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Paper Title: Deflectable Micro-Mirror Arrays for Implementation of a Recirculating Folded Perfect Shuffle Processor

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Deflectable Micro-Mirror Arrays for Implementation of a Recirculating Folded Perfect Shuffle Processor

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Abstract

An optical interconnect system based on deflectable micro-mirrors is discussed. The electrostatically actuated mirrors are surface micro-machined on a silicon substrate and positioned for implementation of an optical folded perfect shuffle. Design criteria and application to smart pixel systems are presented.

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Key Words: deflectable micro-mirrors, Optical Interconnects, perfect shuffle, recirculating architectures, MEMS, MOEMS

Summary

Based on innovations from a wide variety of disciplines, smart pixel technology has progressed from individual optoelectronic devices to fully operational photonic information processing systems. Similarly Micro-Optical Electro-Mechanical Systems (MOEMS) have recently been proposed which utilize Micro Electro Mechanical Systems (MEMS) in the design of photonic systems. In this paper we present the design concepts of such a system.

Figure 1 shows an optical interconnect system which is controlled by four arrays of deflectable micro-mirrors. These mirrors are surface micro-machined on a silicon wafer which also holds the detectors and processing logic of an optoelectronic smart pixel system. Each mirror array has four individually addressable mirrors for a total of sixteen interconnection paths. The optical interconnect system is configured in a recirculating architecture by placing a fixed mirror parallel to the silicon wafer. The four mirror arrays are arranged such that a folded perfect shuffle interconnect system can me implemented by electronically connecting the smart pixel array to the mirror address electrodes. Finally a laser, which illuminates the deflectable micro-mirrors, is mounted above the wafer. For each interconnect path, light from the unmodulated laser is reflected off of the deflectable mirrors, up onto the fixed mirror, and back down to the wafer where it strikes the smart pixel detector array. Since the laser is not modulated, encoding of the optical data is performed by actuation, or tilting of the deflectable mirrors.

In a fully operational smart pixel system the input data could be loaded by illuminating the detector array with optical data in a bit serial fashion. After the input data is loaded, optoelectronic processing is performed by the smart pixel array. To complete the optoelectronic processing each pixels output connection directs data (via a deflectable micro-mirror) through the shuffle network to the input of another smart pixel. Thus a recirculating architecture is realized. Clearly this smart pixel architecture is well suited for implementing recursive algorithms such as sorting. While our long range goal is to implement such a system, this paper will focus on the mirror design and evaluation of mirror arrays for a folded perfect shuffle interconnection.

Figure 1 also shows the design dimensions which are critical to implementing an optical folded perfect shuffle interconnection. The lateral shift of the beam is controlled by the micro-mirror angle of deflection, and the distance between the surface of the wafer and the fixed mirror. Figure 2 plots the micro-mirror deflection angle (θ) vs. the fixed mirror height (h) and the lateral separation (S) between the micro-mirror and corresponding detector. The separation, is given by $S = 2\ h \cdot \tan(2\theta)$. When the mirror is actuated, it will bend until it touches the underlying micro-structures. Therefore, the deflection angle is limited by the micro-mirror's elevation above the substrate, and the size of the micro-mirror. If the micro-mirror is square, with a side of lengh L, and is elevated above the substrate a distance E .The mirror deflection angle is given by $\theta = \sin^{-1}(E/L)$. The surface micro-machining process used by MUMPs allows us to obtain an elevation E of either 0.75µm or 2.0µm. Assuming E = 2 µm, L = 50 µm, and S = 7500 µm, the fixed mirror height, h, is ~3.5 cm.

We have designed an evaluation system which will be fabricated by the Multi-User MEMS Process (MUMPS) facility. In addition to presenting the optical system suitable for implementing the perfect shuffle This paper will discuss the test results of that structure. Our paper will concentrate on the ability of the of a micro-mirror structure to perform an optical folded perfect shuffle. The experiment must address such concerns as interfacing the often high voltage/low power micro-machines with standard CMOS devices.

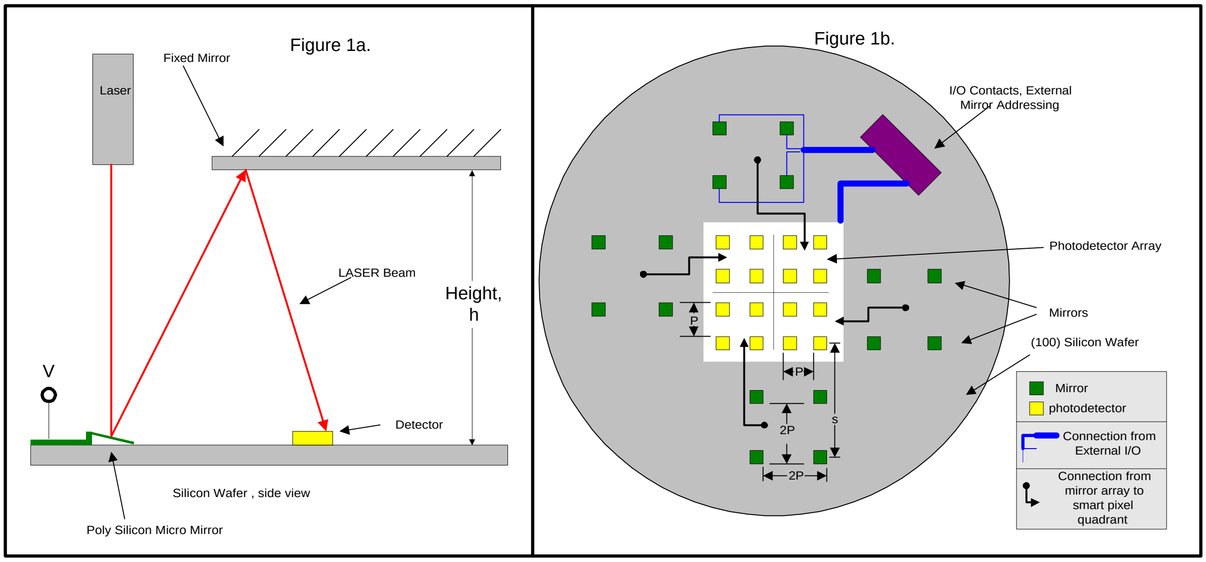

Figure 1a. Simplified side view of the interconnect system. Applying a voltage to the micro-mirrors surface causes the micro-mirror to tilt toward the wafer reflecting the laser light up onto a fixed mirror and back onto the smart pixel detector array.

Figure 1b. Top down view of the wafer depicting the mirrors and smart pixel array. The detector pitch (P) and detector-mirror separation (S) is used to determine the fixed mirror height (h). For clarity some electrical connections have been omitted.

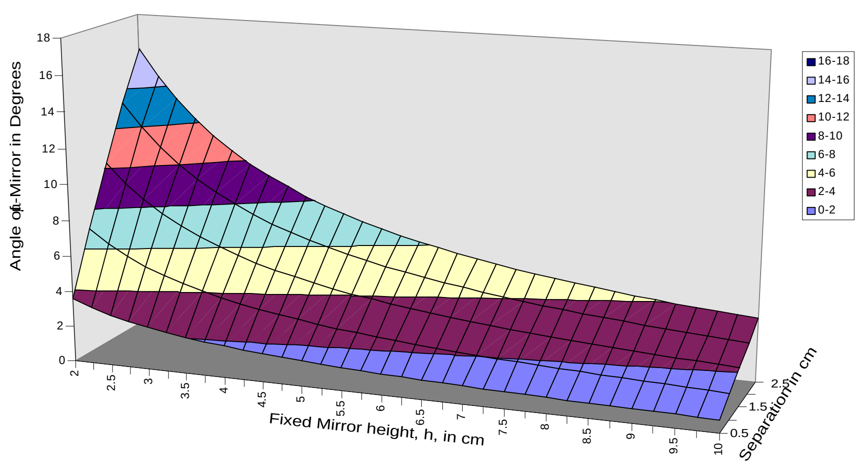

Figure 2. Relationship between angle of deflection (θ) vs. separation (S) and height of the fixed mirror (h).