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# Fabrication Method for Side Viewing Miniature Optical Elements with Free-Form Surface Geometry

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## Technology description

Current methods for fabricating side viewing optics include flat prism, gradient index element combined with a flat prism, and angle polished fused ball lens. A flat prism at the end of a fiber optic or fiber optic bundle can create a side firing probe but lacks a focusing element, affecting the collection efficiency and imaging resolution. This can be addressed with a gradient index element, but variations of index of refraction and absorption of dopant with wavelength leads to chromatic aberrations and limits the useable wavelengths of the probe. Additionally, the circular symmetry of the doping profile prevents correction of astigmatism introduced by a sheath. Alternatively, angle polished fused ball lenses can be used but the size of the ball is limited by constraints on the fusion process, thus limiting its application to small fibers and short working distances. Chromatic aberrations are also present with this design. Here, astigmatism introduced by a sheath can be addressed by creating elongated balls but the process used to obtain the right shape is lengthy and requires multiple trials to optimize the fusion recipe. Finally, the angle polished ball lens relies on total internal reflection so use of the element in liquids requires the probe tip to be fully enclosed.

Researchers at the University of California, Davis have developed a method that enables the fabrication of miniature free-form optical elements capable of precisely focusing and reflecting light with minimal chromatic aberrations. This new method uses a flat piece of glass that is processed using photolithography, grayscale lithography, laser ablation, or other suitable technique to obtain an array of curved surfaces with free-form optical surface geometry to focus a beam. The array is then precisely diced to separate each optic. By leveraging microfabrication techniques to create precise free-form surfaces, the components can be optimized for a wide range of working distances/magnification and correct for any astigmatism introduced by a sheath. The created surfaces can be easily replicated with high precision and in high numbers, leading to a low cost per part. Additionally, a reflective coating can be easily applied to the free-form surface at the wafer level, such that fluid or adhesive in contact with the free-form surface does not adversely impact the optical performances of the element.

## Application area

Imaging devices used in catheterization, endoscopy and optical biopsy
Any devices or applications using micro optics

## Advantages

Allows for high precision and reproducibility manufacturing
Thousands of elements can be manufactured on a single wafer, lowering cost per part
Any optical surface geometry can be created for optimized imaging performance
Works with a wide range of working distances and wavelengths
Corrects optical aberrations introduced by device sheath
Can be used in fluid or potted within an assembly for a low additional cost per part with a reflective coating applied on the wafer

## Institution

University of California, Davis

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