Cryogenic and interferometric characterization of MOEMS devices for astronomical instrumentation

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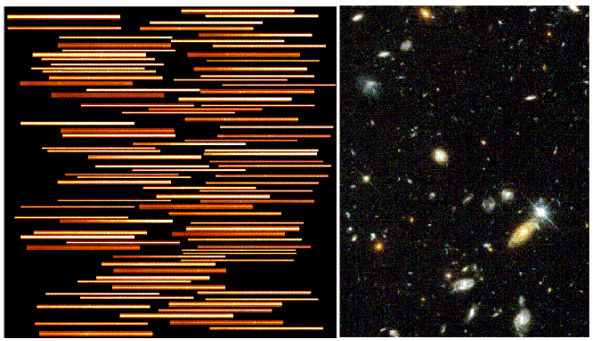
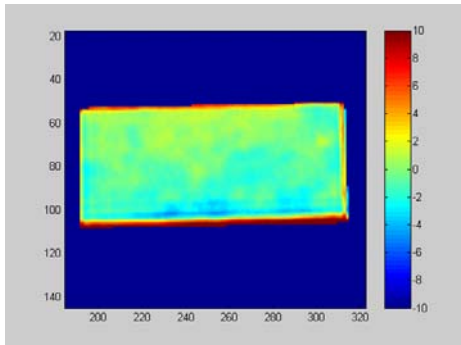
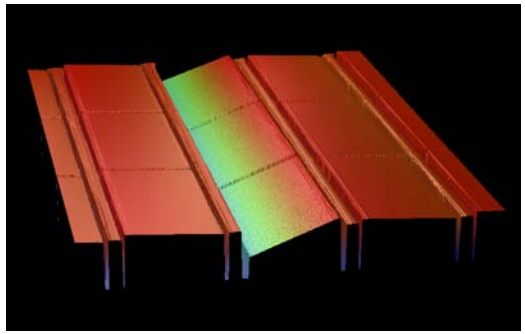
[1]*Laboratoire d'Astrophysique de Marseille, France*
[2]*Institut de Microtechnologies, U. de Neuchâtel, Switzerland*

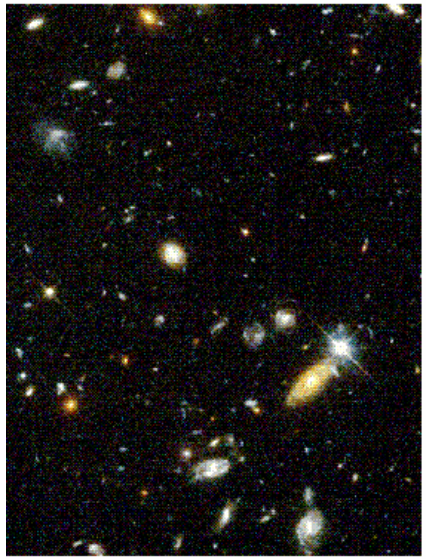


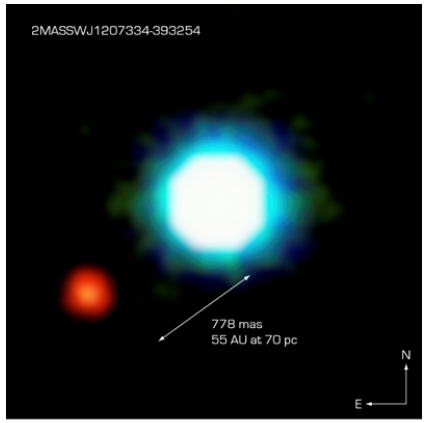




Astronomical cases

- ***Origin's*** quest
  - Galaxies formation and evolution
  - Stars and planetary systems formation
  - Life's Origin



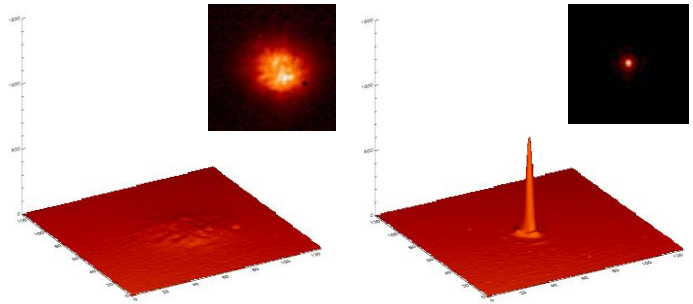


The Brown Dwarf 2M1207 and its Planetary Companion
(VLT/NACO)

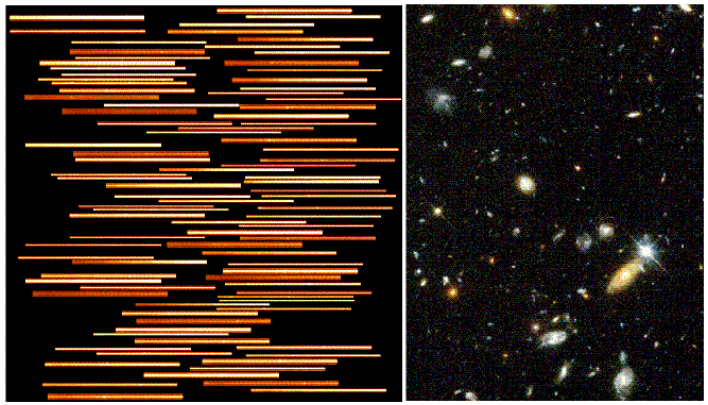
ESO PR Photo 14a/05 (30 April 2005) ©ESO

Instrumental needs

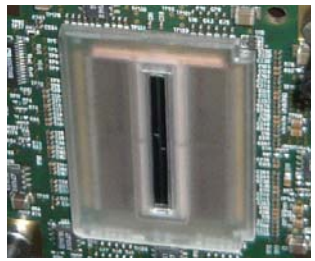
- Instrumental needs
  - Wavefront control
    - Deformable mirrors



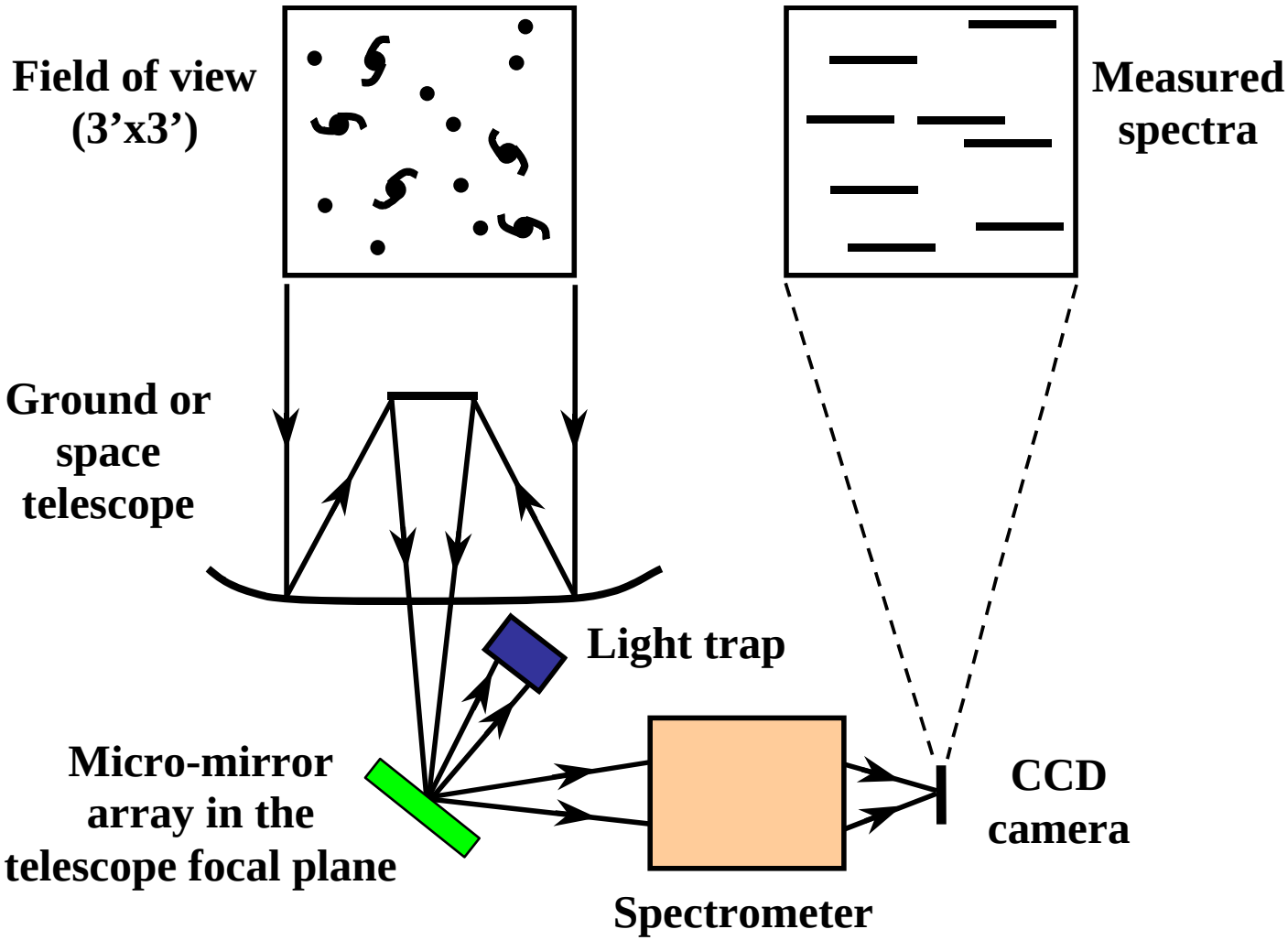
  - Object selection
    - Programmable slits



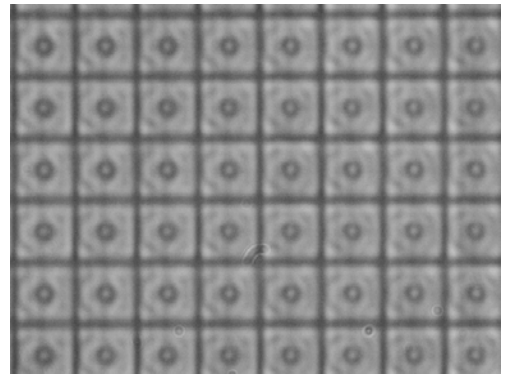
  - Spectral domain application
    - Programmable gratings



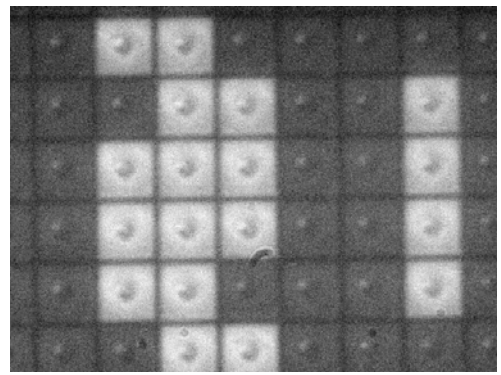
Multi-Object Spectrograph



Park position

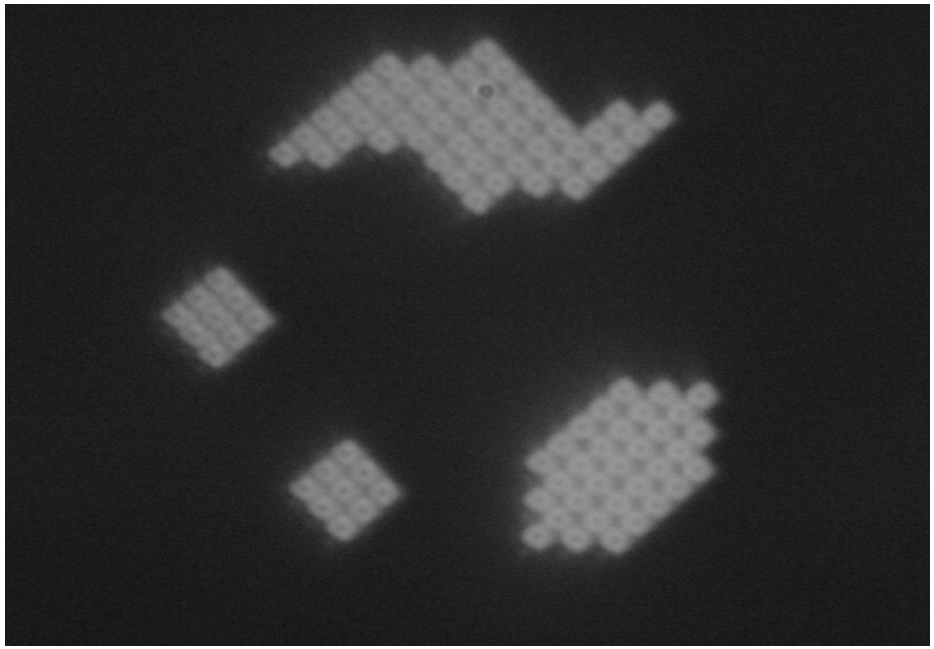


20 µm

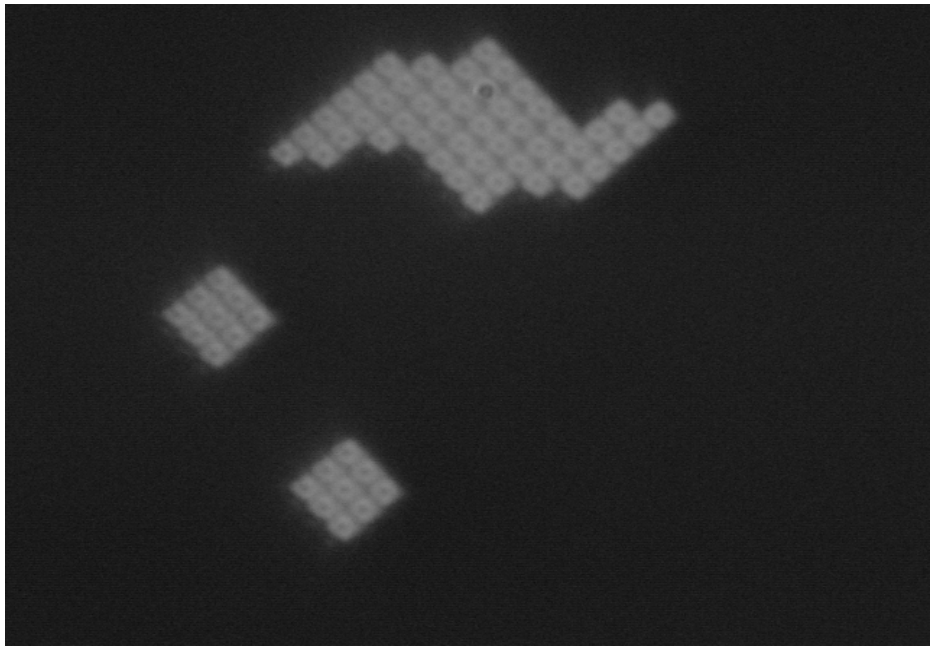


In action

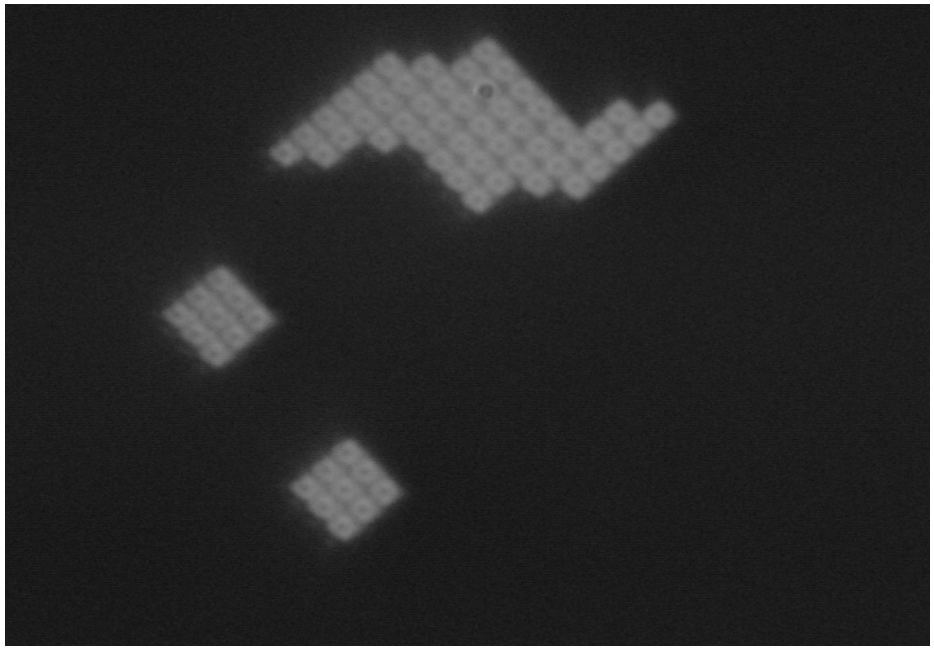
Object selection



Object selection



Scanning slit mode



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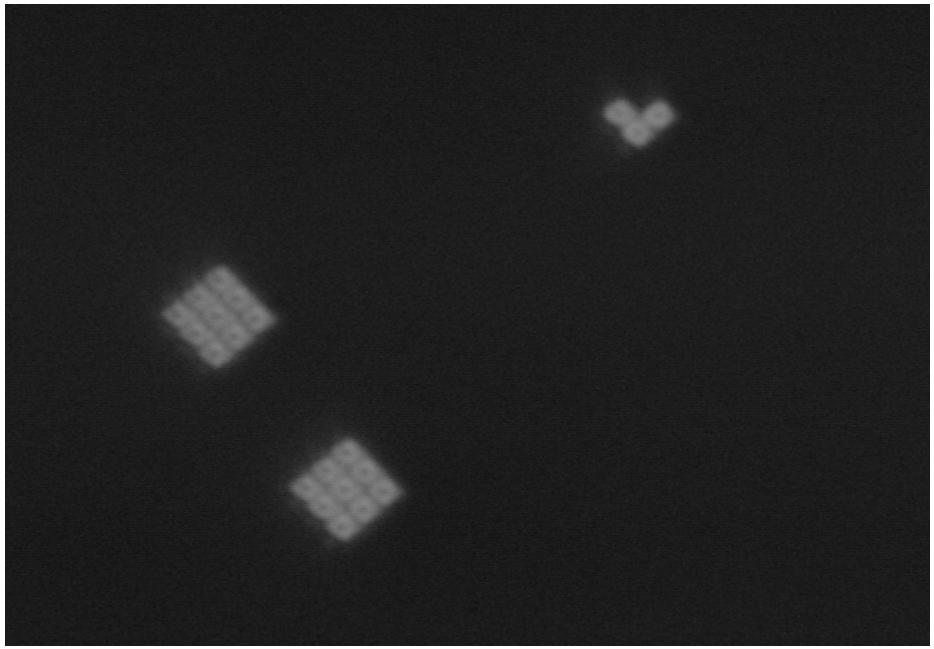

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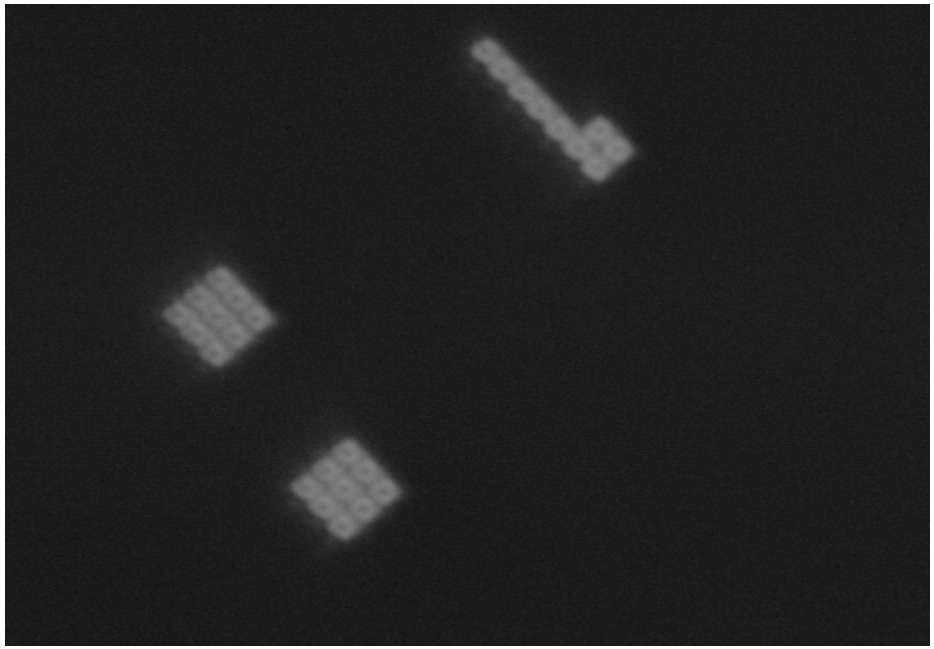

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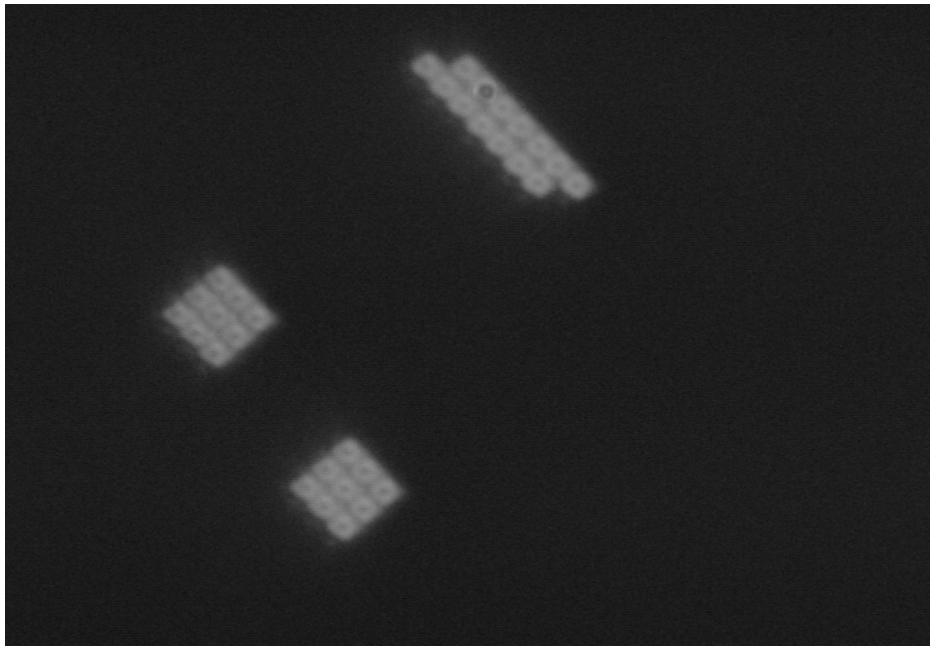
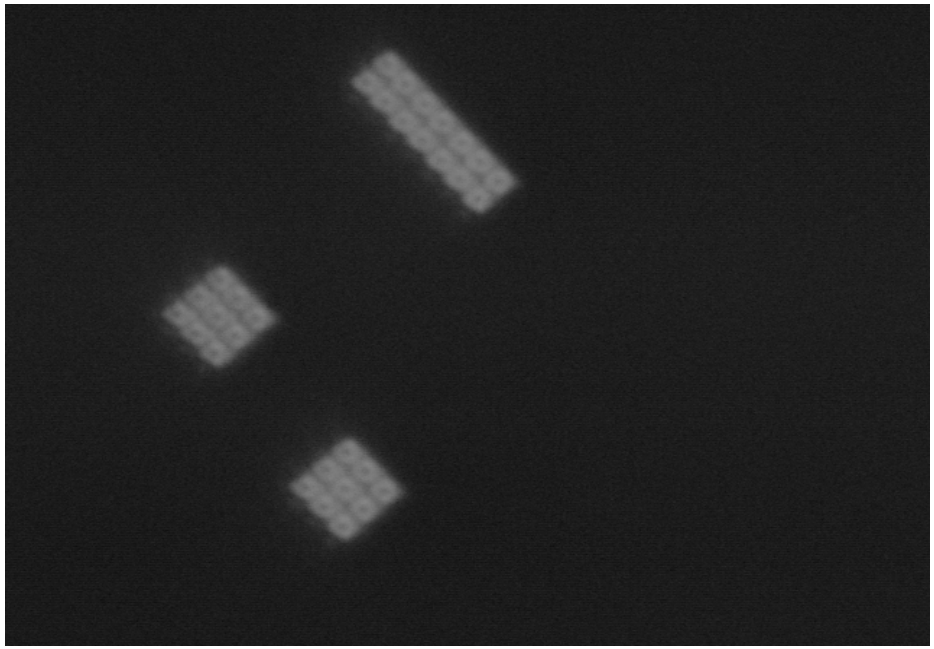


Scanning slit mode



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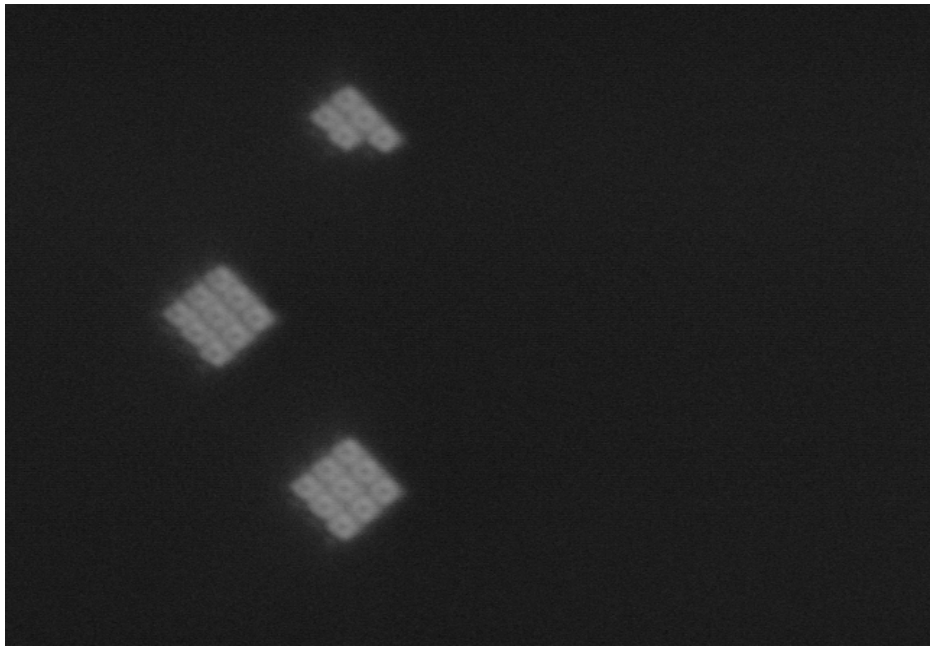

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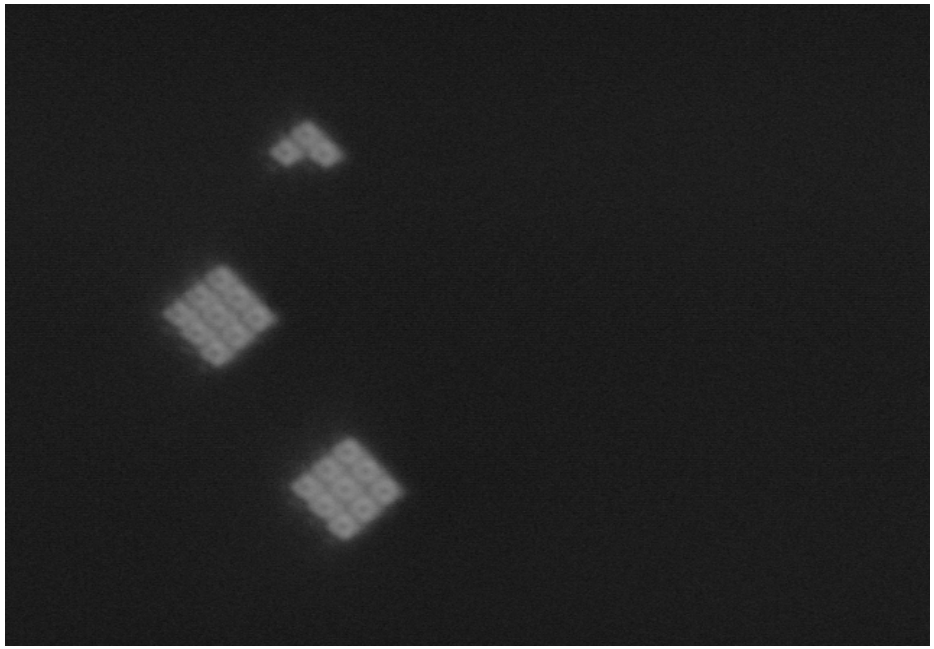
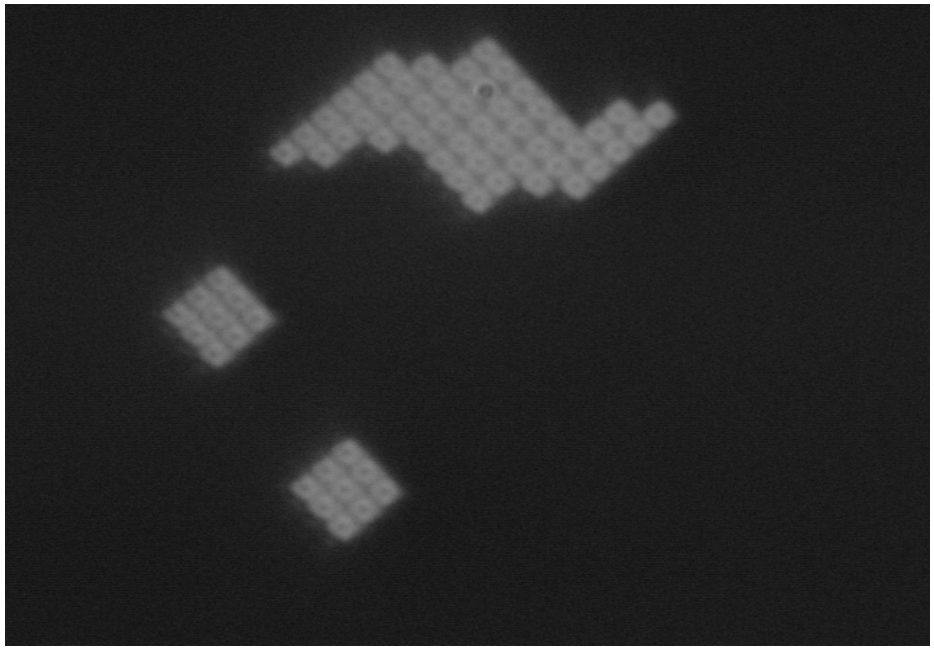


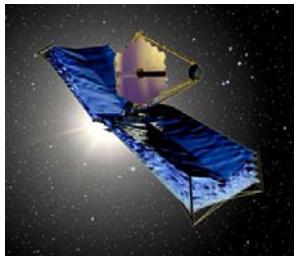
Scanning slit mode

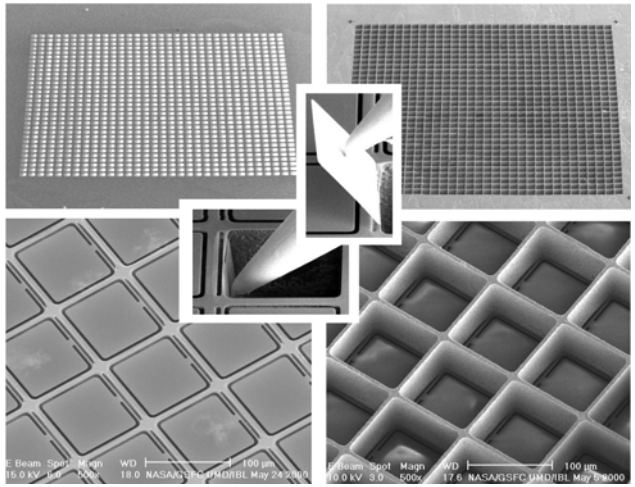


MOEMS developments

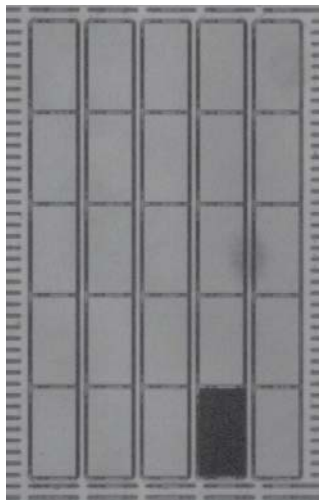
- NASA-GSFC Micro-shutters

Selected for JWST NIRSpec





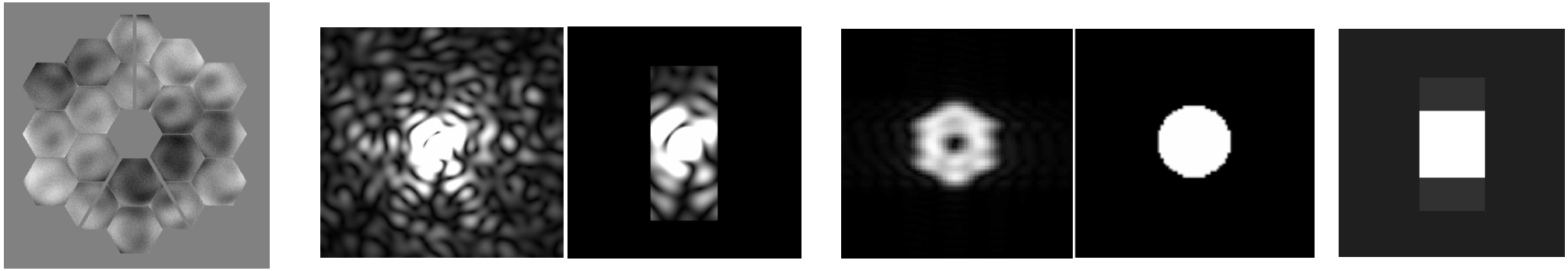
- LAM-IMT Micro-mirrors



Programmable slit modeling

- Fourier model

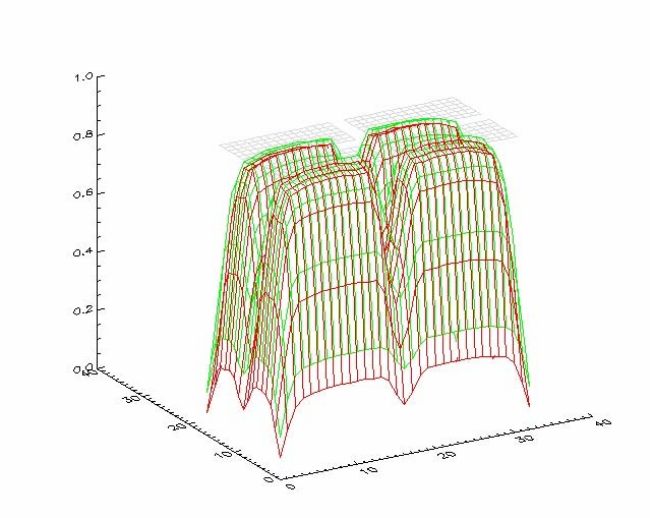
Telescope (JWST) Field Pupil Detector

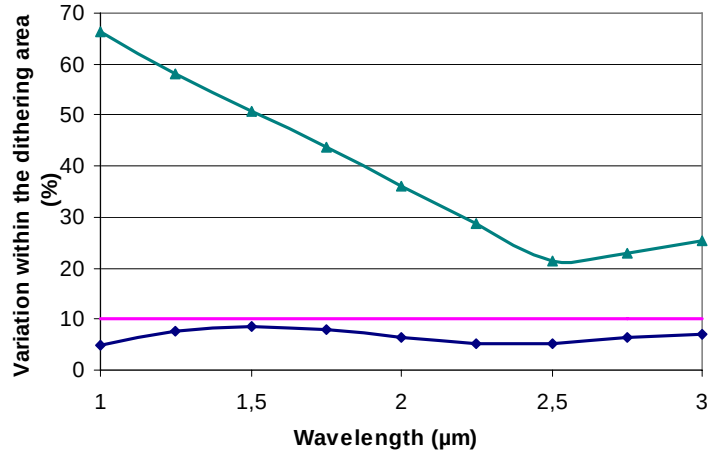


- Spectral photometric variation modeling

Geometrical effect

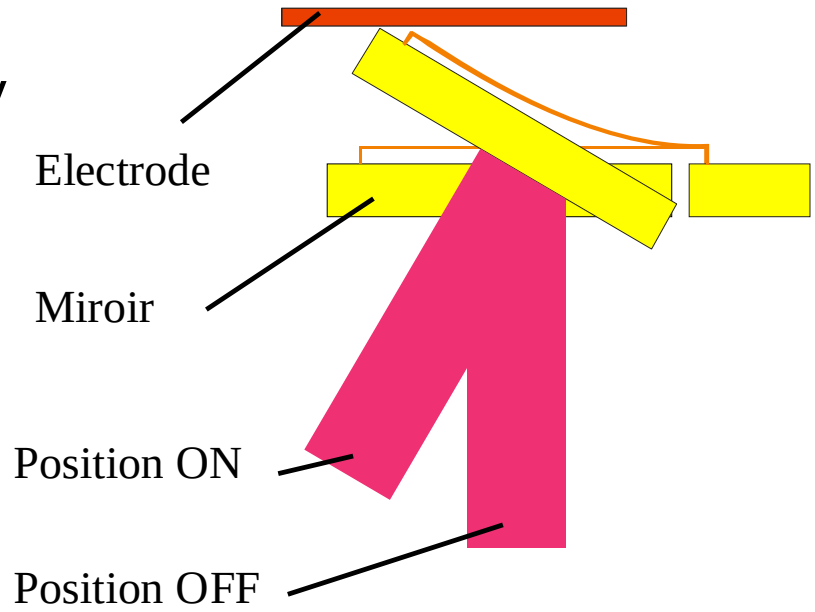
Diffraction effect





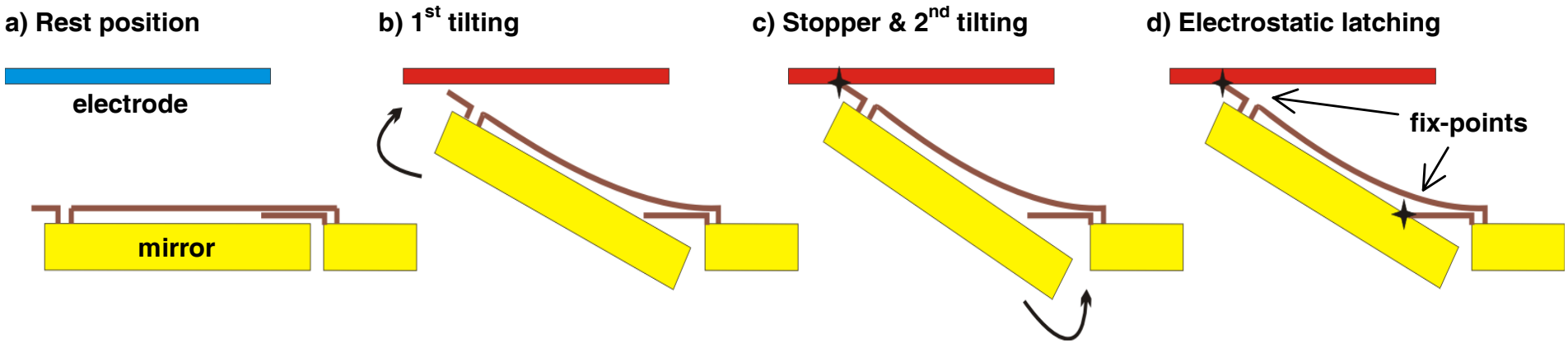
Key parameters

- Micro-mirrors key parameters
  - Design based on underneath cantilevers or torsion bars
  - Deflection angle: 20° (ON position)
  - Micro-element size: 100 µm x 200 µm, or bigger
  - Fill factor: > 90%
  - Mirror surface of good quality
  - Long-slit mode
  - Cryo operation



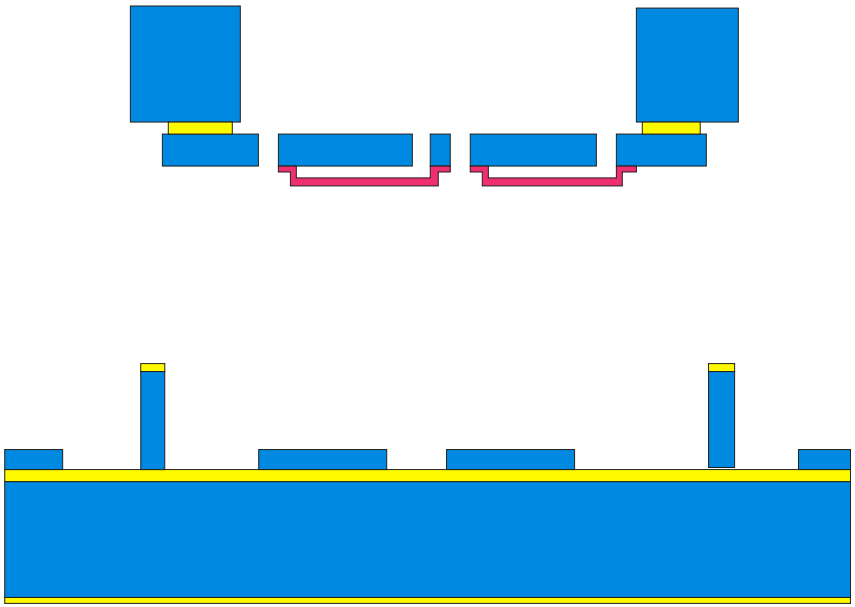
Concept

- Principle



- 2 wafers technology + assembly
  - Mirror chip
  - Electrode chip
  - Assembly

Realization



2 SOI (Silicon-on-insulator) wafers

10µm thick mirrors (flatness)

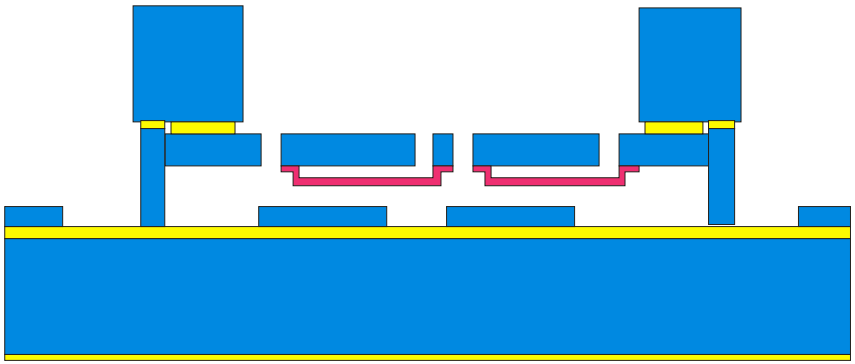
Flexure beams underneath

Uniform spacing height guaranteed

Tilt angle of 15°- 25°, depending on design

Landing posts for tilt angle uniformity

Realization



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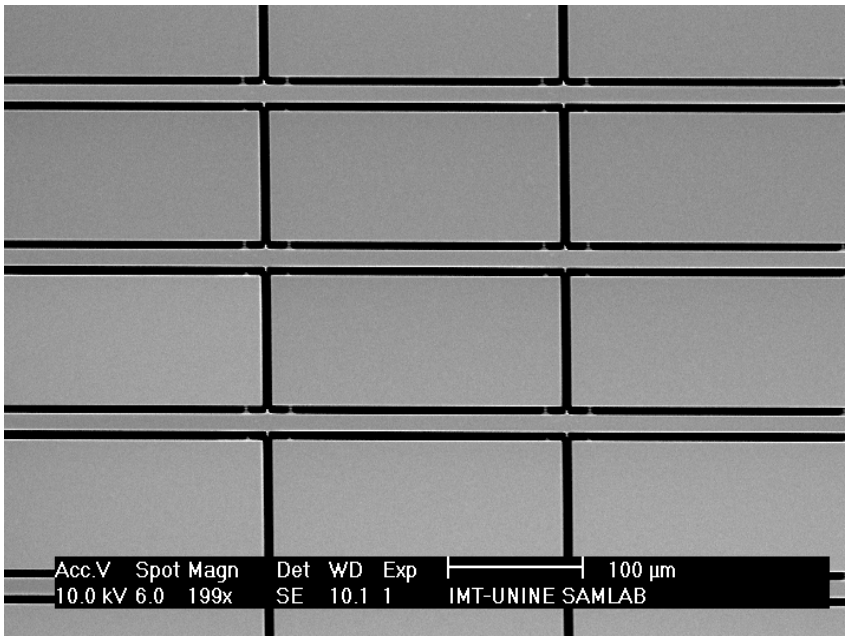
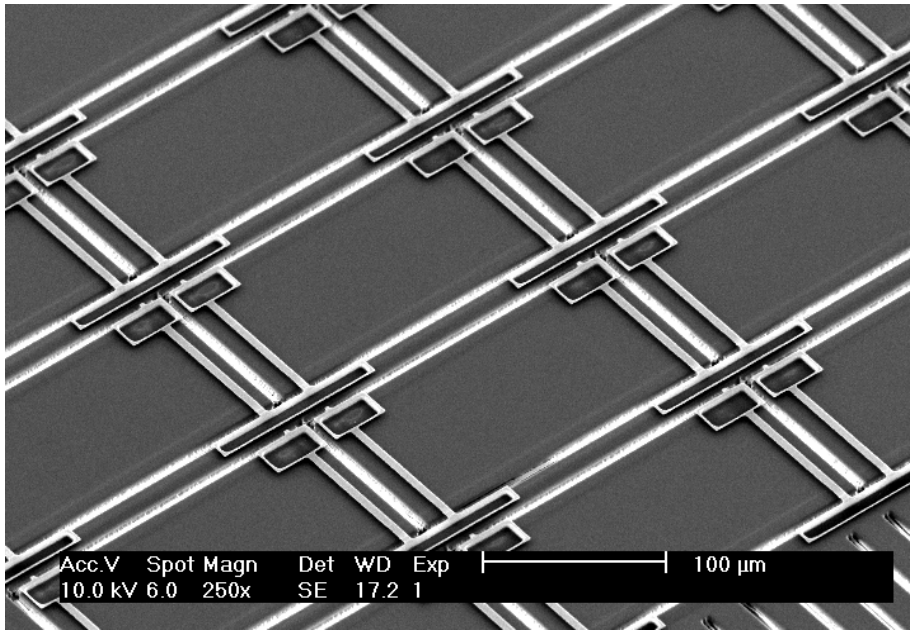
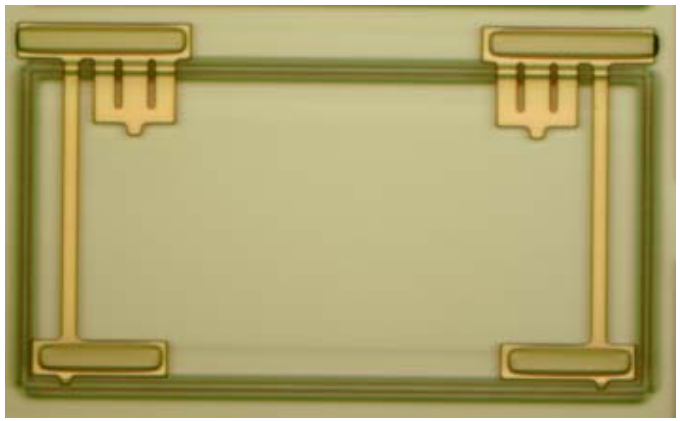




Landing posts



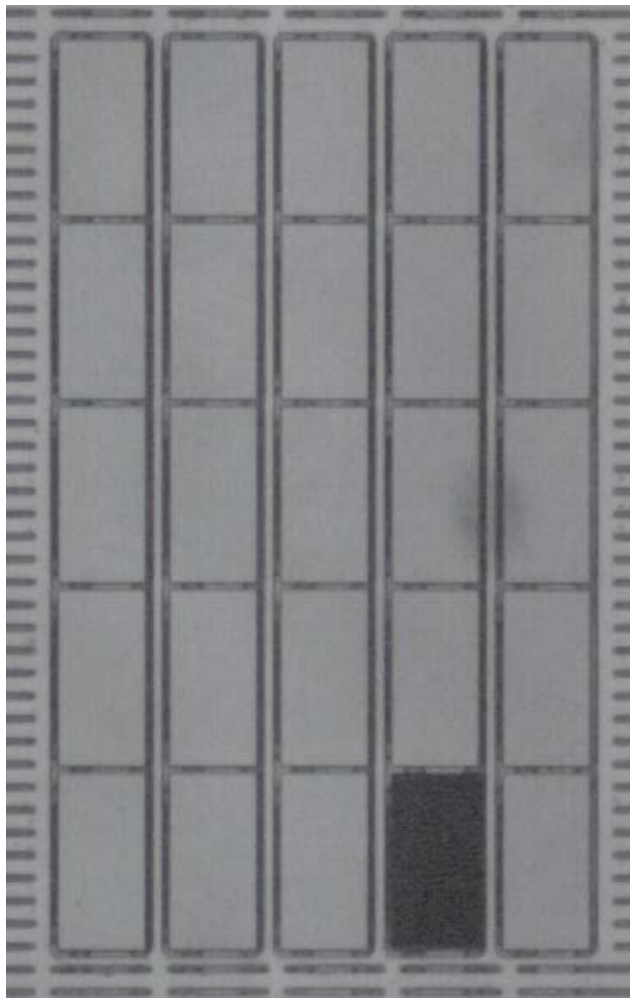
µM: 100 x 200µm^2

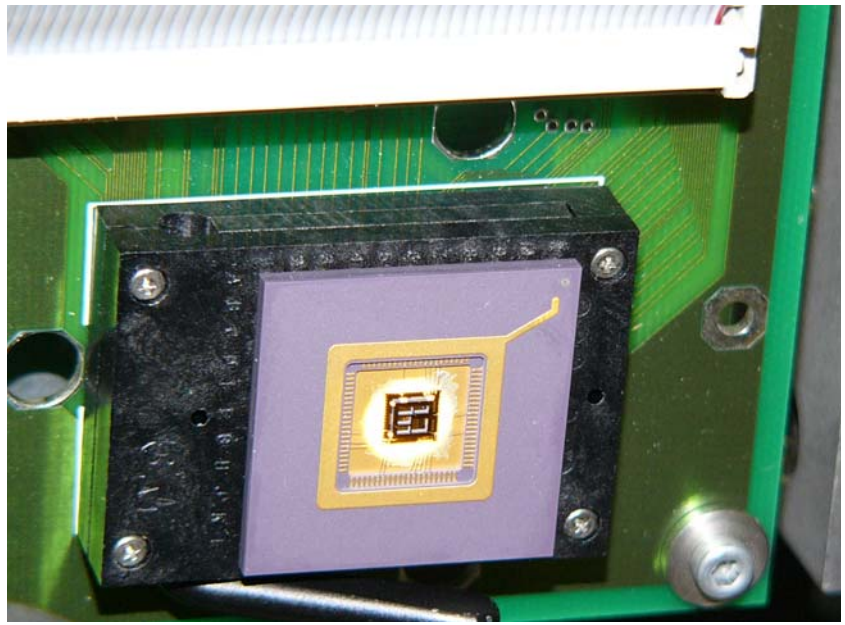
Small test array

- Realization

5x5 µM array

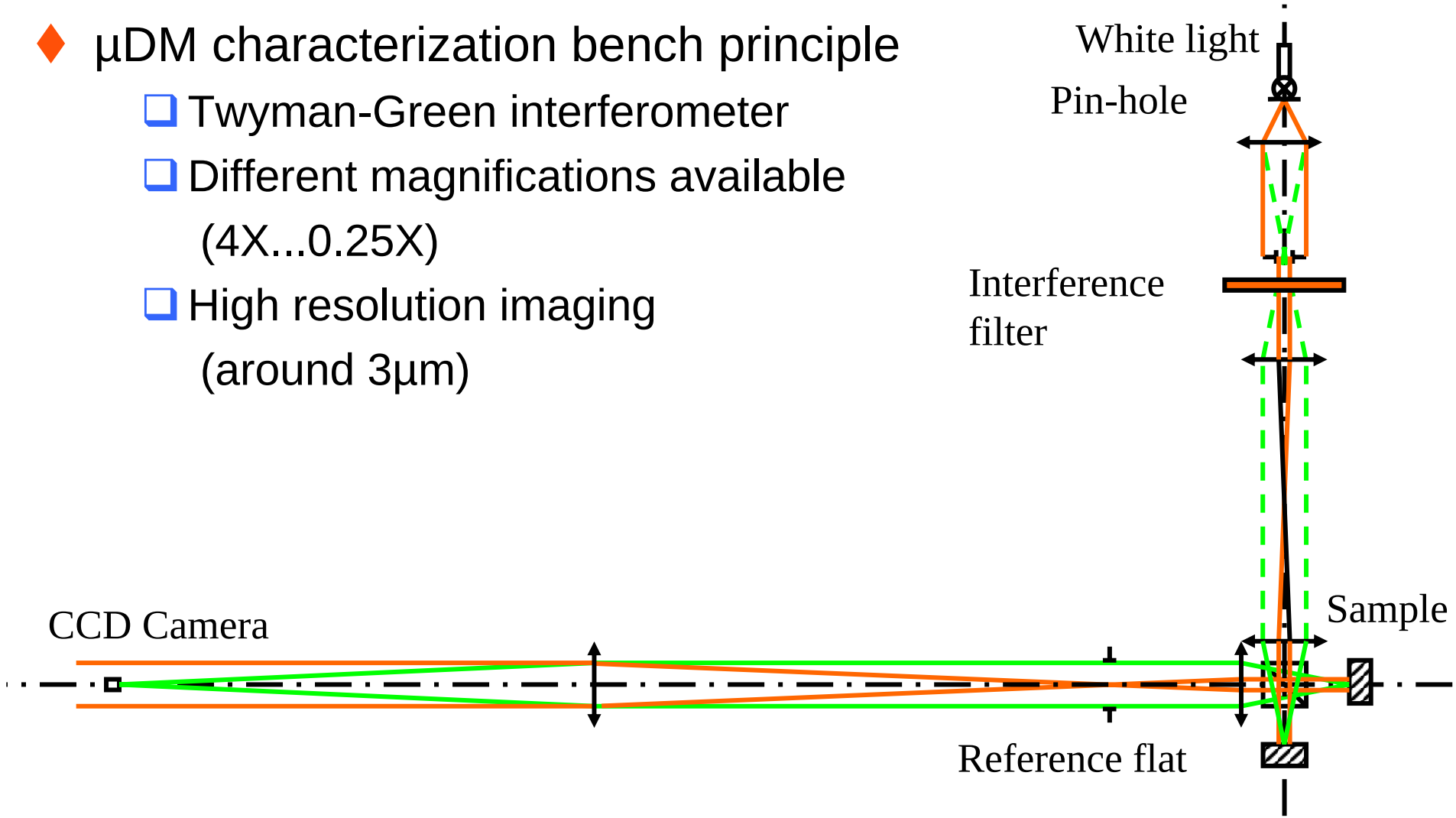
µM: 100 x 200µm^2





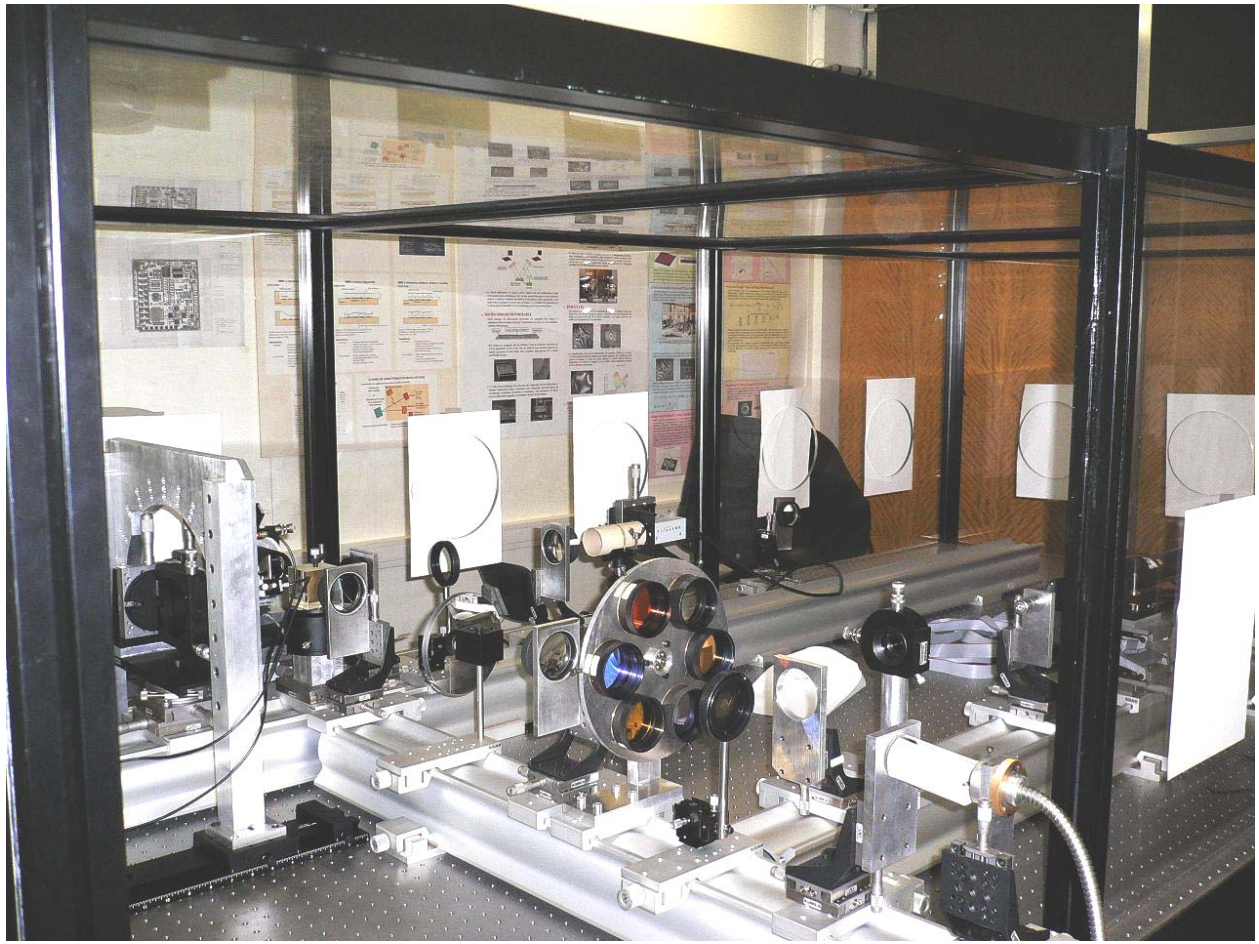
µDM characterization bench (1)

- µDM characterization bench principle
  - Twyman-Green interferometer
  - Different magnifications available (4X...0.25X)
  - High resolution imaging (around 3µm)

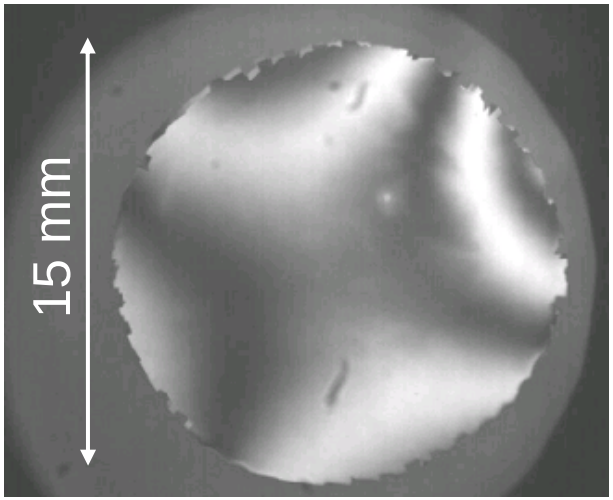


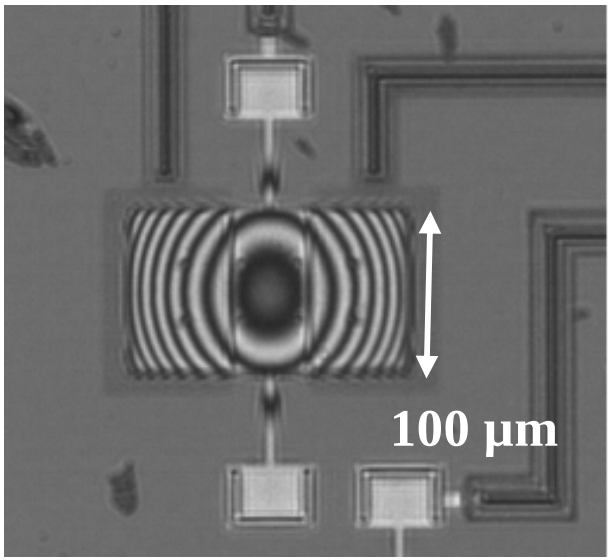
µDM characterization bench (1)

- Damped table
- Plexiglas box
- Filter wheel
- Camera
- Piezo stage
- Probe-tips



Imagery





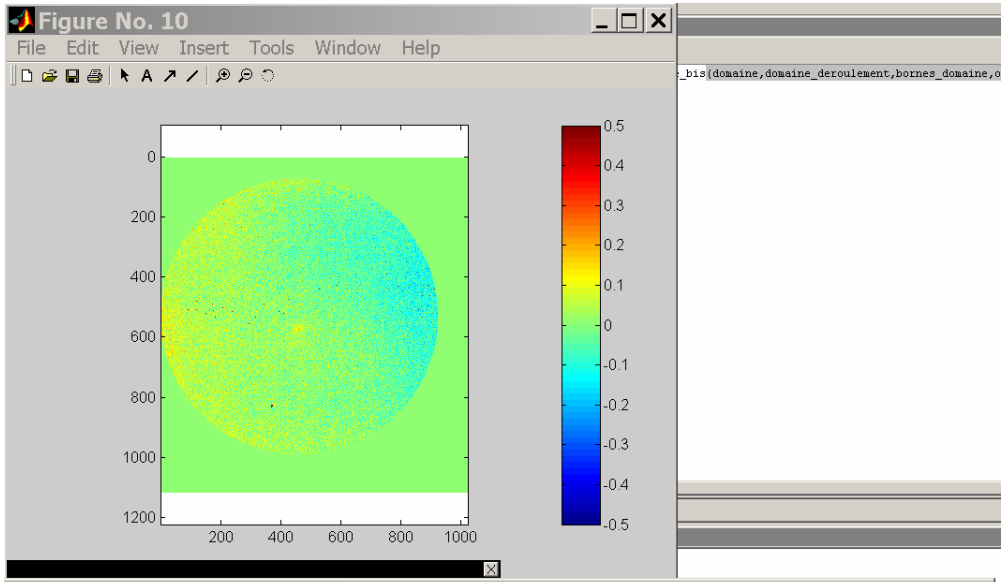
Large FOV

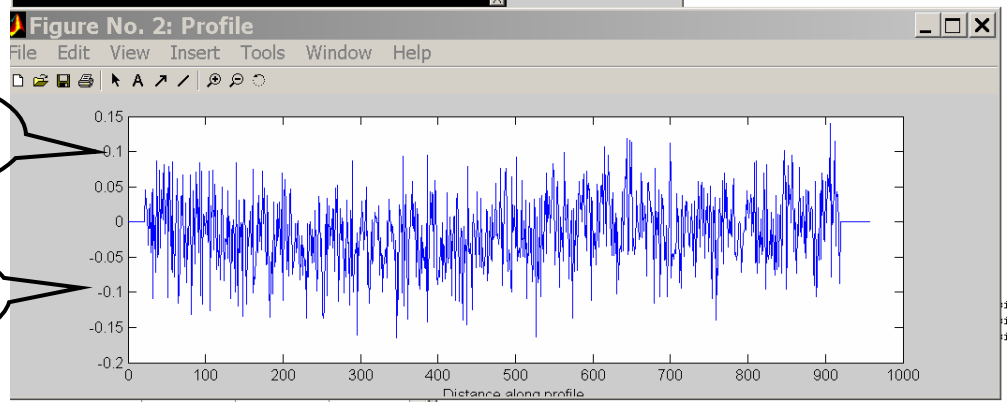
High resolution

0,1 nm

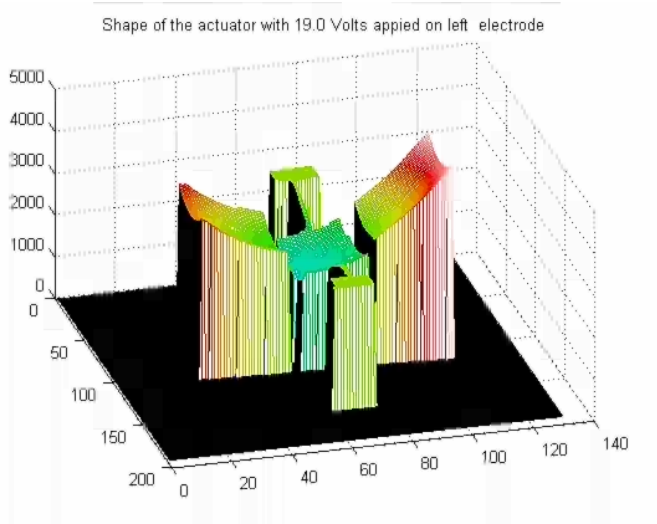
- 0,1 nm

Measurements resolution



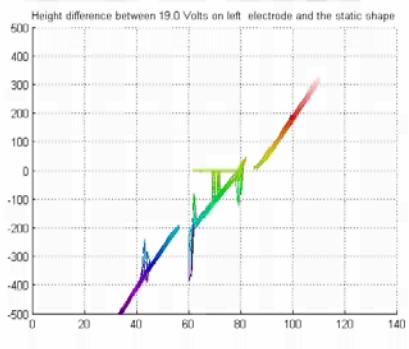


Surface measurement and actuation

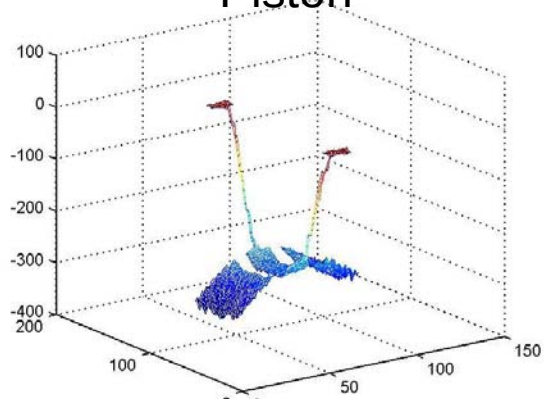


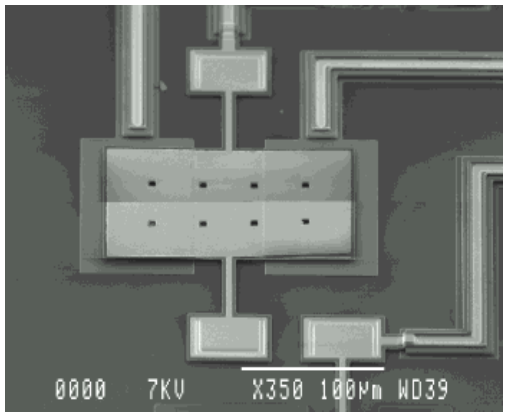
Dynamical measurements

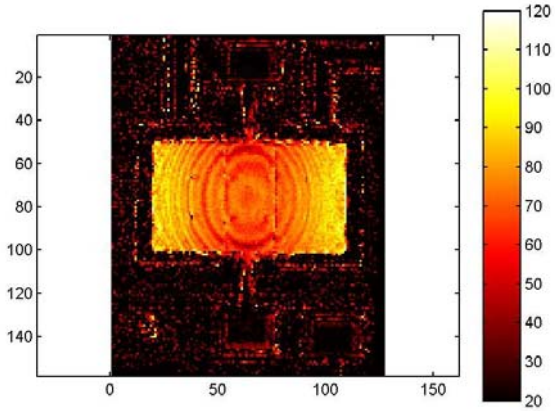
Rotation + piston



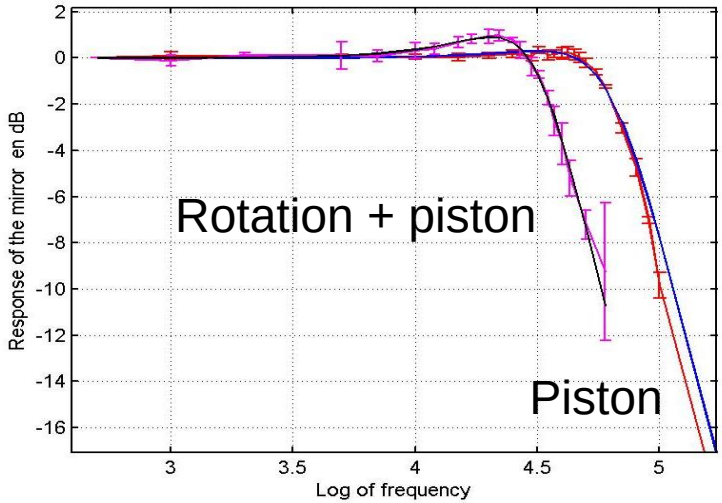
Piston





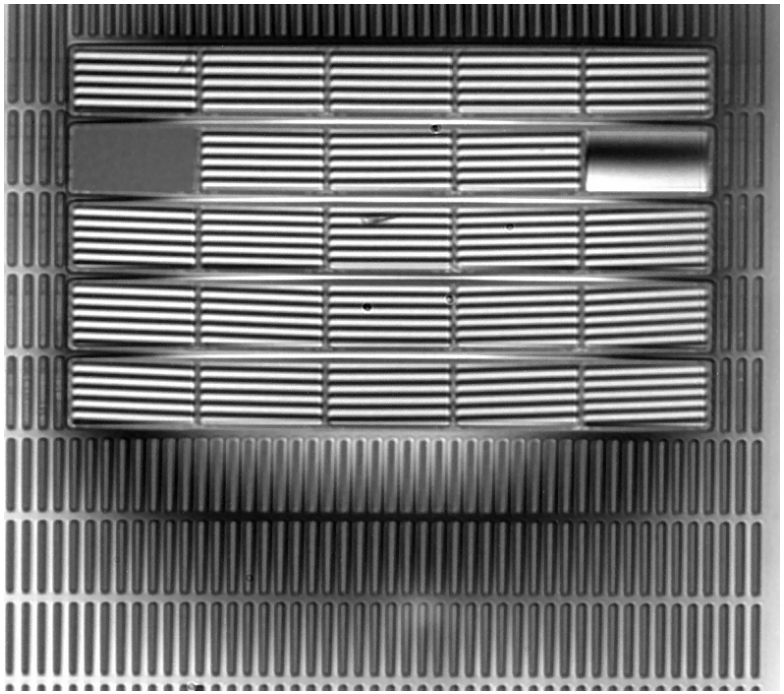


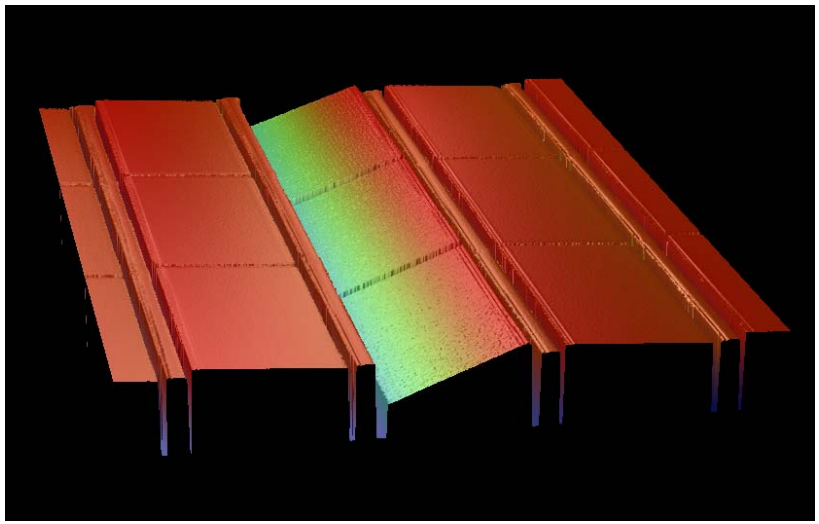
Deformation modes



Micro-mirror actuation

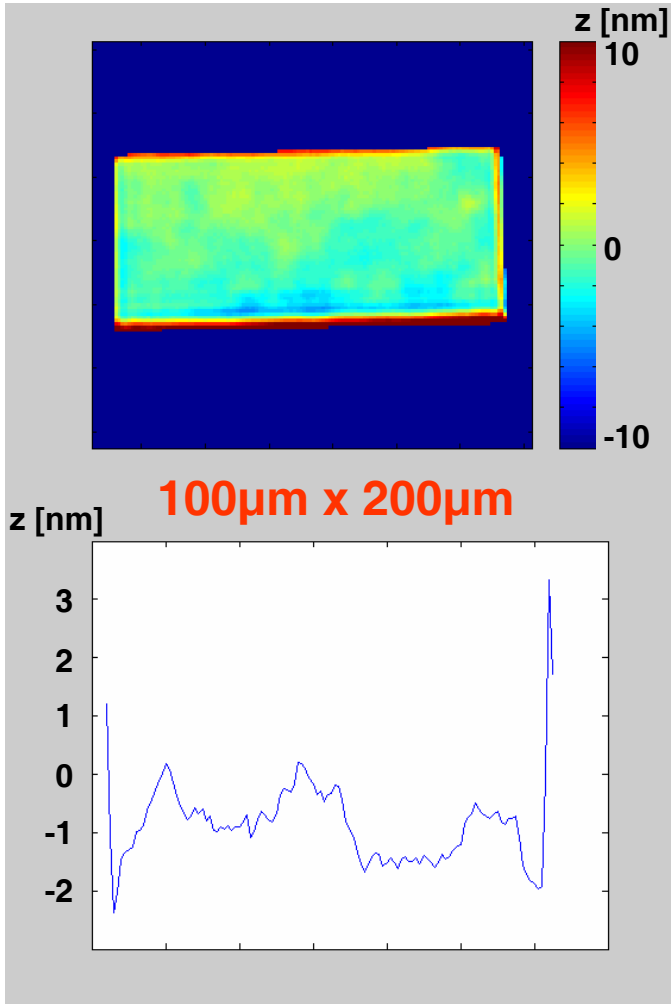
- Test on small arrays (5x5)
  - Electrostatic actuation
  - Long-slit mode
  - Deflection angle: 20°



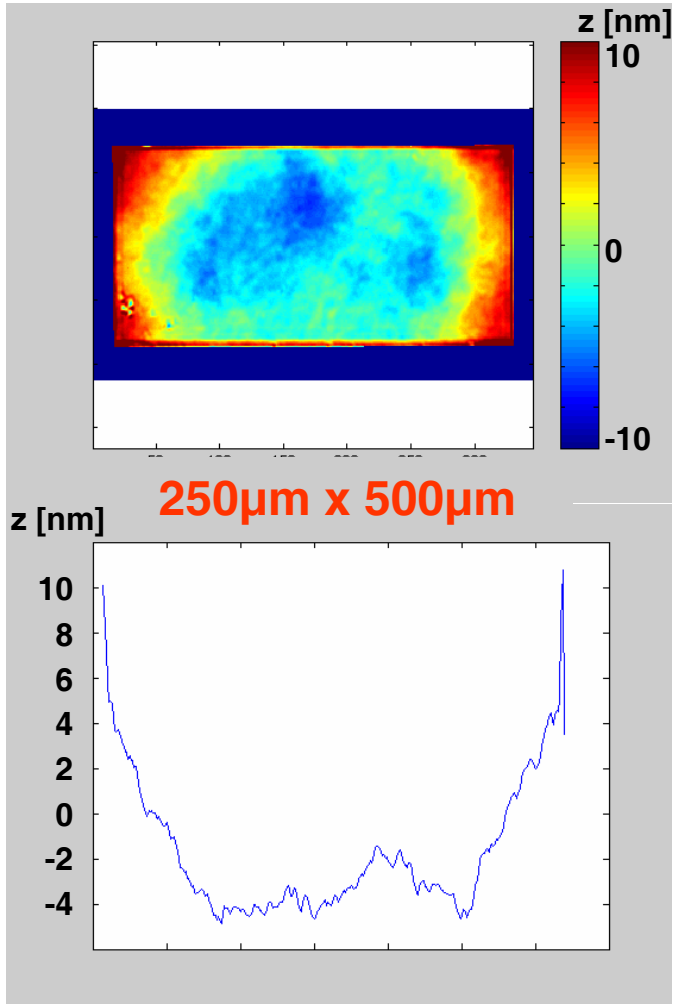


µM: 100 x 200µm^2

Surface quality (ON and OFF)



< 10nm PtV

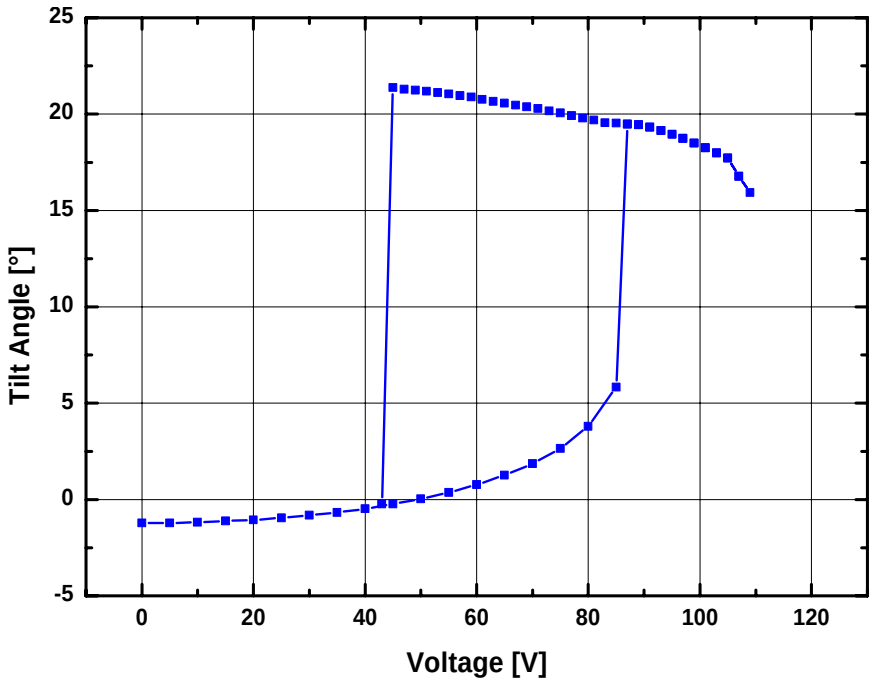


< 15nm PtV

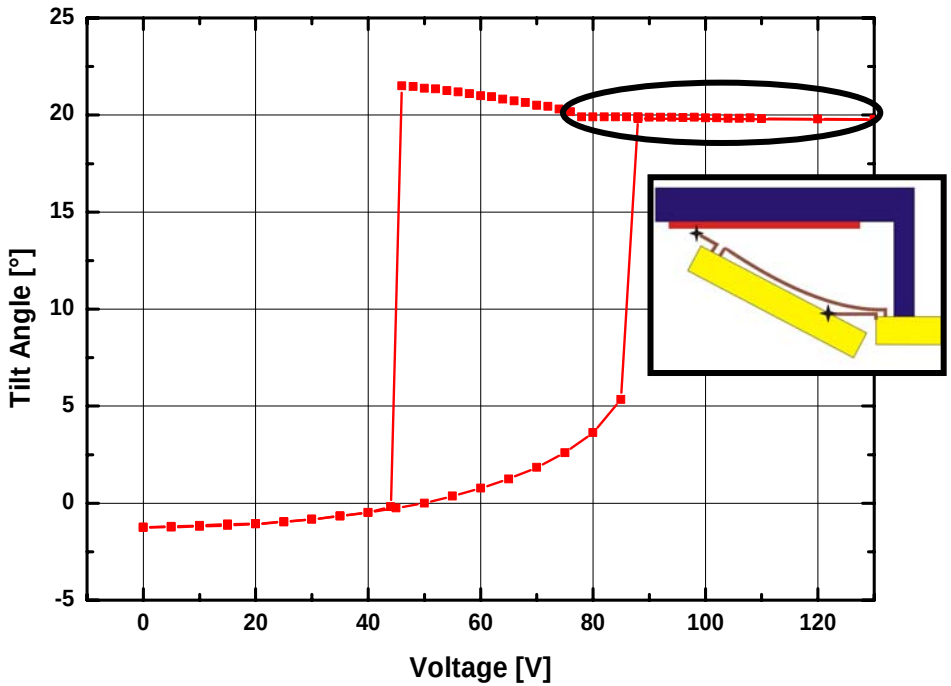
Tilt accuracy

- Electrostatic clamping of the mirrors on landing posts

No stopper beams

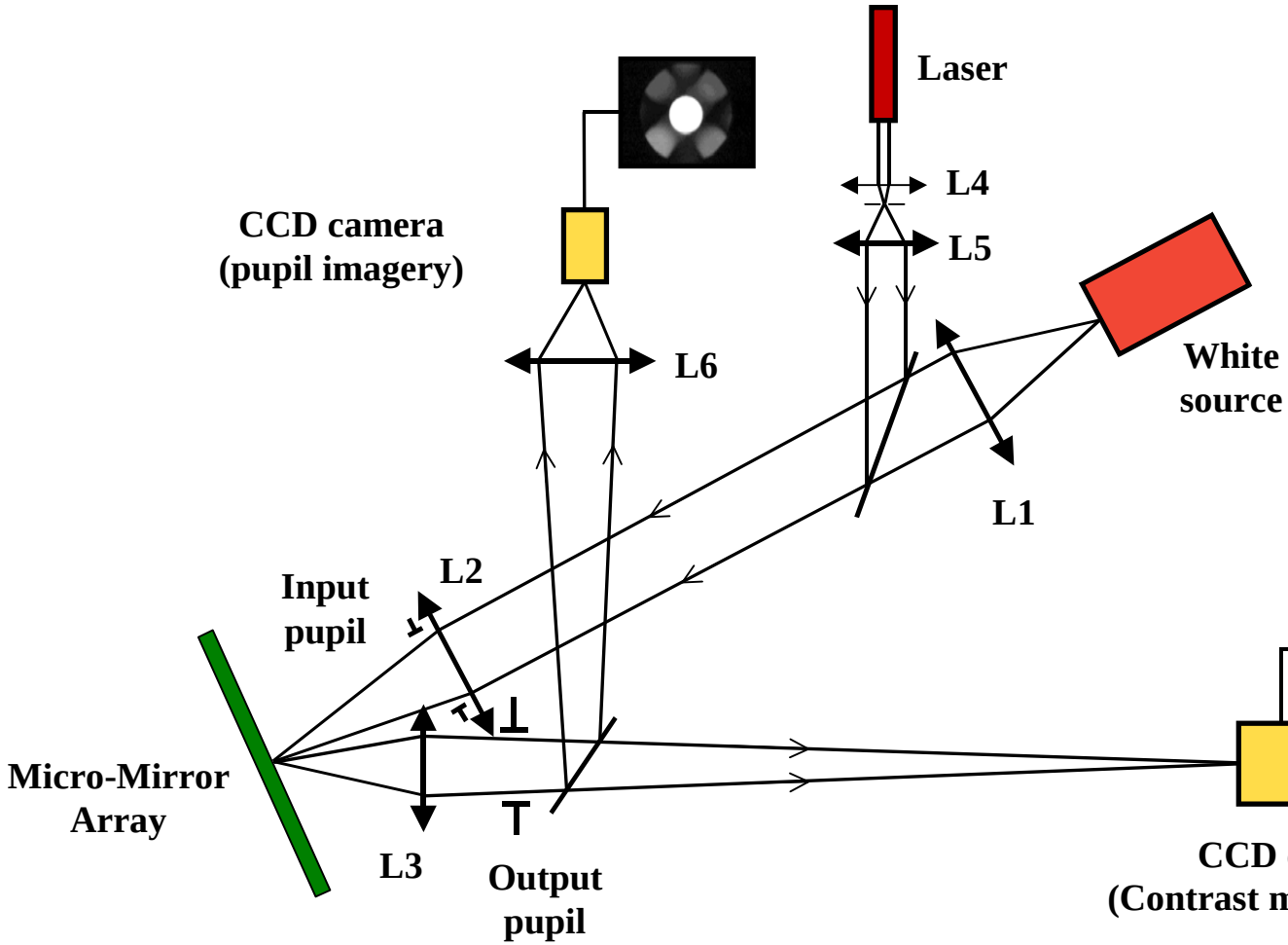


Stopper beams



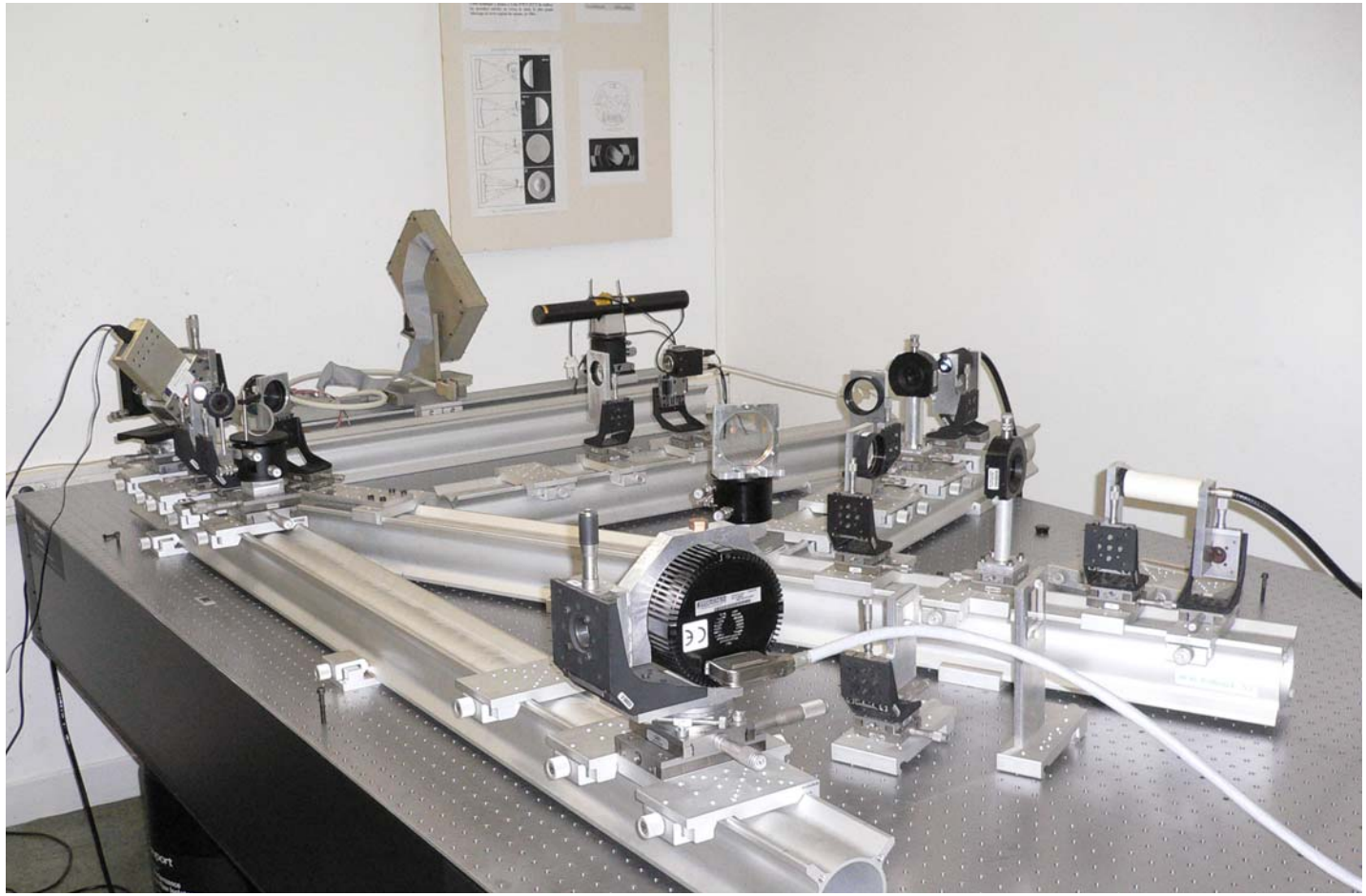
Tilt accuracy < **1 arcmin**

µDM characterization bench (2)



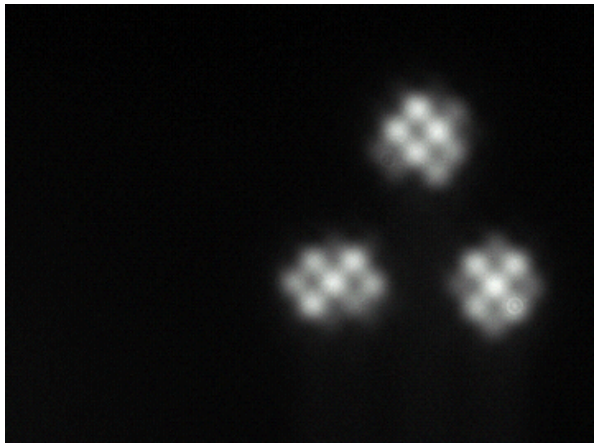
µDM characterization bench (2)

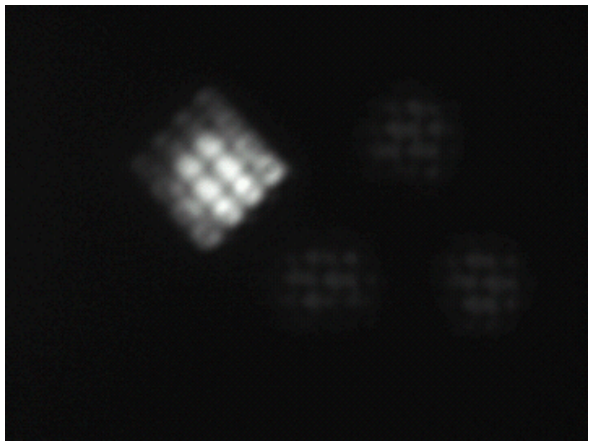
- Damped table
- Field simulator
- Filter wheel
- Field imaging
- Pupil imaging
- 16-bit CCD camera



Contrast measurement

- Field simulator (spoiler impact)

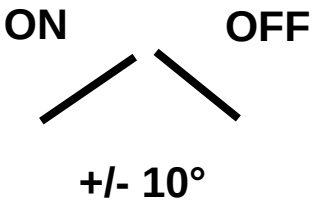


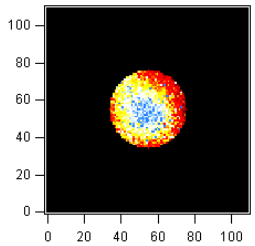


- Contrast in +/-12° configuration (Texas Instrument DMD)
  - 1024x768 micro-mirrors array, 13.8µm square mirrors, enhanced contrast by anti-reflection coating underneath
  - F/20 beam, contrast +/-12° configuration: >10000
  - F/12 beam, contrast +/-12° configuration: >5000
  - F/6 beam, contrast +/-12° configuration: >3000

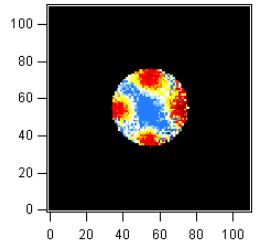
Measurements and developments

- Micro-mirrors

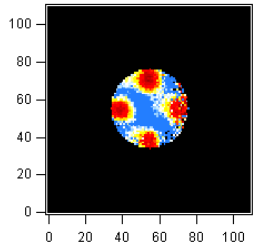




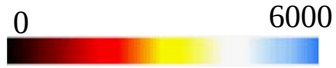
F/34



F/34 +50%



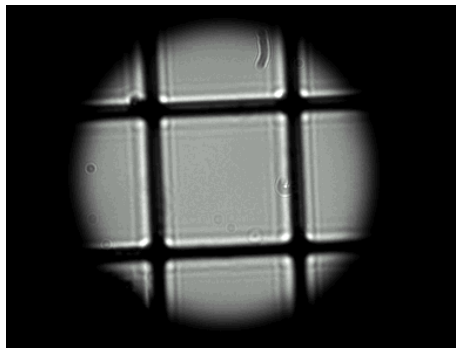
F/34 +100%

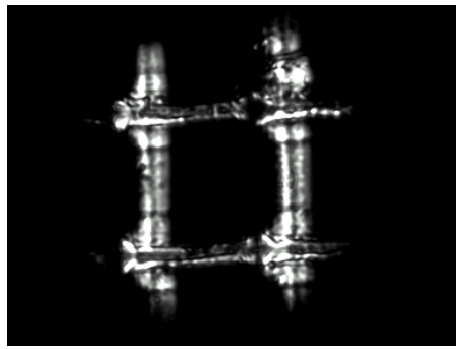


Effective Contrast > 3000

- Micro-shutters

OPEN





CLOSED

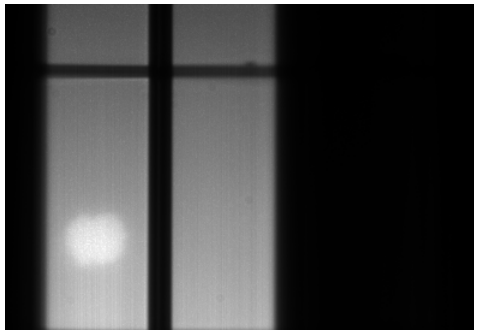
- Collaboration engaged with University of Neuchâtel (Switzerland) for the development in Europe of programmable slits with MOEMS technology (FP6/Opticon/JRA Smart Focal Planes)

Object selection

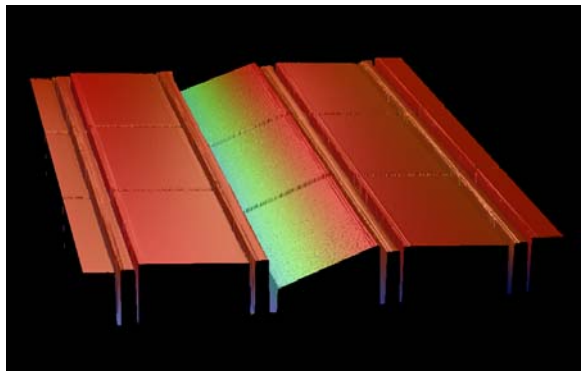
Multi-Object Spectroscopy: bench demonstration

- Large field illumination

2 rows ON
the others OFF



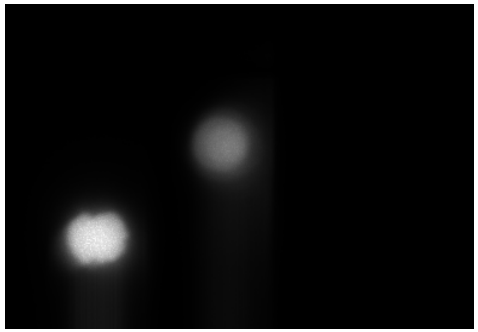
- Long slit mode



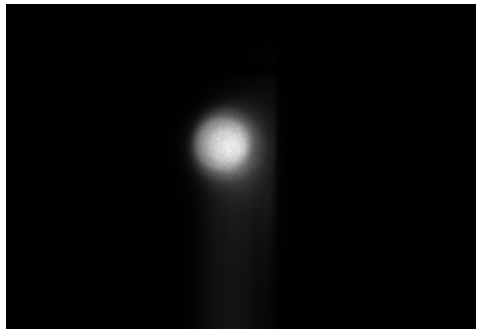
Tilt accuracy

< **1 arcmin**

- Object selection



Two objects in the FOV

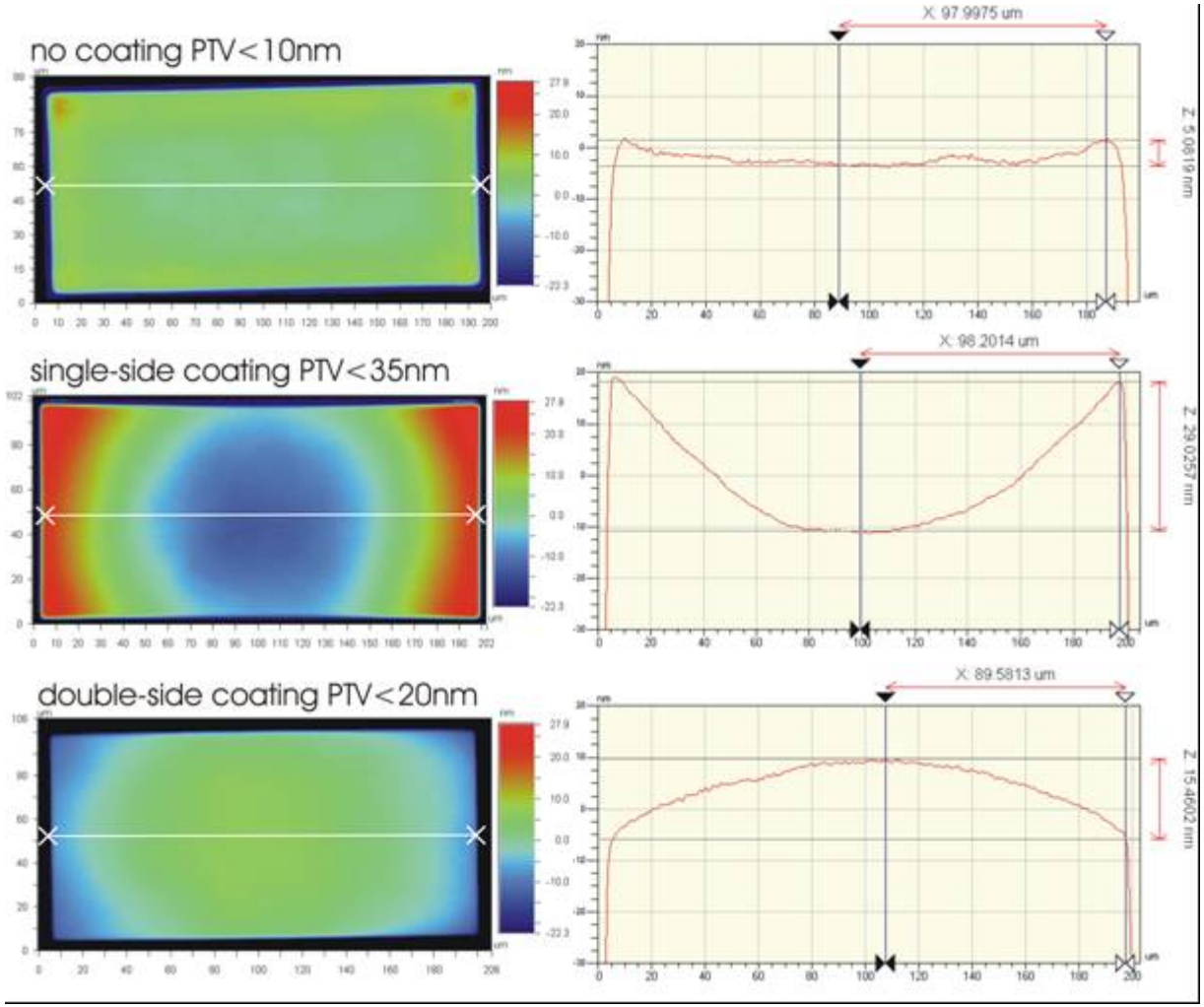


Right object selected

Left object selected

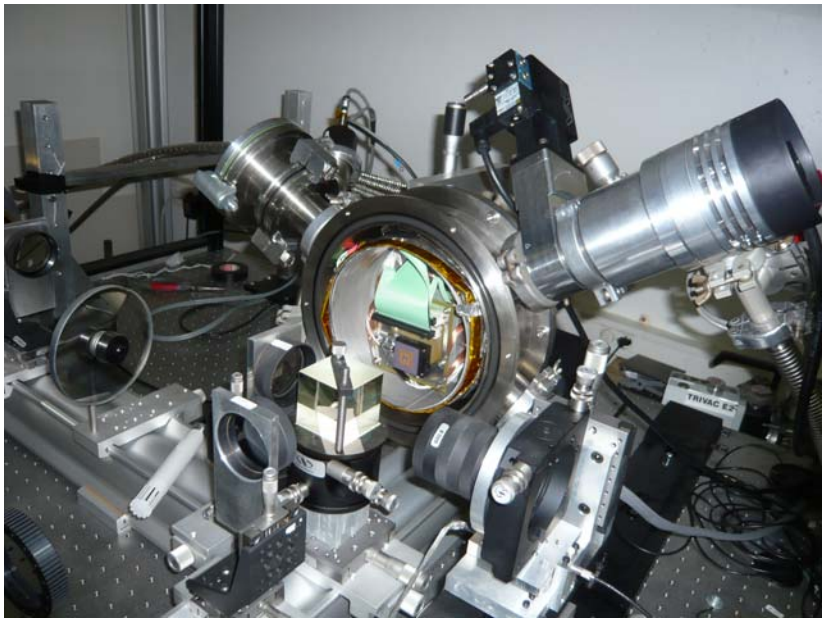
Mirror coating

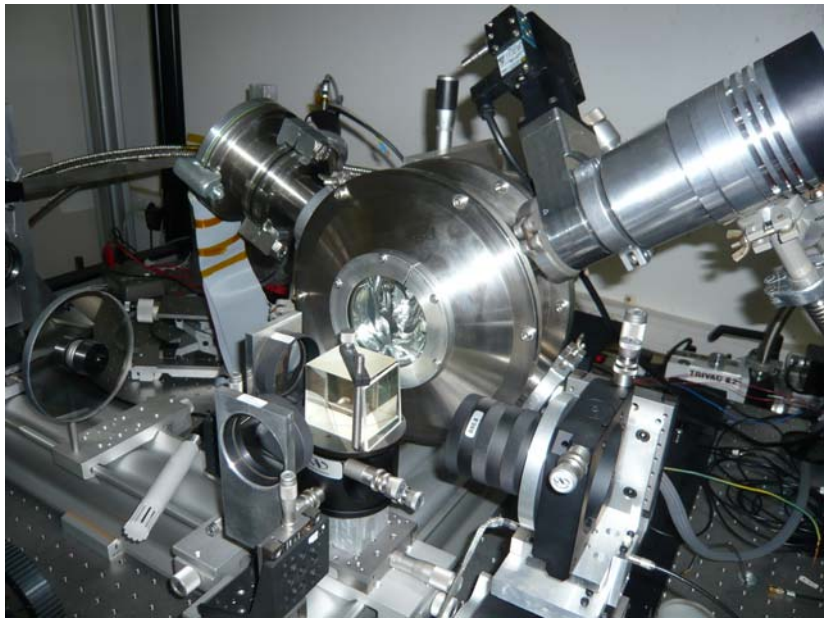
Gold coating on micro-mirrors



Cryo test

- Specific cryo chamber developped, compatible with the interferometric bench
- Vacuum 10^{-6} mbar
- Temperature, below 100K

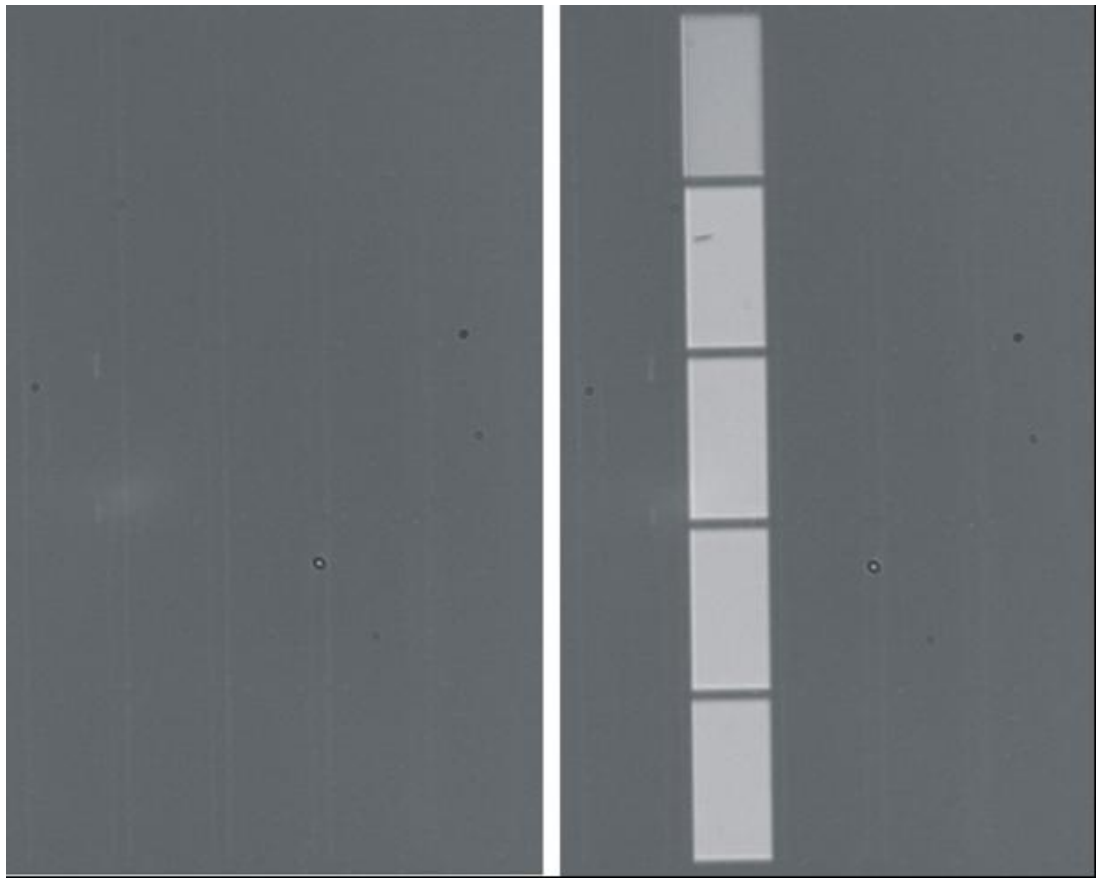




Operation in cryo

92K

0V



92K

90V

Operation in cryo

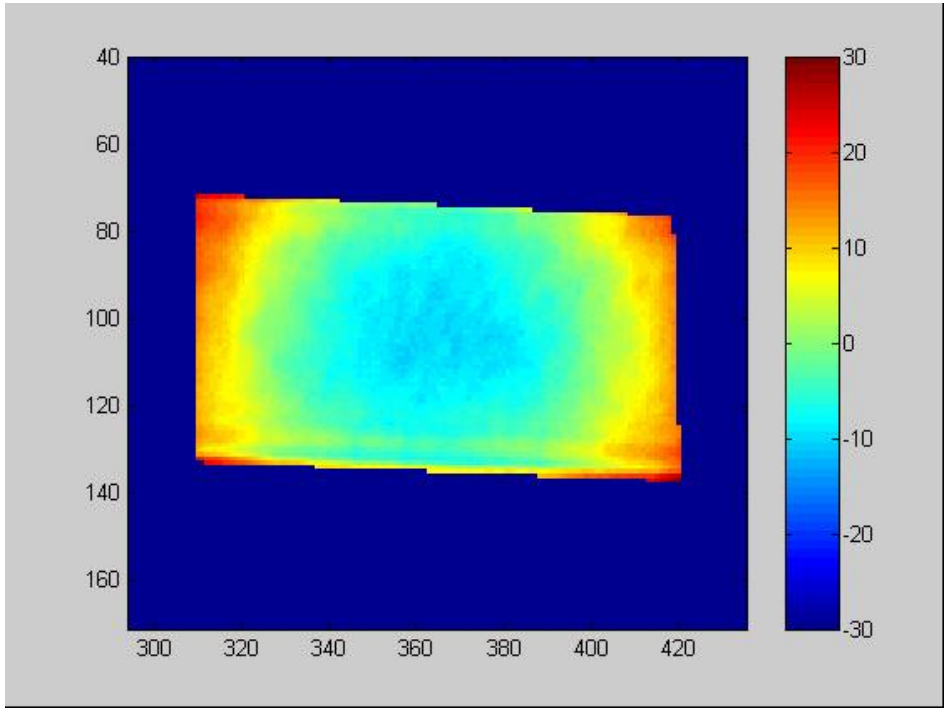
The movie

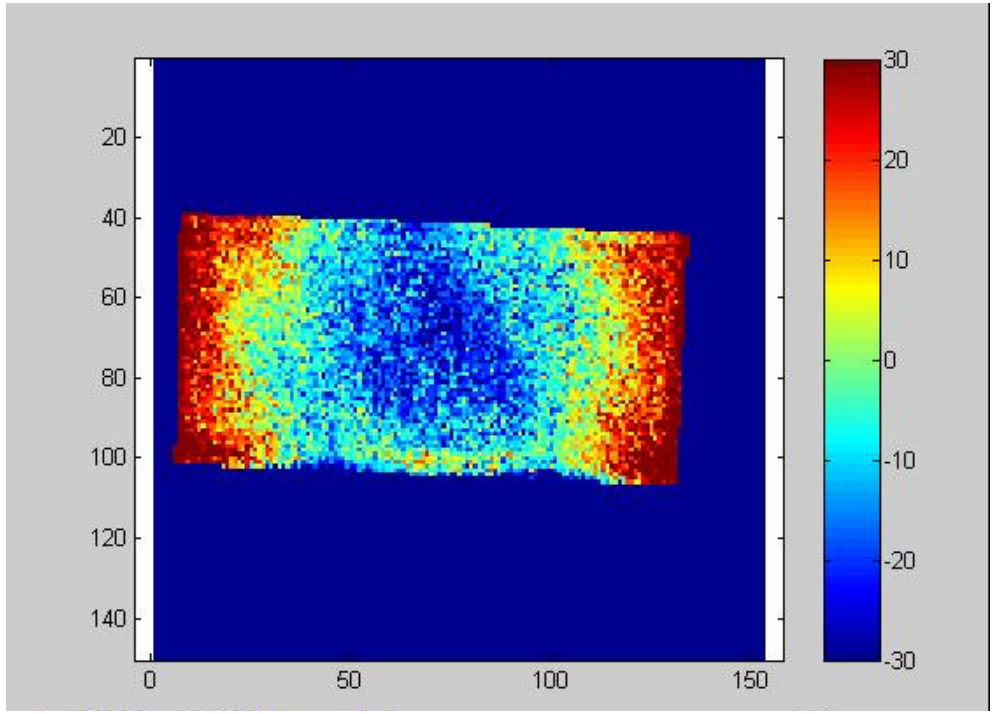
At 92K

Object selection

Surface quality measurement in the ON position

- Room temperature
- At 92K

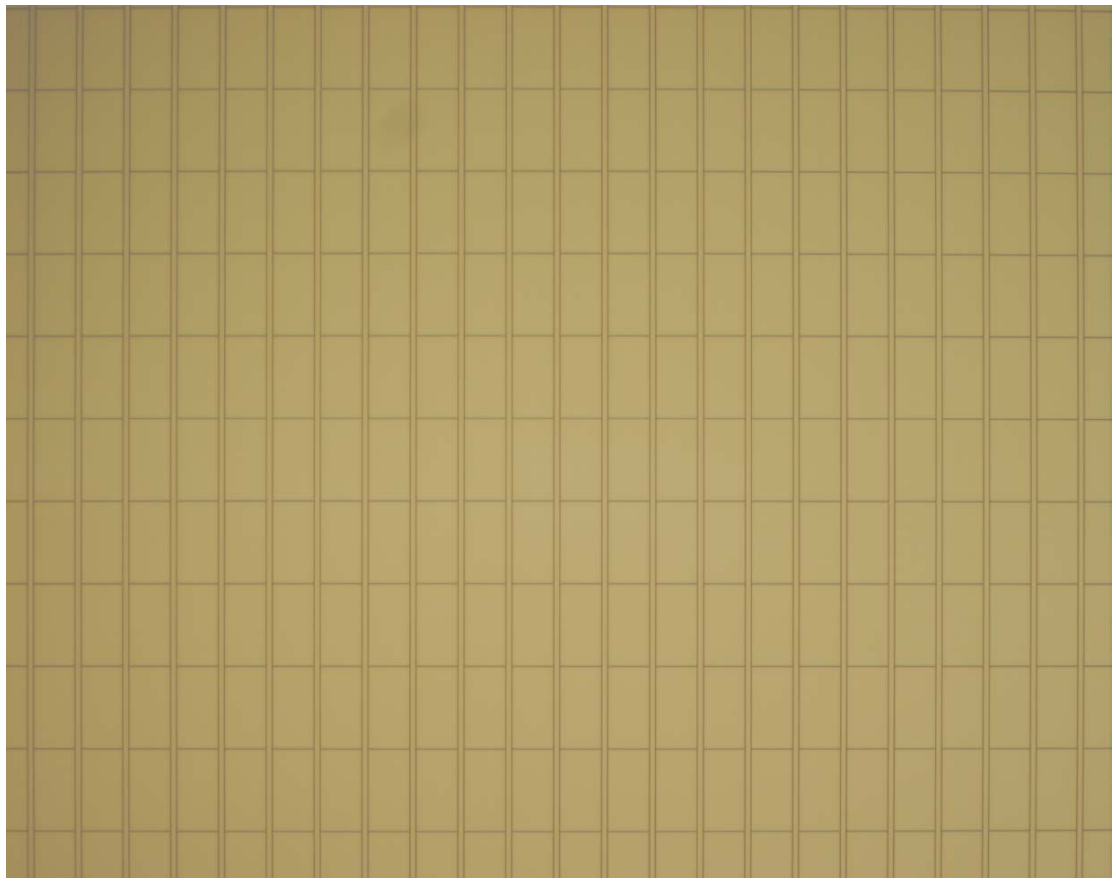




35 nm PtV

50 nm PtV

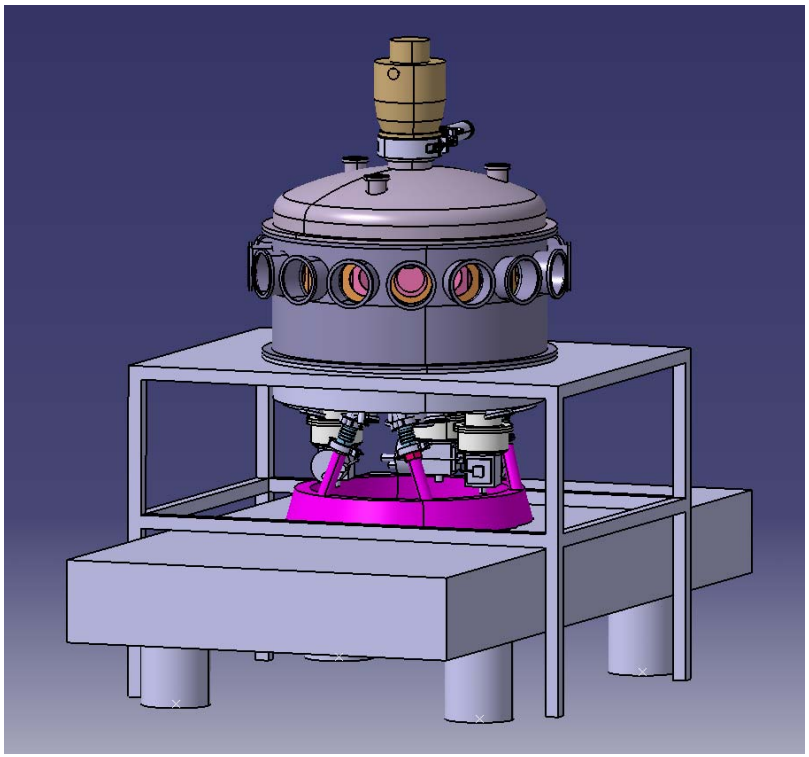
100 x 200 µMirrors array under way

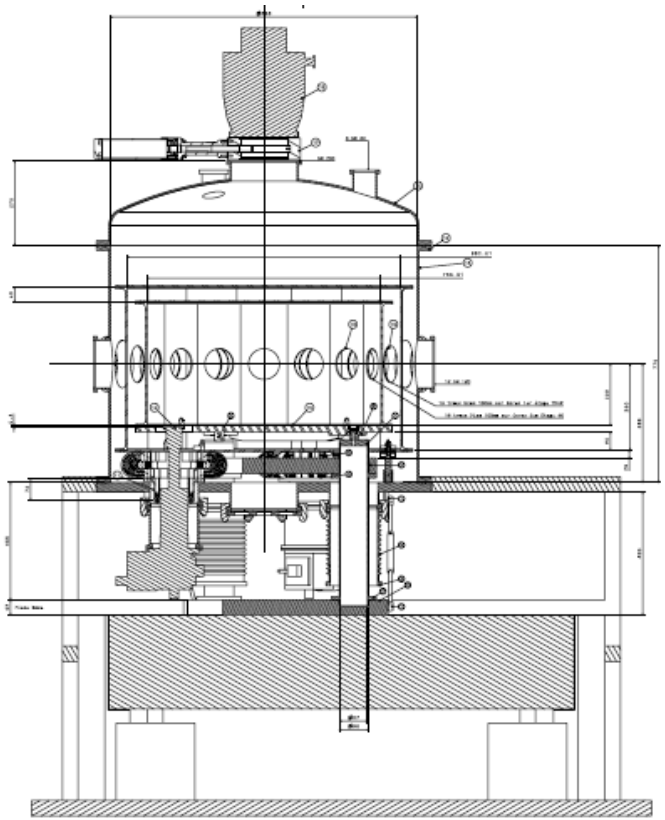


- Large array realization under way
- Line-column addrssing will be implemented

Cryo measurement bench

- Development of a vacuum / cryo characterization bench
  - 30K – ambient
  - Internal optical plate linked to an external damped table
  - Multi-window access

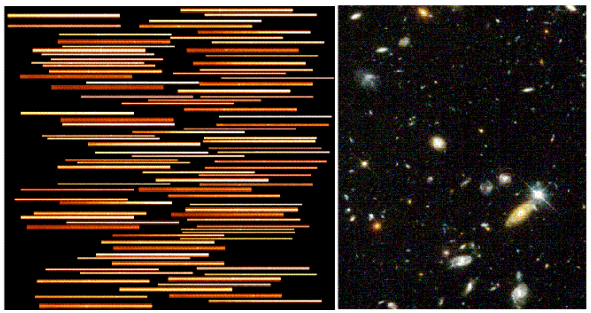


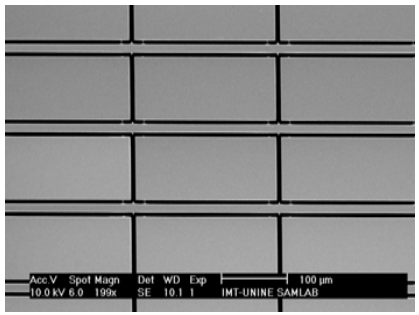


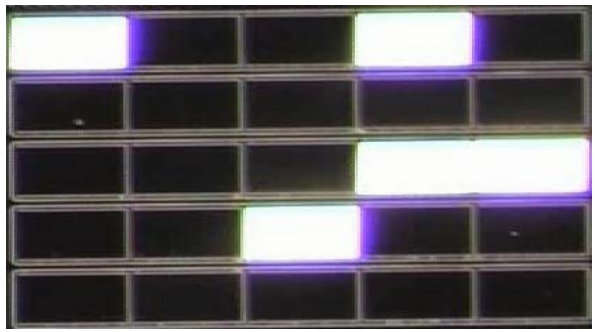
Conclusion

Single micromirrors of 100 x 200 µm² and arrays of 5x5 realized

- 20° mechanical tilt @ 90V
- Mirrors have optical flat surfaces (7nm peak-to-valley)
- Latching mechanism demonstrated
- Proof of operation for object selection
- Cryogenic operation < 100K succesful







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