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INTRODUCTION

As optical sensor technology aims at ever smaller and cheaper systems, there is an increased demand for compact, cost-effective and yet efficient spectrometers. For a wide spectral range, from the UV to the shortwave near-IR, these demands can be satisfied through the application of stationary diffraction gratings in combination with one-dimensional linear detector arrays. For longer wavelengths, high prices and a generally limited availability of linear detector arrays require the use of single-detector spectrometers, using either gratings or Fourier Transform optics.

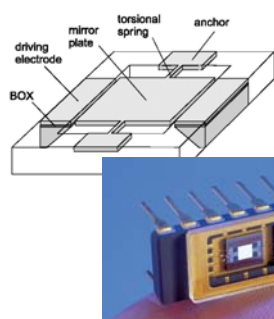
State of the art single-detector spectrometers tend to be bulky, costly and require large and precisely guided optical components, which often causes them to be rather slow. Together, these limitations represent one significant obstacle severely limiting the practical applicability of vibrational spectroscopic 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 yet a high operational reproducibility, simple and compact spectrometers can be designed. The application of MEMS devices allows to miniaturise spectrometers and render them more robust than state of the art devices at the same time.

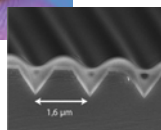
Following this philosophy, MEMS devices can be used to replace transitional mirrors in FT-spectrometers as well as moving grating mirrors, e.g. in scanning grating spectrometers. This opens a wide range of possibilities to design compact, robust low-cost spectrometers for sensor practical applications.

MEMS SCANNING GRATING SPECTROMETER

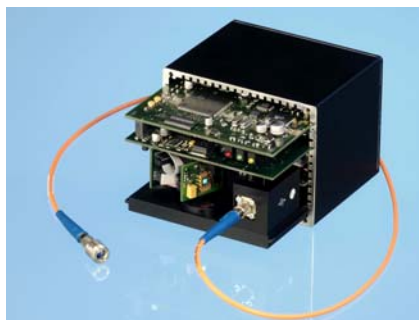
MEMS COMPONENT



- ❖ electrostatically actuated torsional micro device
- ❖ 3 x 3 mm² aluminised sinusoidal grating mirror
- ❖ resonant operation @ e.g. 150 Hz (150 – 500 Hz, design dependent)
- ❖ deflection angles up to ± 12° with amplitude stability better 0,01°
- ❖ mass production using CMOS technology

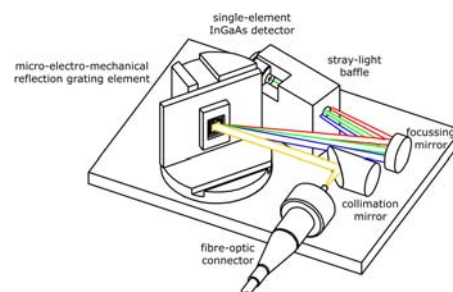


SINGLE-DETECTOR MEMS SPECTROMETER



- ❖ compact single detector NIR spectrometer (100 x 80 x 75 mm³, 0,8 kg)
- ❖ spectral range 1,2 – 1,9 / 2,6 µm
- ❖ spectral resolution ≤ 10 nm
- ❖ forward or forward/backward scanning
- ❖ time resolution better 5 ms
- ❖ DSP-based integrated electronics

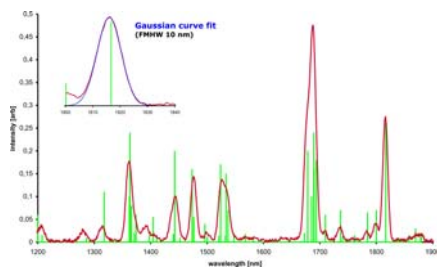
OPTICAL LAYOUT



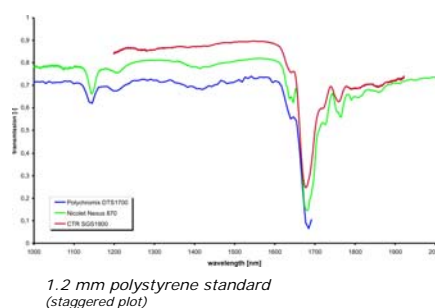
- ❖ Czerny-Turner monochromator principle
- ❖ simple layout with minimised number of optical components
- ❖ 50 µm x 400 µm entrance slit aperture
- ❖ angular mirror position encoding by laser trigger signal
- ❖ simulated spectral resolution < 10 nm

SYSTEM CHARACTERISATION

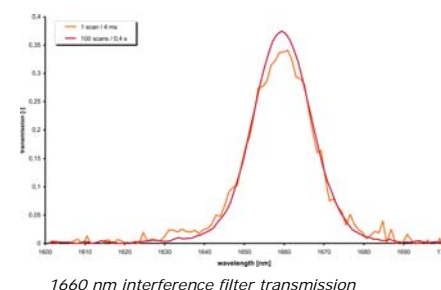
ACCURACY & RESOLUTION



SPECTRAL RANGE



SIGNAL TO NOISE



CONCLUSION

The application of micro-electro-mechanical grating mirror devices with optimised grating structure and high deflection angles allows 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

With the presented MEMS-based near-IR scanning spectrometer aiming at commercialisation in the near future, ongoing work focuses on applications and system improvement:

- ❖ further improvement of overall system sensitivity and robustness
- ❖ extension of the available wavelength ranges
- ❖ 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