An $8mm^3$ Digitally Steered Laser Beam Transmitter

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A laser transmitter for free-space laser communications has been built and tested. This system consists of an edge-emitting diode laser, a ball lens, and a micromachined mirror actuated using two 4-bit mechanical digital-to-analog converters. The mirror and actuators are fabricated in Cronos Microsystem's MUMPS process. The ball lens is assembled using a set of micro-tweezers from MEMS Precision Instruments controlled with a Sutter Instruments MP285 robotic xyz positioner. The laser diode was donated by SDL inc. and emits red (650nm) light. This work includes the demonstration of the first two degree-of-freedom micromirror actuated with mechanical digital to analog converters and its use in a system consisting of a laser diode, ball lens and micromirror.

In previous work we demonstrated low bit-rate communication using manually pointed lasers at 21km using only 1.5mW average optical power, and 2-axis beam steering with an external laser and lens [1]. New in this work is the integration of the laser diode and lens, digital control of the 2-axis beamsteering mirror, and demonstration of free-space communication at 1Mbps in the lab using this system. The use of a mechanical digital to analog converter allows for simpler control electronics – no electronic DAC is necessary; and the high output impedance of the mechanical DAC [2] provides quick, accurate positioning of the mirror without requiring closed loop control.

The dimensions of the active volume of the system are 5mm x 3mm x 0.5mm. All 4 bits of both axes of rotation of the mirror were tested, yielding 256 mirror positions. The maximum deflection for each degree of freedom is 87mrad (azimuth) and 52mrad (elevation). The most significant bit (MSB) of the azimuth axis has been tested, yielding a switching speed of 3.70msec. The resonant frequency of the elevation axis is 1.67kHz. Misalignment between the laser and lens is responsible for the large beam divergence observed (100mrad azimuth x 430mrad elevation). A photodiode and a transconductance amplifier were used to receive high-speed data sent over the optical link in the lab. Communication between the transmitter and this receiver was demonstrated at up to 1Mbps.

[1] Last, M., Pister, KSJ, "2-DOF Actuated Micromirror Designed for Large DC Deflection", MOEMS '99, Mainz, Germany, Aug29-Sept 1.

[2] Yeh, R., Conant, R., and Pister, K.S.J., "Mechanical Digital to Analog Converter," Proc. The Tenth International Conference on Sensors and Actuators (Transducers '99), Sendai, Japan, June 7-10, 1999, pp. 998-1001

Table 1: System Capabilities Demonstrated	
Speed	1Mbps
Scan Angle	87 mrad x 52 mrad
Pointing Resolution	5.44 x 3.25 mrad
Beam Divergence	100mrad x 430 mrad
Mirror switching speed	3.70ms

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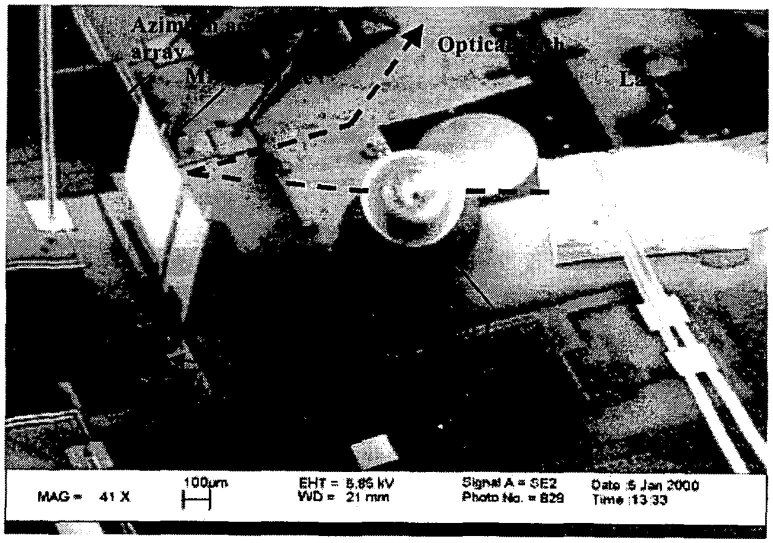

Figure 1: SEM of assembled system. The laser diode and ball lens were affixed to the substrate using silver paint. The optical path runs from the top of the front facet of the laser diode, through the ball lens, reflects off the left-hand plate, and finally reflects off the substrate before leaving the chip.

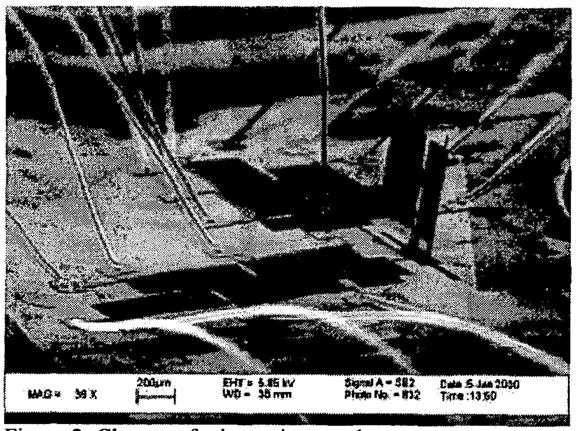

Figure 2: Closeup of micro mirror and actuator arrays. The actuators arrays are each made of 4 banks of 16 thermal bimorphs [2]. A lever tree converts the binary input into each actuator array into a single analog output. Each axis uses torsion hinges, yielding a zero backlash system.

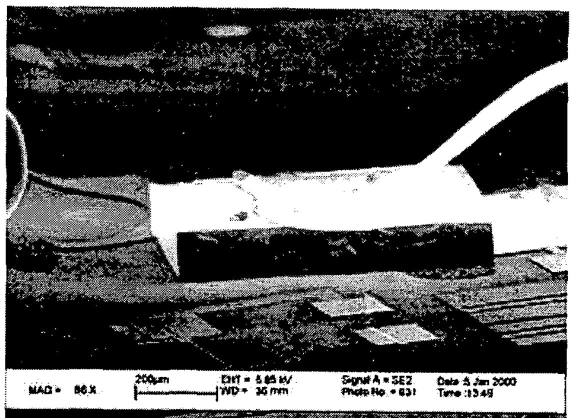

Figure 3: Closeup of laser diode. Wirebonds making contact to the p-side of the junction are visible. Contact with the n-side of the junction is made through silver paint (visible beneath rear portion of laser diode) to a gold pad fabricated in the MUMPS process. Two bondwires (not visible) make contact with this gold pad. The laser stripe is 100um above the substrate.