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Surface-Micromachined Micro-XYZ Stages for Free-Space Micro-Optical Bench

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The surface-micromachined free-space micro-optical bench (FS-MOB) has demonstrated its potential for monolithically integrating the entire micro-optical systems on a single chip [1]. Various three-dimensional micro-optical elements such as microlenses, mirrors, and gratings have been successfully demonstrated [2,3]. The surface micromachining fabrication process further enables on-chip optical alignment by integrating the free-space micro-optical elements with micropositioners such as translation or rotation stages. Vertically scanning micromirrors have been demonstrated for bar-code scanners [3]. In this paper, we propose a novel integrated XYZ stage with three degrees of freedom for precise on-chip optical alignment as well as input/output coupling for FS-MOB.

One application of the integrated XYZ stage is on-chip alignment of hybrid-integrated active optoelectronic components (e.g., semiconductor lasers or photodetectors) in micro-optical systems. Previously, we have demonstrated a self-aligned hybrid integration scheme which utilizes side-mounting approach to match the optical axis of the semiconductor laser with that of the micro-optical elements [2]. On the other hand, vertical adjustment of the optical axis is required in many other applications. Though vertical comb drive has been demonstrated, large travel distance in vertical direction is difficult. Recently, we demonstrated a monolithic optical beam steering structure to convert vertical movement into in-plane translation, which can be readily implemented by the standard surface-micromachining techniques. The beam-steering device, as shown in Fig. 1, consists of a pair of parallel, 45° mirrors. The upper mirror is integrated with a linear translation stage. Translation of the upper mirror achieves vertical adjustment *without angular squinting* of optical beams. This beam-steering device has been used to change the height of the optical axis of an upright-mounted semiconductor laser [4].

By combining the beam-steering device (Z-adjustment) with an XY stage, an integrated XYZ stage with three degrees of freedom can be realized. Figure 2 shows the schematic drawing of a micro-Fresnel lens integrated with the micro-XYZ stage. The incoming beam (a horizontal beam from an upright-mounted semiconductor laser in this example) is bent upward by the lower 45° mirror which is integrated with a linear translation stage. The X-adjustment (see Fig. 2 for definition of X, Y, and Z) is achieved by the translation of the lower mirror. The upper 45° mirror is orthogonal to the lower mirror and is responsible for the Z-adjustment. The Y-adjustment is achieved by the translation of the micro-Fresnel lens. Both the micro-XYZ stage and the free-space micro-optical elements are fabricated using the micro-hinge technique [5]. The translation stages can be integrated with comb drive actuators for fine-adjustment of beam position or combined with actuators with long travel distance to achieve optical scanning. The advantage of this unique design is that the X, Y, and Z position can be adjusted independently without any angular beam squinting. The micro-XYZ stage can be readily integrated with other surface-micromachined micro-optical elements, and is very useful for high performance single-chip micro-optical systems.

References:

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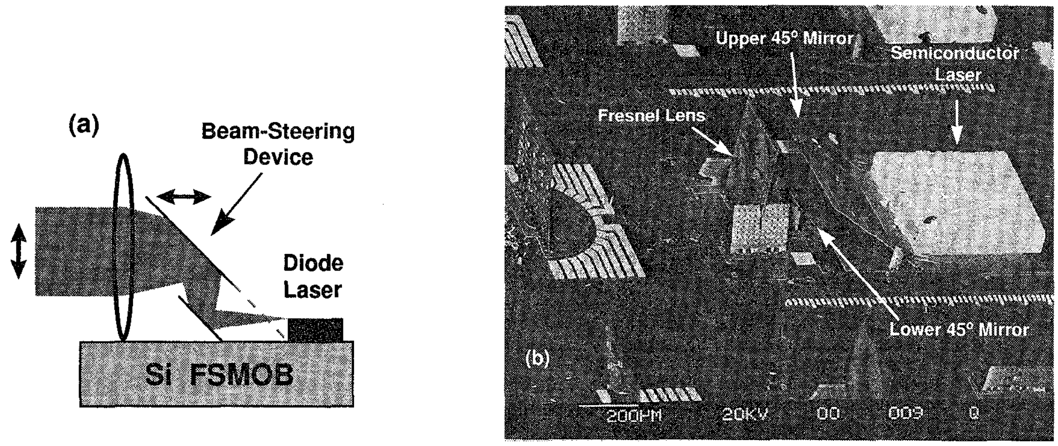

Fig. 1. (a) The schematic drawing and (b) the SEM of the vertical beam-steering device integrated with a micro-Fresnel lens

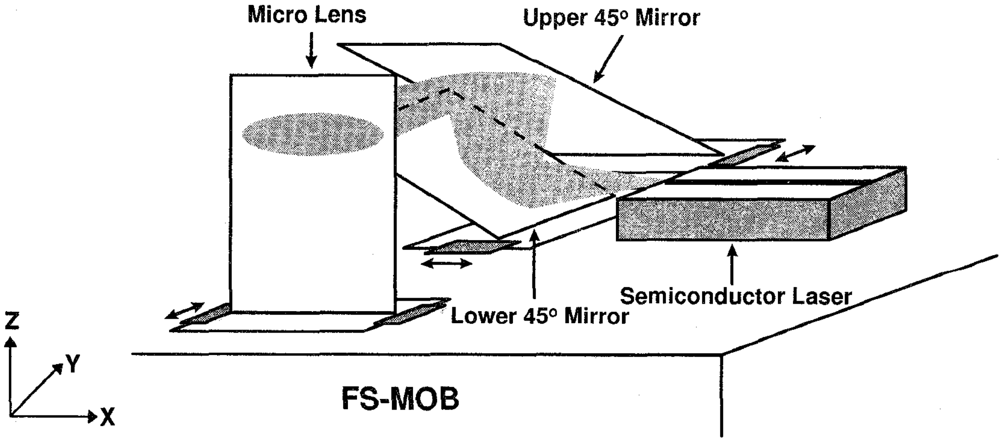

Fig. 2 The schematic drawing of a micro-lens monolithically integrated with the micro-XYZ stage.