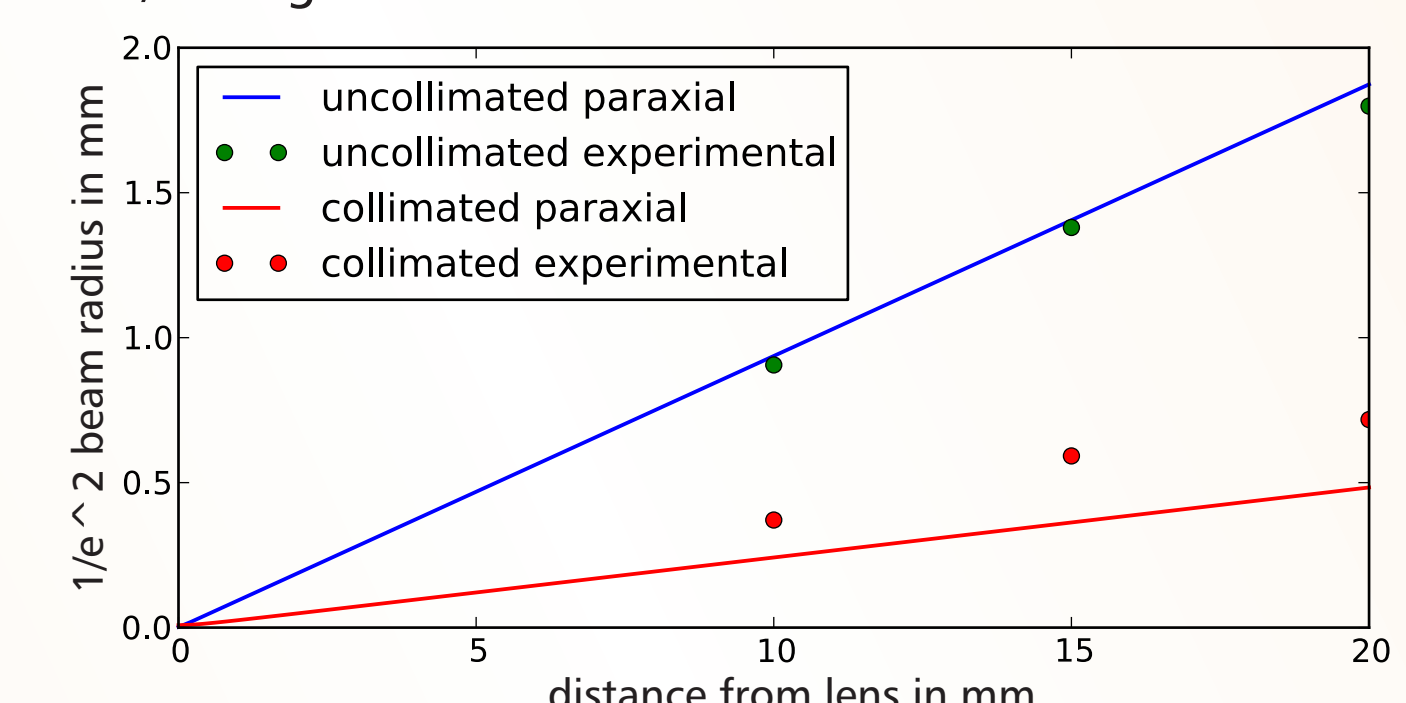
$$NA = 0.1$$

$$2w_0 = 4.3\mu m$$

$$f' = 89\mu m$$



1/e^2 gaussian beam radius behind the GRIN lens



References

- [1] J.-i. Shimada, O. Ohguchi, R. Sawada: Gradient-index microlens formed by ion-beam sputtering, Applied Optics 31 No. 25, 5230 (1992)
- [2] D.R. Beltrami, J.D. Love, A. Durand et al: Planar graded-index pecvd lens, Electronic Letters 32 No. 6, 549 (1996)

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