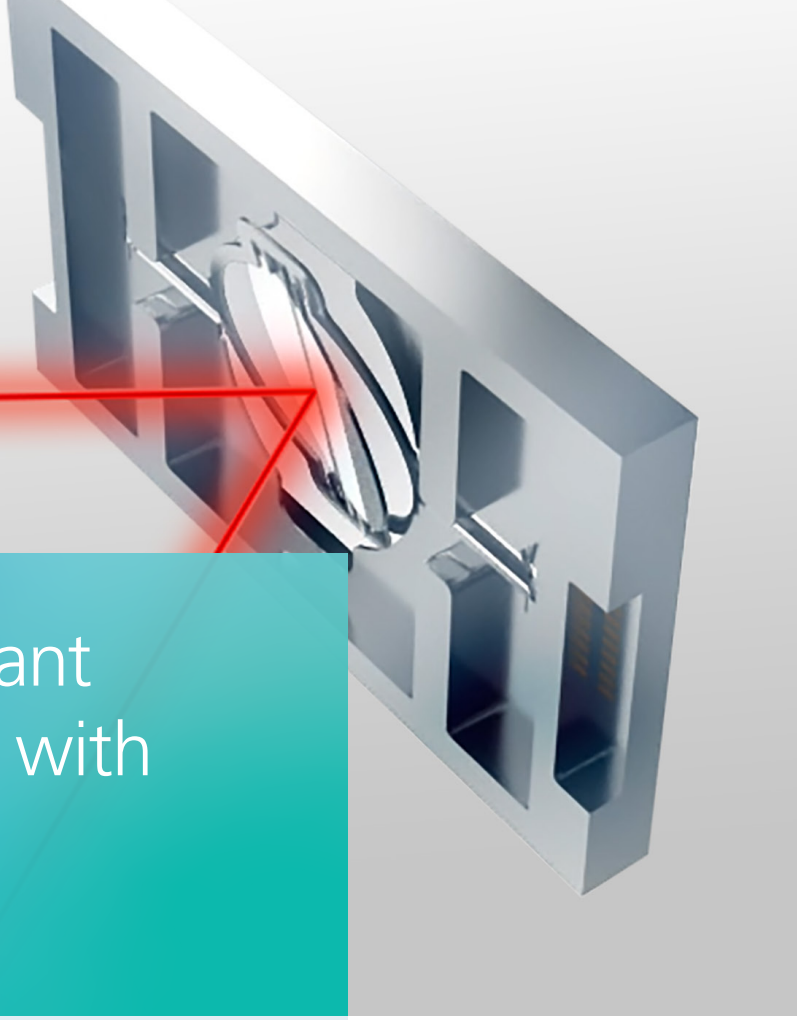
Fraunhofer IPMS



# Quasistatic and resonant MEMS microscanners with electrostatic drive

**Based on many years of experience, Fraunhofer IPMS offers the customer-specific development and fabrication of highly miniaturized quasi-static or resonant MEMS scanner devices. These consist of an optically active surface – a mirror or a diffraction grating – which can either be tilted about one or two axes of rotation or moved translationally.**

In quasi-static MEMS scanning mirrors, the tilting motion can be arbitrarily modulated from static deflection to an angle to freely defined angular changes (with an upper frequency and amplitude limit). Resonant scanner mirrors have a natural frequency defined by their design at which they reach their maximum deflection. In two-axis designs, the eigenfrequencies of the two axes differ.

The variety of available scanning mirrors is characterized by a large optical scanning range, a wide range of feasible frequencies, different mirror geometries and various options for the design of the mirror surface. In operation, the microscanners are extremely reliable. For precise control and regulation of their mechanical movement, they are equipped with a monolithically integrated position sensor system.

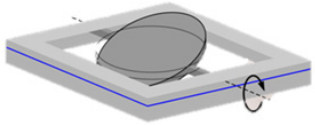
The reflective surface of the MEMS scanners has a reflectance of approx. 90% in the visible range. In addition, it is possible to apply a customized, highly reflective dielectric mirror coating.

The 1D and 2D scanner devices are manufactured in volume micromechanics technology from single-crystal silicon in a qualified, CMOS-compatible MEMS process ready for series production. The technology of these scanner mirrors is continuously extended in its range of applications by novel and patented design solutions as well as application specific technology modules. More than 200 different microscanner designs have already been developed at Fraunhofer IPMS and manufactured in our own clean room.

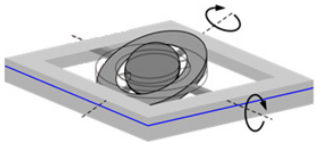
Supporting customers in the development of specific module setups, electronic solutions for closed-loop control that exploits the precision of the scanners, and evaluation kits round off the Fraunhofer IPMS portfolio in the field of MEMS scanner mirrors.

## Selection of designs of the MEMS microscanners

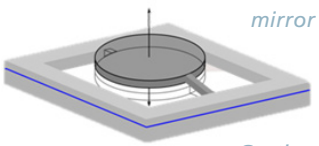
*1D tilting mirror*



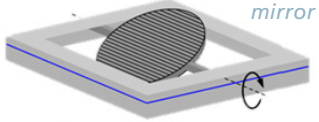
*2D tilting mirror*



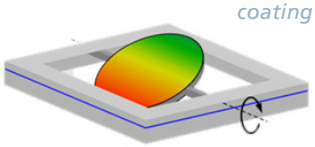
*Translational mirror*



*Grating mirror*



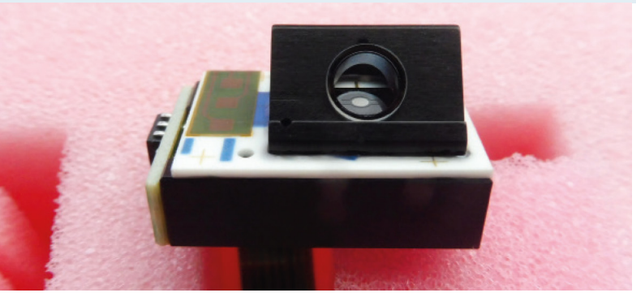
*Highly reflective coating*



### MEMS types and parameter ranges

| Type | Mode | Parameter ranges of different designs | | | Parameters of selected sample designs | | |
|---|---|---|---|---|---|---|---|
| | | Mirror size (1) | Amplitude (2) | Frequency (3) | Mirror size (1) | Amplitude (2) | Frequency (3) |
| **Tilting mirror 1D** | quasi-static | 1 … 6 x 8 mm² | up to 10.5° | up to 2.4 kHz | 2 x 3 mm² | 9.5° | 550 Hz |
| | resonant | 0.5 ... 7 mm² | up to 25° | up to 100 kHz | 3 x 3 mm² | 9.5 ° | 6.0 kHz |
| **Tilting mirror 2D** | quasi-static \| resonant | up to 5 x 7 mm² | up to 10° \| up to 22° | up to 1.2 kHz \| 37 kHz | 2.5 x 1.8 mm² | 10° \| 17° | 180 Hz \| 4.5 kHz |
| | resonant \| resonant | up to 3 x 4 mm² | up to 28° \| up to 21° | up to 25 kHz \| up to 42 kHz | 3.3 x 3.5 mm² | 11° \| 8° | 150 Hz \| 110 Hz |
| **Translational** | resonant | up to D=5 mm | up to 500 µm | 12 kHz | 2.0 x 2.0 mm² | 500 µm | 12 kHz |

1) Typical mirror geometry: round/elliptical, rectangular for selected designs
2) Amplitude: **Mechanical scan amplitude** (mechanical scan range = 2x amplitude, optical field of view = 4x amplitude due to reflection)
3) Frequency: **Resonance frequency** (the maximum frequency of linearized trajectories in quasi-static scanners is about one fifth of this value).



*Scan module with 1D resonant IPMS scanner, used in the ZEISS Lightsheet 7 microscope*

## Excellent mechanical and optical properties

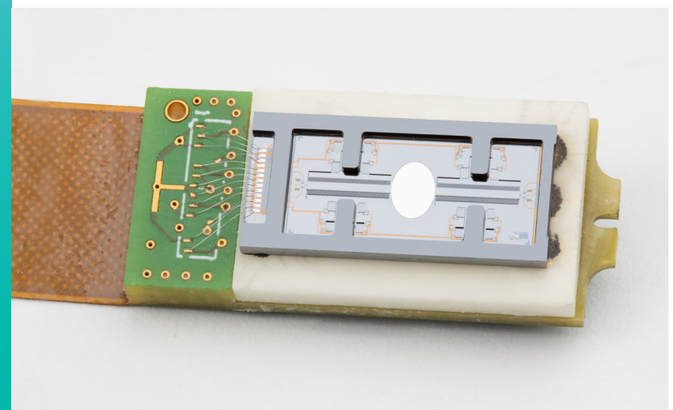
All mechanically stressed elements are defined in a single-crystal silicon functional layer and fabricated on a BSOI substrate in a volume micromechanical manufacturing process. This material is characterized by excellent elastic and fracture mechanical properties. In particular, no fatigue phenomena occur during operation due to its single crystallinity. The standard manufacturing process and the design process accompanied by FEM simulations guarantee the following properties:

- High mechanical stability (> 2500 g shock resistance)
- High static planarity (radius of curvature > 5 m)
- High dynamic planarity (typically better / 20)

## Application areas of MEMS microscanners

- Image acquisition e.g. for technical and medical endoscopes
- Confocal microscopy / OCT
- Fluorescence microscopy
- Barcode reading
- Object measurement / triangulation
- 3D cameras, LIDAR
- Object recognition / 1D and 2D light curtains
- Spectroscopy
- Laser marking and processing of materials
- Laser wavelength modulation
- Laser projection / display
- Linear scanning
- Optical vibration compensation, e.g. hand-held laser craniotome
- Beam positioning / trajectory tracking
- Material marking / material processing

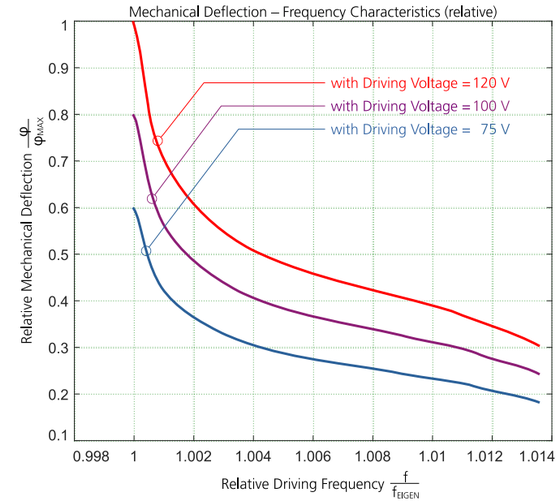
*Quasi-static scanner in a module for head-mounted displays*



## Specifics of resonant microscanning mirrors

The mirror plate of the microscanner demonstrators is excited to resonant oscillation by electrostatic, planar comb drives. The vibration amplitude is set by adjusting the drive voltage or excitation frequency. In 2D microscanners, the mirror is gimbaled. The frequency of the two oscillations is set independently in the design. Each of the two axes is excited individually so that the amplitude of each oscillation can be adjusted and controlled independently of the other.

Resonant scanner mirrors are driven by a high voltage square-waveform, which can be supplied by a commercially available generator, if necessary with an amplifier. Alternatively, we will be pleased to offer you appropriate electronics – optionally with trigger generation and amplitude control.

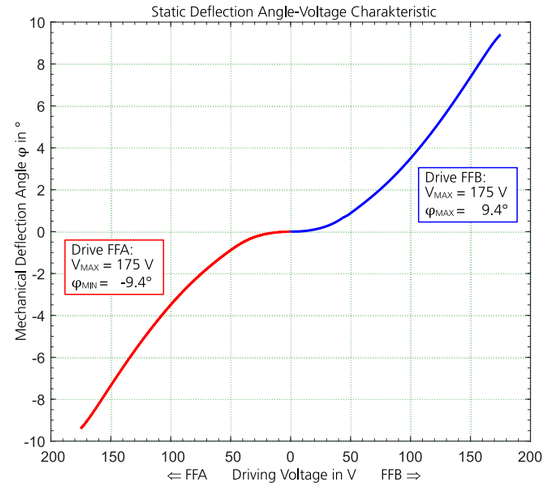



*Typical frequency-deflection characteristics of resonant scanner mirrors*

## Specifics of quasi-static "LinScan" microscanners

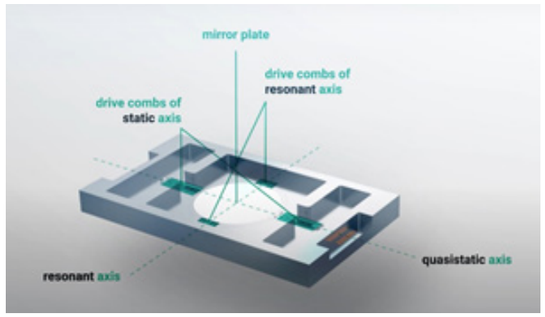
LinScan microscanners have an electrostatic-quasistatic drive axis, which is realized via vertical comb drives. Depending on the application and specifications, angled (AVC or CAVC) or layered (SVC) vertical comb drives are used. For 2D microscanners, the inner gimbaled mirror axis is realized via a resonant drive. Planar comb drives are used for this purpose.

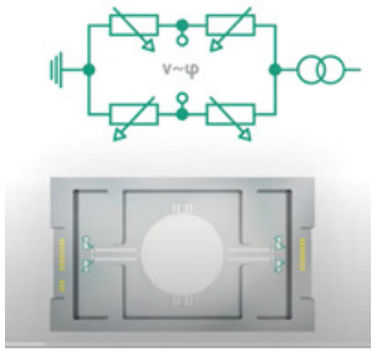
All mechanical components are created as two-dimensional structures in a layer of single-crystal silicon. In an adhesive wafer bonding process with a second planar structured silicon wafer, the vertical comb electrodes are formed by pre-deflection from the substrate and subsequent fixation by the wafer bond. Here, the vertical displacement of the electrodes is performed by solid-state mechanical mechanisms. This results in a mechanical decoupling from manufacturing tolerances, resulting in a very precise alignment of the electrodes to each other.



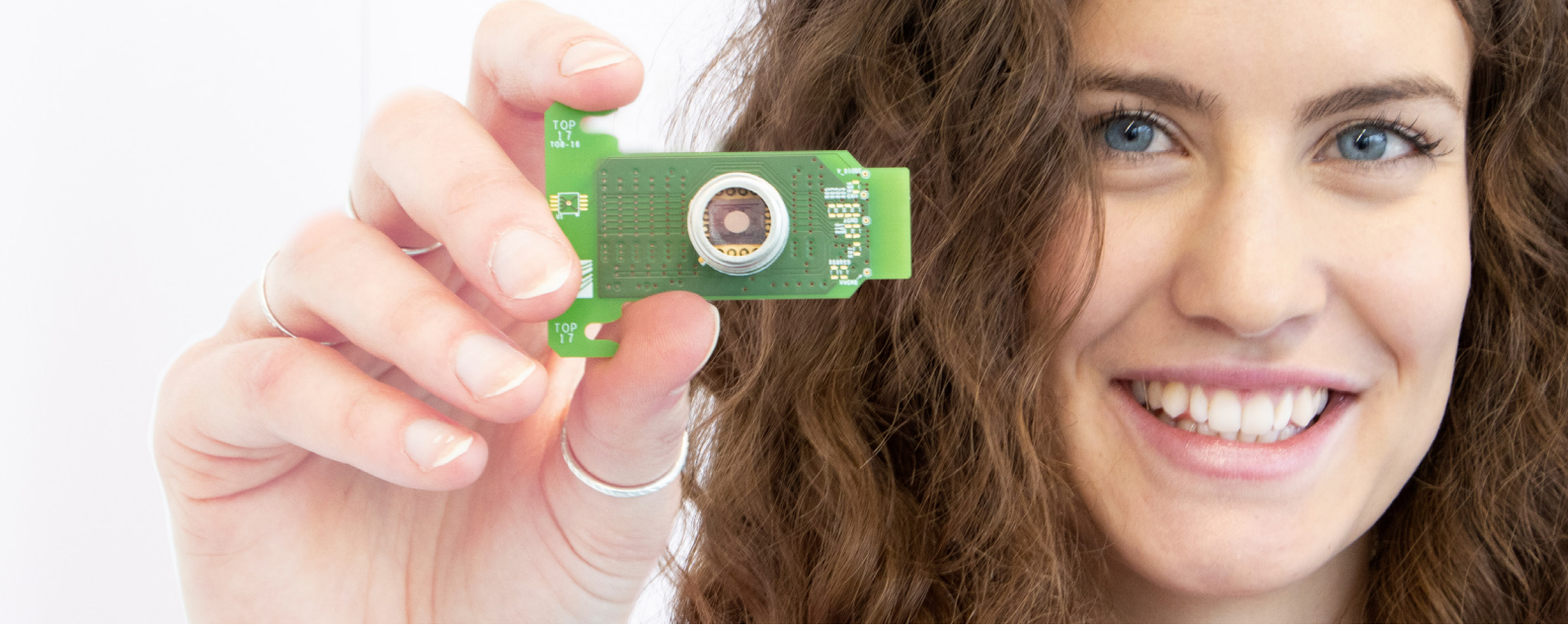

*Typical static voltage deflection characteristics of quasi-static scanners*

*Setup of a Linscan microscanner with second resonant axis*




*Monolithically integrated position sensor technology*

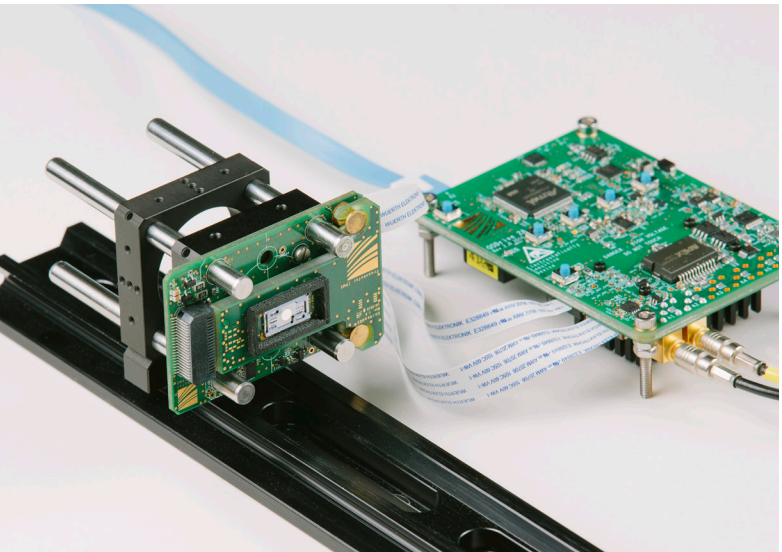


# Evaluation kits

**Fraunhofer IPMS offers various evaluation kits, which enable small and medium-sized companies in particular to operate MEMS scanner devices from Fraunhofer IPMS in accordance with the specifications without having to develop their own complex control electronics. Only a power supply is additionally required as well as a computer for running the provided control software.**

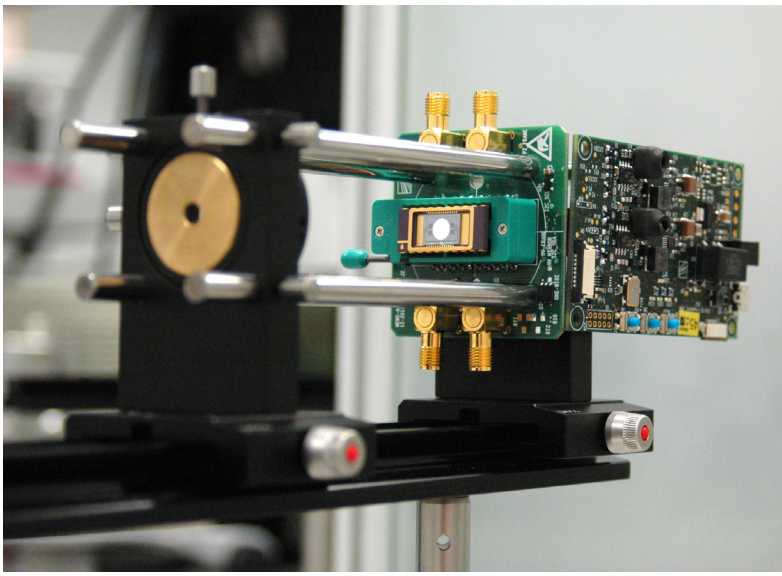
## QSDrive scan kit for quasi-static MEMS

The customer evaluation kit "QSDrive Scan Kit" consists of a ResoLin device – a gimbaled MEMS scanner with a linear axis and an optional, orthogonally oriented resonant axis – as well as control electronics, which enable the operation of the device with a supplied optimized trajectory. The device is held by a scan head, also included in the scope of delivery, which can be easily integrated into common optical experimental setups thanks to its special design. Depending on the design of the MEMS device, controlled operation of the device and synchronized operation of the resonant axis are also possible. Function control is performed by software that communicates with the electronics via USB.



## SiMeDri for resonant MEMS scanners

The SiMeDri evaluation kit is a driving electronics for the control of resonant 1D and 2D microscanner mirrors. It consists of a driver board and a MEMS board, which can be plugged together directly.



## Contact


Dr. Christine Ruffert
Active Microoptical Components and Systems Business Development
+49 355 69-4763
christine.ruffert@ipms.fraunhofer.de

Dr. Ulrich Todt
Active Microoptical Components and Systems
+49 351 8823-134
ulrich.todt@ipms.fraunhofer.de

Fraunhofer Institute for Photonic Microsystems IPMS
Maria-Reiche-Str. 2, 01109 Dresden, Germany
www.ipms.fraunhofer.de