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# Biaxial tripod MEMS mirror and omnidirectional lens for a low cost wide angle laser range sensor

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# Introduction



Central ideas of the MiniFaros project:

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- development of a sensor with almost omnidirectional view

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- development of a sensor with almost omnidirectional view
- compact size

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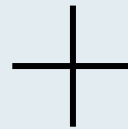
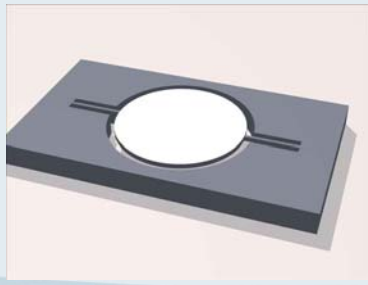
Central ideas of the MiniFaros project:

- development of a sensor with almost omnidirectional view
- compact size
- mass-producible at low cost

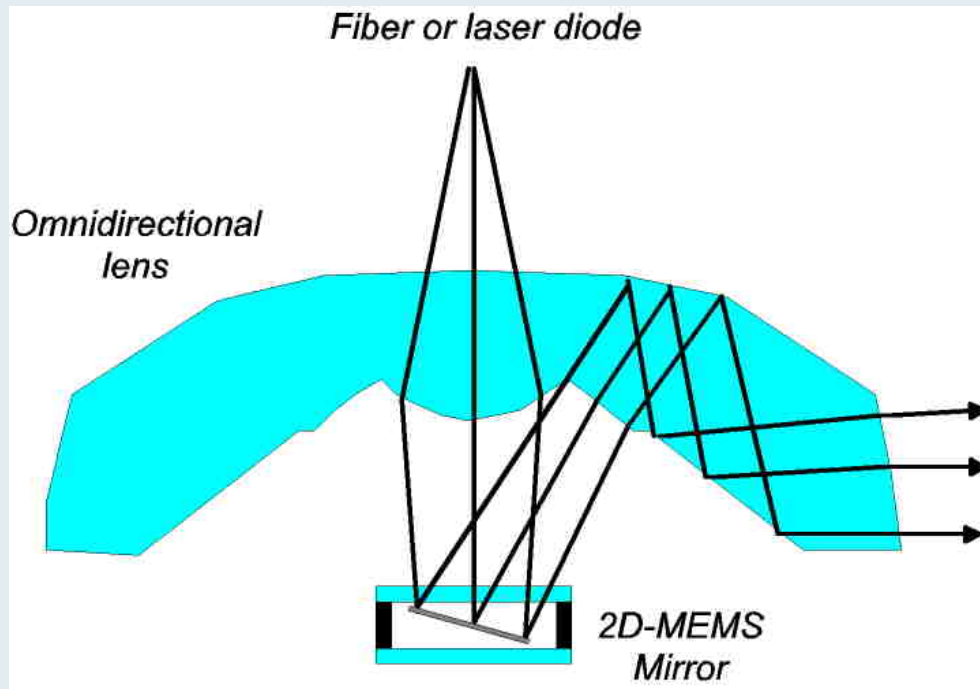
Central ideas of the MiniFaros project:

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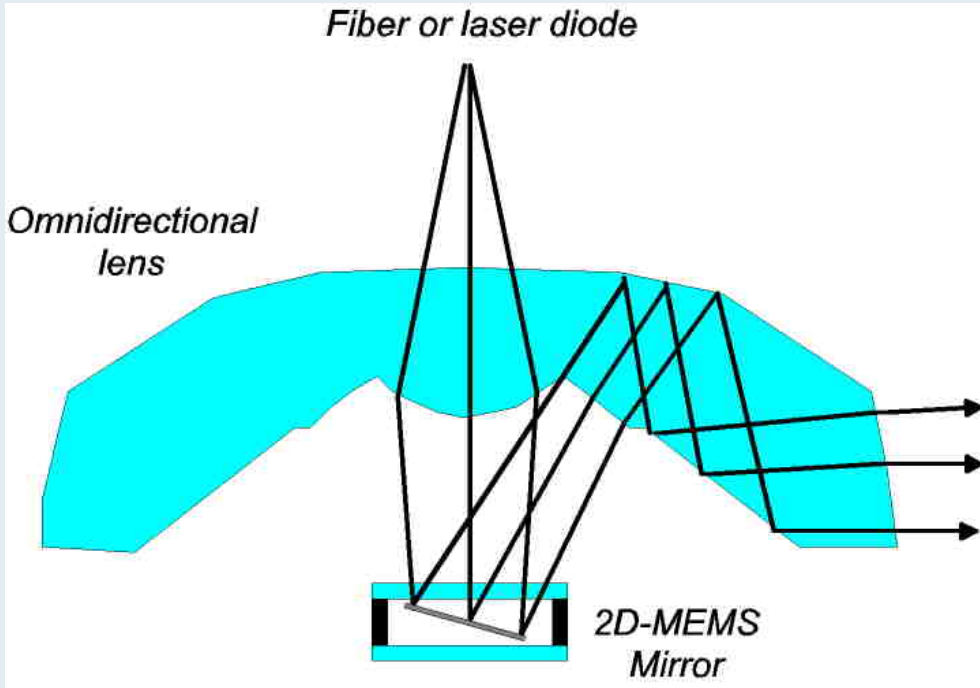
=> MEMS scanning mirror technology + replicable plastic optics



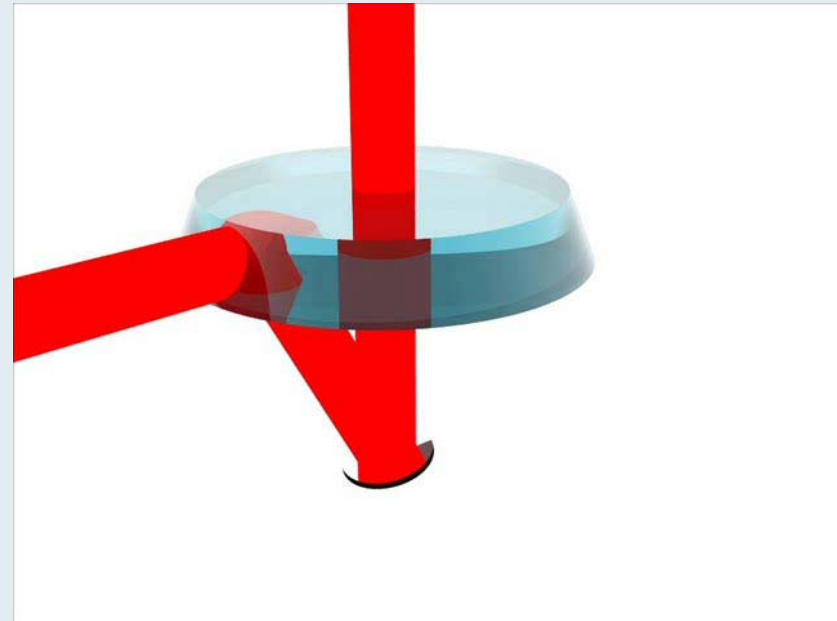
# Omnidirectional scanning concept



# Omnidirectional scanning concept



Omnidirectional lens

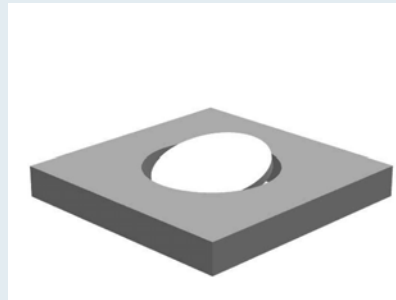


2D-MEMS Mirror



# MEMS mirror requirements

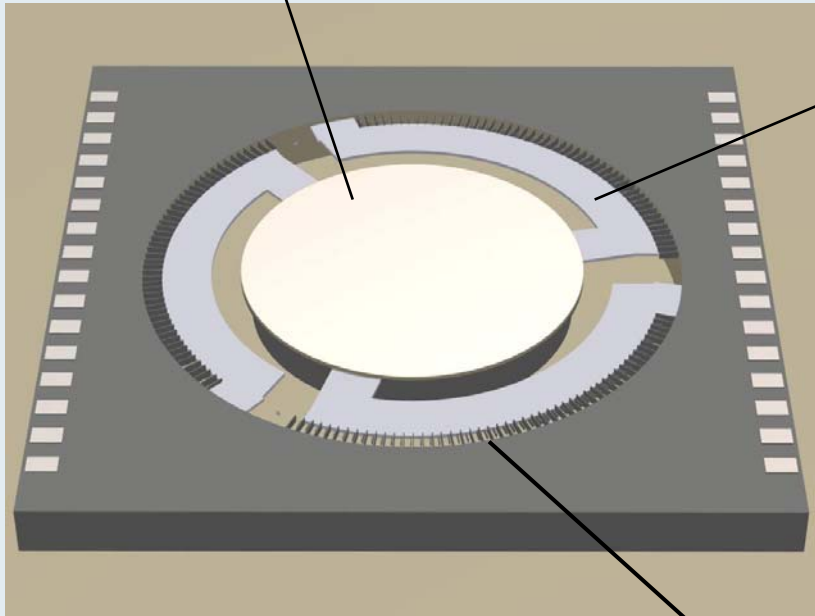
1. large mirror aperture size of 7mm
2. circular scan pattern => two axes of identical scan frequency
3. large tilt angle of 15 degrees in both axes



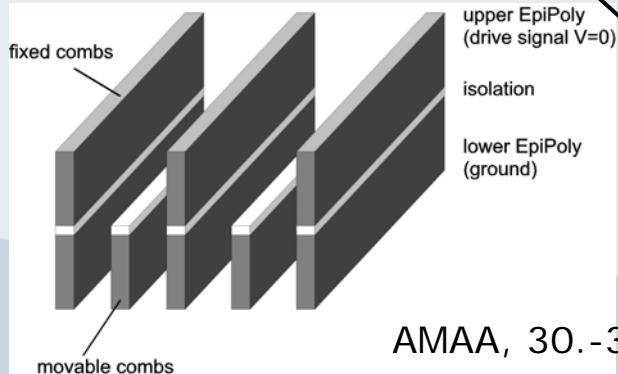
# Tripod MEMS mirror design

mirror plate (diameter 7mm, thickness 500  $\mu\text{m}$ )

circular bending springs  
(thickness 40  $\mu\text{m}$ )

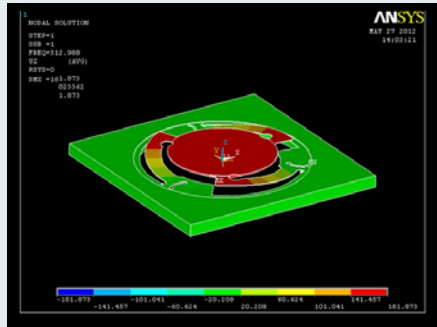


- identical resonant frequencies in xy
- minimum footprint
- circular springs enable large tilt angle
- advantageous eigenmode spectrum

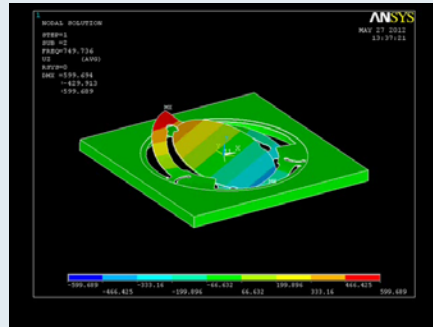


stacked vertical comb electrodes  
for electrostatic driving  
and capacitive position sensing

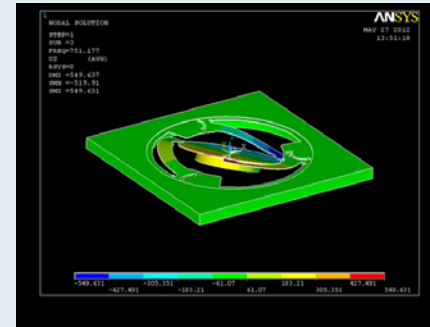
# FEM modal analysis



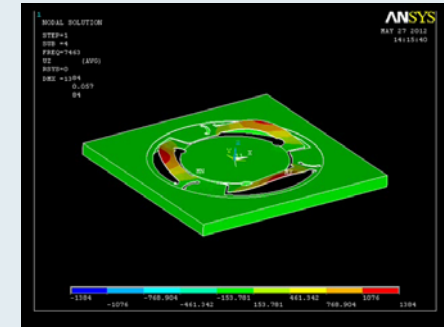
1st mode:  
parasitic piston mode  
@ 310 Hz



2nd mode:  
first scan axis  
@ 750 Hz



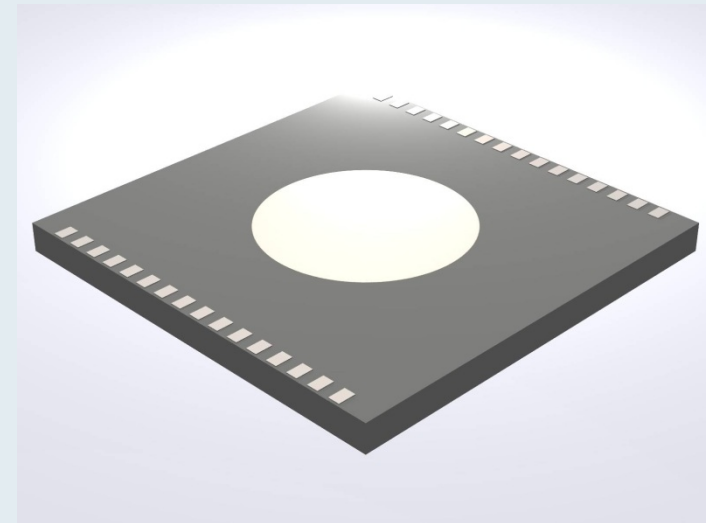
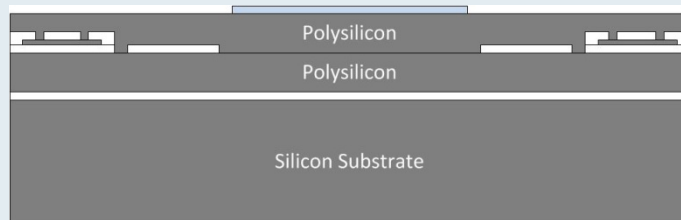
3rd mode:  
second scan axis  
@ 750 Hz



4th mode:  
parasitic mode  
@ 7.4 kHz

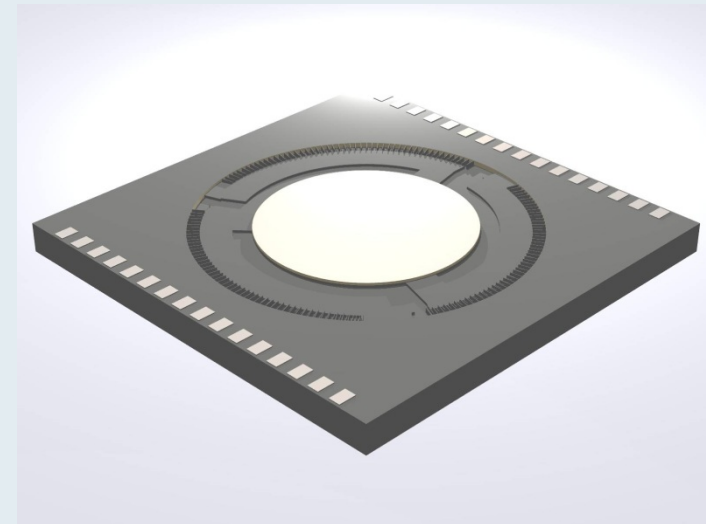
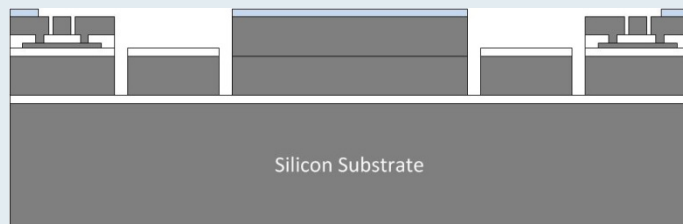
# Tripod MEMS mirror fabrication process

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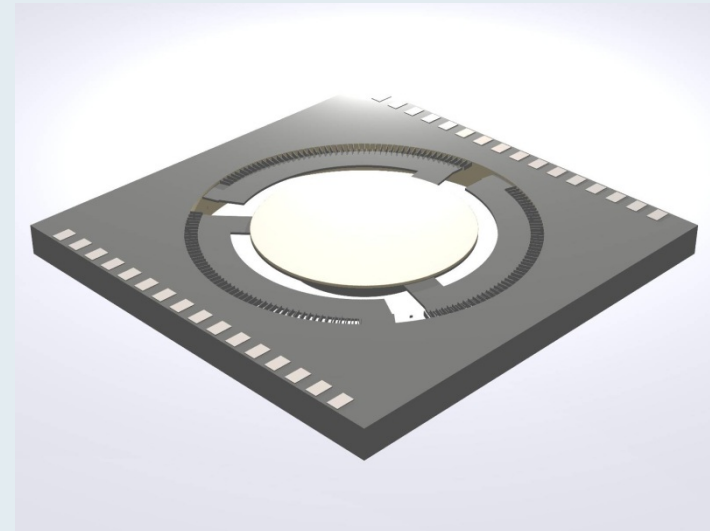
# Tripod MEMS mirror fabrication process

mini faros



# Tripod MEMS mirror fabrication process

mini faros



# Fabricated tripod MEMS mirrors

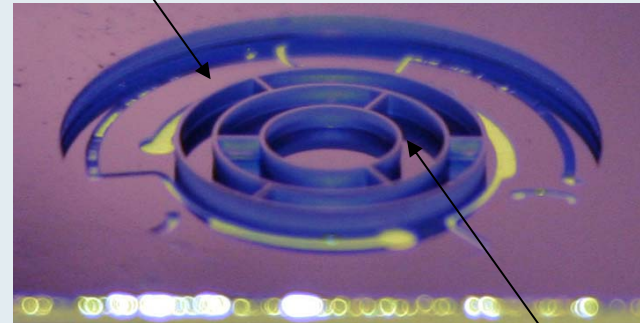
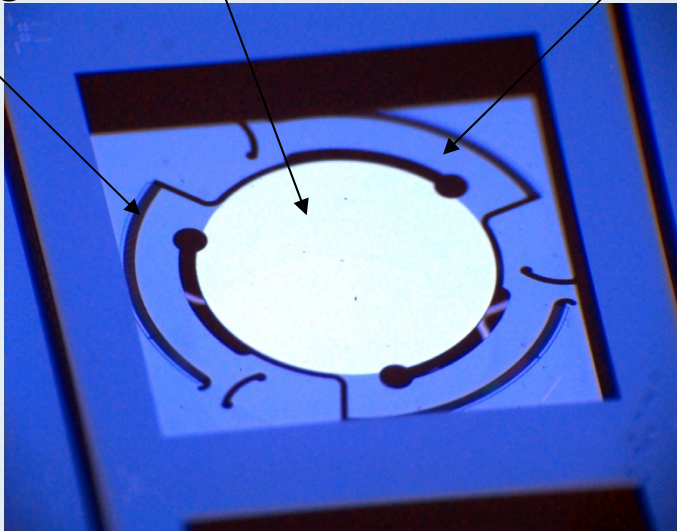


comb drive electrodes

mirror

circular suspension

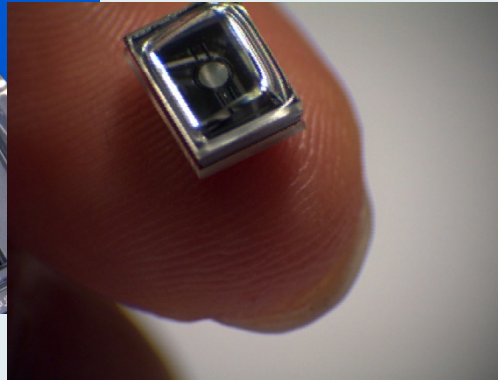
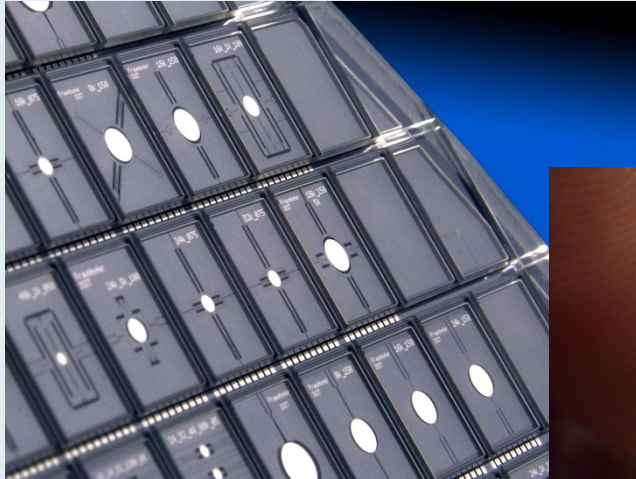
rear side of the mirror



stiffening rings



# How to enable the large tilt angles?



only possible by a vacuum package

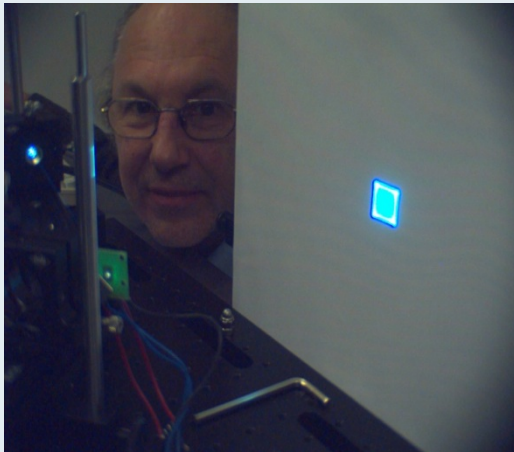
1. minimum damping
2. maximum scan angle
3. low driving voltage
4. effective protection against contamination



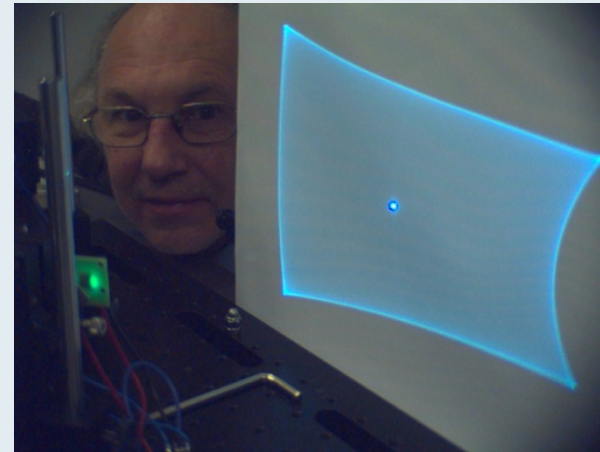
# Benefit of vacuum encapsulation



in atmosphere

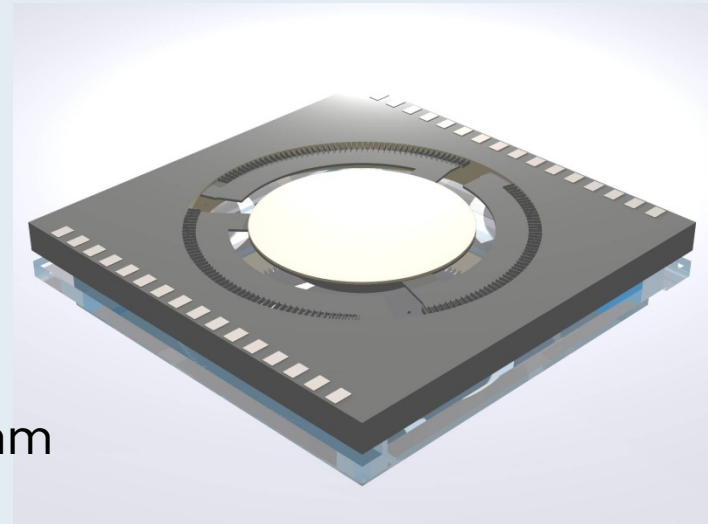
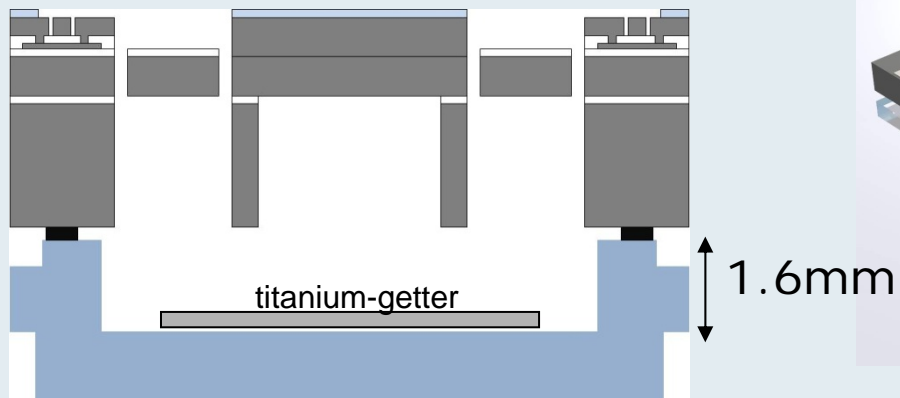


in vacuum



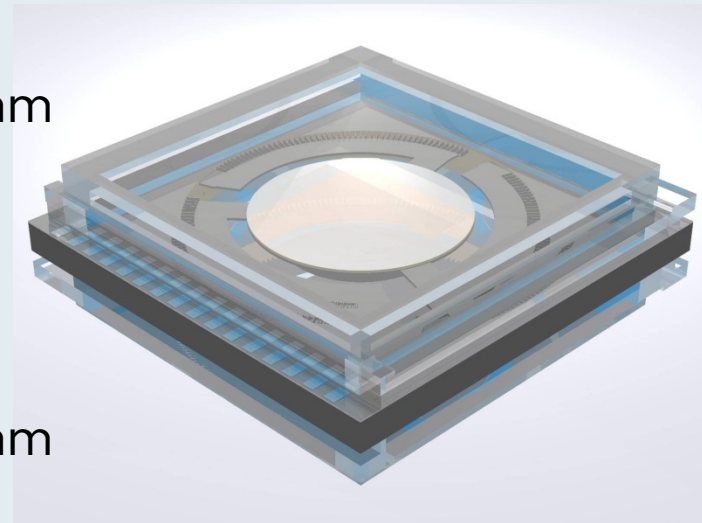
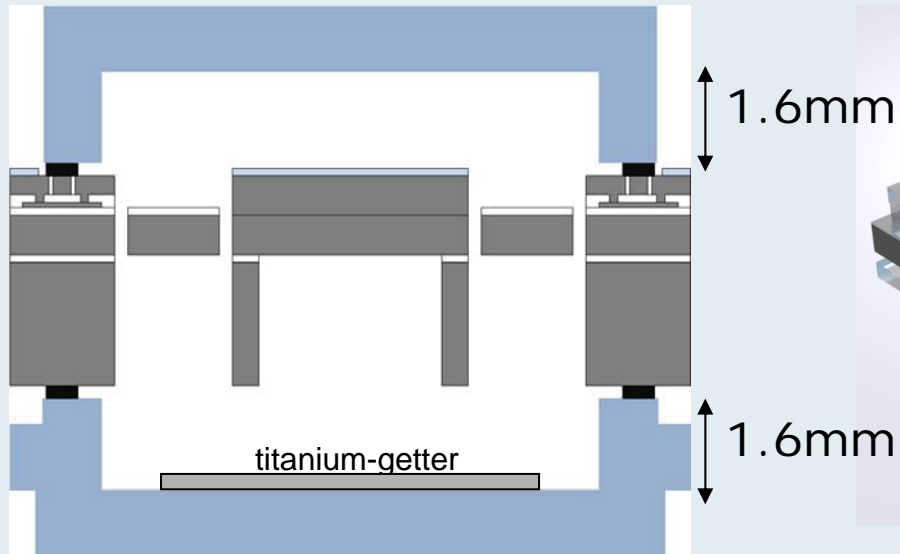
# Wafer level vacuum packaging

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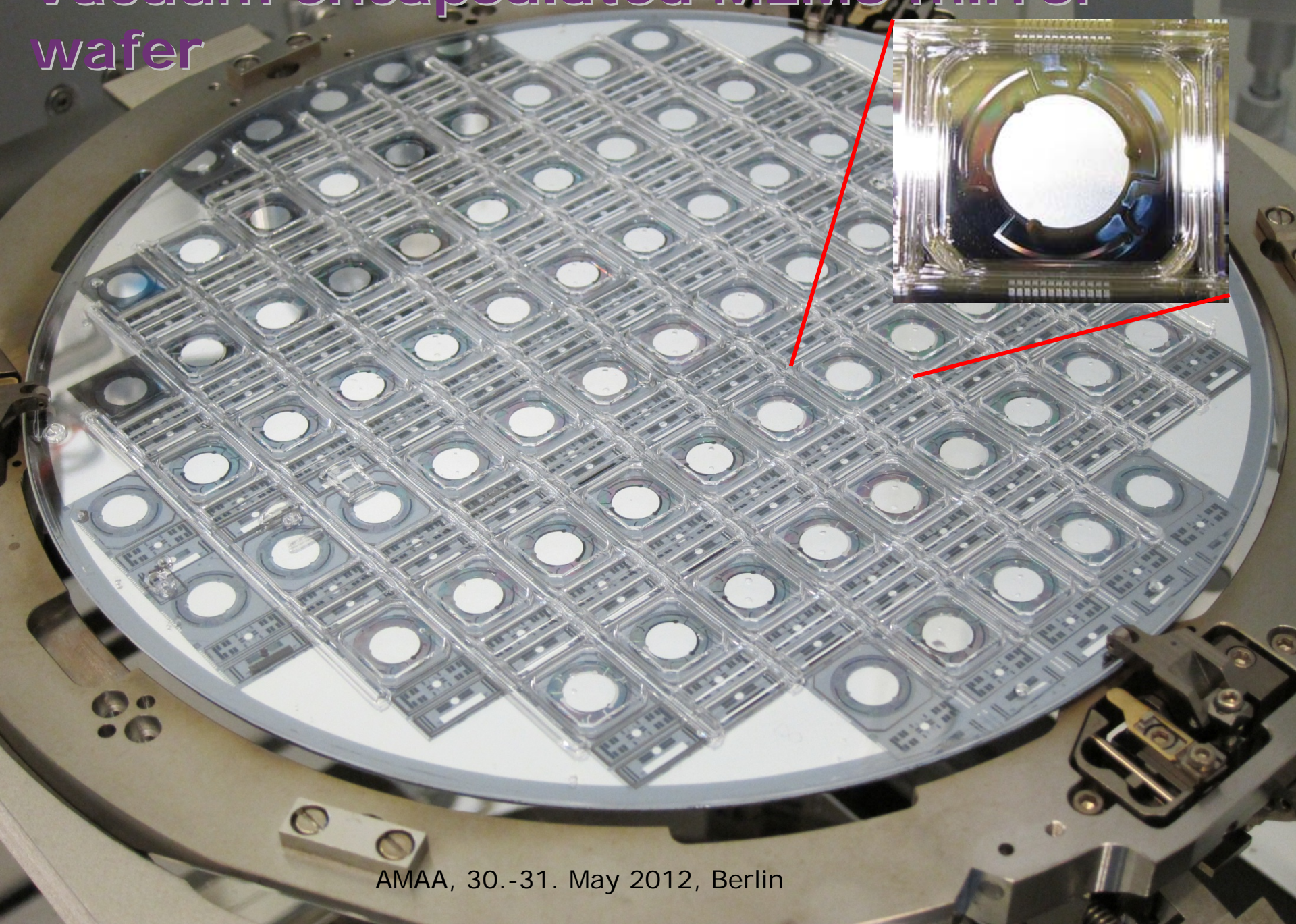
# Wafer level vacuum packaging

mini faros





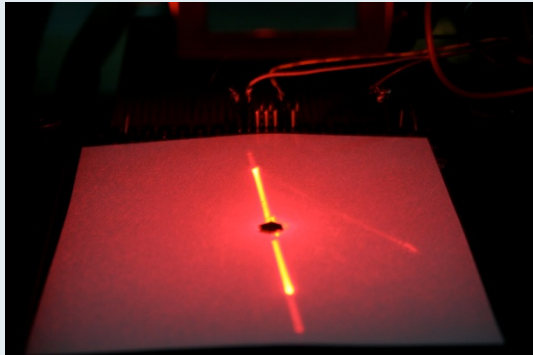
# Vacuum encapsulated MEMS mirror wafer



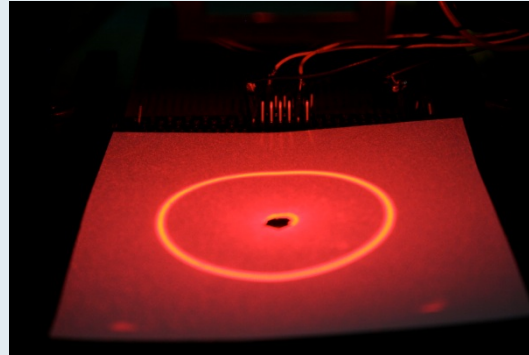


# Proof of concept of tripod MEMS design

mini rars



single axis excitation



dual axis excitation

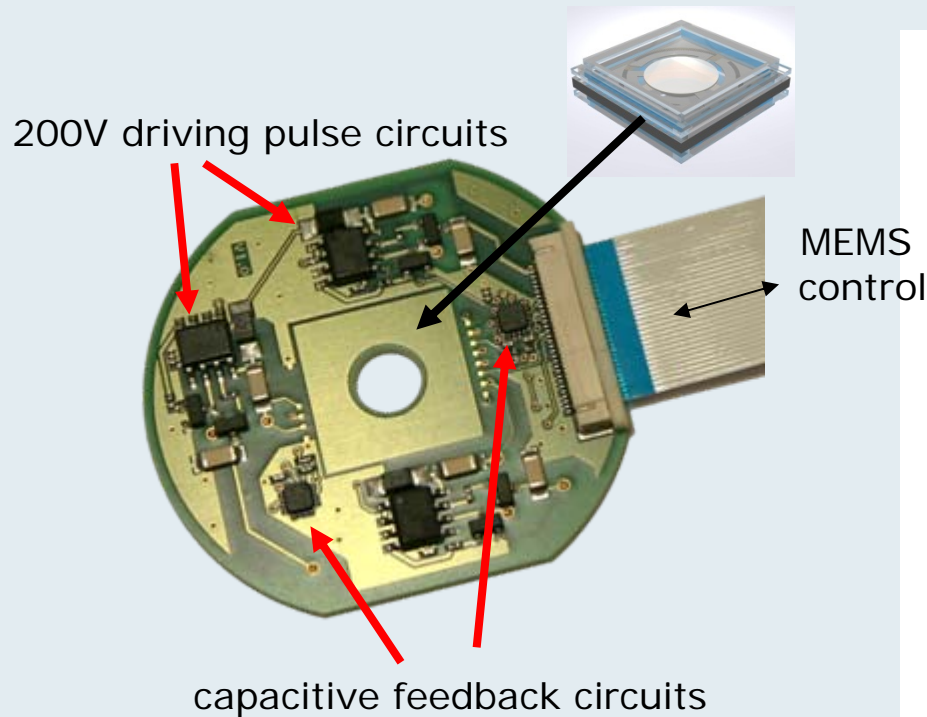


single electrode excitation  
 $f = 800 \dots 865 \text{ Hz}$

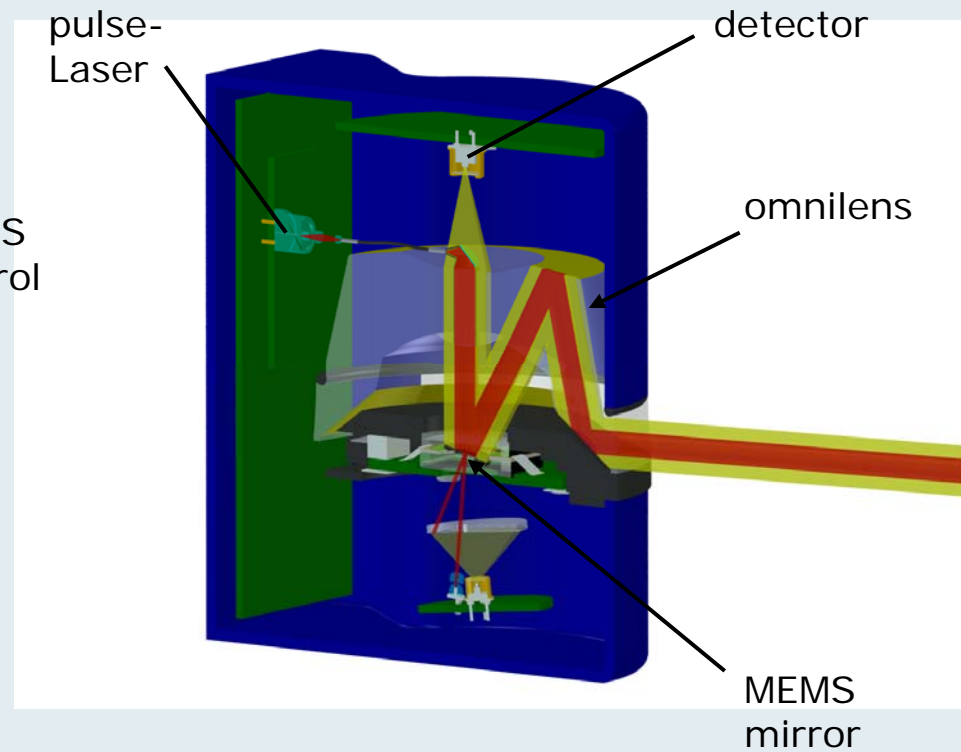
# Electronic control of tripod mirror



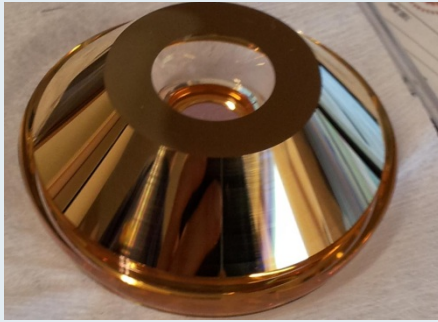
MEMS mirror pcb



coaxial LIDAR sensor

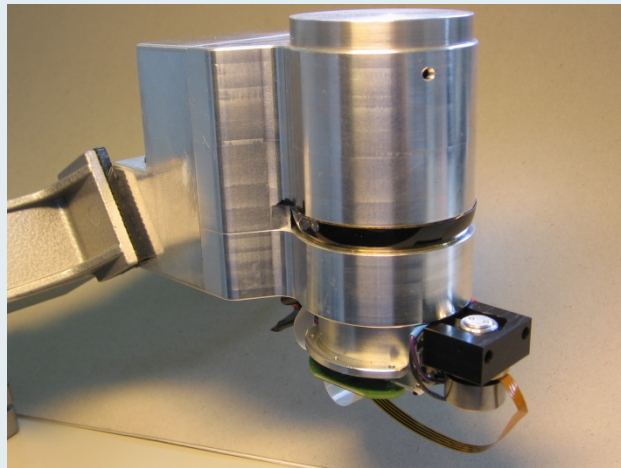


# Sensor prototypes with omnilenses



omnidirectional lens designed by VTT Finland

coaxial sensor



combined transmitter  
and receiver paths

biaxial sensor



separate transmitter  
and receiver paths

# First result of biaxial sensor



58 meter range to a half specular, half diffuse reflective target

The screenshot displays the Sick ResearchLaserView software interface. The main window, titled "3D View", shows a 3D point cloud scan of a target. The scan is represented by a series of red dots forming a curved path. The interface includes a menu bar (File, Edit, View, Tools, Help) and a toolbar with various icons. A status bar at the bottom indicates "Speed 1x".

An "iBeoLUX Dialog" box is open on the right side of the interface, displaying the following information:

- Scanner Type: IbeoLUX3
- Serial Number: 0101 9999
- Firmware Version: 4.0.07 2011-12-08 09:38 r31985
- FPGA Version: F1.15 2012-02-09 15:56
- Scanner Status: 0x0
- Temperature: 32.6 degree Celsius

The dialog box also contains several buttons: "Update", "Backup Configuration", "Restore Configuration", "Set Timestamp", "Start", and "Stop".



# Acknowledgement



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