A New Addressable Corner Micromirror Array for Free-Space Optical Applications

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ABSTRACT

We report on a novel addressable corner micromirror array for wide free-space optical applications. The corner mirror, composed of two mutually orthogonal reflective surfaces, may reflect incident light beam at any angle back to its incoming direction. In this report the corner micromirror array are able to be batch fabricated. Each micromachined corner mirror is constituted by three elements: a vertical mirror, a movable horizontal mirror, and a bottom electrode. The corner micromirror is able to provide actuation on one of the reflective planes, causing destruction of preset orthogonal planes. Incorporated with a grating and other optical components, the new array may provide simultaneous wavelength selection in free space and switching function for wavelength as well as intensity. In such an appropriate optical system, the corner micromirror may alleviate alignment problems and simplify assembly procedure. As experimentally achieved, the corner micromirror array may have the potential on an external-cavity tunable semiconductor laser, optical add/drop multiplexing, dual wavelength of interferometry or other applications.

INTRODUCTION

In the recent years, micro optics has gradually been playing an important role in optical communication, imaging and instrumentation. A corner mirror, composed of two orthogonal surfaces as shown in Fig. 1, can be used to reflect incident light back to its incoming direction. In this report an array of micromachined corner mirrors is first reported to manipulate light beam in free space. Through MEMS technology, the corner micromirror is able to provide actuation on one of the reflective planes, causing destruction of preset orthogonal planes.

Fig. 1 The schematic of an addressable corner micromirror

Incorporated with a grating and other optical components [1], the corner mirrors are preset to maintain reflective light to its incoming direction, or may be actuated to destruct mirror verticality in order for free-space wavelength selection or intensity variation. In addition, the use of the corner mirrors may not need a lens for collimation in an appropriate optical configuration, thus simplifying the optical system and reducing alignment problems in assembly.

FABRICATION

A corner micromirror requires two orthogonal planes with virtually flat and mirror-like surfaces. The addressable micromachined corner mirror is constituted by three elements: a vertical mirror, a movable horizontal mirror, and a bottom electrode. Meanwhile, the microstructures of the flat mirror and bottom electrode were anisotropically micromachined from Si(100) wafers. The thin gold film was evaporated onto the mirror surfaces and electrodes. The electrostatically switchable flat mirror was then assembled by anodically bonding both elements on the same glass carrier. Meanwhile, the gap for electrostatic actuation is critical, and thus requires a precise control in process and assembly. In the fabrication of vertical mirrors, the crystal plane was also bulk micromachined, but from a Si (110) wafer. The gold film was deposited for high reflection. To constitute the addressable corner mirrors, the patterned polymer BCB was heated in joining the fixed vertical mirror onto the flat mirror substrate. Consequently, the corner mirror array was achieved in final assembly.

EXPERIMENTAL RESULTS

Fig. 2 shows the SEM picture of the corner micro mirror. The switchable horizontal mirror lies between two neighboring vertical mirrors. The flat mirror can be electrostatically actuated by voltage application across the hidden bottom electrode.

The optical properties of mirror surface roughness and flatness were inspected through the atomic force microscope (AFM) and instrumental interferometer WYKO MHT III. In the roughness of both virtually orthogonal planes, the vertical and horizontal surfaces were measured in root-mean-square (RMS) value to be 3.32 nm and 4.18 nm, respectively, which demonstrates insignificant surface scattering. As for the flatness, the horizontal mirror of the thickness of

12 μm in thickness and 700 $\mu\text{m} \times 700 \mu\text{m}$ in mirror size is more even critical in radius of curvature than the 150 μm thick vertical mirror. As shown in Fig. 3, the radius of curvature was measured to be 34.31 mm.

Fig. 2 The SEM picture of the addressable corner mirror

Fig. 3 The surface profile image of a horizontal mirror

Fig. 4 The setup of optical spectrum of wavelength measurement

Fig. 4 shows the optical setup for wavelength selection using the addressable corner mirror array. The array lies at the path of the first-order diffractive light after the emitted light is incident on the grating (700 lines/mm). Although no collimated lens was used in the experiment, the reflected light beam shown in Fig. 5(a) was detected from the corner mirror array. Meanwhile, the sharp recession between two signal peaks was attributed to the loss in which light was incident on the ridge surface of the thick vertical mirror. No light can be reflected back as does the corner mirror. As indicated in Fig. 2, the 150 μm thick vertical mirror was made initially for effective process handling and robustness. Therefore, thinner vertical mirror structures may increase the effective

reflection accordingly.

Fig. 5(b) demonstrates that, with the actuation of one corner mirror, the structure configuration failed to maintain its right angle, thus destructing the light path back to the incoming direction. The signal at the wavelength of 634 nm was not detected. The results significantly ensure the feasibility of the corner mirror array for wide optical applications.

Fig. 5(a) The optical spectrum of selective wavelengths using two units of addressable corner mirrors. Fig. 5(b) The picture shows that the signal was not found after one of the corner mirror was actuated.

In such an appropriate optical system, the corner micromirror array provides simultaneous wavelength selection in free space and switching function for wavelength as well as intensity. Additionally, no lens was used in the system. The new device may simplify the optical system, and alleviate alignment problems in system assembly. Therefore, the device presents its potential in an external-cavity tunable semiconductor laser, optical add/drop multiplexing, or dual wavelength of interferometry or other applications.

CONCLUSION

The new addressable corner micromirror array is successfully presented. The optical properties of mirror roughness and flatness have been investigated, and the free-space optical performance has also been conducted in demonstrating its feasible applications. The new device may provide simultaneous wavelength selection and switching function, and present wide applications.

REFERENCE

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