FRAUNHOFER INSTITUTE FOR SILICON TECHNOLOGY ISIT

1 *Array of nine piezoelectric, quasi-static MEMS mirrors with gold reflector*

QUASI-STATIC MEMS MIRROR FOR VECTOR SCANNING

Motivation

Scanning micro-mirrors based on the resonant driving mode have a long history track at ISIT. However, the non-deterministic movement in resonant operation is not suitable for all applications, in particular in the industrial field that requires perfect control of laser trajectories with arbitrary speed down to full stop ("quasi-static" positioning).

Vector scanning MEMS mirrors use actuators that directly translate a static DC voltage into an angular deflection. They have low inertia, small footprint and low power consumption. A constantly increasing market interest can be observed for a broad diversity of applications, like optical communication, material processing and LIDAR (light detection and ranging).

Current State

In a customer project, Fraunhofer ISIT demonstrated an array of efficient vector scanning MEMS mirrors with 0.8 mm aperture diameter. The actuators are based on piezoelectric driving structures that are created by depositing a stack of thin films and subsequent underetching. The scanner reaches a high static mechanical deflection of up to 12.5°. Excellent linearity, great repeatability and long-term stability have been achieved by using Aluminium-Scandium-Nitride (AlScN) as a driving material. Additionally, the efficient construction and patented, "rose-leaf" shaped suspension structures (see figure 3) eliminate mechanical non-linearity and minimize pitch size. Current efforts target to build a technology platform that supports many different applications only by adapting the MEMS design.

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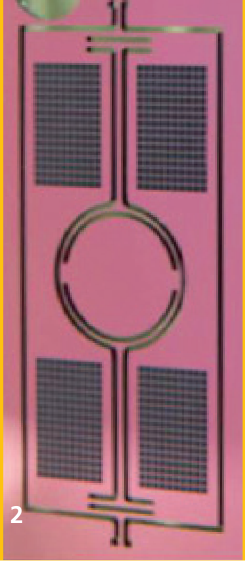
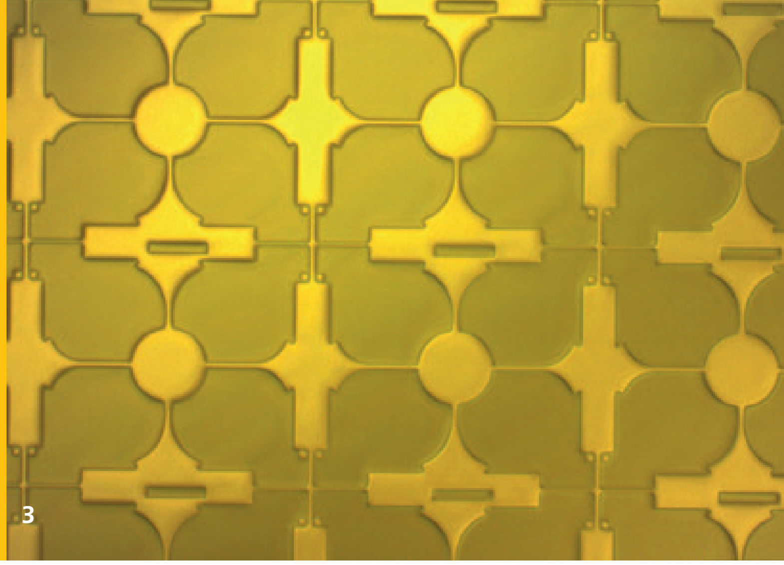
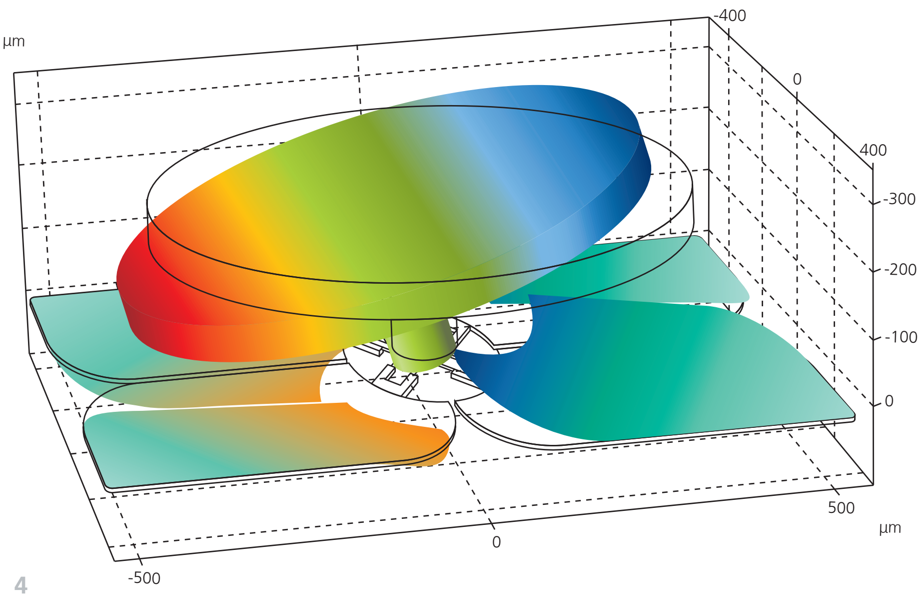




Next Steps

Current design efforts for quasi-static MEMS mirrors target only small aperture sizes (≤ 2 mm). However, ambitious market expectations for larger mirrors must not be ignored: Traditional options like galvanometer mirrors show stable performance, but cannot avoid a large inertia due to their high mass. Scanning speed and angles (in particular for 2D scanners) are very limited and the price cannot be reduced. More and more application designers therefore urgently wish to replace their galvanometer scanners by large quasi-static MEMS mirrors.

Using conventional MEMS driving principles, however, will not show significant advantages: A trade-off always has to be made between mirror size, scanning speed and scanning angle. If a MEMS technology can deliver driving forces of one order of magnitude greater than today, the design limits could be extended. Former attempts for magnetic MEMS actuation by integrating coils on Si-wafers and utilizing external magnetic fields do not deliver sufficient performance, but Fraunhofer ISIT is working on a unique technique of integrating permanent micro-magnet structures into Silicon wafers. In this way, forces up to 10 mN are possible, which is much stronger than piezoelectric drives. Furthermore, the embedded micro-magnets can be arbitrarily shaped and placed as arrays to upscale the available driving force. Besides setting up the technology platform, the current working focus for magnetic actuation lies also on developing the most efficient electronic driving unit including coils for low power consumption and accurate motion control.



2 Microscope image of the piezoelectric actuator layer.

3 The patented "rose-leaf" actuator with suspension structures minimizes the pitch size and improves mechanical linearity.

4 Quasi-static MEMS mirror actuator using four arrays of embedded permanent micro-magnets.

Outlook

MEMS mirror scanners are massively entering the market. However, many – in particular industrial – applications are not yet in reach of available actuator technologies. Fraunhofer ISIT is strongly involved in developing materials and their wafer level integration as an enabler for future MEMS generations. The latest progress on piezoelectric drives and magnetic structures offers great opportunities for a broad diversity of applications requirements. ISIT's technology platforms will allow efficient customization of application specific microsystems consisting of drive units, sensing elements and controller circuits.

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