MEMS mirror for miniaturized Fourier transform spectrometer

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Business from technology

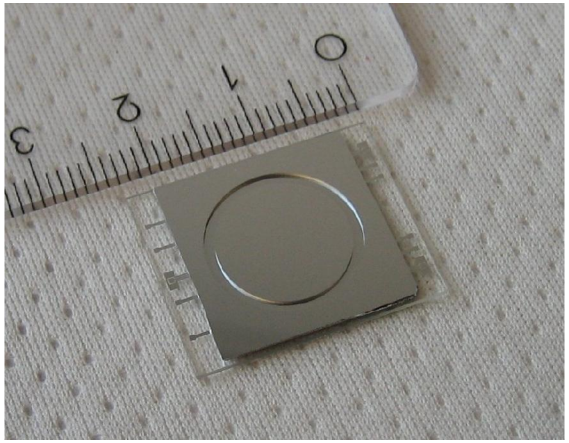
Outline

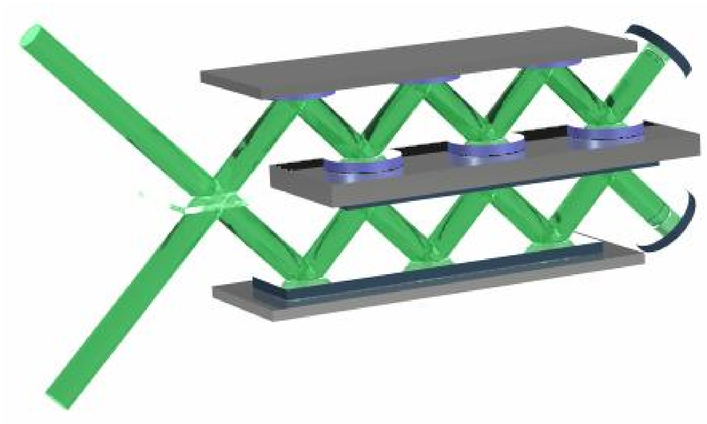
Large diameter micro-electro-mechanical (MEMS) mirror component

- Design
- Performance

Possible applications

- Miniaturized interferometer platforms





VTT Technical Research Centre of Finland

VTT Technical Research Centre of Finland is a government owned research agency, which will be privatized in 2009.

- 2780 employees, of which ~ 60 people are working in *Optical Instruments Knowledge Centre*.

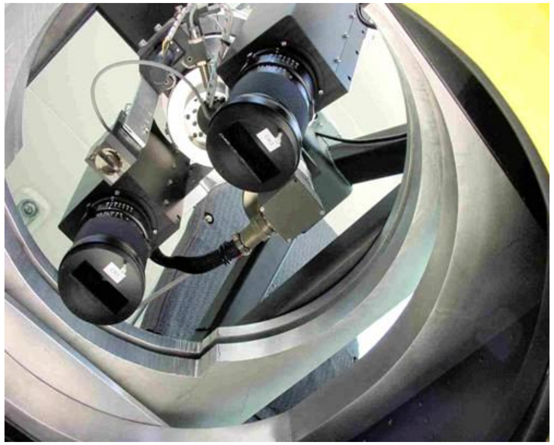
VTT has modern cleanrooms (ISO 4 ... ISO 7) with state-of-the-art equipment for fabrication of MEMS, CMOS and thin film devices.

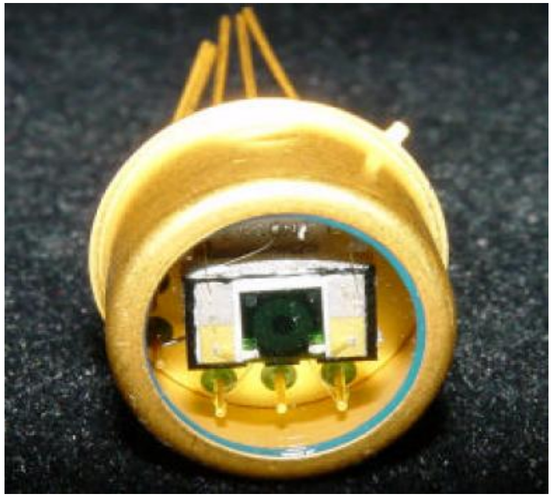
- E.g. The core of the *Micronova* building is the 2 600 m^2 cleanroom.

VTT possesses all parts of the micro-nano innovation chain, from basic research and applied research to prototype development, and small scale manufacturing. Our services are tailored to the customers' needs.

- Research
- Confidential contract research
- Material and device characterization

Optical sensors and space instruments / Optical instruments centre

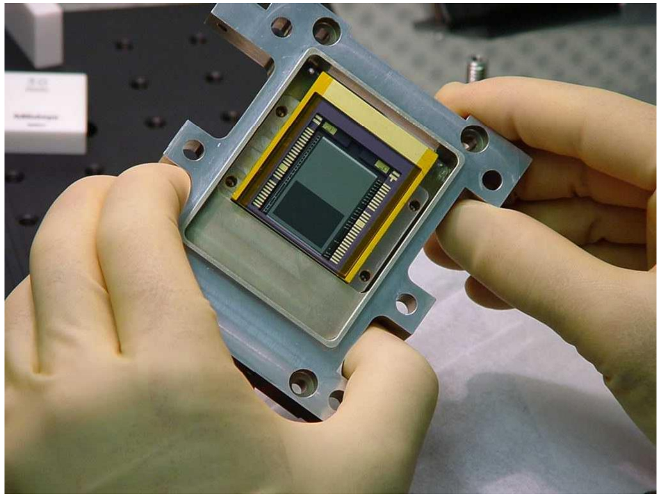




__MOEMS spectrometer__ in a TO-8 can including a MEMS Fabry-Perot interferometer (MFPI), a detector and a cooler.

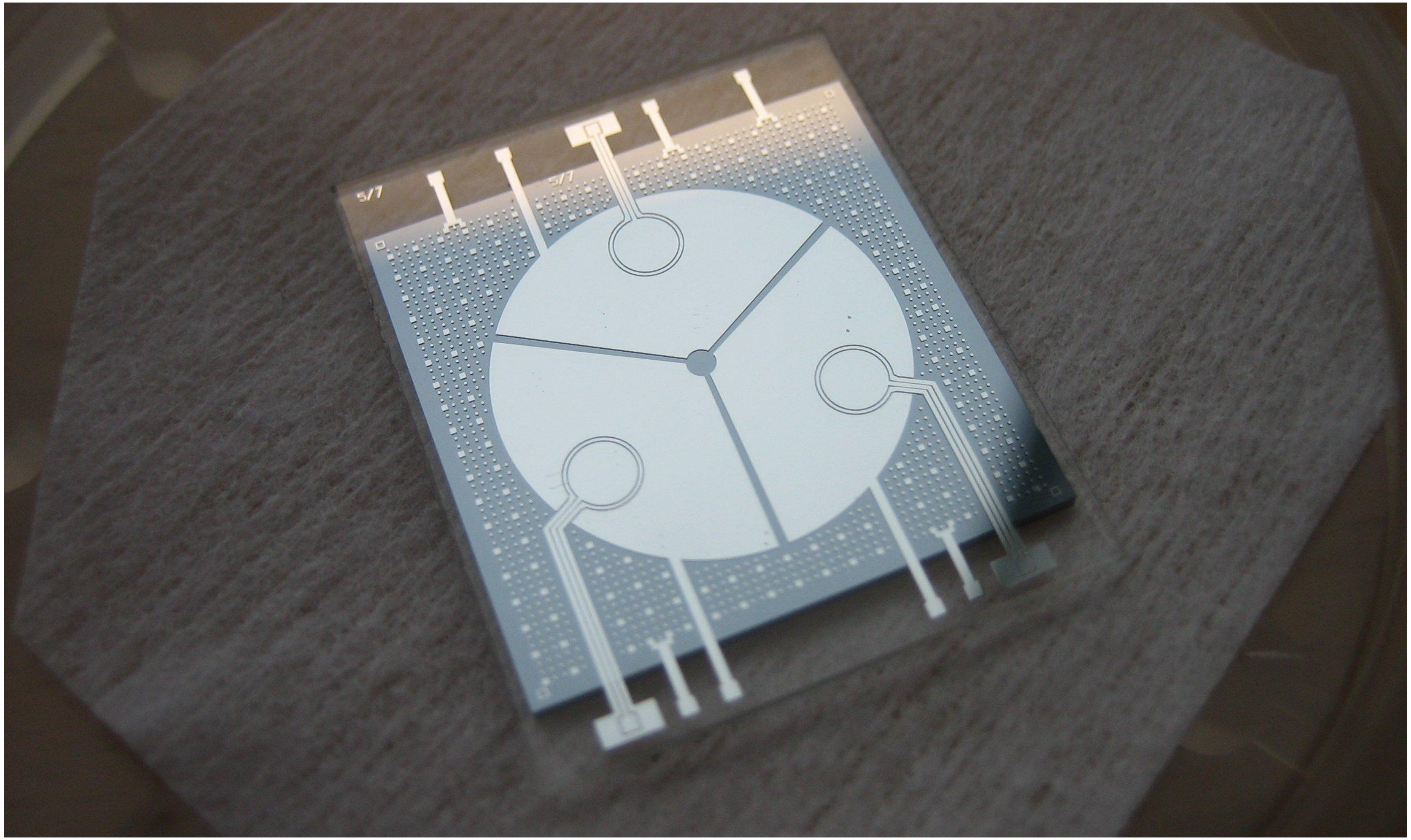
A high-resolution remote sensing camera *featuring a novel prism structure with several CCDs creating an image mosaic of 10200 x 1600 pixels. The image is taken from the Barcelona area.*

Vaisala Remote Road Surface State Sensor DSC111. *Features remote surface state sensing with spectroscopic measuring principle, identifying the presence of water, ice, slush, snow or frost.*



Ozone Monitoring Instrument (OMI) *including VTT's detector module - the instrument is currently flying onboard NASA's EOS-AURA satellite creating high resolution ozone maps.*

MEMS mirror component

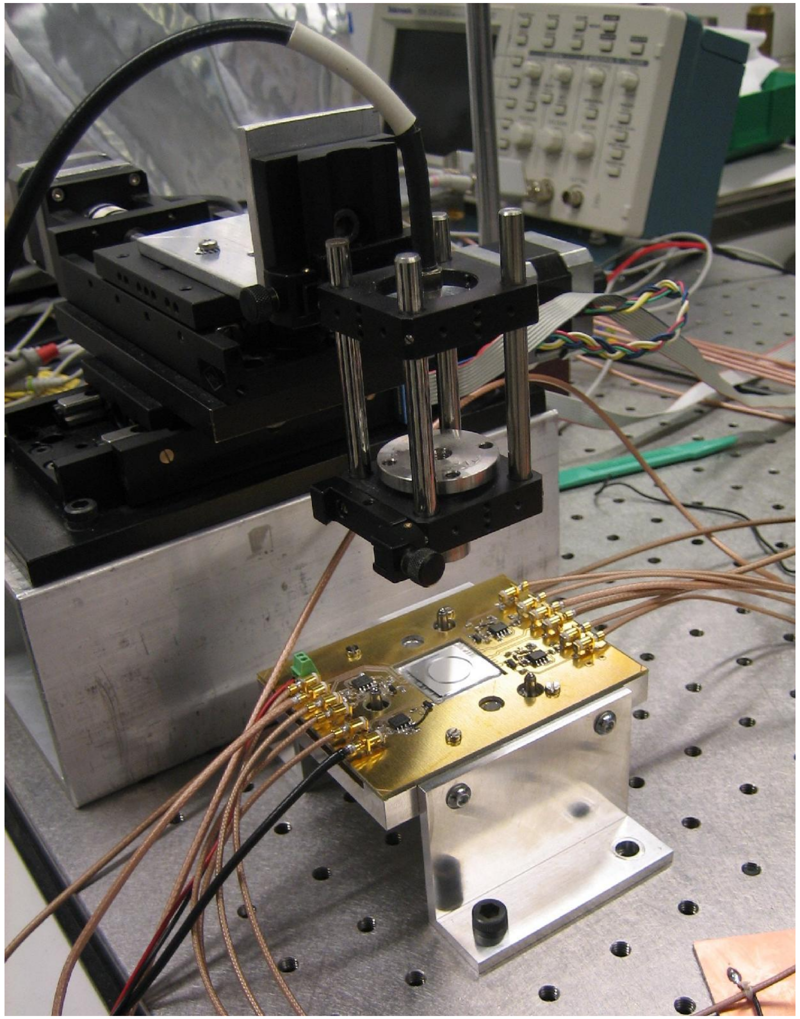


MEMS mirror component

- First MEMS mirror components of this type were manufactured in March 2007.
  - Air gap ~ 50 µm
  - Yield over 50%

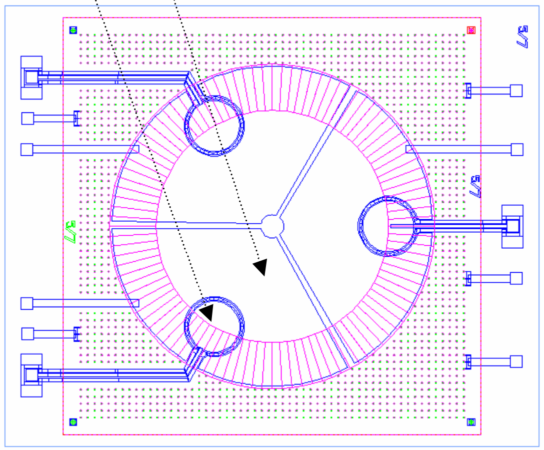
- Control electronics for laboratory tests have been characterized
  - Electrostatic deflection
  - Capacitive position measurement

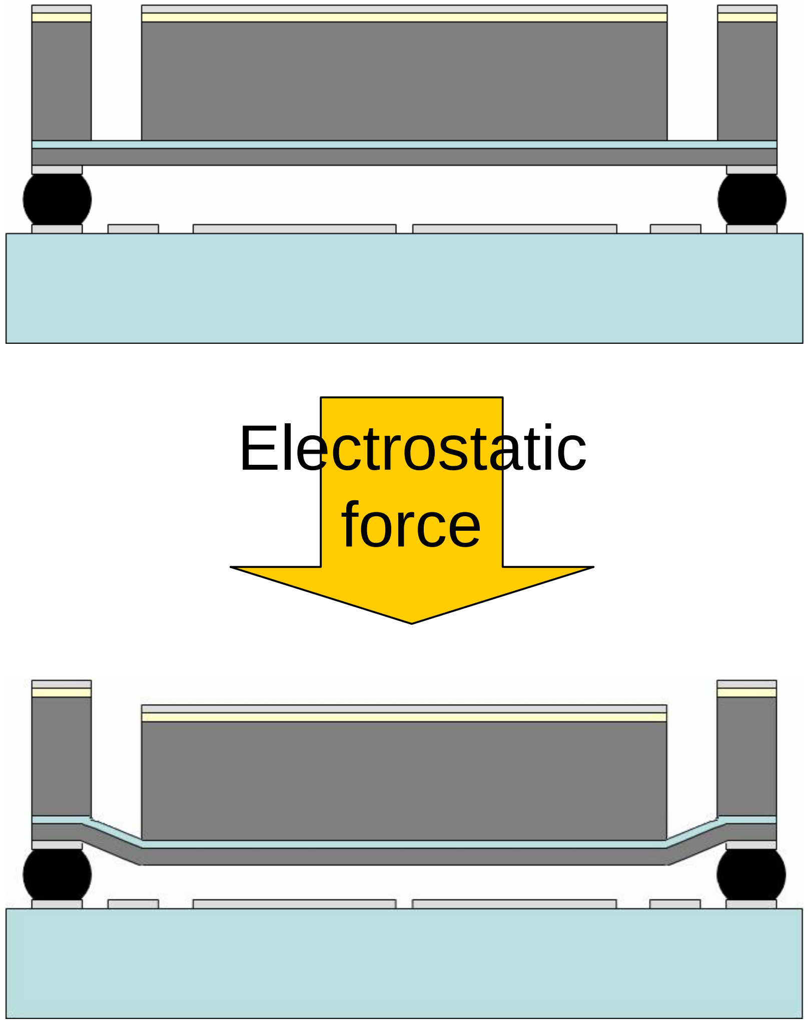
- Possibility to monitor mirror movement optically with white light interferometer.



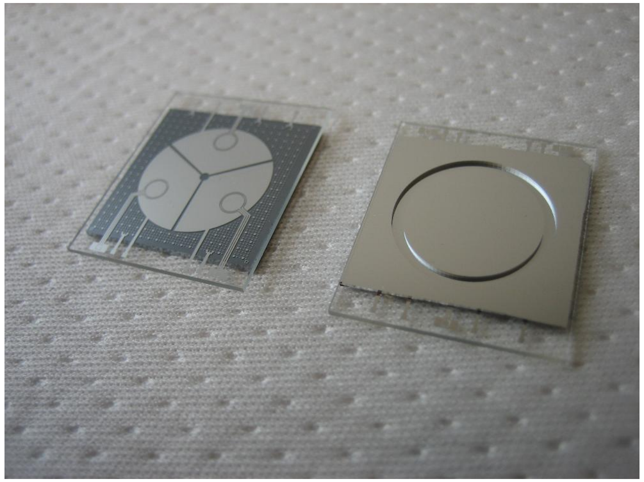
MEMS mirror component

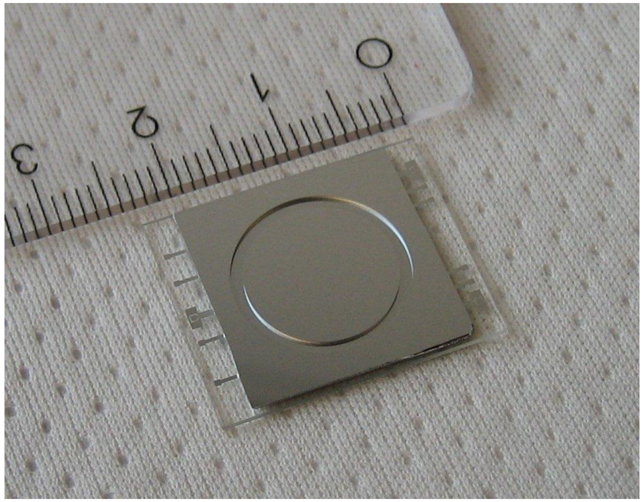
- Displacement of the mirror is caused by electrostatic force.
  - 3 electrodes on the glass substrate.
- Mirror movement is monitored with capacitive position measurement.
  - 3 electrodes on the glass substrate.





MEMS mirror component

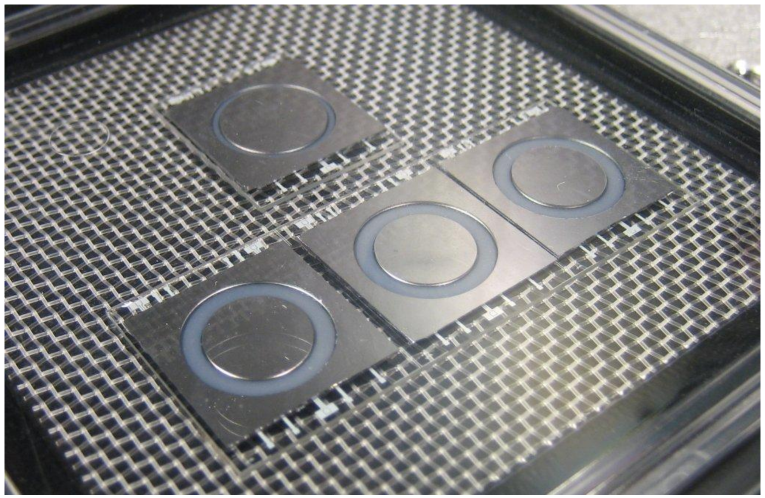




- The air gap between glass substrate and metallized silicon mirror part is created using flip-chip bonding and SnPb-bumps
  - Parallelism of bonded chip and substrate is of the order of one micron.
  - Air gap can be adjusted possibly even more than 100 µm.
  - By varying spring geometry, spring constant can be tailored.

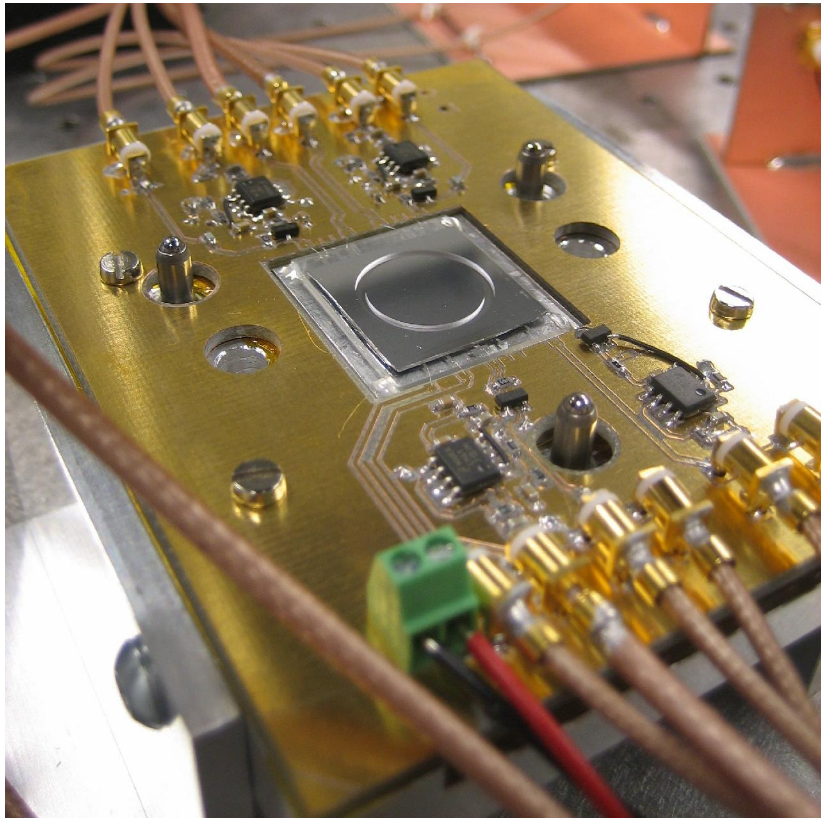
Alignment of multiple mirror on a single substrate

- Technique allows several silicon chips to be bonded on the same substrate.
- Positioning can be done at the mask level.
- Extremely good parallelism between independently controllable mirrors.
- Makes possible to use multiple reflections accurately.

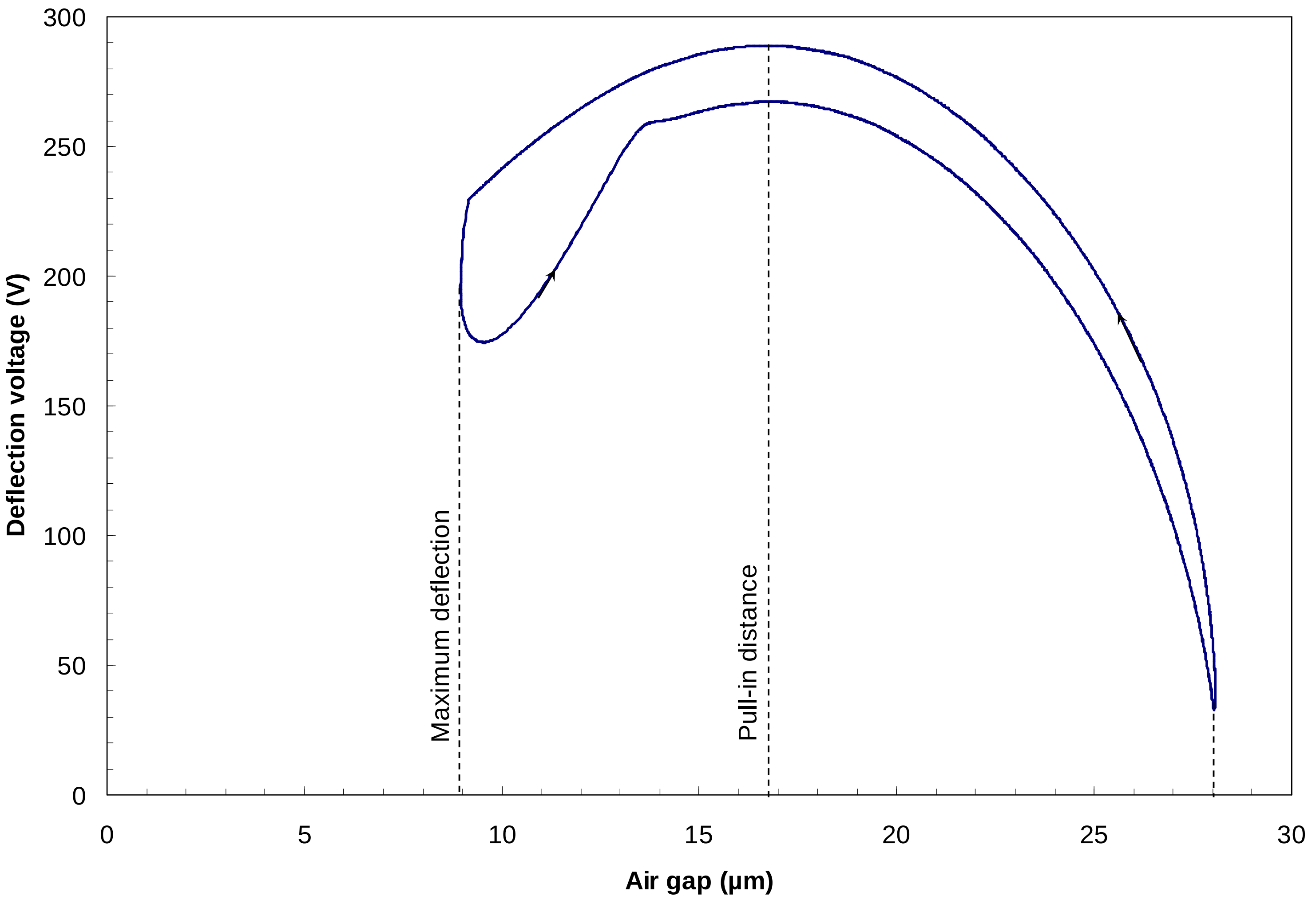


Electronics and mechanical performance

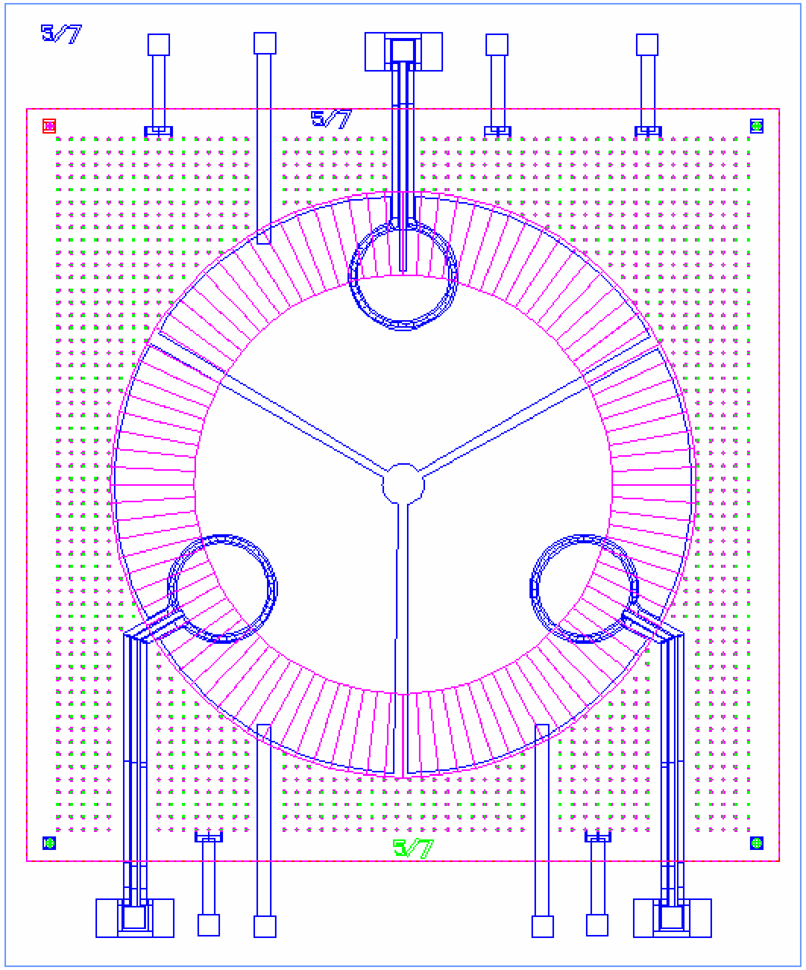
- First test electronics
  - mirror displacement is controlled with closed loop.
  - Position accuracy < 1nm.
- Currently the maximum velocity of the MEMS mirror is limited by the air damping.
  - Maximum frequency ~ 60 Hz @ ~ 10 µm displacement
- Pull-in distance has been exceeded in laboratory.
  - 2/3 of the gap has been exploited.



Exceeding pull-in distance with closed loop control

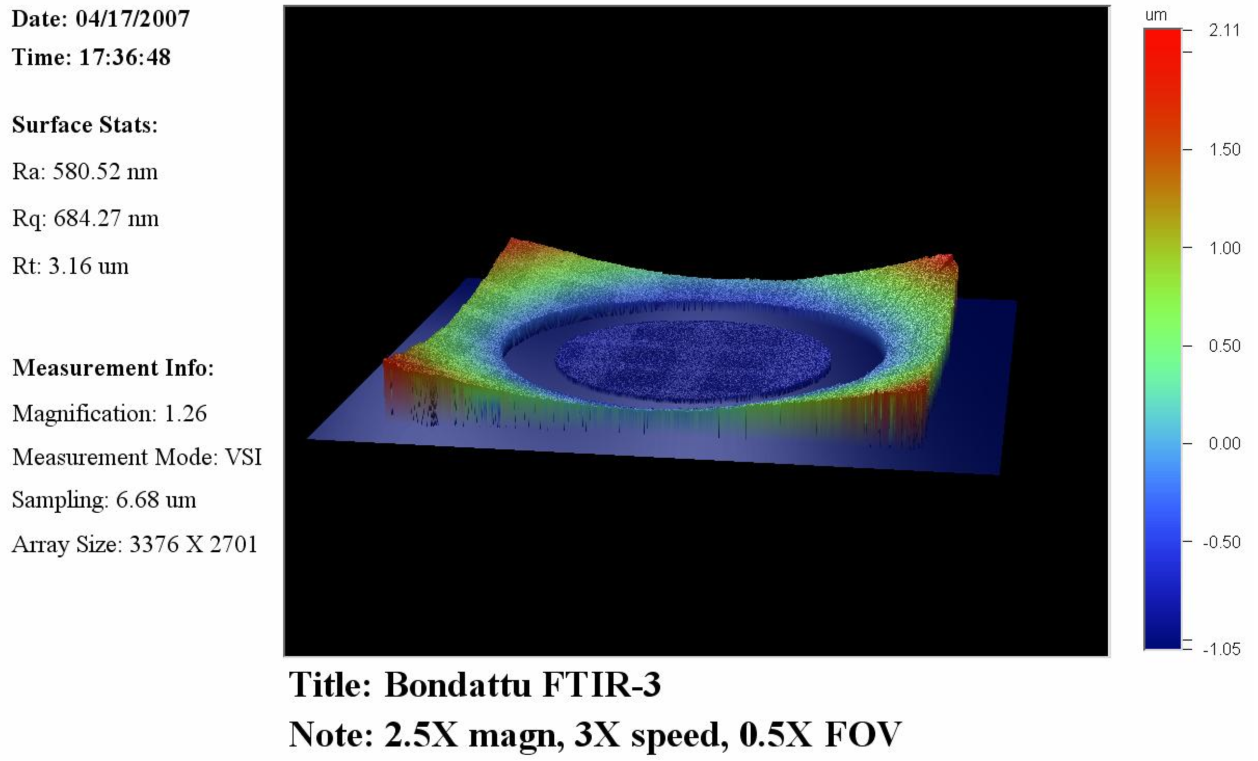


First improvements



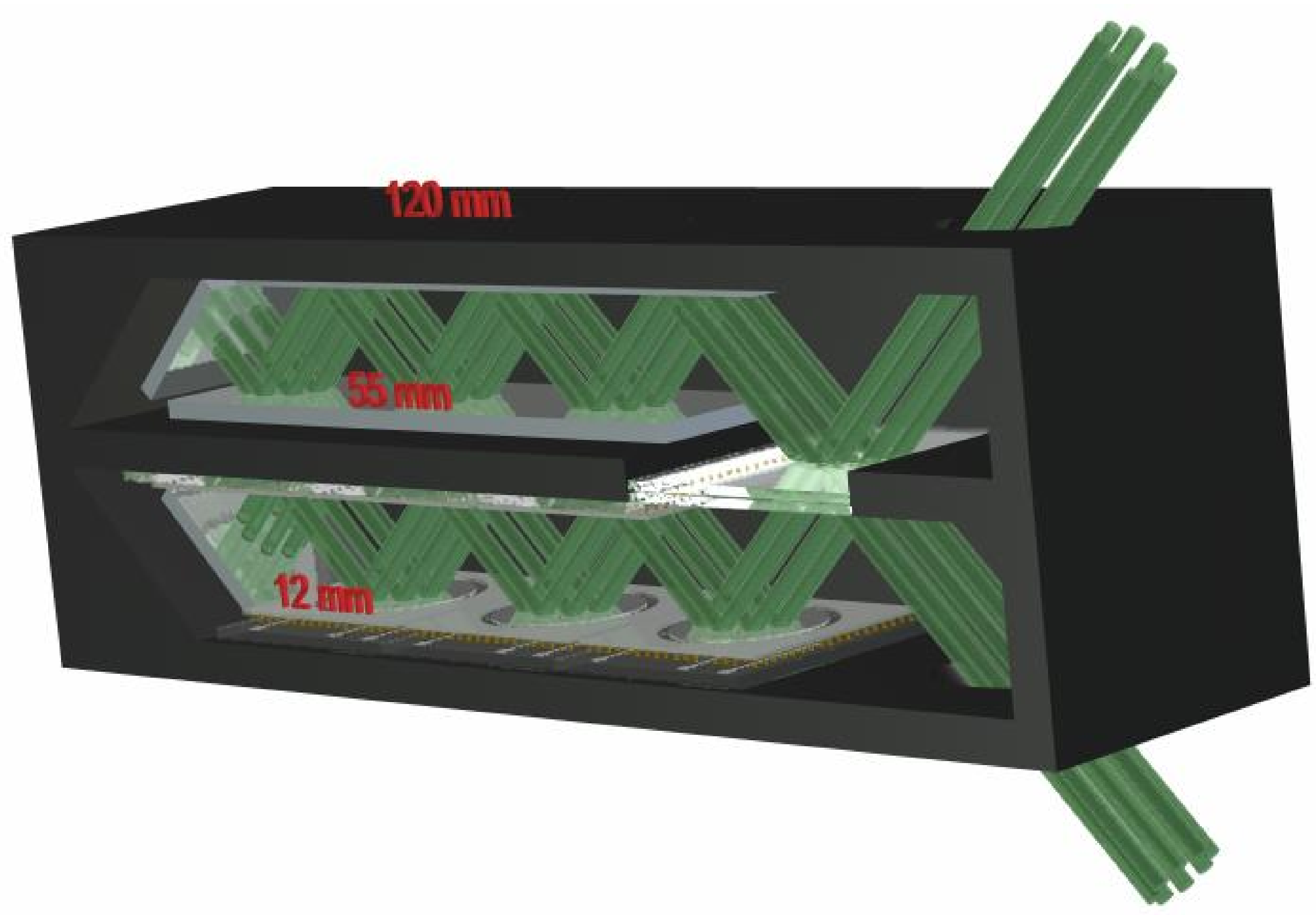
- Based on characterization experiences, first improvements have been implemented on the photolithographic masks.
  - Improved voltage breakdown limits
  - Better possibility to monitor mirror movements also optically
  - Improvement of ohmic contact to common silicon electrode
- Next improvements for the symmetry of the layer structure and layer thicknesses.

Mirror surface quality

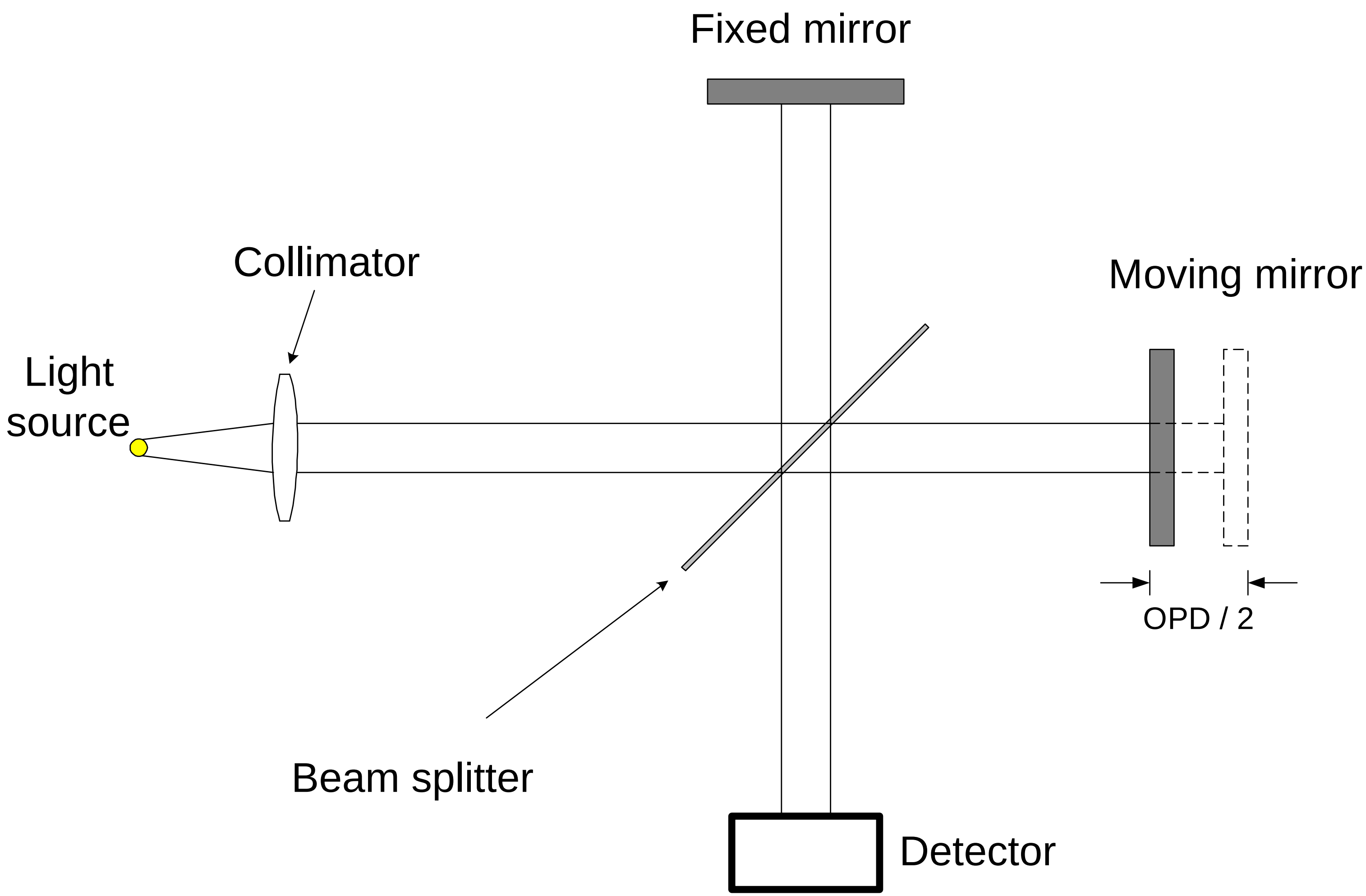


- Surface flatness of three MEMS mirrors was measured with profilometer.
- Mirror surfaces are saddle shaped
    - Curvature magnitude in range of 1 … 200 nanometers
    - Probable reason lack of symmetry in layers structure

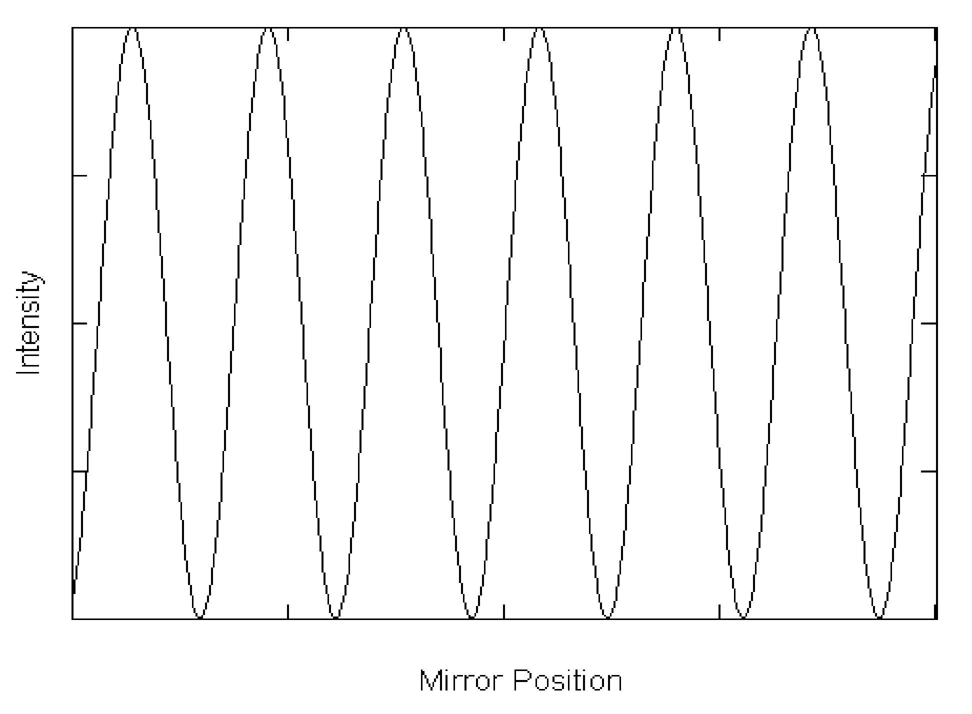
Laboratory tests and designed Fourier Transform Spectrometer

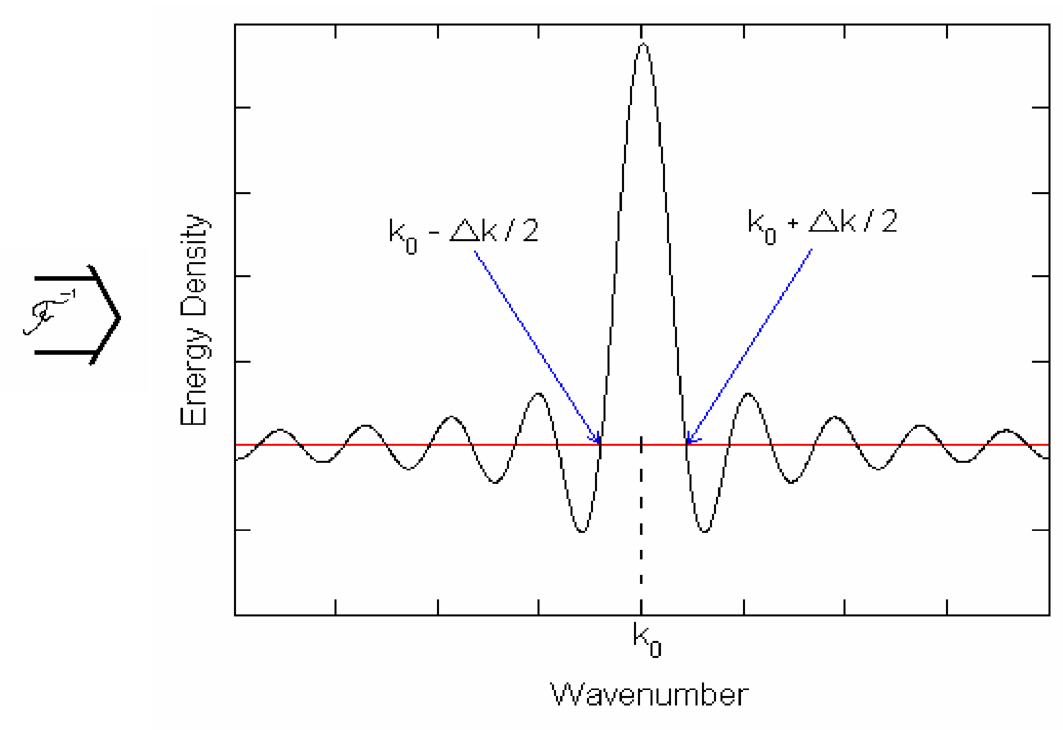


Michelson interferometer



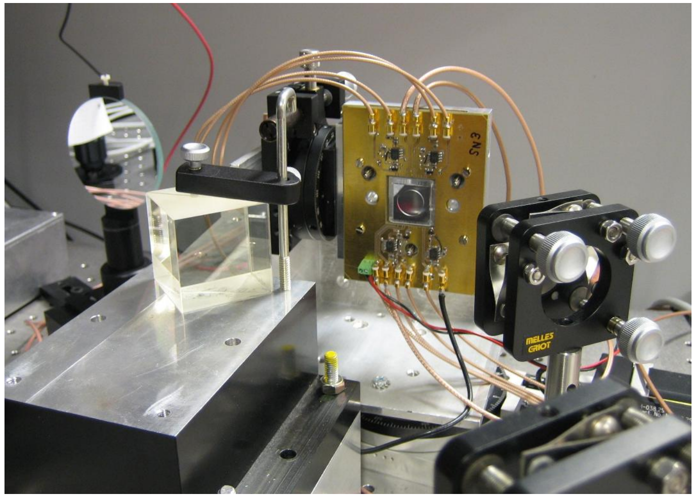
Monochromatic source

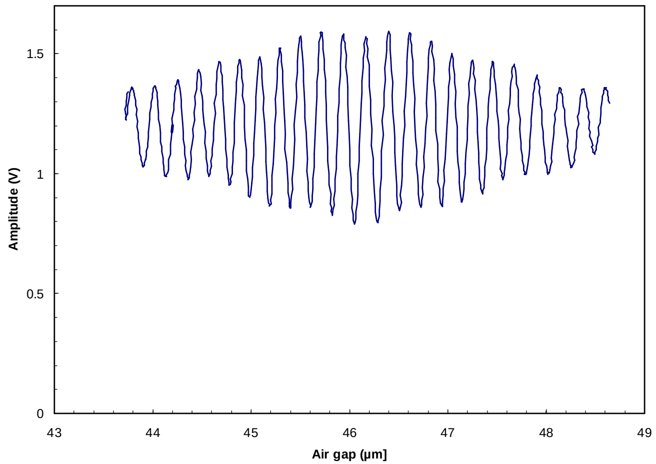




Laboratory test setup for MEMS mirrors

- Fourier transform spectrometer utilizing a MEMS mirror, with two reflections, has been constructed in laboratory environment.
- Preliminary test measurements with laser, diode and white light have been carried out.
- No adequate beam collimation.
- Difficult to use whole mirror diameter due to the surface flatness.





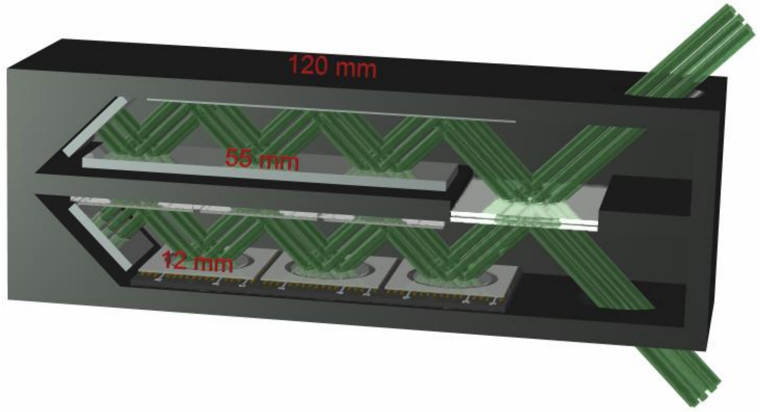
Miniaturized interferometers based on MEMS mirrors

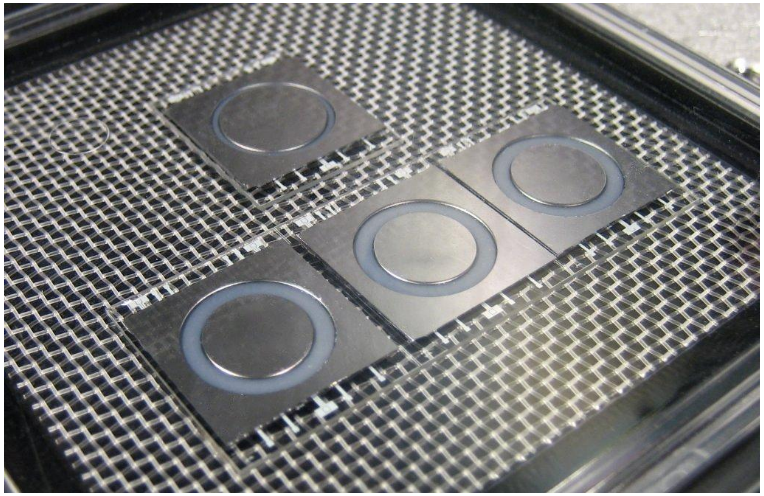
- VTT has designed interferometer platforms that could utilize several precisely moving MEMS mirrors and multiple reflections.

- Chosen technology promises fast, rugged spectrometer platforms suitable for various online process measurements and other demanding environments.
  - chemical, biological, pharmaceutical,
  - industrial control measurements,
  - and space applications.

- Issues for the feasibility study
  - Wavelength reference
  - Geometry and packaging
  - Handling of vibrations and temperature gradients

- Key target specifications for hand-held Fourier spectrometer
  - optical path difference >1 mm
  - spectral resolution <3 nm @ 1500 nm
  - mirror position accuracy <1 nm





Conclusions

- VTT has developed accurately controllable MEMS mirror component with extraordinary large mirror surface.
- Mirror component could be used in harsh environments, such as space applications.
  - Fast and accurate position measurement
  - Closed loop-control

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