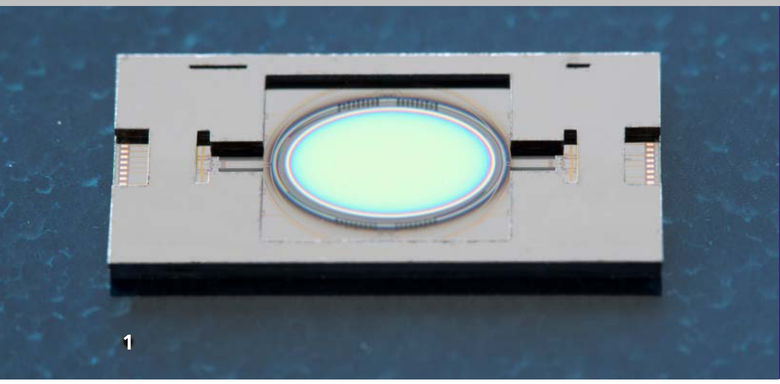
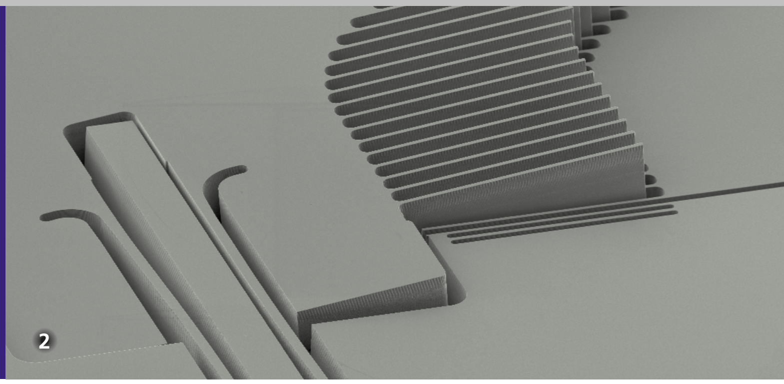
FRAUNHOFER INSTITUTE FOR PHOTONIC MICROSYSTEMS IPMS





**1** *Quasi-static/resonant 2-D-LinScan-microscanner demonstrator.*
**2** *Vertical comb drive (CAVC).*

# MICRO-SCANNING MIRRORS FOR HIGH-POWER APPLICATIONS IN LASER SURGERY

High-energy ps-lasers with high repetition rates (> 10 kHz) allow for the laser treatment of bone and hard tissue without the usual accompanying thermal problems (tissue carbonization). However, novel miniaturized scanning techniques for fast and precise beam guidance are required. As a part of the Fraunhofer WISA program, researchers at the Fraunhofer IPMS, together with their colleagues at the Fraunhofer Institute for Laser Technology ILT and at Integrated Circuits IIS have developed a novel handheld laser instrument for the laser cutting of cranium bone. The use of a laser allows a careful opening of the skull and can replace the usual mechanical bone sawing process which poses a high risk to the patient. The centerpiece of the tool holder is a pair of novel two-dimensional micromirrors developed by the Fraunhofer IPMS.

## Motivation

A major infarction may cause the brain to swell. The pressure in the cranial cavity increases, perfusion to the brain diminishes and the brain suffers further damage. To protect it from contusions, the surgeon will often open the patient's cranial vault – this is referred to as a release craniotomy. Until now, surgeons cut the cranial bones mechanically, that is, with a trephine. However, that approach comes with a truly high risk to the patient: By using the trephine, the surgeon could inadvertently injure the meninges. The researchers of the Fraunhofer intend to lower this risk by replacing the trephine with a highenergy femto-second laser.

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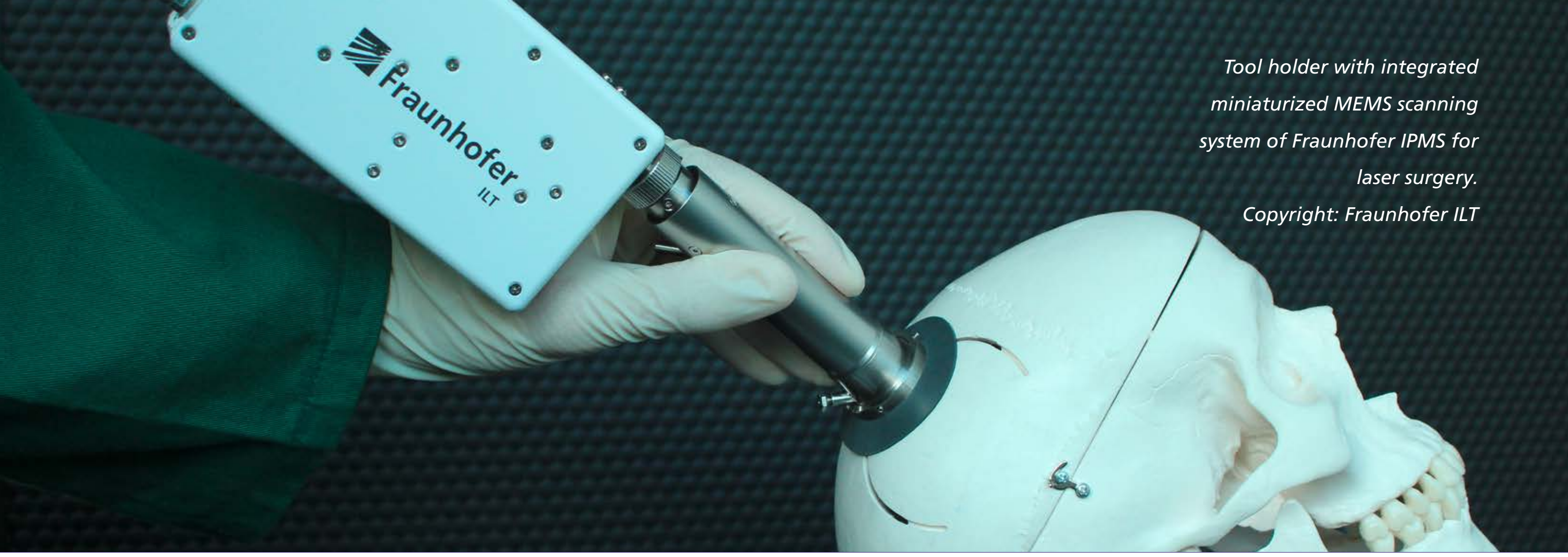


*Tool holder with integrated miniaturized MEMS scanning system of Fraunhofer IPMS for laser surgery.*
*Copyright: Fraunhofer ILT*

**Technology**

For the laser instrument the Fraunhofer IPMS has developed two different 2D scanning mirror devices. The first one is based on the electrostatic, resonant / linear LinScan technology and was optimized for an efficient cutting process with fast beam guidance. With LinScan devices the mirror is operated quasistatically on one axis via so-called vertical comb drives. The vertical comb drives are application specifically optimized as angular (AVC), centered angular (CAVC) or staggered (SVC) vertical comb drives. If it is a 2D device the gimbal mounted second axis is resonantly driven by planar comb drives.

The second magnetically driven mirror allows two-dimensional static deflections up to ± 5° and thus allows for a correction of the laser beam position.

In order to be able to use the microscanner at a high laser power (P = 20 W cw, power density > 100 MW/cm²) it was necessary to use large mirror apertures (> 5 mm), high reflectance coatings (> 99%) as well as highly robust optical coatings with a high optical planarity of < λ/10. Therefore micromirrors with mirror apertures of 5 × 7 mm² and 6 × 8 mm², coated with robust and thermally compensated dielectric high reflectance coatings (R > 99%, 532 nm, P = 20 W cw) have been developed.

LinScan is based on the technology developed by Fraunhofer IPMS for resonant microscanners. The components are manufactured in the in-house cleanroom in volume micro-mechanical manufacturing process on a BSOI substrate. All of the micro-mechanical components are produced as two-dimensional structures in a layer of monocrystalline silicon. The device concept is extremely flexible and makes it possible to realize a broad spectrum of MEMS device characteristics.

The active laser surgical instrument was developed by the Fraunhofer Institute for Laser Technology ILT.

**Sample Component Characteristics of a 2D LinScan Microscanner**

- Mirror diameter: 5 × 7,1 mm
- Reflectivity: > 99,9% at 532 nm and 45° angle of incidence
- Static planarity: radius of curvature > 5 m
- Dynamic planarity: ≤ λ /10
- Integrated Piezo-resistant position sensor system

**Quasi-static Drive Axis:**

- Scanning frequency: DC - 250 Hz
- Static mechanical deflection angle: ± 1° @ 150 V

**Resonant Defection Axis:**

- Scanning frequency: 585-670 Hz
- Nominal mechanical deflection angle: ± 5° @ 70 V

**Sample Component Characteristics of the Magnetic Micromirror**

- Mirror diameter: 6 × 8 mm
- Highly reflective dielectrical coating
- Reflectivity: 99,9% at 532 nm and 45° angle od incidence
- Scanning frequency: DC - 250 Hz
- Static mechanical deflection angle: > ± 3° - 5°

Characteristics can vary according to customer specifications.