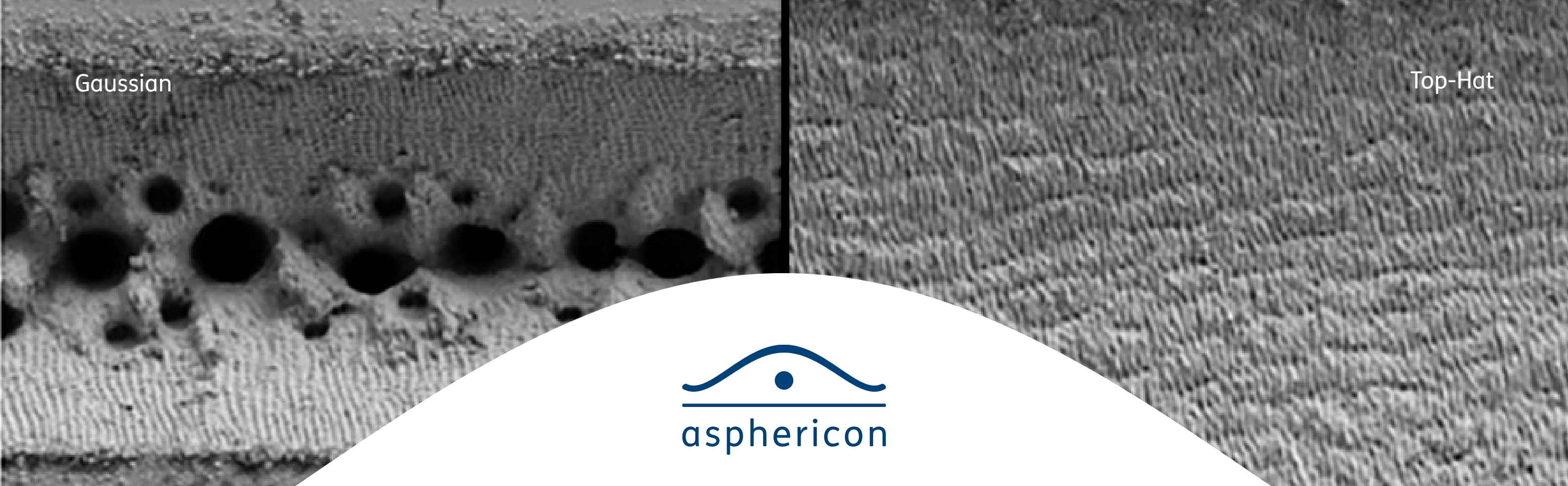
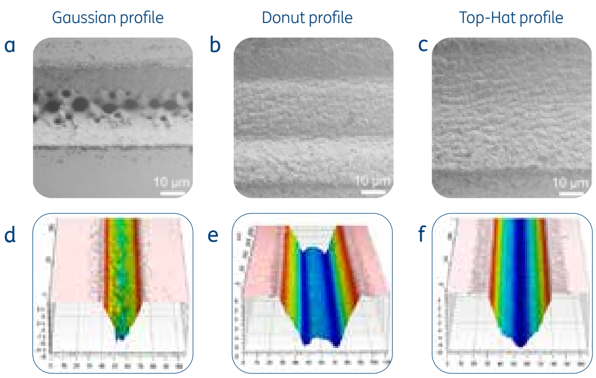


Improving laser material processing with beam shaping

Project description: Beam shaping is especially suitable for laser material processing, such as cutting, welding and marking in the field of micromachining. Although Gaussian intensity distributions can be used to realize small structure sizes by direct material removal, there are weaknesses regarding removal depth and quality. The intensity decreases at the edges of the beam and thus causes inhomogeneous ablation. In addition to optimizing the laser and processing parameters, the adaptation of the focal intensity distribution offers great potential for high-precision results. In cooperation with Otto Schott Institute of Materials Research (OSIM) in Jena, asphericon analyzed various tailored intensity distributions (e.g. Top-Hat, Donut) regarding their suitability for femtosecond laser material processing on micro- and nanoscales such as cutting and marking.

Project realization: To obtain different focused intensity distributions (especially Top-Hat) asphericon's a|AiryShape was used. It first converts a collimated Gaussian beam into a collimated Airy- or Bessel-sinc shaped intensity profile by means of a phase plate. Second, a focusing lens performs a Fourier transformation on the input intensity function and the corresponding Fourier counterpart occurs in its focal plane. The a|AiryShape allows several intensity distributions (e.g. Top-Hat, Donut) to be generated in different working planes with one set-up, while convincing by its extremely short overall length (17.3 mm). Fig. a - c show the line scans performed with different beam profiles. Compared to the (inhomogeneous) Gaussian profile (Fig. a/d), beam profiles generated with a|AiryShape (b/e: Donut; c/f: Top-Hat) show a very homogeneous ablation. The beam shaping device is suitable for working with a scanner and F-Theta lens as commonly used for material processing.

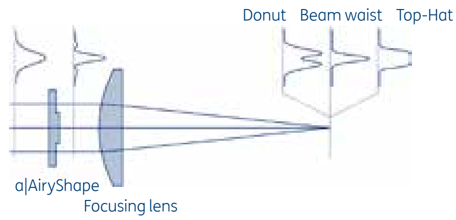
Focal intensity distributions on stainless steel



Gaussian	Donut	Top-Hat
ablation depth ~ 13 µm ablation width ~ 60 µm	ablation depth ~ 20 µm ablation width ~ 35 µm	ablation depth ~ 16 µm ablation width ~ 40 µm

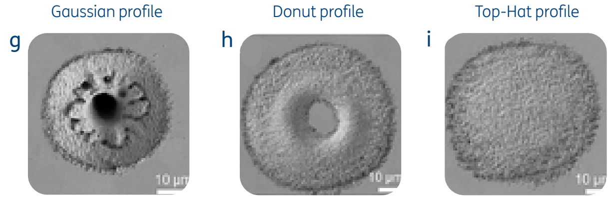
- a - c: scanning electron microscope (SEM) micrographs of channel-like structures of pulses fabricated by fs-laser ablation (scanning single line v=0.1 m/s, 1000 iterations, E_{im}=11.3 µJ as function of the number of overscans using different focal intensity distributions)
- d - f: white light interference microscopy (WLIM) micrographs, 3D geometry of corresponding channels obtained from ten overscans
- Donut and Top-Hat result in larger channel widths and smaller ablation depths due to distribution of the pulse energy on a larger area

Principle layout of a|AiryShape



Consisting of phase plate and focusing lens, with correlated intensity distributions in the focal region

Results of single spots on stainless steel



- g - i: SEM micrographs of ablation spots obtained from irradiating surface as a function of fs-laser pulse (N=200); E_{imp}=13 µJ
- Donut and Top-Hat have smaller ablation depths (range of 5-10 µm) due to distribution of the pulse energy on a larger area

A. Möhl, S. Kaldun, C. Kunz, F. A. Müller, U. Fuchs, St. Gräf: „Tailored focal beam shaping and its application in laser material processing“, In: Journal of Laser Applications, Volume 31, Issue 4, Nov 14 2019, https://doi.org/10.2351/1.5123051

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