Micromachined Vertical Three-Dimensional Micro-Fresnel Lenses For Free-Space Integrated Micro-Optics

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We report the first fabrication of vertical three-dimensional micro-Fresnel lenses with polysilicon materials by surface micromachining technique. Micro-Fresnel lenses play a very important role in micro-optics because of their thin film structures and their ability to achieve very short focal lengths. Although micro-Fresnel lenses have been studied and well understood [1], the lens planes usually are restrained on the surface of the substrate. Therefore, their abilities of integration with other optoelectronic components in micro-optics are limited. In this paper, we present a vertical three-dimensional binary-phase micro-Fresnel lens which overcomes the disadvantage of conventional micro-fresnel lenses and is able to rotate out of the plane and stands perpendicular to the substrate. This lens and other similarly constructed micro-optical elements can shrink the whole free-space optical system to a single micro-chip. They have applications in free-space optical interconnect, packaging and optical storage.

The fabrication of the vertical micro-Fresnel lens has been reported [2]. The lens plate is supported by micro-hinges and spring latches [3]. In this paper, we report the coupling experiments of semiconductor laser diodes and optical fibers using the vertical micro-Fresnel lens. The schematic structure of the micro-Fresnel lens is shown in Fig. 1. A 1.3μm laser diode or an optical fiber is placed at the focal point of the lens to collimate the optical beams. The collimated beam profile is shown in Fig. 2 and Fig. 3 for laser diode and optical fiber sources, respectively. The divergence angles of the laser diode 20°×40°, and the collimated beam shows an elliptical contour. A circular contour is observed for the collimated beam from optical fibers, which has a divergence angle of 7.0°. The collimated beam has a divergence angle of 0.43°. The three-dimensional beam profile is also shown. The collecting efficiency of the lens is higher than 50%. Efficiency can be further improved by using transmissive binary lens rather than bright/dark Fresnel lens. Since the vertical micro-Fresnel lenses and other similarly fabricated three-dimensional micro-optical components can be pre-aligned during the design stage of the layout, they can be integrated in a micro-chip with other active micro-optical elements such as semiconductor lasers and isolators. Therefore, we believe that they are very promising in the integrated micro-optics.

In conclusion, a micromachined vertical three-dimensional micro-Fresnel is demonstrated. It is shown to be very successful in collimating beams from both an optical fiber tip and directly from a semiconductor laser. With the micro-Fresnel lens' unique three-dimensional structure and with other similarly fabricated three-dimensional micro-optical components such as rotatable mirrors, beam-splitters and gratings, we can implement integrable free-space optics with this technique. These results show a promising future in reducing the cost of the most optical systems today.

Reference

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[2] L. Y. Lin, S. S. Lee, K. S. J. Pister, and M. C. Wu, " Three-dimensional micro-Fresnel lenses fabricated by micromachining technique" , Electronics Letter. (to be published, 1994)
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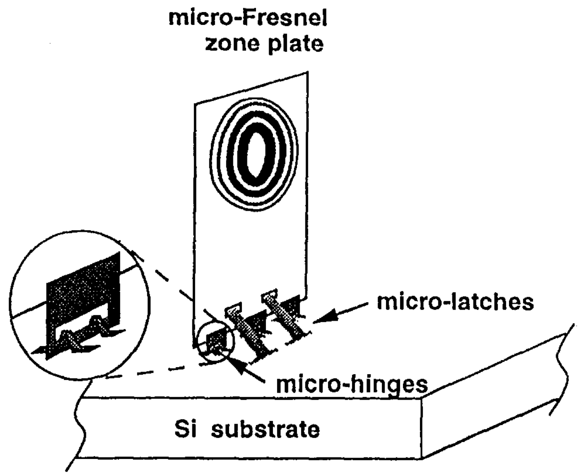
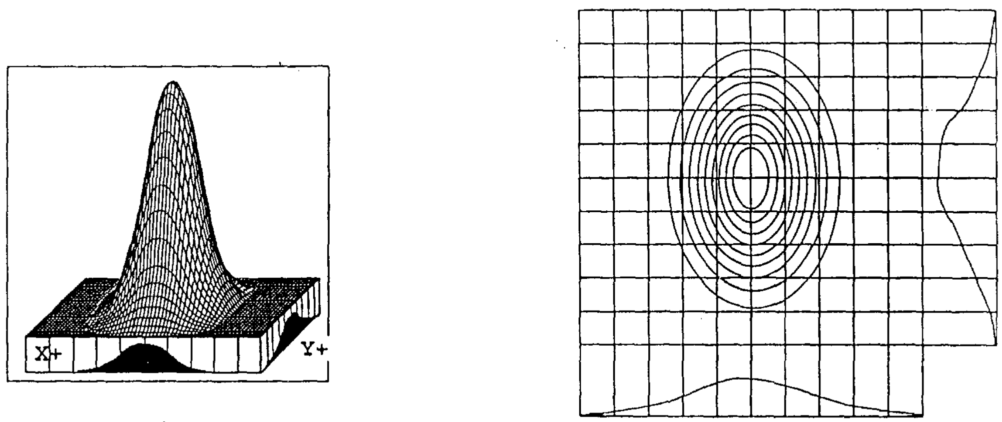
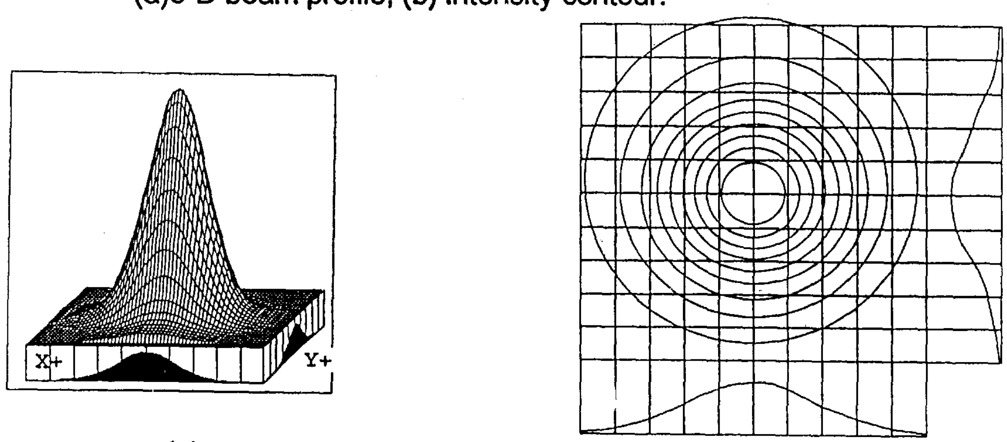


Figure 1. Schematic diagram of the vertical three-dimensional Fresnel lens.



(a) (b)

Figure 2. The beam profile of the collimated beam from the 1.3 μm laser, (a)3-D beam profile, (b) intensity contour.



(a) (b)

Figure 3. The beam profile of the collimated beam from the optical fiber, (a) 3-D beam profile, (b) intensity contour.