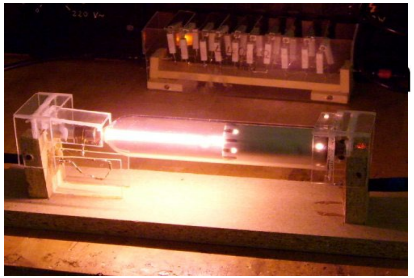
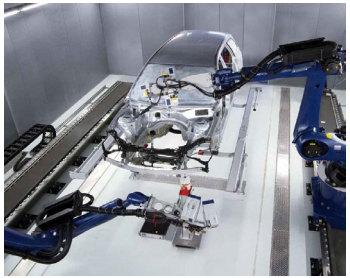
MEMS Test – MEMS dynamic response and 3D topography analyses

Polytec as market leader in of non-contact vibration measurements





1967 Gründung als Handelsfirma

1971 Erstes Eigenprodukt FIR-Spektrometer

1987 Erstes Vibrometer

1992 Erstes Scanning Vibrometer und erstes Velocimeter

1998 Startschuss in der Bildverarbeitung

2001 Erstes Diodenzeilen-Spektrometer

2004 Durchbruch in der Oberflächen-messtechnik

2004 Start Polytec PT GmbH

2008 Erstes vollautomatisches RoboVib® Testcenter

2017 50 Jahre Polytec

Principle & Setup of a Laser Doppler Vibrometer

LASER

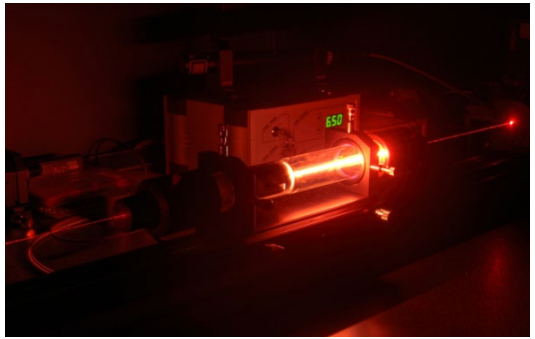
- E.g. Helium Neon Laser as coherent light beam source

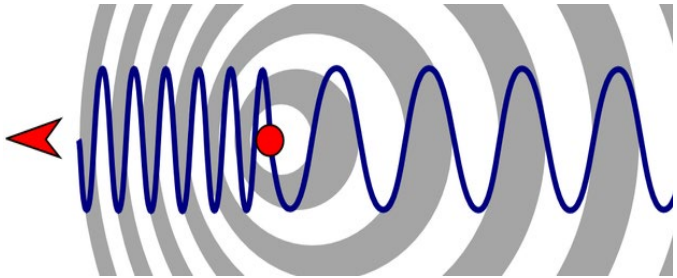
DOPPLER

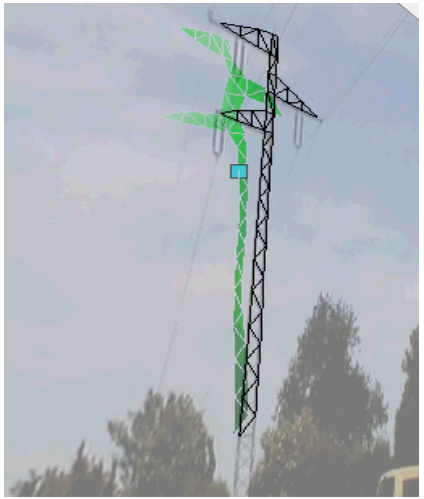
- optical Doppler effect
- Frequency shift proportional to object velocity

VIBROMETER

- vibration measurements from micro to macro scale



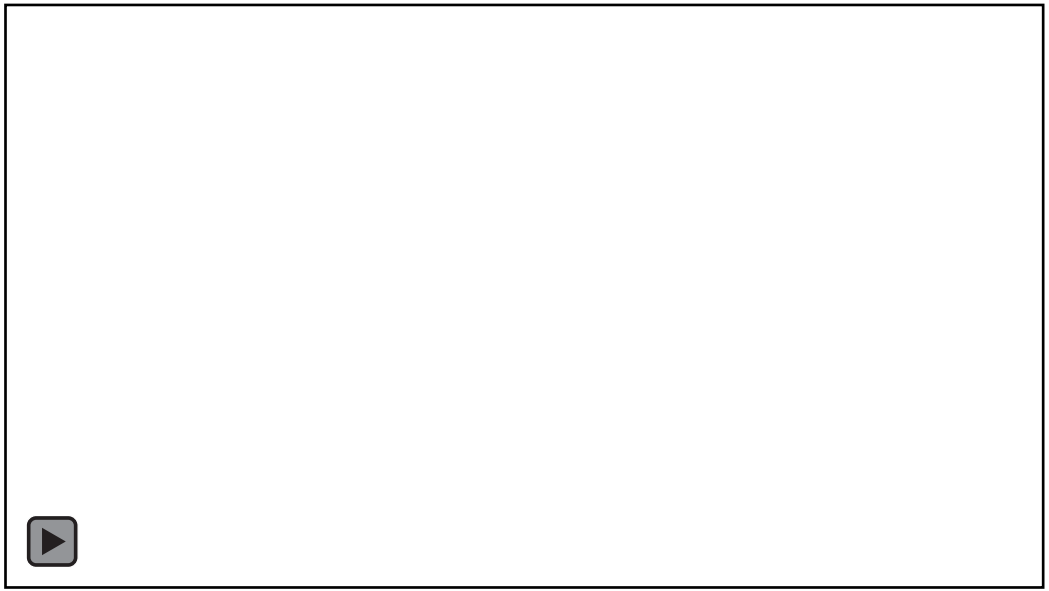




Laser Doppler Vibrometer - Advantages

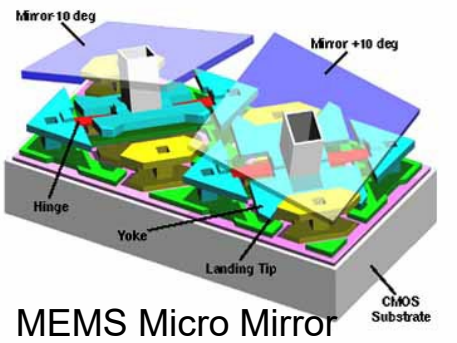
- Non-contact and non-reactive vibration measurement
- highest vibration measurement resolution → vibrations down to femtometer level can be measured
  - 1 Femtometer = 10^{-15} m
  - 1,7 fm – diameter of a proton
- Vibrations from 0Hz up to 8GHz
- Real time an FRF
- Universal tool an many applications

Principle & Setup of a Laser Doppler Vibrometer:

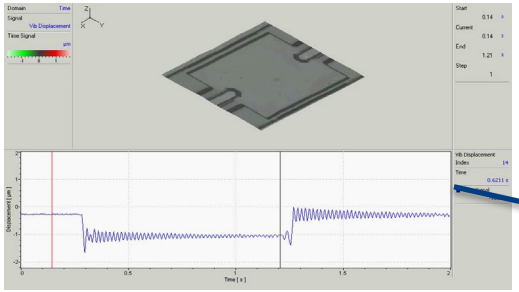


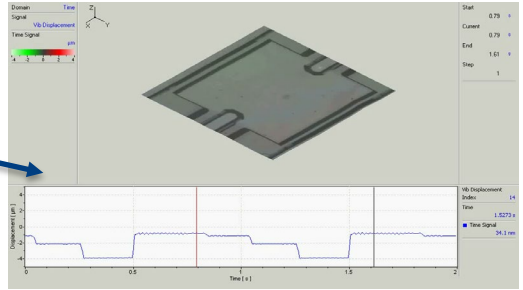
Polytec – vibration is everywhere - small…

Swiss mechanical Watch

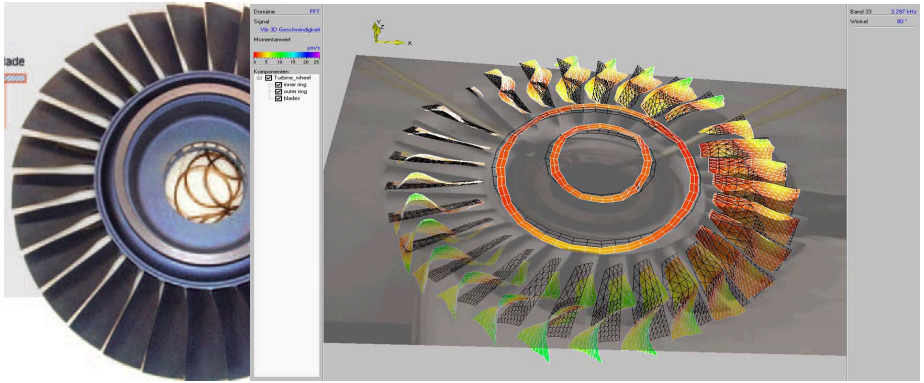


MEMS Micro Mirror



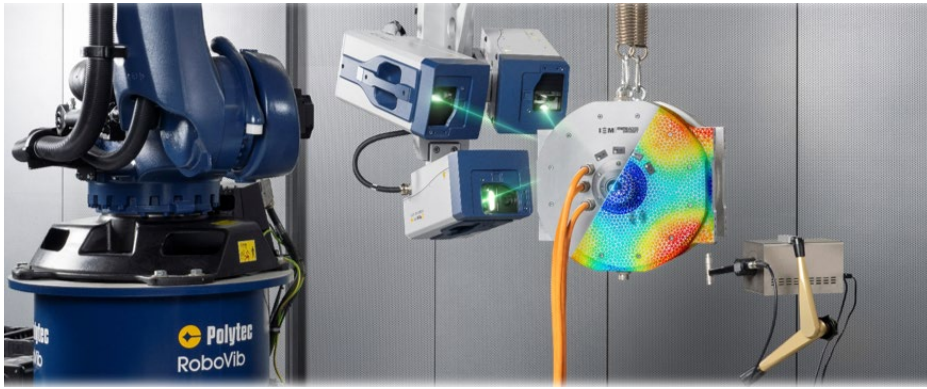


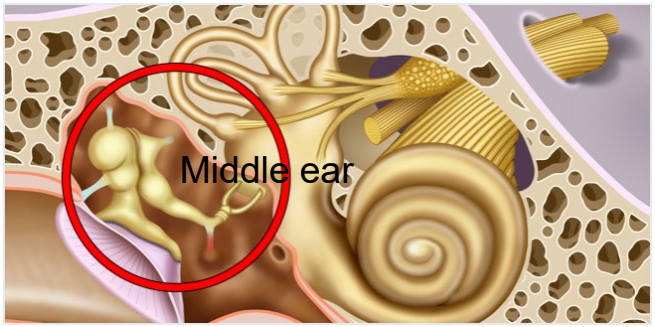
Polytec – vibration is everywhere - medium…



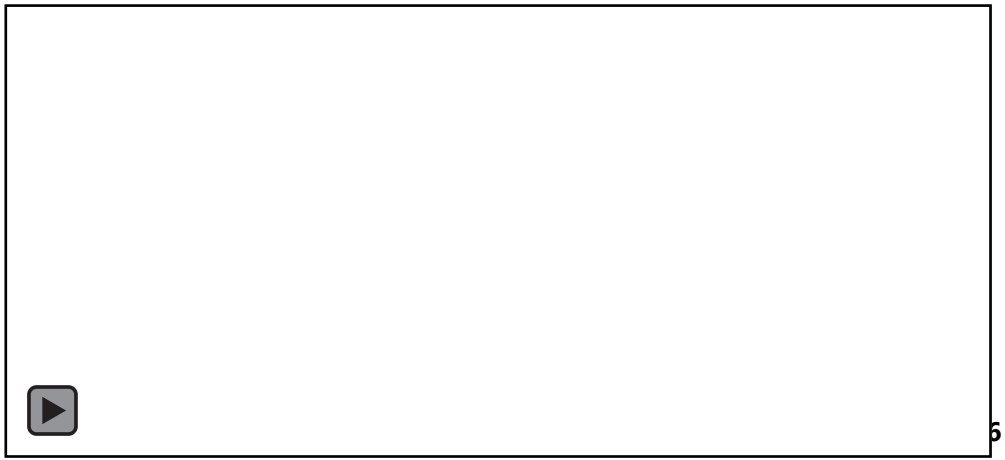
Airplane turbine - BLISK

E-drive



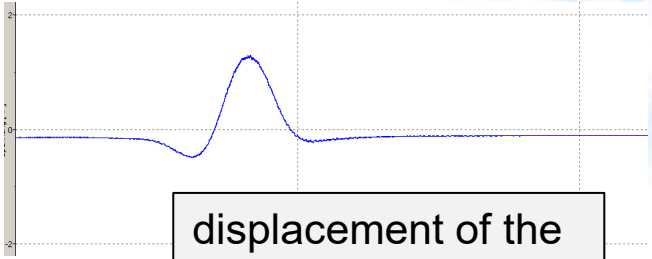


Gehörknöchelchen Hammer (malleus), Amboss (incus) und Steigbügel (stapes) im Mittelohr.

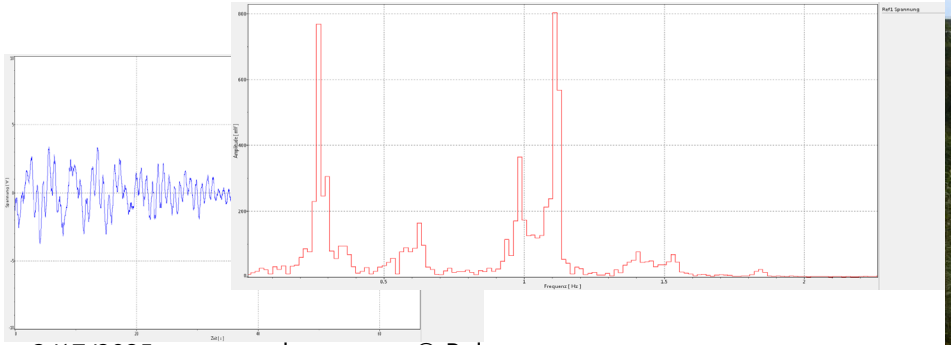


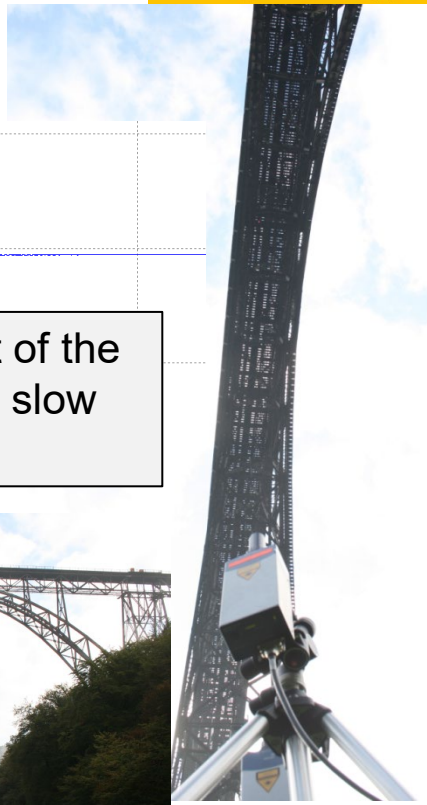
Polytec – vibration is everywhere - large…

Bridge vibrations



displacement of the bridge during slow train pass-by





Polytec – vibration is everywhere - special…

Polytecs VibroGo in neuer Netflix-Doku mit David Attenborough

In der sensationellen Naturdoku-Serie „Secret World of Sound“ auf Netflix USA spielt das Polytec Vibrometer VibroGo eine entscheidende Rolle. Folge 2 der Serie spürt die verborgenen, für uns unhörbaren Symphonien der leisesten Kreaturen der Natur auf. So machen Biologen auch die geheime Kommunikation von Buckelzikaden, die sich über Vibrationen unterhalten, mit unserem VibroGo hörbar und können so deren Sprachwelt erforschen.

Systems for Microstructures – e.g. MEMS

Optical Measurement of MEMS – The Tools

MSA-650 IRIS
Micro System Analyzer

Characterization inside Si-capped MEMS

- Dynamics and Topography
- Full-Field Scanning Out-of-plane up to 25 MHz
- Full-Field In-plane up to 2.5 MHz

MSA-600
Micro System Analyzer

All-in-One MEMS Analyzer

- Dynamics and Topography
- Full-Field Scanning Out-of-plane up to 8 GHz
- Full-Field In-plane up to 2.5 MHz

MSA-100-3D
Micro System Analyzer

3D Vibration Measurement

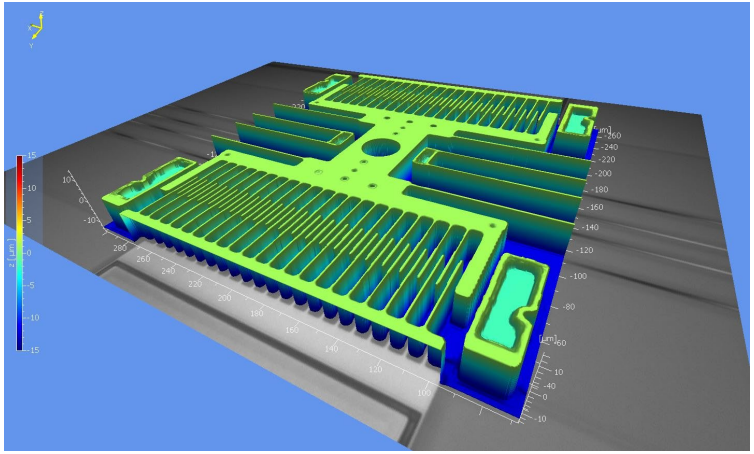
- 3D Single Point or
- Full-Field 3D Scanning
- Up to 25 MHz

MSA-600 our optical Micro System Analyzer

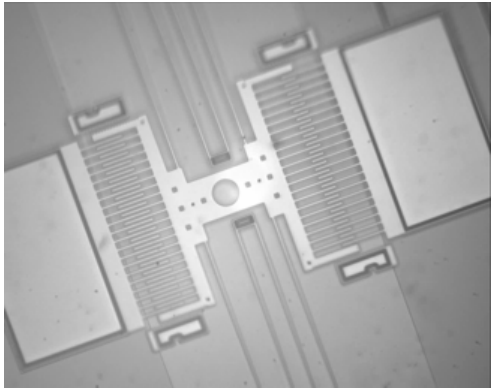
- **All-in-one optical MEMS-Testing solution –** for **full field**
  - **out-of-plane** vibration up to 8GHz with fm resolution - **Scanning Laser Doppler Vibrometer**
  - Result: vibration animation, amplitude, resonance frequency, damping, quality factor
  - **very short measurement time** (below 0,1s per point - 400 Points/24 seconds - 16 points/s)

MSA-600 Micro System Analyzer

- **3D shape and topography analysis**
  - Scanning White Light Interferometer
  - **1nm z-resolution**
  - **below 1µm lateral resolution**
  - Measurements within few seconds
  - flatness, step height, parallelism

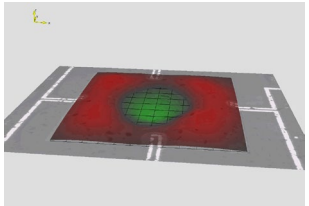


- **All-in-one optical MEMS-Testing solution – for full field**
  - **in-plane vibration up to 2,5MHz** with nm resolution
  - Stroboscopic video microscopy



Virbation Measurement of MEMS – Some Examples

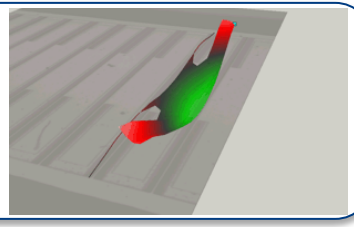
Pressure Sensors



Inertial Sensors

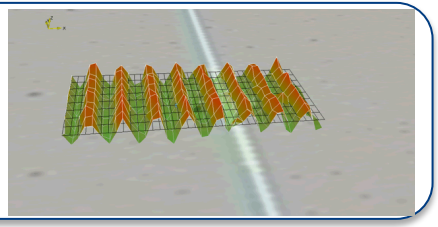
Microphones

Micro Mirrors



PMUTs & CMUTs

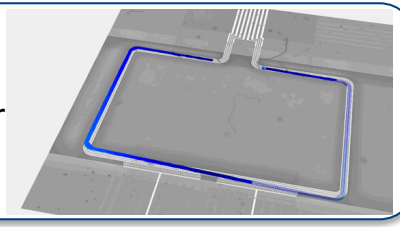
SAW



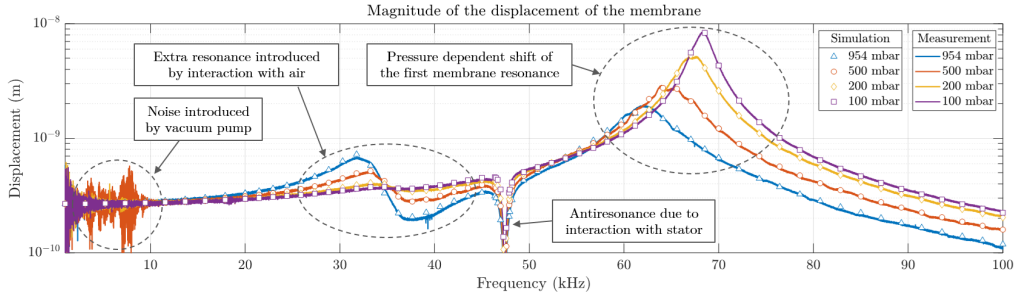
RF-MEMS

Cantilever & AFM Tips

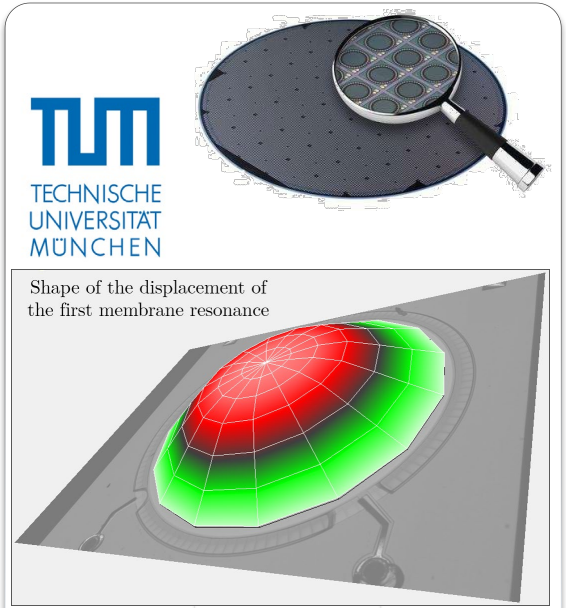
Flow-Sensor



LDV in MEMS Microphones R&D



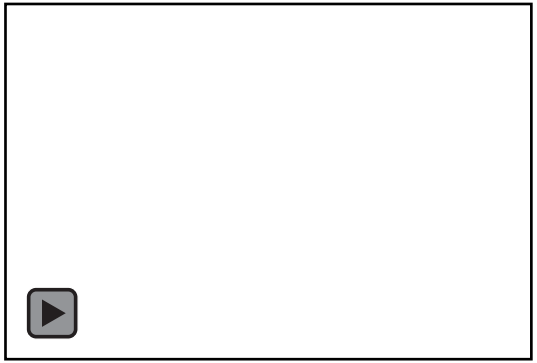
***Task**: Pressure dependence of FRF*

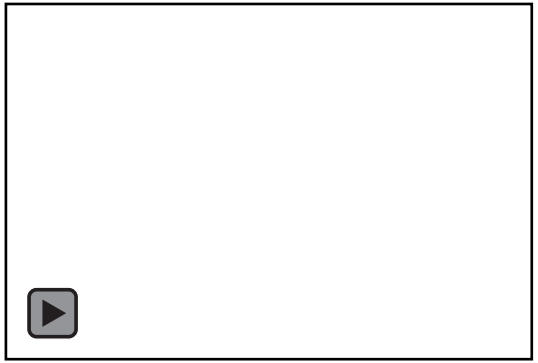


By courtesy of G. Schrag, TUM

Indirect Membrane thickness measurements of thin membranes with resonance frequency analysis

Task: Identification of membrane thickness of e.g absolute pressure sensors, no direct measurement possible





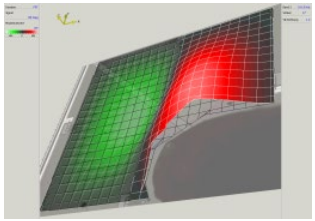
Approach: Modell based parameter identification from experimental modal data of sensor membrane

MEMS Pressure Sensors

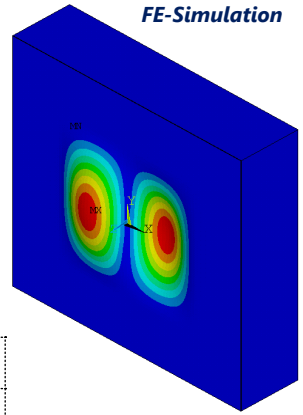
- One of the first MEMS devices, various types, diverse applications, safety critical
- Some performance relevant parameters like membrane thickness or internal stress can not be measured electrically

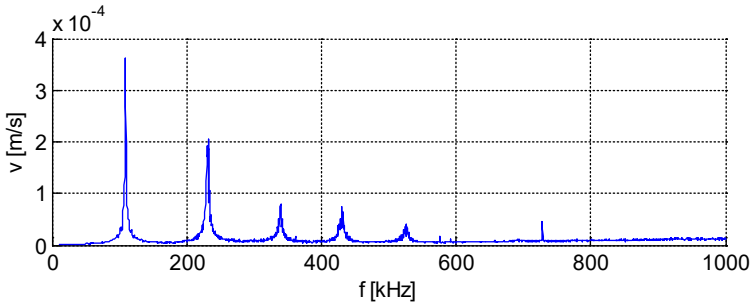
Pressure Sensors: Parameter Identification

MSA measurement data

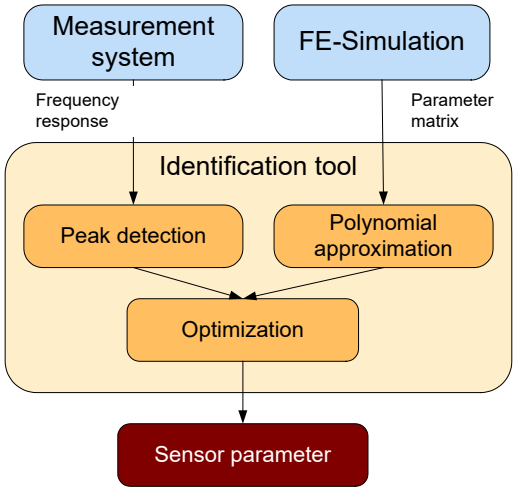


FE-Simulation





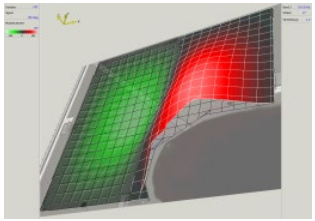
Task: *...Identification of membrane thickness of absolute pressure sensors (accuracy < 1%)*



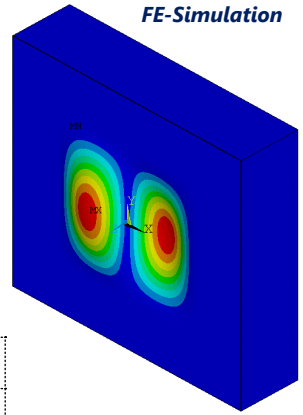
By courtesy of IMMS Ilmenau

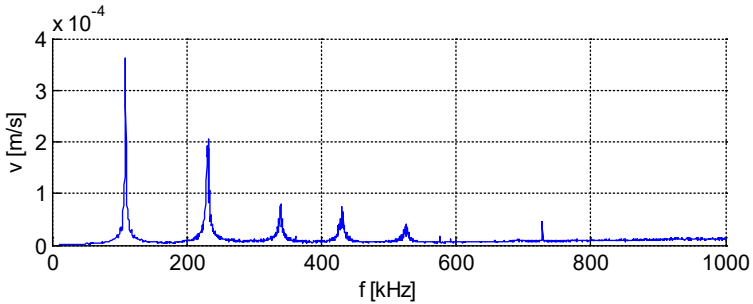
Pressure Sensors: Parameter Identification

MSA measurement data



FE-Simulation

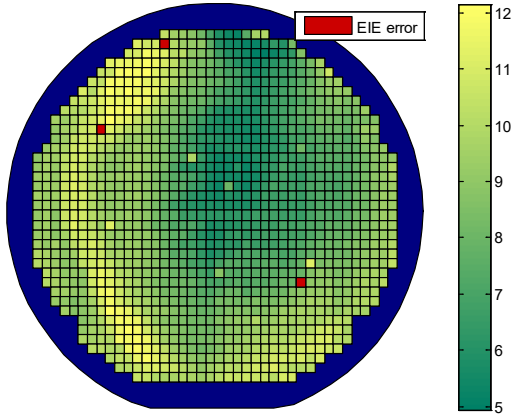




Task: *...Identification of membrane thickness of absolute pressure sensors (accuracy <1%)*

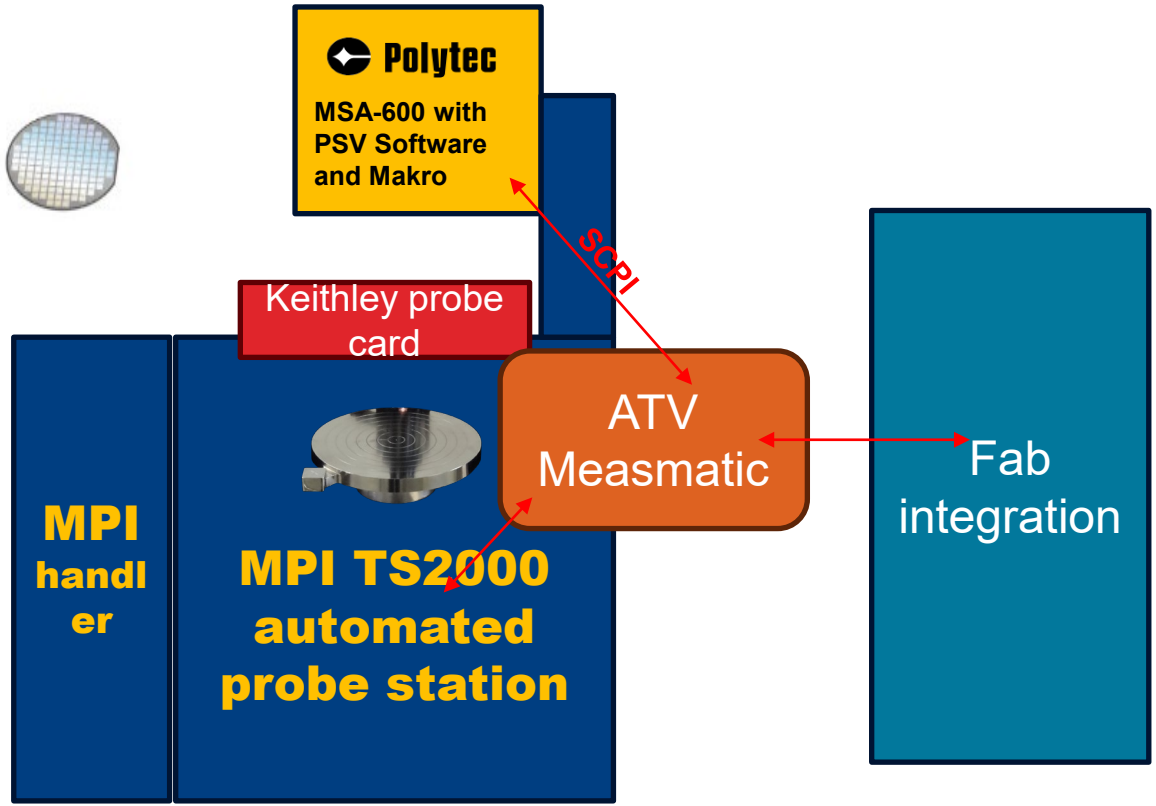
Result: Wafer Map

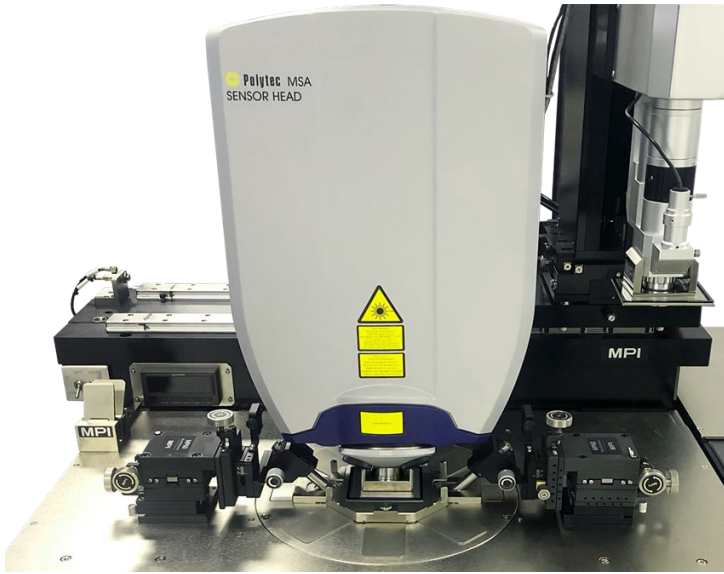
with membrane thickness, **accuracy better 1%, sensitivity better 1nm**



By courtesy of IMMS Ilmenau

New: Automated Wafer Mapping





New: MSA-600 with new tools for automation

- New: **Image correlation** for automated scan point alignment (better 1µm)
- New: **small piezo autofocus** to have a fast focus adaption in case the wafer is not flat

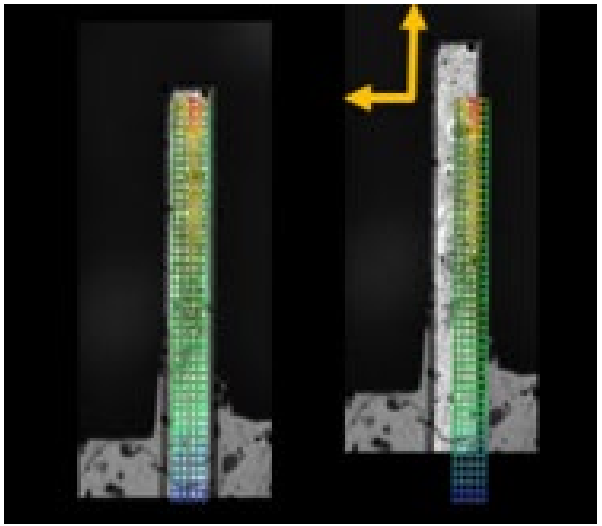
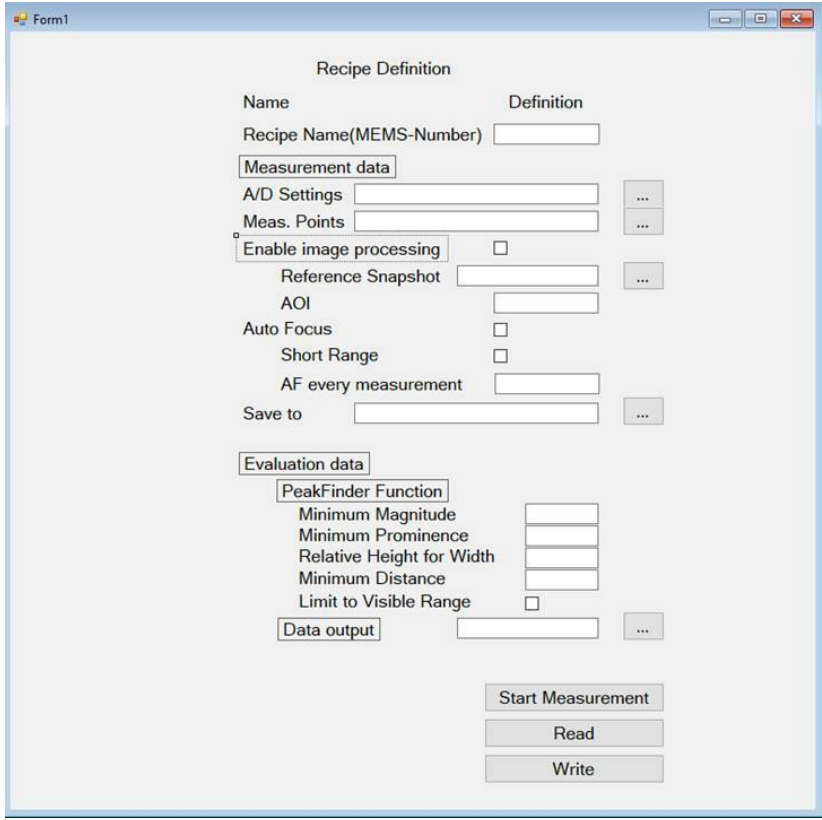


Image correlation

small piezo autofocus

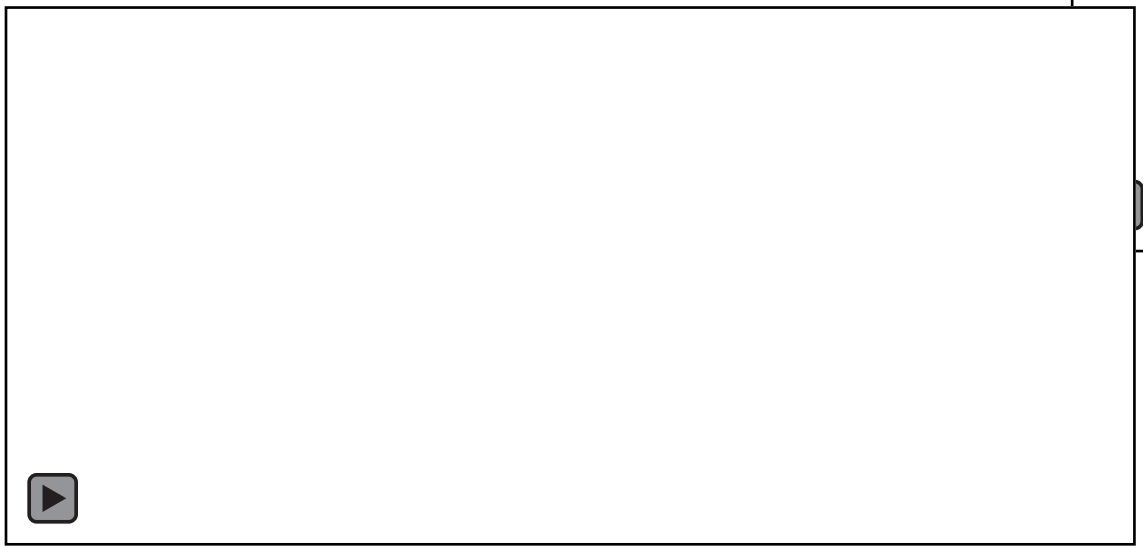
New: **Recipe Creator** for automated measurements

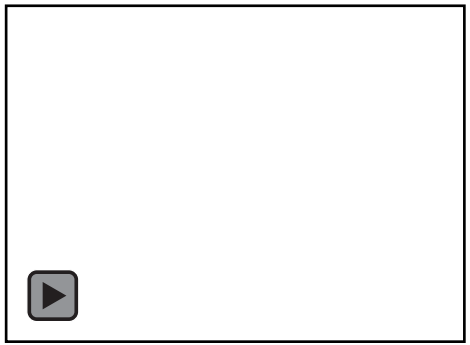
- Idea: Polytec MSA as slave for e.g. measmatic software
- Measmatic controls Prober und MSA
- **New:** With the new **Recipe Creator**, recipes / automated measuremnts can be easily generated, tested and written
  - **For each MEMS sample there is a recipe** in a recipe database
  - **Measmatic stats** up **recipe for automatic measurement** and communicate with PSV
  - **Communication via TCP/IP and SCPI interface**
- MSA-600 send back key parameter for wafer Mapping such as resonance frequencies, Q-values, amplitudes



Examples – SAW:

SAW @ 129MHz





Microfluidics using SAWs: Blood cell sorting