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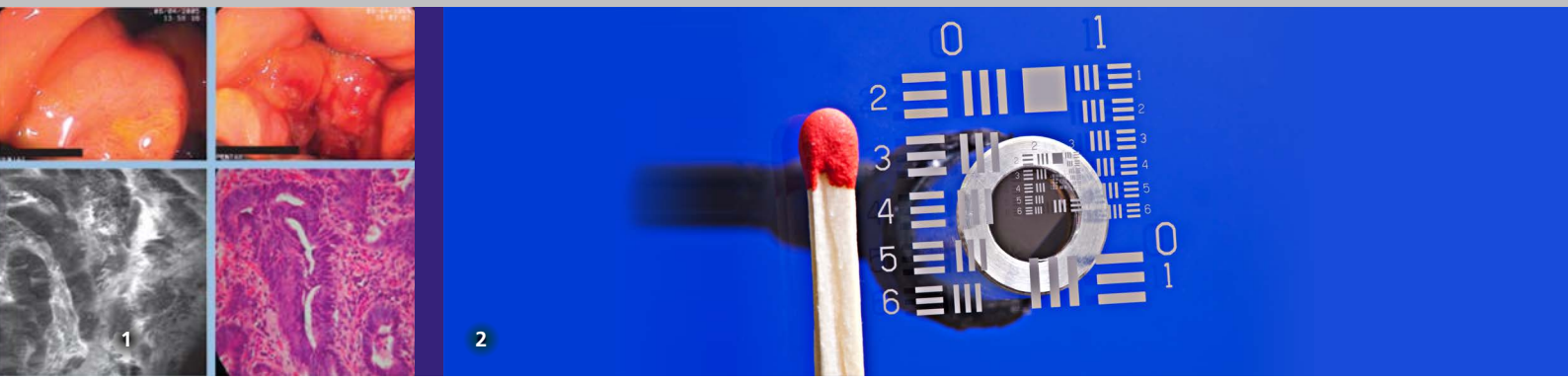


1 *Stomach mucosa seen through an endoscope (at the top) and through a microscope (Dr. R. Kiesslich, University of Mainz).*
2 *Size of the endo-microscope tip versus a match.*

MEMS-BASED ENDO-MICROSCOPE

Fraunhofer Institute for Photonic Microsystems IPMS

Maria-Reiche-Str. 2
01109 Dresden

Contact

Dr. Michael Scholles
Phone +49 351 8823-201
michael.scholles@ipms.fraunhofer.de

Dr. Uwe Schelinski
Phone +49 351 8823-204
uwe.schelinski@ipms.fraunhofer.de

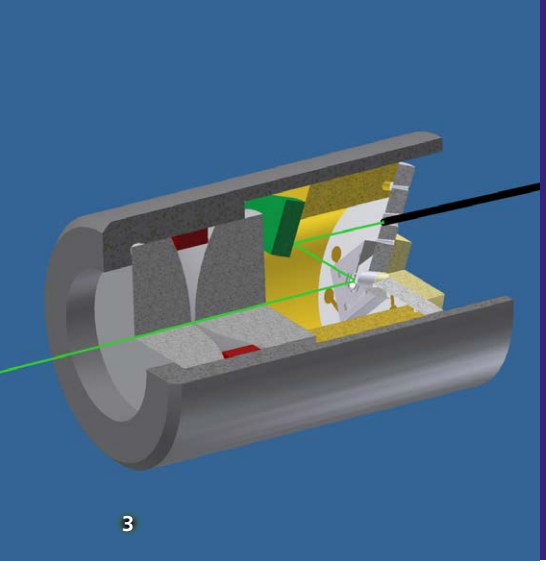
www.ipms.fraunhofer.de

Motivation

Since 400 years microscopes have been employed to visualize and investigate very small objects in many ways. The progress in microscopy has enabled e.g. three-dimensional imaging and allows to use computers for digital storage and processing. However, advanced microscopes are desk devices having some volume and weight, or they are even larger. Furthermore, there is often need to isolate the objects of interest from their original ambience and to prepare them in a suitable manner.

For example, medical diagnosis of cancer requires biopsy of suspicious tissues and their histopathological examination under the microscope. In order to reduce pain and stress for the patients it is desirable to make this procedure easier and faster.

By introducing endoscopes in medical practice, many examinations and surgery became less invasive and wearing to the patient during the last decades. However, most endoscopes are not capable to magnify their targets until cell structures are visible. Fig. 1 exemplifies the difference of endoscopic gastric mucosas images (at the top) compared to microscopic pictures (at the bottom).



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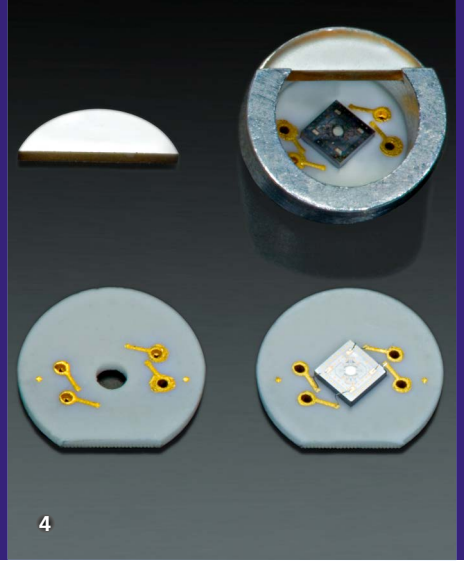

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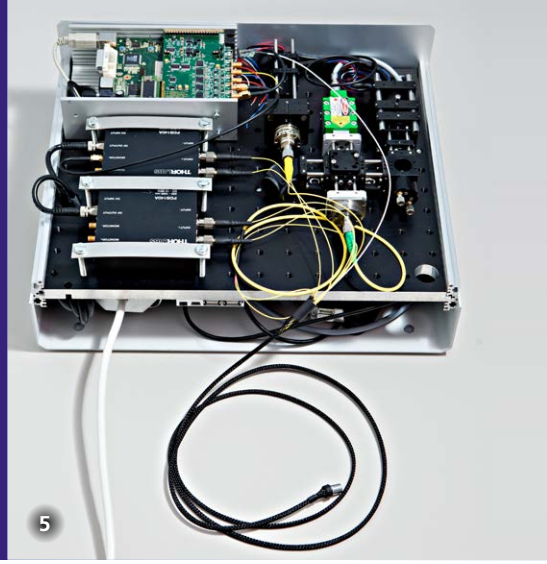

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Objective Endo-Microscopy

Therefore, the Fraunhofer IPMS has developed an endo-microscope that is only 8 mm in diameter, i.e. lean enough to be applied in minimally invasive medicine. Fig. 2 illustrates the size of the optical tip. The endo-microscope permits in vivo visualization of suspicious tissues with microscopic resolution and may help to quicken the examination and to supply an aiming biopsy.

Technical Approach

The endo-microscope uses a MEMS scanning mirror that has been developed and manufactured at the Fraunhofer IPMS. The device moves a focused light beam in a defined trajectory over the object while reflected light is received and electronically re-constructed to get the image. Fig. 3 depicts the optical design. The tip of the microscope mainly consists of the MEMS device, a ceramic carrier with electrical connections, a fold mirror and lenses for focusing the beam at target distance. The light is transmitted to the tip and reverse via an optical fiber which is joined with the electrical connections to a thin composite cable. The endo-microscope achieves a resolution of 15 … 20 µm within an object field of about 3 × 3 mm.

Newly established "Micro Assembly" competencies and resources at Fraunhofer IPMS have been used to build up the tip of the microscope. Nevertheless, the hybrid design and completion has proven to be a challenging task because of different material properties, the size of the parts and the required precision. Fig. 4 shows a couple of small parts of the inner "Scan Engine" that had to be manufactured and mounted very precisely in order to meet tight optical tolerances. Therefore, one of the finishing assembly steps has been performed with active optical fiber illumination to compensate aggregated deviations.

Further optical components, light sources, detectors and the entire control electronics are located in a distant unit and connected to the tip through the composite cable. This control unit owns an USB interface to a PC for operating the system interactively, transfer, visualize, and store the digital image data. Fig. 5 illustrates the overall system setup (with opened control unit case).

The separate construction of the control unit enables full flexibility in choosing and combining its optical and electronic contents. For example, different light sources can be used and optically combined, several detectors and filters allow to capture spectral properties or to exploit fluorescence.

Further Applications

The endo-microscope can also be applied in biology, biotechnology and in technology, e.g. for viewing very small objects in narrow environments, or to inspect the interior of cavities through tight inlets for microscopic details.

For example, the device is useful in controlling the densities of active micro-organisms in bioreactors. This has to be conducted through smallest openings in order to minimize impact on the biochemical process.

Many technical equipment like combustion engines, technical pumps, turbines and pipes need to be regularly examined inside for abrasion / erosion without disassembly.

Acknowledgement

This project named "Micro Imaging" has been funded by the Fraunhofer-Gesellschaft.

3 *Optical design.*

4 *Assembly of the "Scan Engine".*

5 *Overall system setup.*