MEMS Scanner with Integrated Position Sensors

S. Lani, D. Bayat, A. Guillet, P.-A. Clerc, M. Despont

A position feedback has been integrated in a 2D micro mirror device for high optical power applications and high precision vector display. The developed solution consists of doped silicon piezoresistive sensors integrated directly on flexible parts of the membrane.

Scanning and beam deflecting devices present high interest for various applications like picoprojectors, LIDARs or galvo-scanners. For beam deflecting devices, the actuation is, in general, made with a DC analog signal. The investigated, basic device was previously described by Ataman, *et al.* [1] and consists of a mirror fixed on silicon springs where a permanent magnet is attached. The MEMS scanner concept is presented in Figure 1 and the fabricated system in Figure 2.

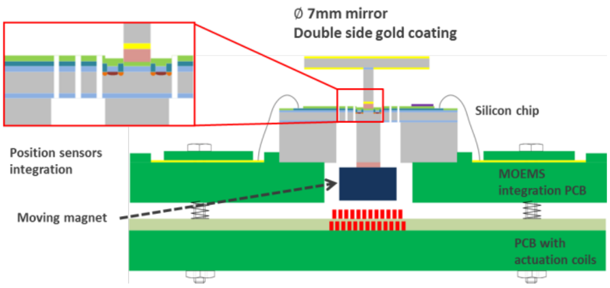

Figure 1: 2D tilting electromagnetic deflecting mirror concept.

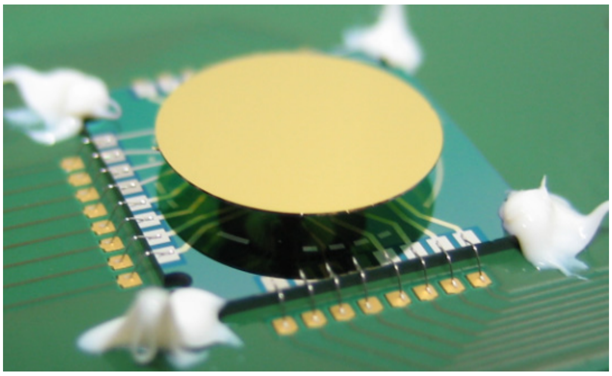

Figure 2: Assembled MEMS scanner with integrated position sensors.

The system is composed of a coated silicon mirror assembled on a silicon chip having a deformable membrane integrating the position sensors and assembled on a PCB to ensure electrical interconnections. The actuation is insured by two pairs of coils enabling a 2D analog tilting capability. It has a large tilt angle of +/- 9° and high resistance to optical power with a combination of a specific membrane design and reflective coating. To achieve a fine positioning of the mirror a sensor is needed that could, in general, be optical, capacitive, magnetic, thermal or piezoresistive. The most adapted sensing solution to the design and cost target was piezoresistive sensors, consisting of four silicon doped resistances arranged in a Wheatstone bridge to decrease the effect of resistance variation with temperature. One of the resistances is placed on a part of the device having a deformation proportional to the tilt angle, on a flexible arm of the membrane. A total of four Wheatstone bridges are required to obtain the tilt angle and the tilt direction.

The performance of the piezoresistive sensors is evaluated by measuring the output signal of the piezoresistors as a function of the tilt of the mirror and the temperature. White light interferometry was performed for all measurements to measure the exact tilt angle. The minimum detectable angle with such sensors was 30 µrad (around 13 bits for an output voltage resolution of 20 µV) in the range of the minimum resolution of the interferometer. The tilt reproducibility was 0.0186%, obtained by measuring the tilt after repeated actuations with a coil current of 50 mA for 30 min, and the stability over time was 0.05% in 1h without actuation. Electrical noise measurements were performed on the MEMS device with a probe station, an x1000 homemade signal amplifier and an HP3562a dynamic signal analyzer. To control the amplifier level, a standard resistance of 5.6 kΩ was measured to calibrate the measurement system. A typical noise figure is depicted in Figure 3, giving a noise close to a standard resistance (5nV/√ Hz). Accordingly, at the targeted sampling frequency for position control of 20 kHz, the noise level is below 1 µV. With an improved electrical design (low noise amplifier, improved wires) a 16 bit resolution corresponding to several µrad resolutions can be achieved.

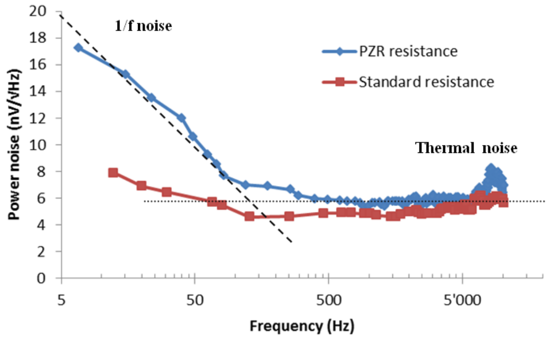

Figure 3: Noise level of a piezoresistor bridge.

[1] C. Ataman, S. Lani, W. Noell, N. de Rooij, "A dual-axis pointing mirror with moving-magnet actuation", J. Micromech. Microeng. 23 (2013) 025002