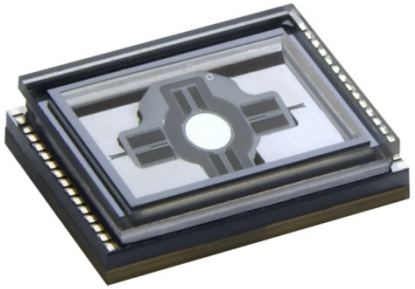
# Hermetically Sealed 2D-MEMS Scanning Mirrors for High Resolution Imaging Applications

Ulrich Hofmann, Joachim Janes, Lars Ratzmann, Oliver Schwarzelbach

**Fraunhofer Institute for Silicon-Technology ISIT**

Ulrich Hofmann, Fraunhofer ISIT, Fraunhofer Strasse 1, D-25524 Itzehoe, Germany,
email: ulrich.hofmann@isit.fraunhofer.de,
Tel.: +49 4821 174553



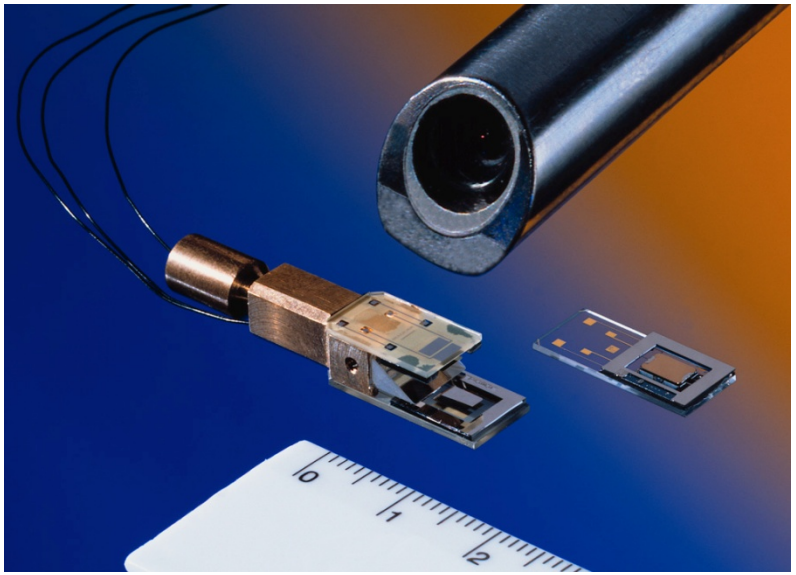


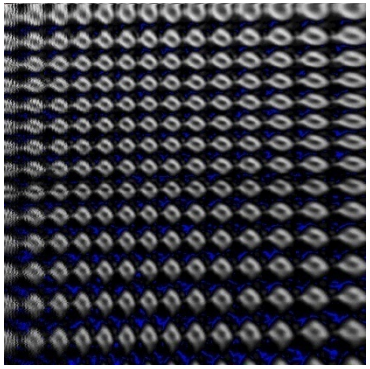
Fraunhofer ISIT

7th ESA Round-Table on MNT
for Space Applications

# MEMS-scanning mirrors developed at ISIT since 1995

Miniature confocal laser scanning microscope for endoscopic *in situ* tumor diagnostics

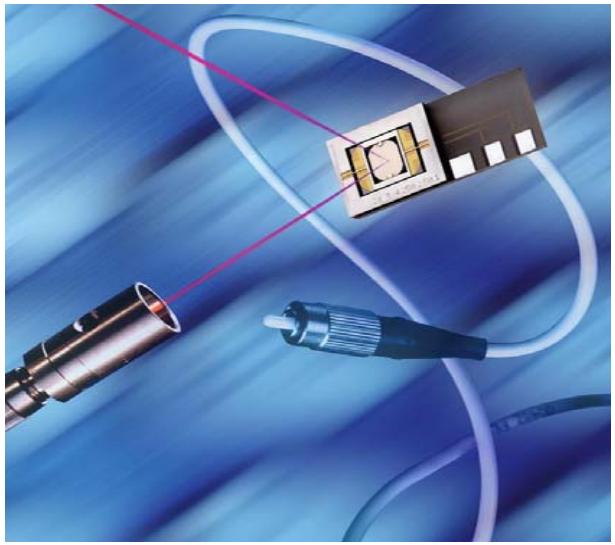


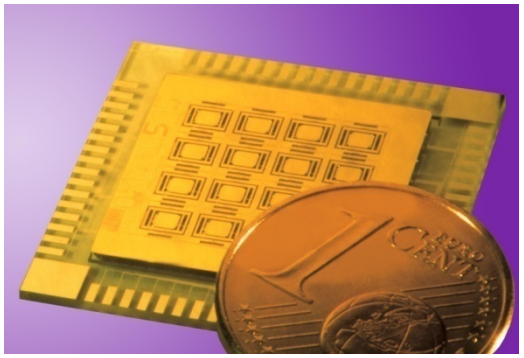


1024 x 1024 pixels
resolution: 2µm

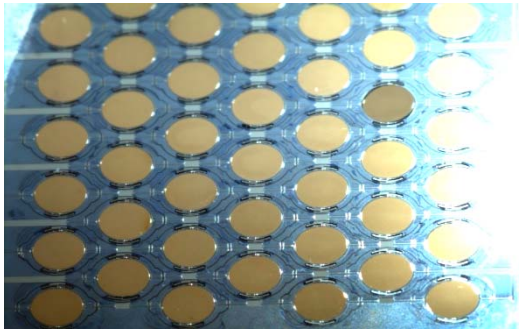
# MEMS scanning mirrors developed for telecommunication industry (1999..2003)

Optical cross connects





4 x 4
2D-scanner
array



6 x 7
2D-scanner
array

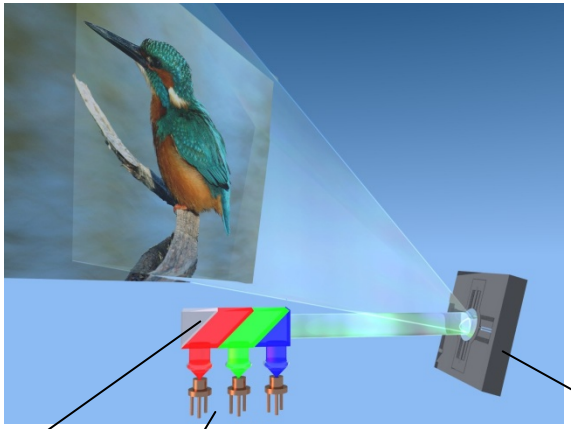




Fraunhofer ISIT

# high speed MEMS scanning mirrors for laser video projection displays

embedded cell-phone
projector for ‘personal TV‘



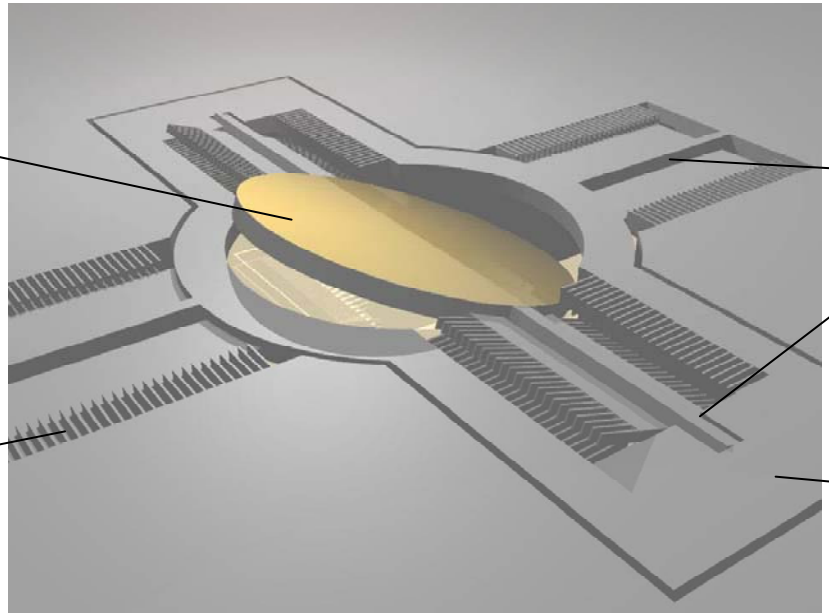
beam combiner

RGB-laser

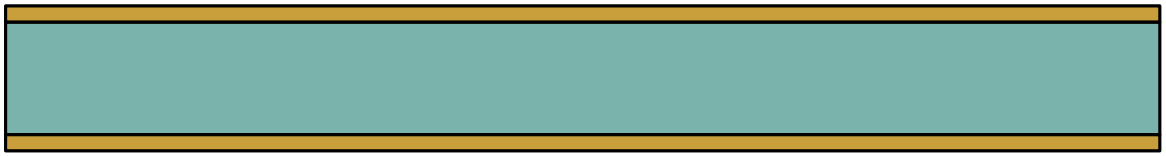
2D-MEMS
scanning
mirror

HDTV resolution (720 x 1280) requires a line projection frequency of 43,200 lines / sec !

# electrostatic actuation of resonant 2D-MEMS-scanning mirrors



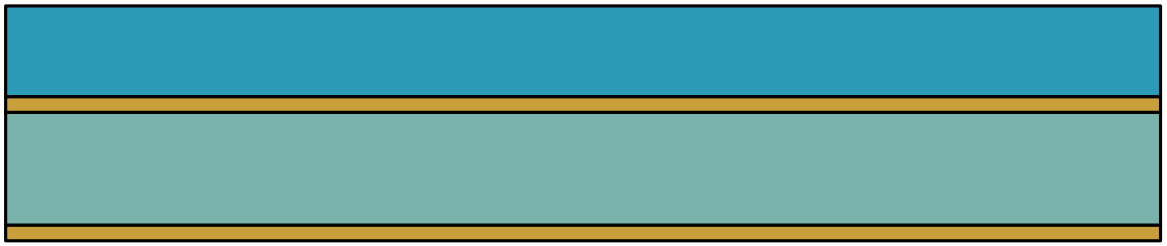
# MEMS mirror fabrication



silicon oxide

silicon substrate

# MEMS mirror fabrication

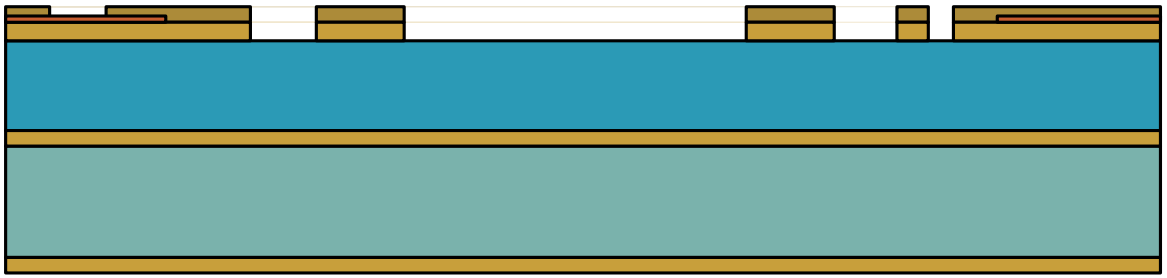


polysilicon 30µm

silicon oxide 1µm

silicon substrate 500µm

# MEMS mirror fabrication



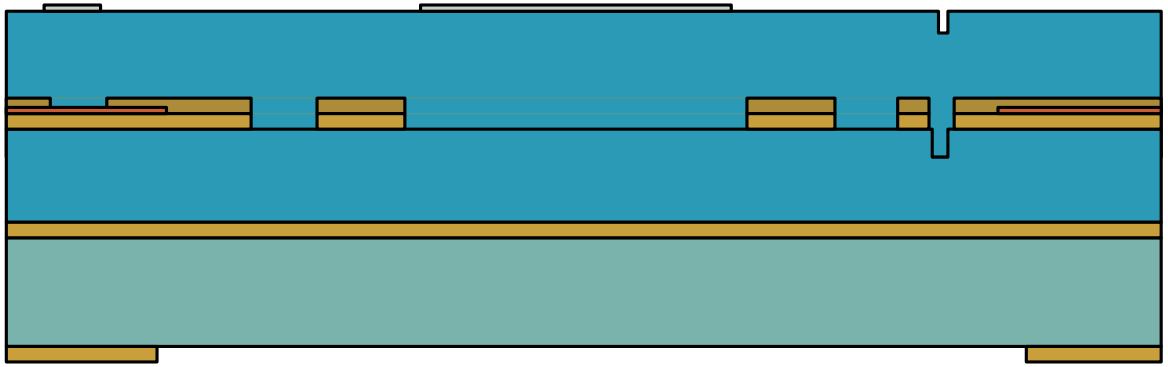
buried oxide mask +
embedded poly interconnects

polysilicon 30µm

silicon oxide 1µm

silicon substrate 500µm

# MEMS mirror fabrication



aluminum 400nm

polysilicon 30µm

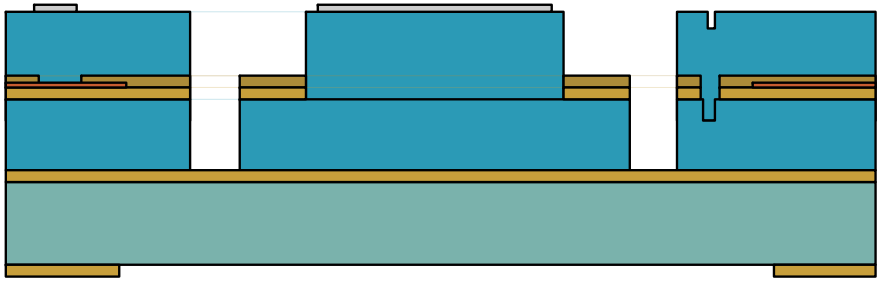
buried oxide mask +
embedded poly interconnects

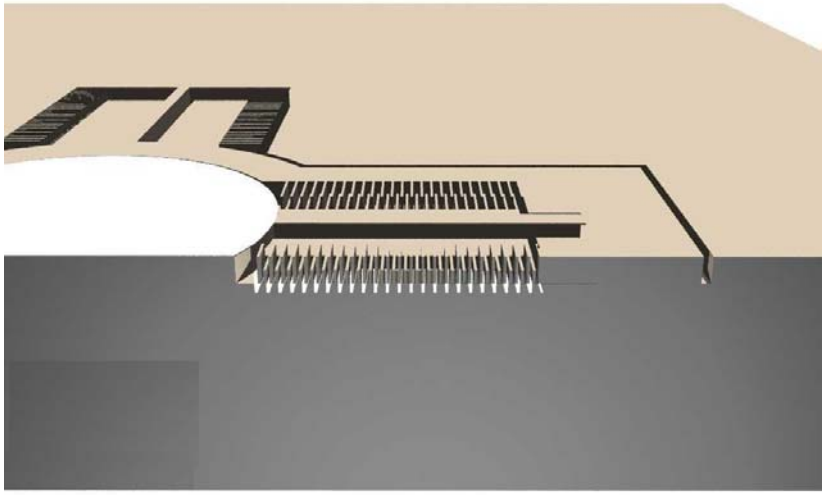
polysilicon 30µm

silicon oxide 1µm

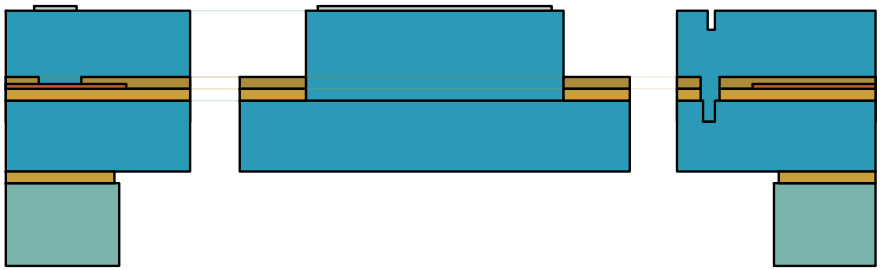
silicon substrate 500µm

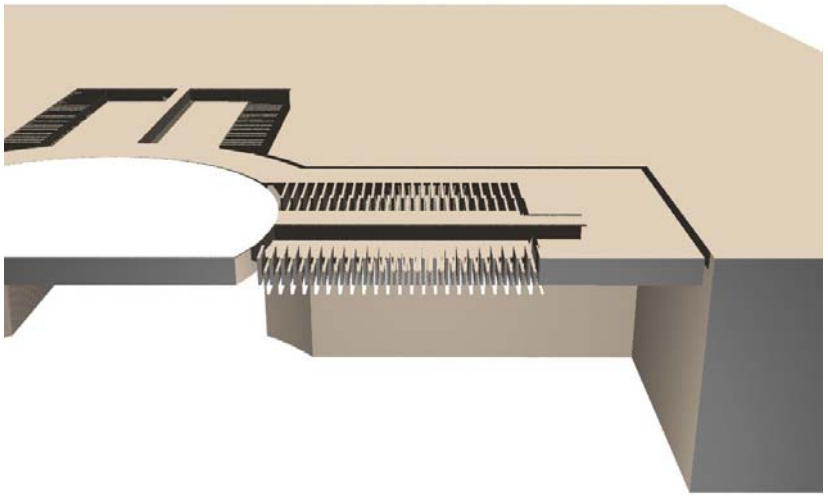
# frontside patterning by deep reactive ion etching (DRIE)



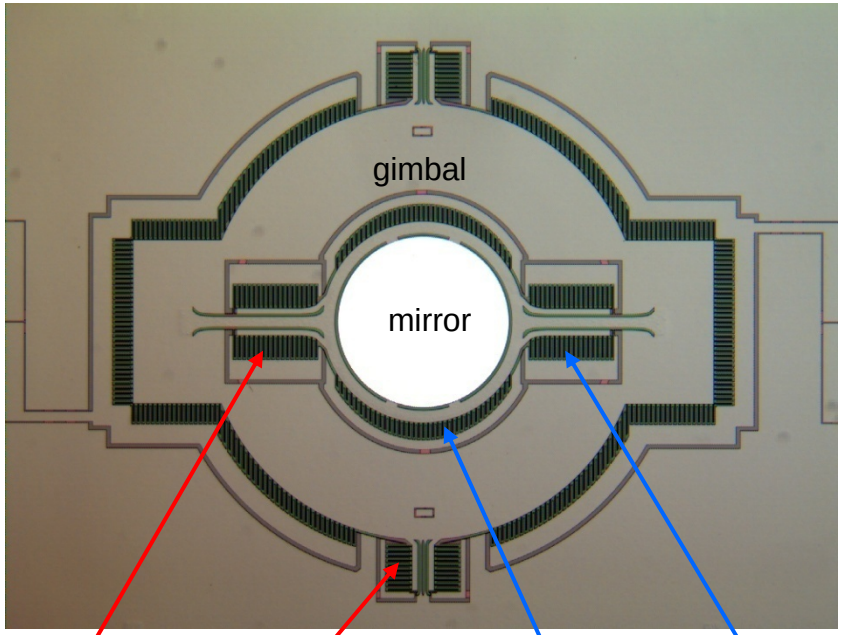


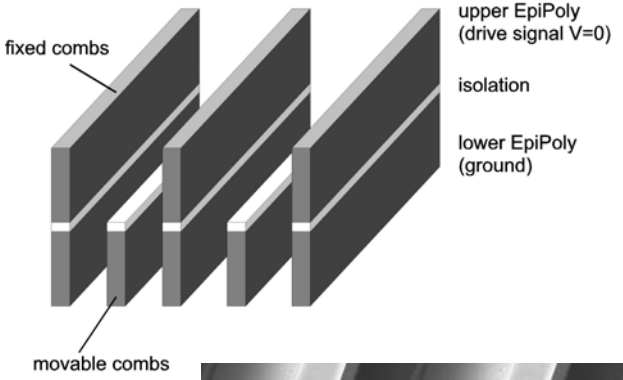
# backside-patterning by deep reactive ion etching (DRIE)

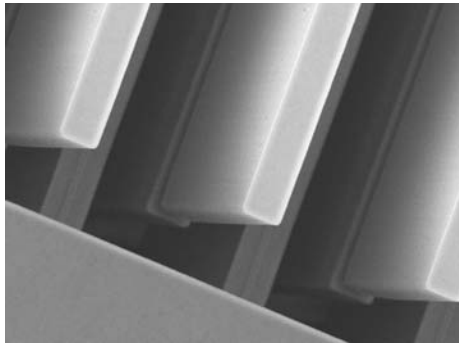




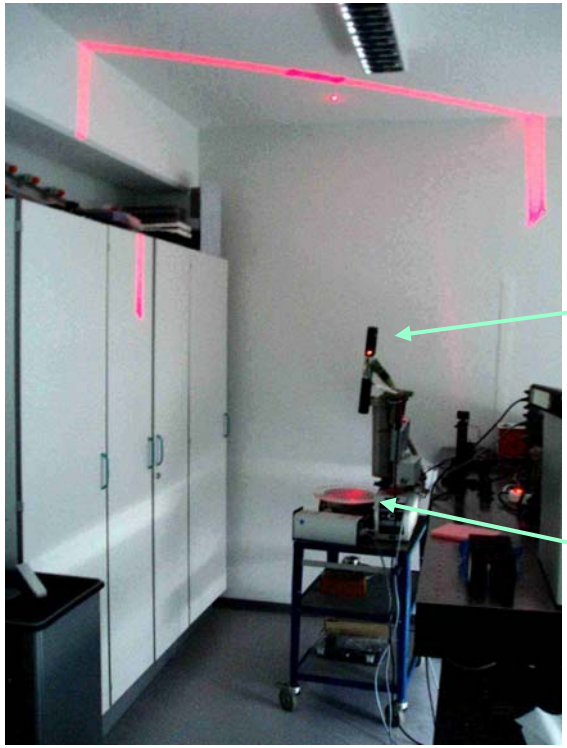
# two-axis MEMS scanning mirror for laser projection



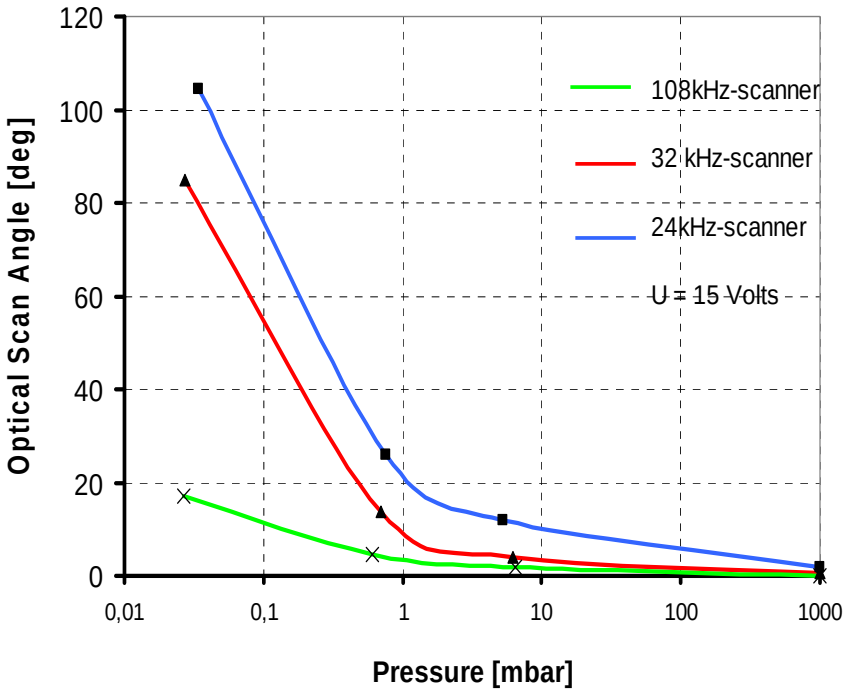



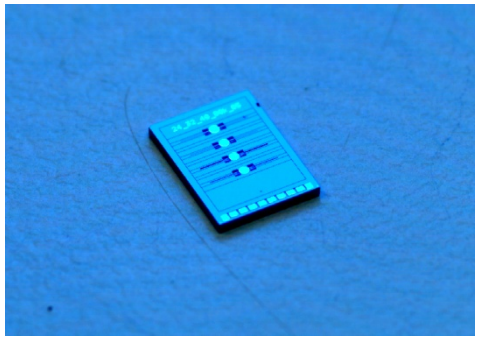



# test of MEMS scanners in a vacuum chamber

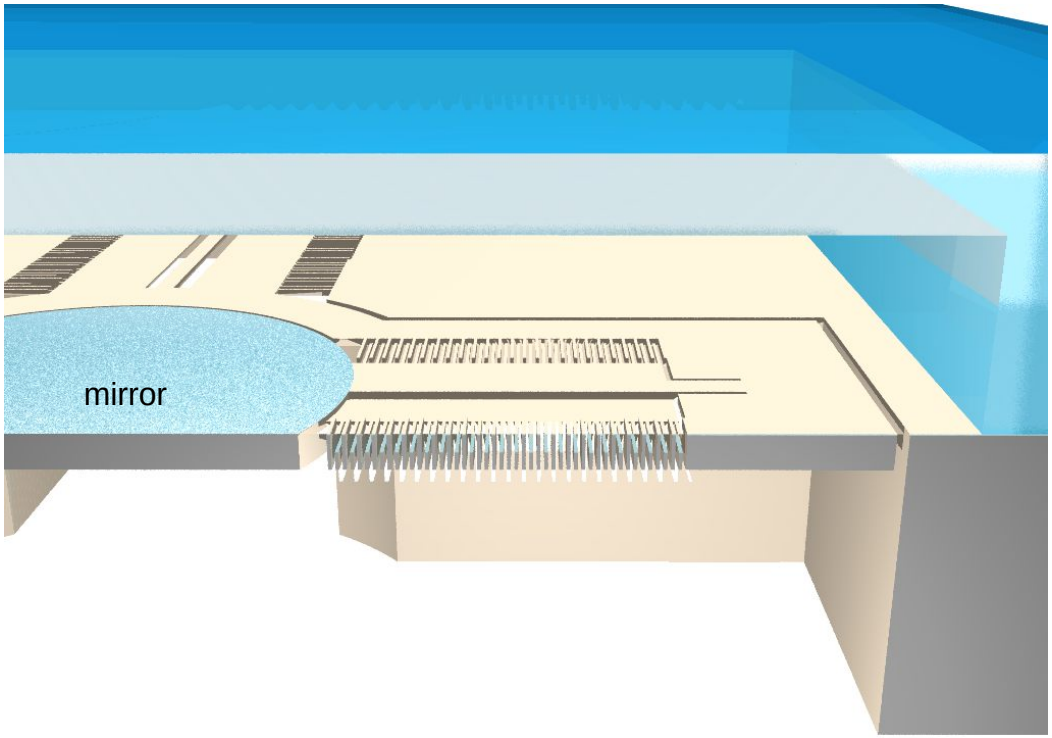


# significant effect of air pressure on the resonance amplitude

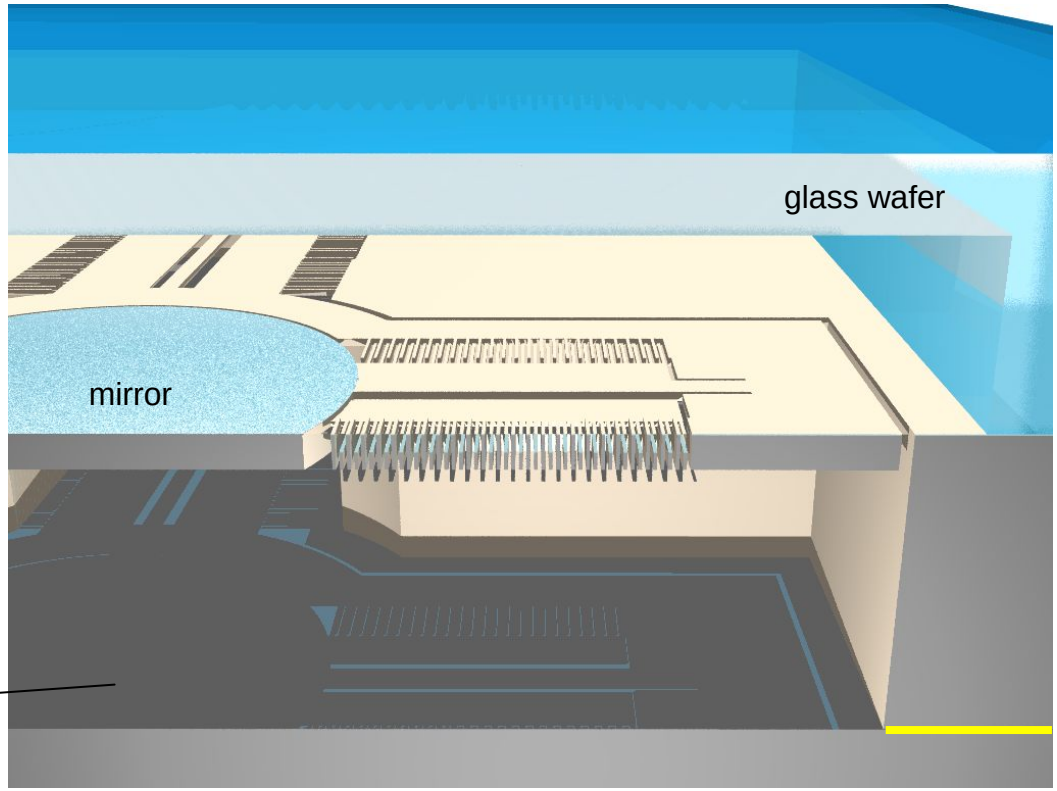


# vacuum encapsulation on wafer-level

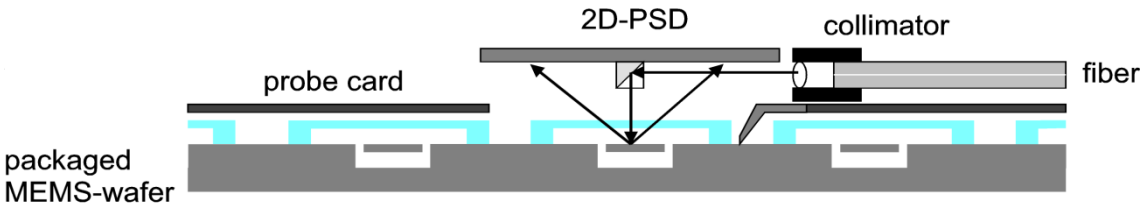


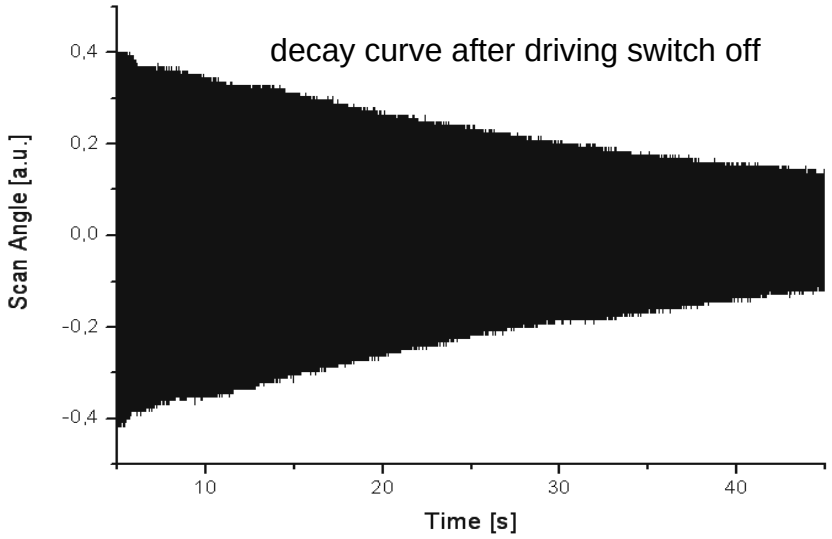
# vacuum encapsulation on wafer-level

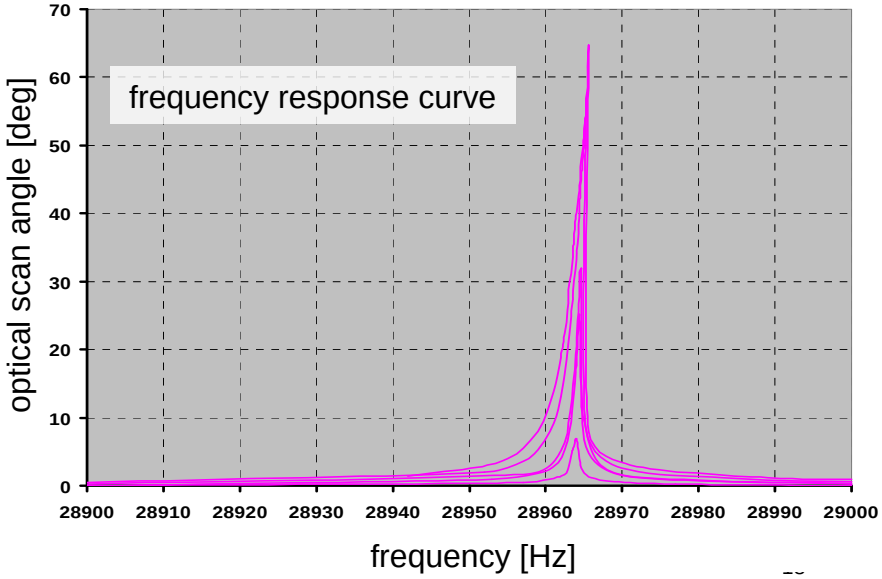


**MEMS scanning mirrors**
**vacuum packaged on wafer level**

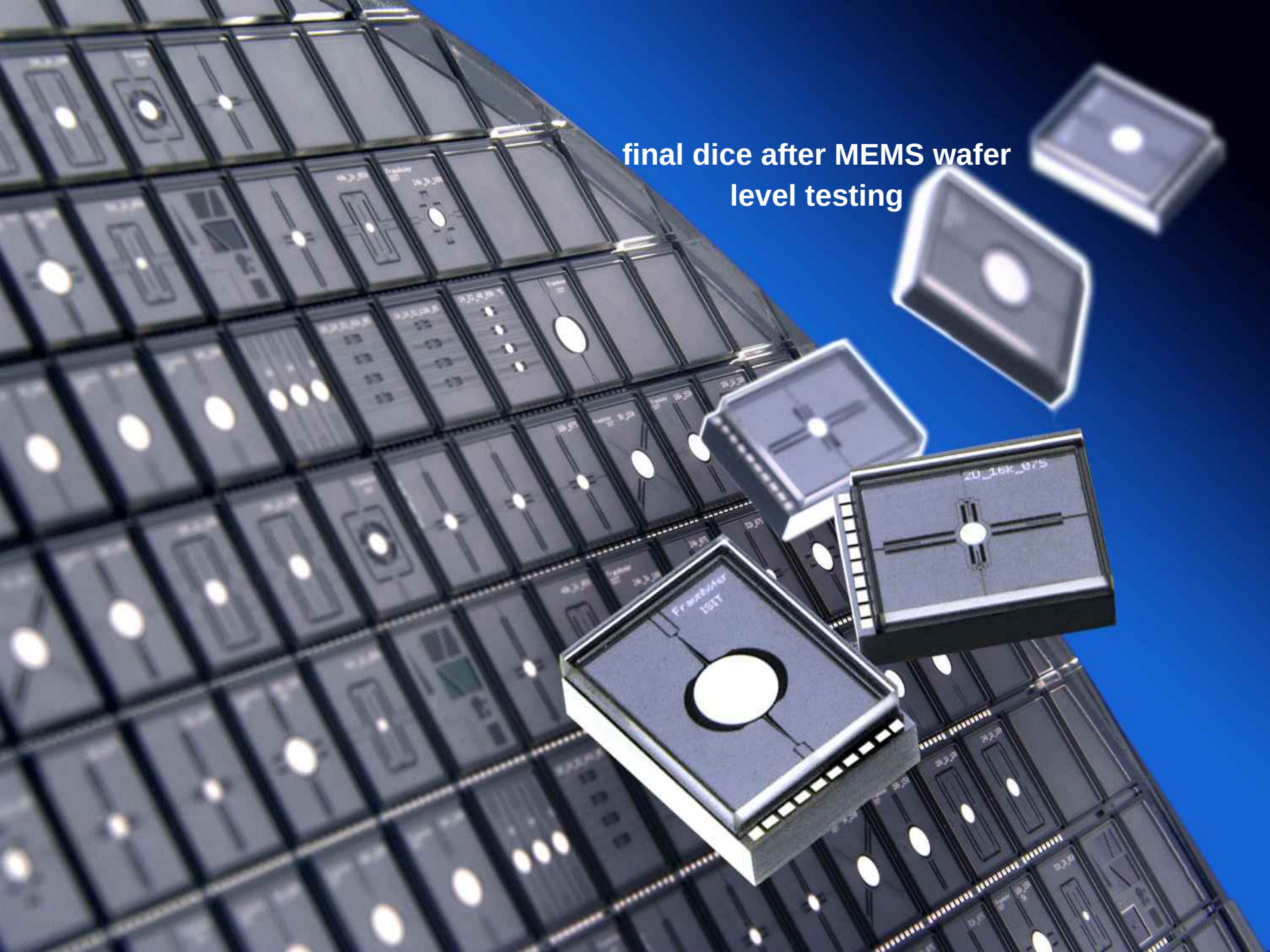
# opto-electromechanical characterization on wafer-level



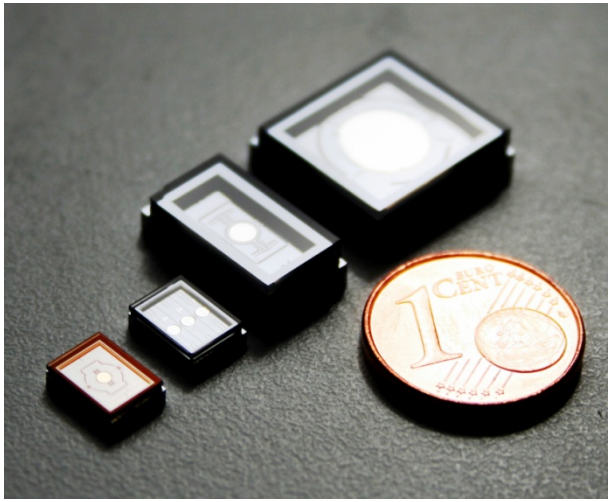




Fraunhofer ISIT

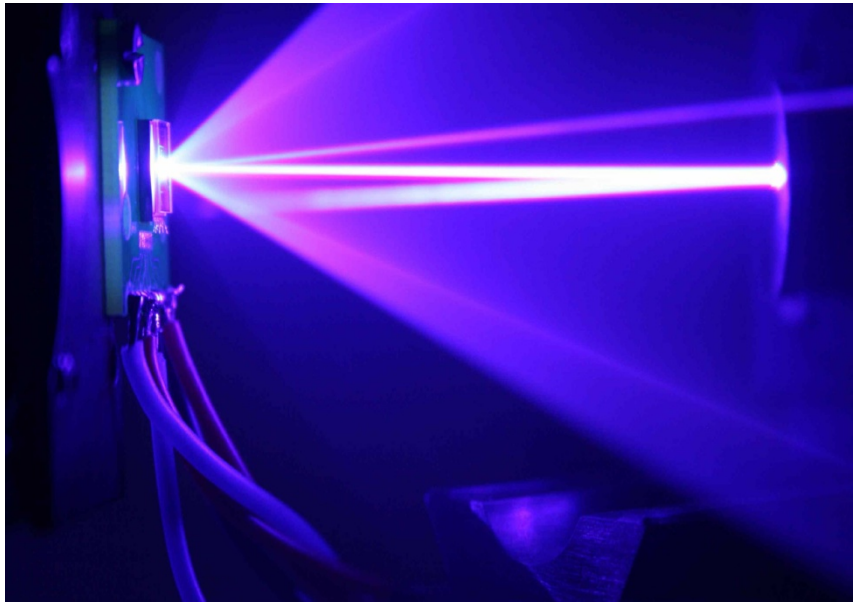

final dice after MEMS wafer level testing

# parameter-range of fabricated MEMS scanning mirrors

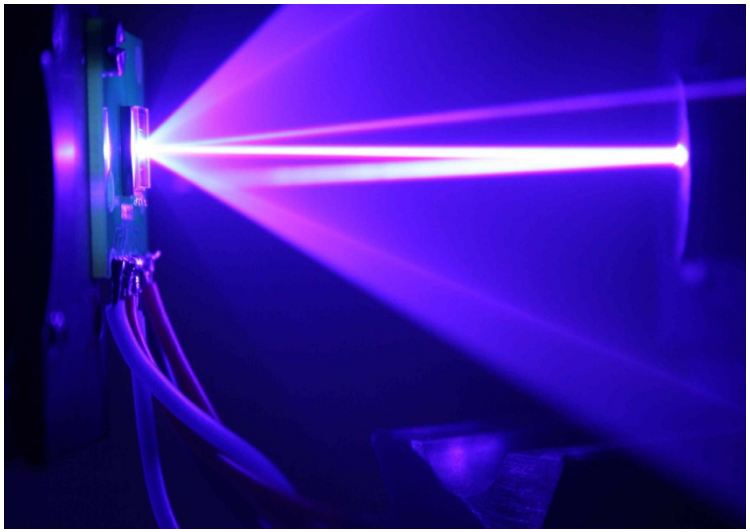
| | |
|---|---|
| mirror aperture size: | 0.5 mm .. 7 mm |
| scan frequencies fast axis: | 16 kHz .. 108 kHz |
| scan frequencies slow axis: | 150 Hz .. 2 kHz |
| total optical scan angle: | 20° .. 120° |
| Q-factor: | > 60,000 |
| power consumption: | 0.1µW .. 1 mW |
| driving voltage: | 5 .. 70 V |

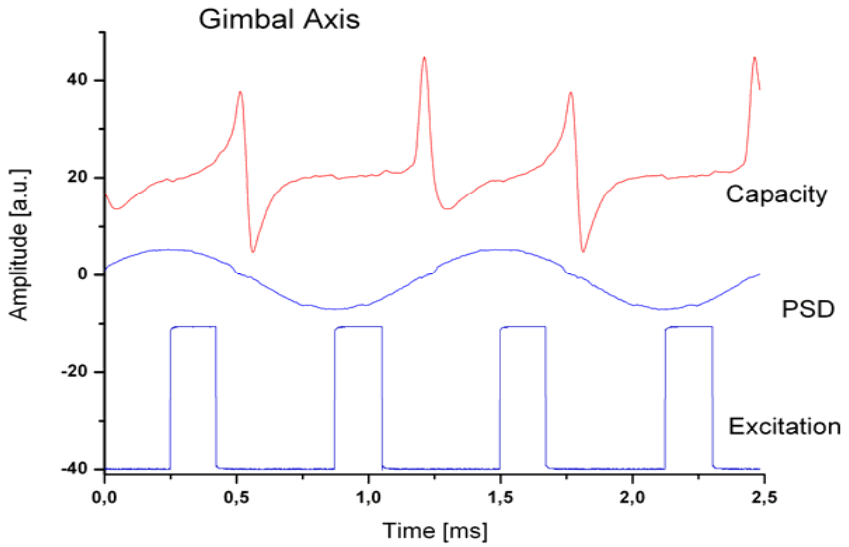


# phase controlled Lissajous-scanning



# phase controlled Lissajous-scanning






- capacitive feedback enables stable phase controled mirror operation
- enables synchronization of MEMS mirror and laser output for display and LIDAR applications
- enables also synchronization of MEMS mirror and detector signals in all imaging applications

# synchronisation of MEMS mirror and laser in a Lissajous-projector

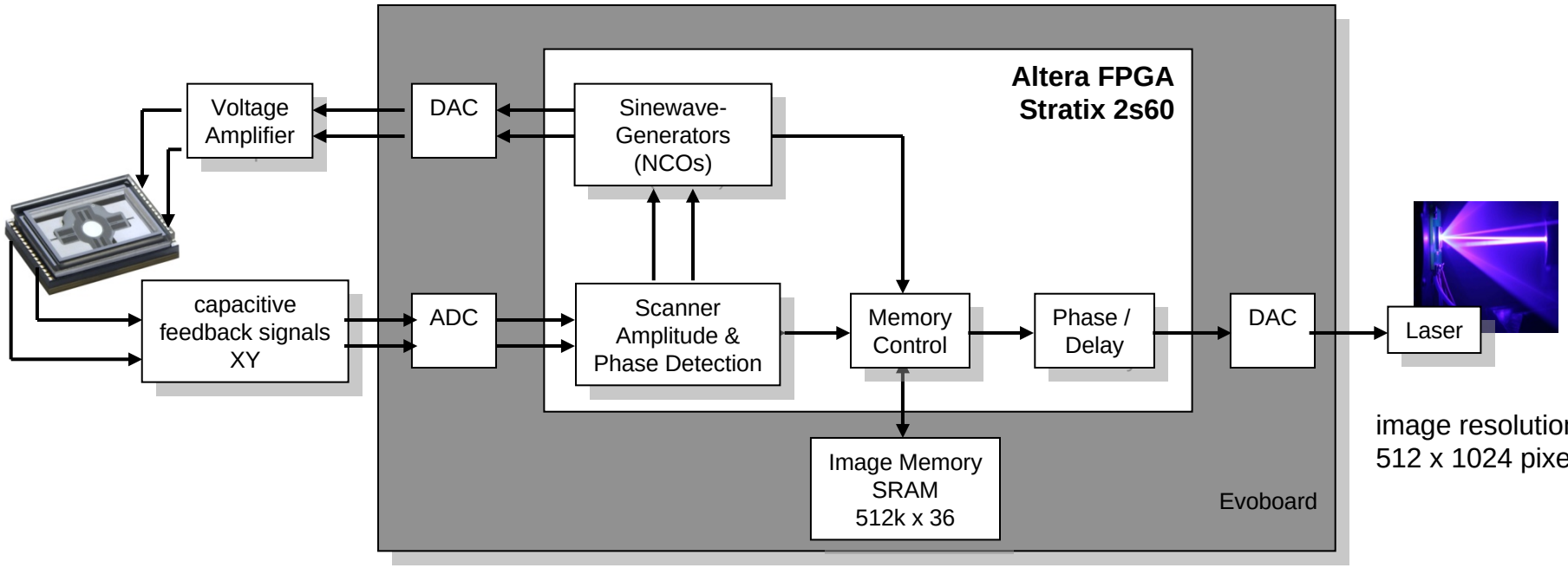



image resolution:
512 x 1024 pixels


Lissajous laser projection
Attention Assist:
Pause!
1706.0 km
56684 km
0 km/h
Reise
Navi
Audio
Telefon
15.0°c
R
N
P
D
S
20
40
60
80
100
120
140
160
180
200
220
240
260


Lissajous laser projection

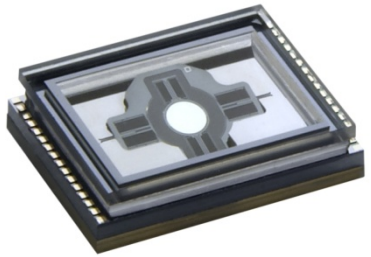
## Summary

• hermetic wafer level packaging of MEMS scanning mirrors provides reliable protection against contamination by particles fluids or gases

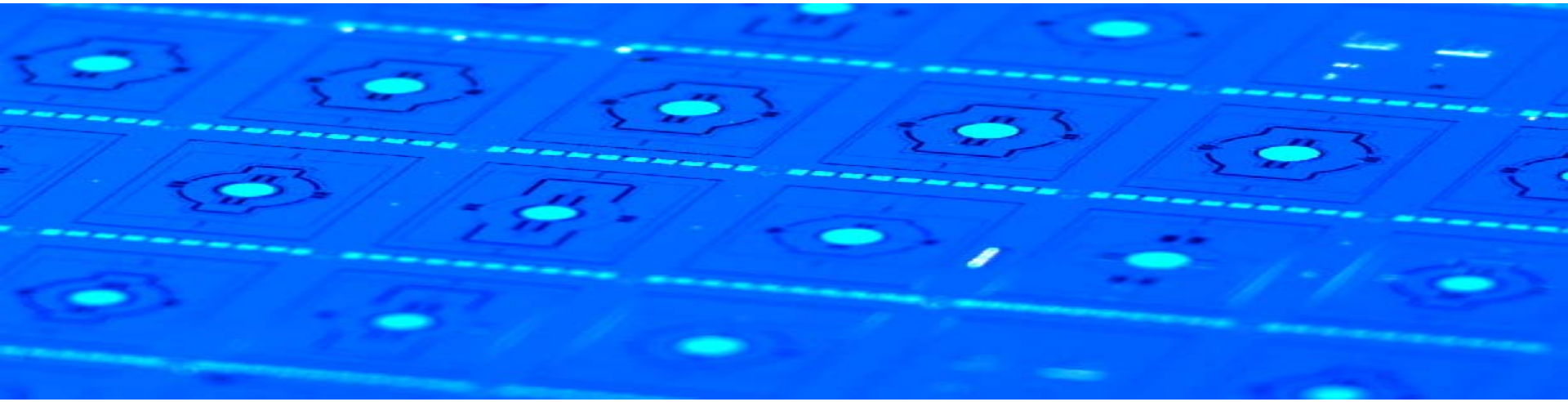
• because of neglectable gas damping vacuum packaged MEMS scanning mirrors achieve outstanding dynamics i.e. scan angles up to 120 degree and scan speed up to 200,000 lines/sec

• vacuum encapsulation enables to drive very large mirrors with apertures up to 10 mm

• besides display applications the developed synchronization electronics can be used in high resolution real time imaging applications and LIDAR sensors.



# Thank you
# for your attention !



Fraunhofer ISIT