MULTI-MICRO-AXICON IMAGING SYSTEM

Niklas Weber, Andreas Seifert, Dominik Spether, Hans Zappe
Department of Microsystems Engineering
University of Freiburg
Georges-Köhler-Allee 102, 79110 Freiburg, Germany
andreas.seifert@imtek.uni-freiburg.de

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Self-reconstructing Bessel beams, usually generated by means of axicons [1], allow adjusting of depth of focus [2] and imaging around opaque barriers. We demonstrate here a new triple-axicon design and miniaturized realization based on silicon optical micro-bench technology capable for implementation in endoscopic imaging. The micro-axicons with a diameter of 1 mm are fabricated by multi-step molding and supported in Si frames of 1.5 x 1.5 mm$^2$. A new optical design consisting of one concave axicon, and two convex axicons operating as telescope, allows the adjustment of depth of focus $L_B$, and axial displacement $\Delta L_B$ of the Bessel beam in a highly compact optical layout compared to conventional telescopic setups (size scaling: factor 5 – 10), as sketched in Fig. 1. The configuration can be adjusted by varying the axicon angles $\gamma$ and the distance between the first two axicons $L_{1,2}$. Figure 2 reveals the advantage of using Bessel beams instead of Gaussian optics. The self-reconstructing properties are demonstrated by an OCT (optical coherence tomography) image of an onion skin with copper wires at the surface. In case of normal lenses, shadowing below the opaque barriers occur as expected. Using the optical micro-bench with the triple-axicon design, obscuration is virtually eliminated and structures are even visible beneath the wires. The predicted depth of focus, focus shift and resolution with values of $L_B = 3.7$ mm, $\Delta L_B = 1.6$ mm, and $2 \times R_B = 11 \mu$m could be validated experimentally; $R_B$ denotes the radius of the inner Bessel ring. The modular and highly flexible micro-optical-bench concept facilitates a variety of different optical setups and functionalities. By adding adaptive optics, lateral resolution and depth of focus, for example, can effectively be tuned making further imaging options possible.