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Three-dimensional microgratings for free-space optical interconnects and clock-distribution systems

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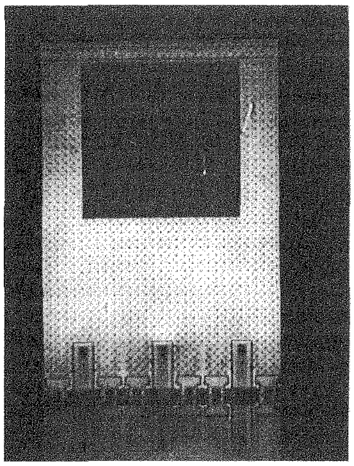
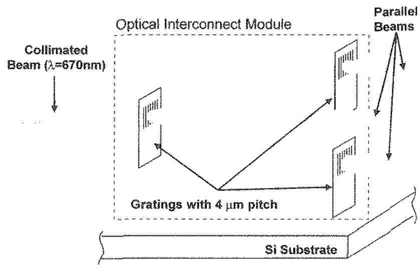
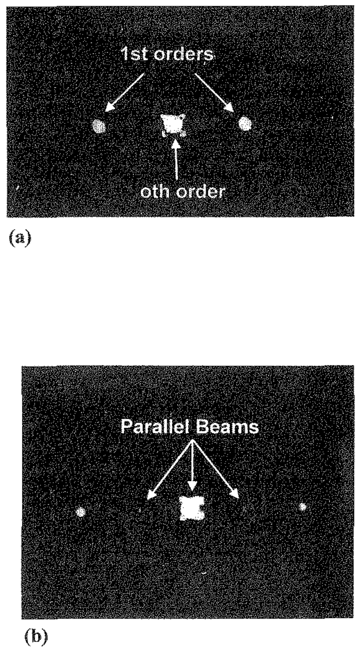
We report what we believe to be the first fabrication of a monolithic free-space optical-interconnect module consisting of multiple three-dimensional micro-gratings and obtained by using surface micromachining. The first-order diffraction patterns are successfully demonstrated. Free-space implementations of micro-optical systems, such as free-space optical interconnects and optical clock-distribution systems, offer advantages over conventional electrical or planar waveguide approaches. Free-space micro-optical systems can possibly achieve high-density optical interconnections and routing. Gratings have applications in many optical systems, such as tunable external-cavity lasers, optical interconnects, wavelength-division multiplexed (WDM) systems, optical-beam clock-distribution systems and micro-spectrometers. However, conventional gratings lie on the surface of the substrate and are not suitable for monolithic integration for a free-space optical system. In order to achieve



CFF7 Fig. 1. Photograph of the three-dimensional micro-grating standing perpendicular to the substrate.



CFF7 Fig. 2. The schematic diagram of a optical interconnect module consisting of three micro-gratings.



CFF7 Fig. 3. The CCD images of the first order diffraction patterns of a single micro-grating and the optical interconnect module.

monolithic integrability, which is needed for integrated optics, we propose a novel three-dimensional micrograting fabricated by surface micromachining. Similar to the three-dimensional micro-Fresnel lens,[1] the grating plates are made into a three-dimensional structure that can stand perpendicular to the substrate with the help of micro-machined microhinges and microspring latches.[2] Therefore, micromachined microgratings are very attractive for free-space optical interconnect and clock distribution systems.

A photograph of a three-dimensional micrograting standing on the substrate is shown in Fig. 1. The fabrication of the micrograting is similar to that of the micro-Fresnel lens.[1] By utilizing micromachined micro-hinges and spring latches, we can fabricate the grating plate to rotate out of substrate plane and stand perpendicular to the Si wafer. Figure 1 also shows the reflection image of the micrograting plate on the substrate. The grating plate is 900 μm tall and 600 μm wide, and the grating itself is designed to have dimensions of 400 μm × 400 μm and a pitch of 4 μm.

We have also demonstrated a free-space optical interconnect module that uses three microgratings and is potentially able to achieve more complicated optical-switching and optical-interconnection functions. The schematic diagram of this optical-interconnect module is shown in Fig. 2. The microgratings and the optical interconnect module are designed for a wavelength of 670 nm, visible light. The CCD images of the first-order diffraction patterns of a single micrograting and the optical interconnect module are shown in Figs. 3(a) and 3(b), respectively. The performance of the single-grating diffraction was very good. This optical-interconnect module can be combined with many other micromachined microstructures, such as micro-Fresnel lenses, beam splitters, and rotatable mirrors, to implement more sophisticated free-space micro-optical systems. Furthermore, surface micromachining is compatible with IC processing, and, therefore, it is possible to monolithically integrate the micromachined three-dimensional optical-interconnect module with the ICs.

In conclusion, a free-space optical-interconnect module consisting of microgratings has been designed and successfully fabricated by using surface micromachining for what we believe to be the first time. The performance of the macrograting has been successfuly demonstrated by observing the first-order diffraction patterns obtained by using a collimated light source with $\lambda = 670$ nm. With its three-dimensional structure and IC-like processing, the micrograting is very attractive for free-space micro-optics, optical interconnects and clock-distribution systems.

1. L. Y. Lin, S. S. Lee, K. S. J. Pister, M. C. Wu, Electron. Lett. **30**, 448 (1994).
2. K. S. J. Pister, M. W. Judy, S. R. Burgett, R. S. Fearing, Sensors and Actuators A **33**, 249 (1992).