LIDAR Camera based on resonant scanning MEMS Mirrors

Large scan angle / fast / mechanically robust

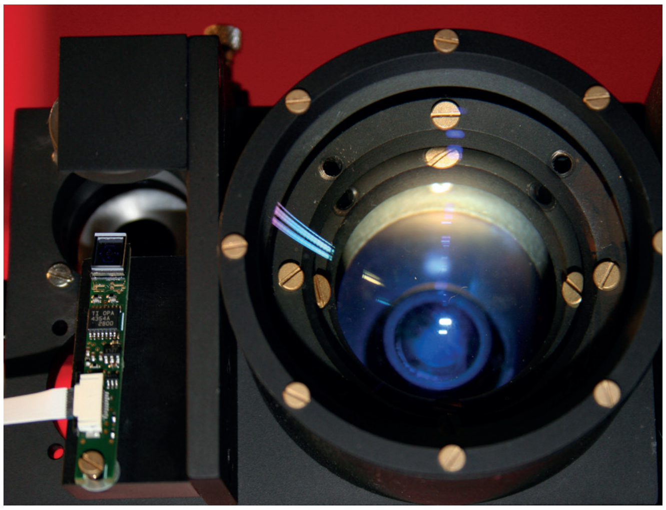
Piezoelectric driven MEMS scanner with large scan angle of 160°

Motivation

Actual demands in traffic and society like autonomous driving, drones and multiple 3D object recognition tasks drive the development of small, cost-efficient LIDAR (light detection and ranging) systems. Existing 3D imaging systems based on focal plane arrays with a modulated light source suffer from a limited resolution, a relatively high energy consumption of the light source and potential interference with other systems. These limitations can be overcome by using a MEMS scanner with a directed laser beam. Current LIDAR scanning systems with electrostatic MEMS reach 40° scanning angle in both directions, while Fraunhofer ISIT's new generation of piezoelectric driven MEMS scanners can achieve extreme optical scan angles close to 180°, owing to the high torque delivered by the piezoelectric material.

Achievements

Resonant MEMS scanners are much smaller and faster than polygon- or galvanometric scanners. They are manufactured in wafer-level processes, which is suitable for high volumes but involves a significant amount of non-recurring engineering costs. The achievable scan speed and the capability to integrate two scan axes in a very compact device are fundamental advantages of MEMS scanning mirrors over conventional galvanometric scanners. Significant effort is being spent to increase their field of view and to fulfil automotive qualification targets, especially concerning the mechanical and thermal robustness. Although resonant scanners reach much larger scanning angles than our piezo-based, quasi-static mirror drives, there are interesting application perspectives for both technologies. Internal tests have shown that MEMS scanners are very reliable in standby as well as in working mode. A closed-loop resonant mirror drive will provide a very stable mirror oscillation. Moreover special designs for mechanical shock resistance have been developed.



Front view of the full LIDAR system demonstrator

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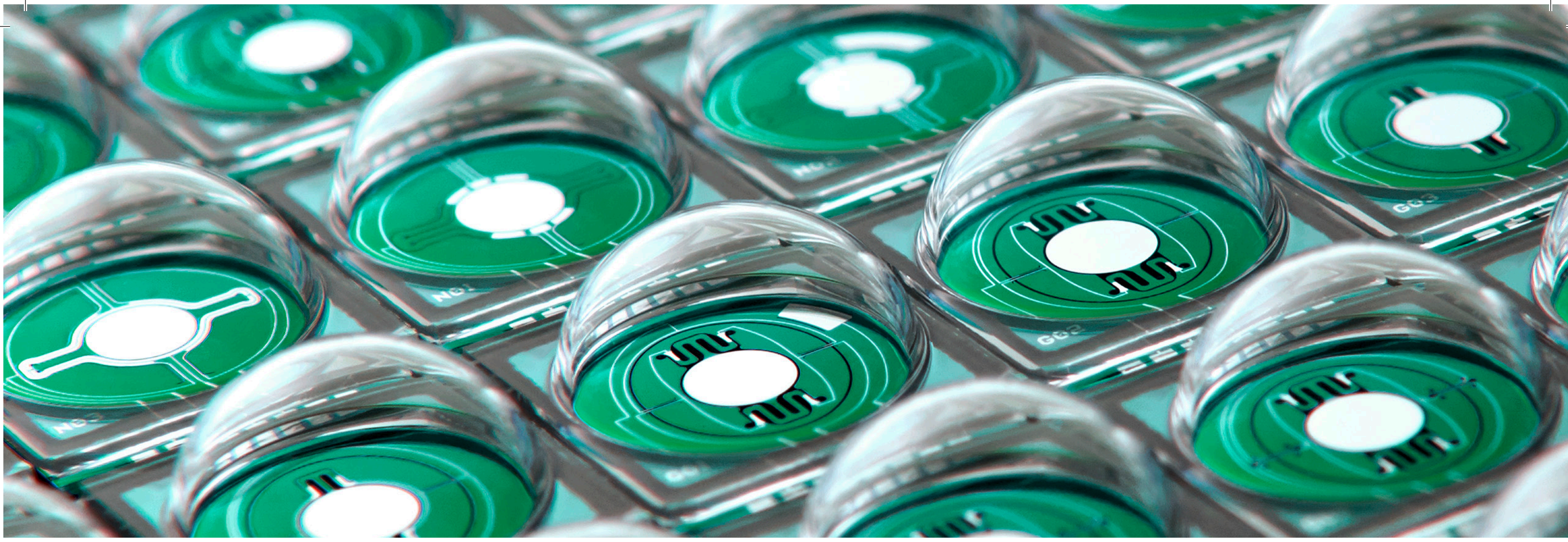


MEMS scanner encapsulated with glass domes

What we offer

Fraunhofer ISIT has developed a LIDAR camera demonstration with 2D scanning resonant MEMS mirrors. The amplitude of a laser beam is modulated and the phase difference between the light source and the reflection is measured. A real-time measurement is realized by using a single pixel APD (avalanche photo diode). The light projection engine can be miniaturized to almost sugar cube size, but requires a large camera objective to retrieve sufficient signal strength from the reflections.

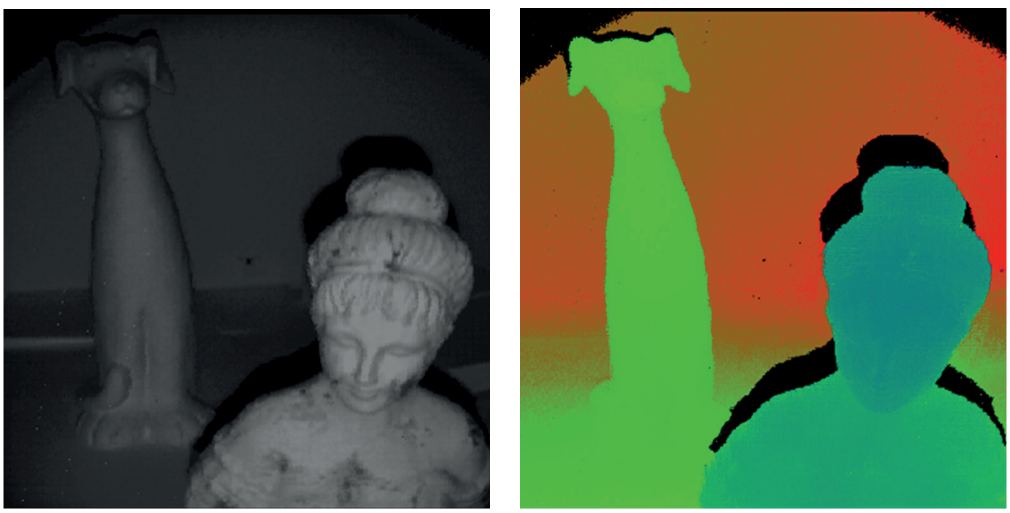
The first demonstration – consisting of a 2D MEMS scanner, a digitally modulated laser, detection optics and the APD sensor – achieved the following specifications:

- Resolution 450 pixel x 450 pixel
- Framerate 6 fps (currently limited by the viewing software)
- Detection range 0.1 m – 8 m
- Relative depth measurement accuracy 5 mm – 10 mm
- Sample rate 80 MHz
- UDP Ethernet interface

The laser beam is directed towards the scanning mirror under an angle of 22.5°. A 2D scanning MEMS mirror will project a so-called Lissajous trajectory, which is a sinusoidal movement along two orthogonal axes. The slow horizontal axis oscillates with a frequency of 525 Hz, covering a total optical scan angle of 40°. The fast vertical axis has a resonant frequency of 16.4 kHz, also covering a scan angle of 40°. These parameters correspond to a projection area of about 1.5 m x 1.5 m in a distance of 2 m.

In order to reach such high amplitudes, the scanner is hermetically sealed in a wafer-level package under vacuum. A tilted glass lid shifts the parasitic specular window reflex out of the projection plane – this particular design was developed by Fraunhofer ISIT using a unique glass forming technology for wafer-level optics.

For demonstration, the laser illumination is in the visible range (658 nm), but near-infrared light can also be used with this scanner type. The continuous laser power of 130 mW can be modulated digitally with a maximum bandwidth of 350 MHz, at low duty cycle for the reason of eye safety. In the present setup, a modulation frequency of 75 MHz is used. The detection optics with its large aperture size (d = 60 mm) allows to capture reflected light from objects within the total optical scan angle of the 2D-MEMS scanner. By using different algorithms, either the light intensity or the phase shift of the monochromatic illumination can be visualized.



Different working modes of the camera.
Left: Reflected lingt intensity.
Right: Phase shift between light source and reflection.

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