M(O)EMS SPECTROMETERS
MAKING SPECTROSCOPIC SENSORS FAST AND MOBILE

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INTRODUCTION

State-of-the-art spectrometers tend to be bulky, costly and require large and precisely guided optical components, which often causes them to be rather slow. Together with a high price these limitations severely hinder the practical realisation of – otherwise highly promising – direct spectroscopic (chemical) sensors.

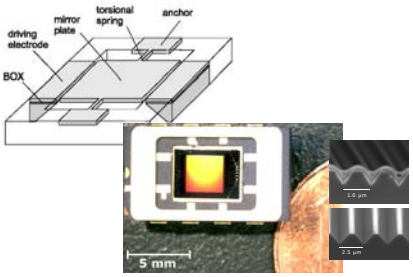
Our approach aims at replacing large and inert optical components in spectrometers with micro-electro-mechanical (MEMS) devices. As MEMS components can be designed to be extremely compact, having almost no inertial mass and a high operational reproducibility, simple and compact spectrometers can be designed.

The application of suitable MEMS devices thus allows to miniaturise spectrometers and render them more robust than state of the art devices at the same time.

Following this philosophy, MEMS devices can be used to replace transitional mirrors in FT-spectrometers as well as moving grating mirrors, e.g. in scanning grating spectrometers. This opens a wide range of possibilities to design compact, robust low-cost spectrometers for practical sensor applications.

MEMS SCANNING GRATING SPECTROMETER

SCANNING MEMS COMPONENT



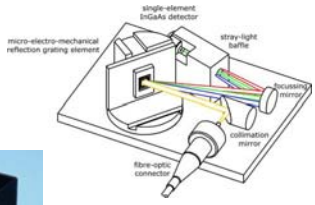
MEMS MIRRORS

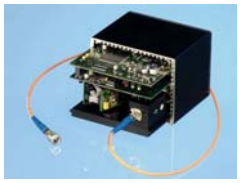
- ❍ virtually mass-free
- ❍ electrostatic low-voltage actuation (< 100 V)
- ❍ IR-reflective Al-finished mirrors
- ❍ millisecond scan times in resonant operation (resonance frequency design dependent)
- ❍ mass production using CMOS technology

- ❍ 3 x 3 mm² grating mirror with customised grating structures
- ❍ deflection angles up to ± 12° with amplitude stability better 0,01 °

OPTICAL LAYOUT

- ❍ Czerny-Turner monochromator
- ❍ angular mirror position encoding by laser trigger signal
- ❍ spectral resolution < 10 nm, peak accuracy better 1 nm
- ❍ time resolution < 4 ms



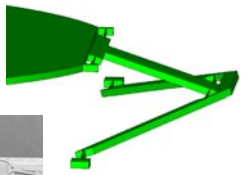


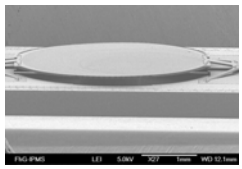
MEMS SYSTEM DESIGN

- ❍ compact, self-contained design
- ❍ dedicated, individually optimised layouts
- ❍ customised drive & control electronics

MEMS FOURIER-TRANSFORM SPECTROMETER

TRANSLATIONAL MEMS COMPONENT

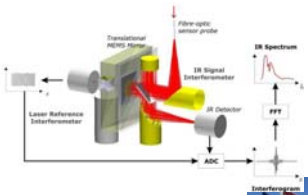


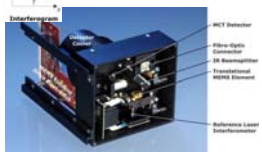


- ❍ ∅ 3 mm planar mirror with minimised warping
- ❍ ± 250 µm travel distance at low kHz frequencies

OPTICAL LAYOUT

- ❍ 90° Michelson Interferometer
- ❍ mirror position encoding by rear-side diode laser interferometer
- ❍ spectral resolution < 30 cm^{-1} spectral accuracy better 4 cm^{-1}
- ❍ time resolution < 1 ms





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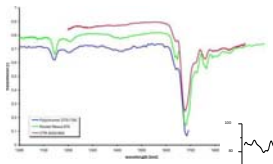
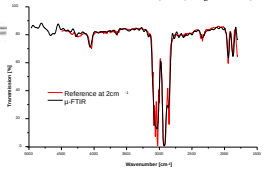
SPECTROSCOPIC SYSTEM PERFORMANCE

WIDE SPECTRAL RANGE ... &

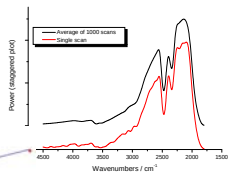


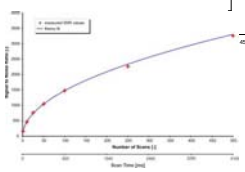
MEMS grating spectrometer principle applicable for limited spectral ranges in the VIS, near-IR and mid-IR
e.g. *1000 – 1900 nm*, *1200 – 2500 nm* or *3,8 – 5,3 µm* (CO_2 sensor)



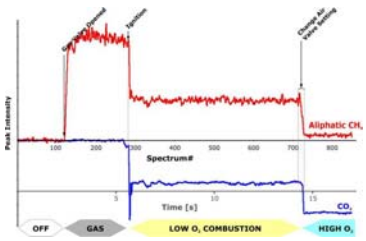
MEMS FT-spectrometer layout applicable for wide spectral ranges in the near- and mid-IR
e.g.: *5000 – 1500 cm^{-1} / 2 – 6,7 µm*

... GOOD SNR CHARACTERISTICS ... &





... HIGH-SPEED DATA ACQUISITION



fibre-optic open path transmission set-up, 60 mm open gas path
6W tungsten source / TE-MCT, **50 scans per spectrum** - 20 ms time resolution

CONCLUSION

Micro-electro-mechanical mirror devices allow to build compact, reliable spectrometers with good spectral properties and outstandingly fast response times. As MEMS components can be mass produced using standard CMOS production technology, this allows to design and build competitively priced handheld spectrometers for a range of (sensor) applications that up to now has been restricted to large and expensive instruments.

This removes one significant obstacle preventing the more widespread use of vibrational spectroscopic sensors and allow to exploit the highly advantageous properties of such sensors, in particular the high analyte specificity and inherent multi-analyte detection capability.

OUTLOOK

Ongoing work focuses on applications and system improvement:

- ❍ further improvement of overall system sensitivity and robustness
- ❍ integration of chemometric evaluation routines for qualitative and/or quantitative sensing applications
- ❍ replacement of laser encoding by laser trigger signals by capacitive position sensors integrated into the MEMS device
- ❍ MEMFIS – Ultrasmall MEMS FT-IR Spectrometer
  www.memfis-project.eu
  EC FP7 Research Project ICT - 224151

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