MOEMS devices for future astronomical instrumentation

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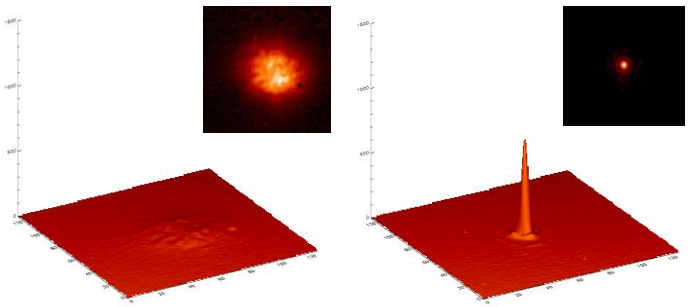
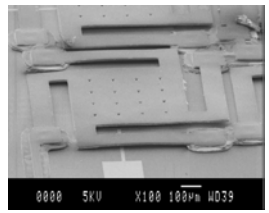
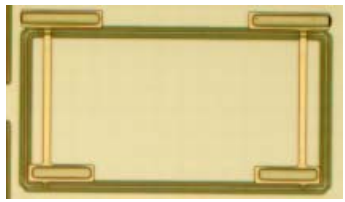
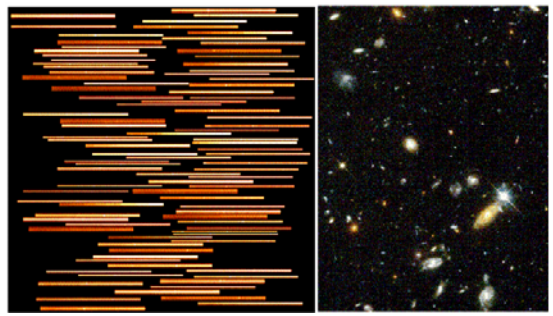


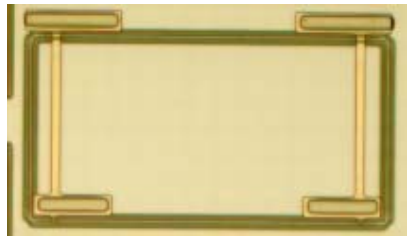


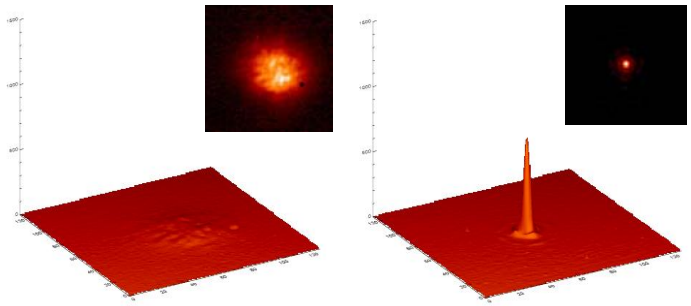


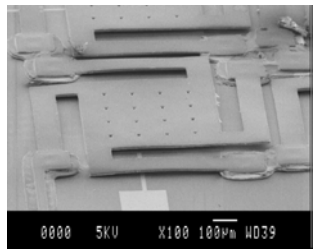


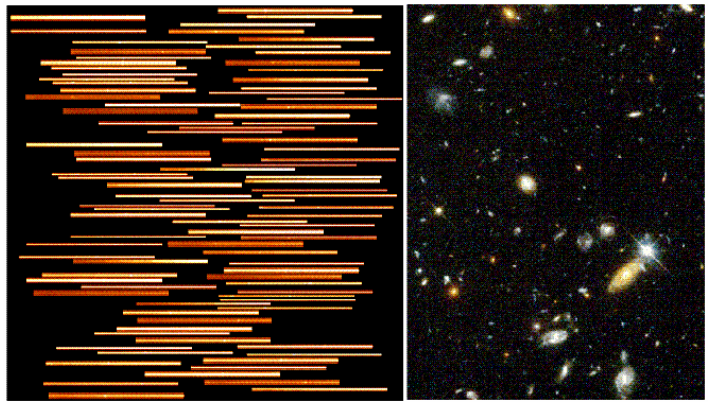
Astronomical cases

- ***Origin's*** quest
  - Galaxies formation and evolution
  - Stars and planetary systems formation
  - Life's Origin
- Instrumental needs
  - High resolution
  - Multiplex measurements

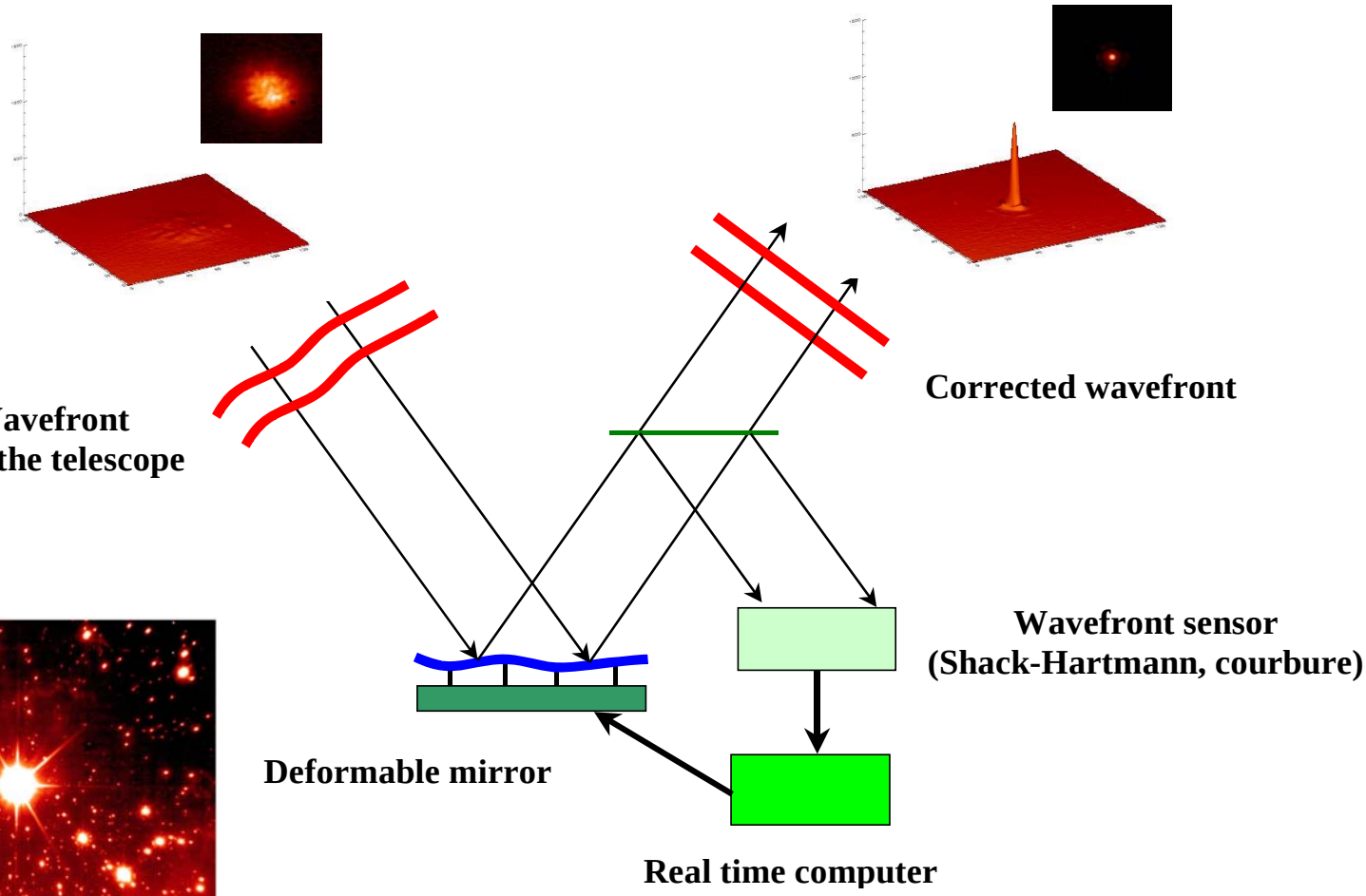


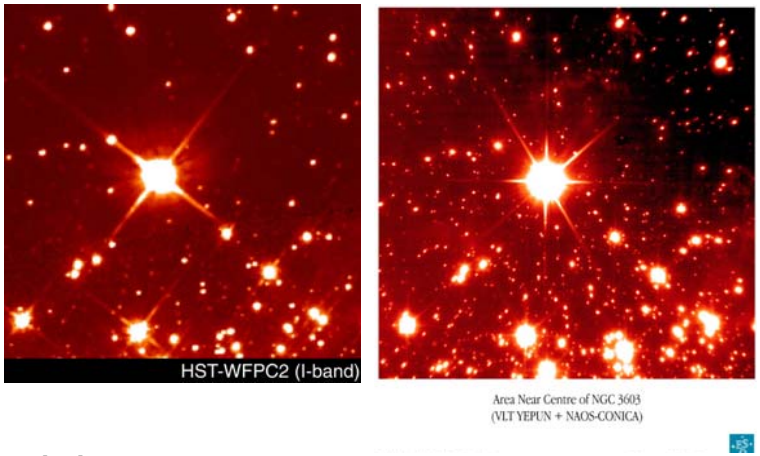






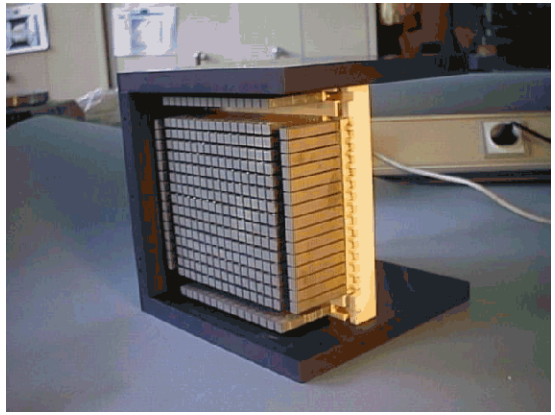
Wavefront correction

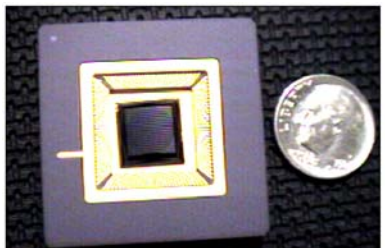


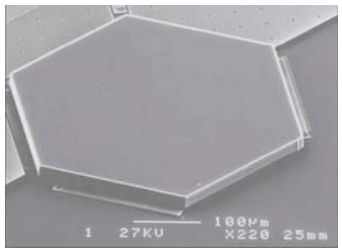


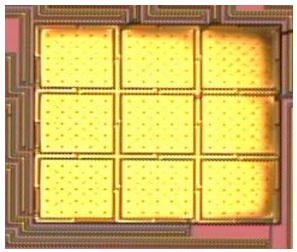
Deformable mirrors

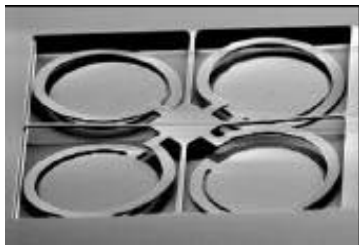
- **Mirrors with classical technology**
  - Piezo and magnetic actuators
  - Few 100 actuators
  - Inter-actuator spacing 5mm
- **Micro-deformable mirrors (MDM)**
  - Electrostatic force
  - Up to 500 000 actuators (Extremely Large Telescope)
  - Inter-actuator spacing 500µm-1mm
- **MDM with membrane**
- **MDM with attached actuators**

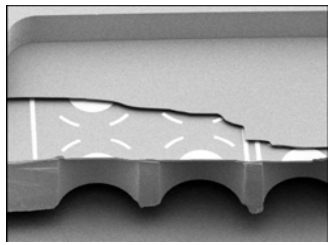






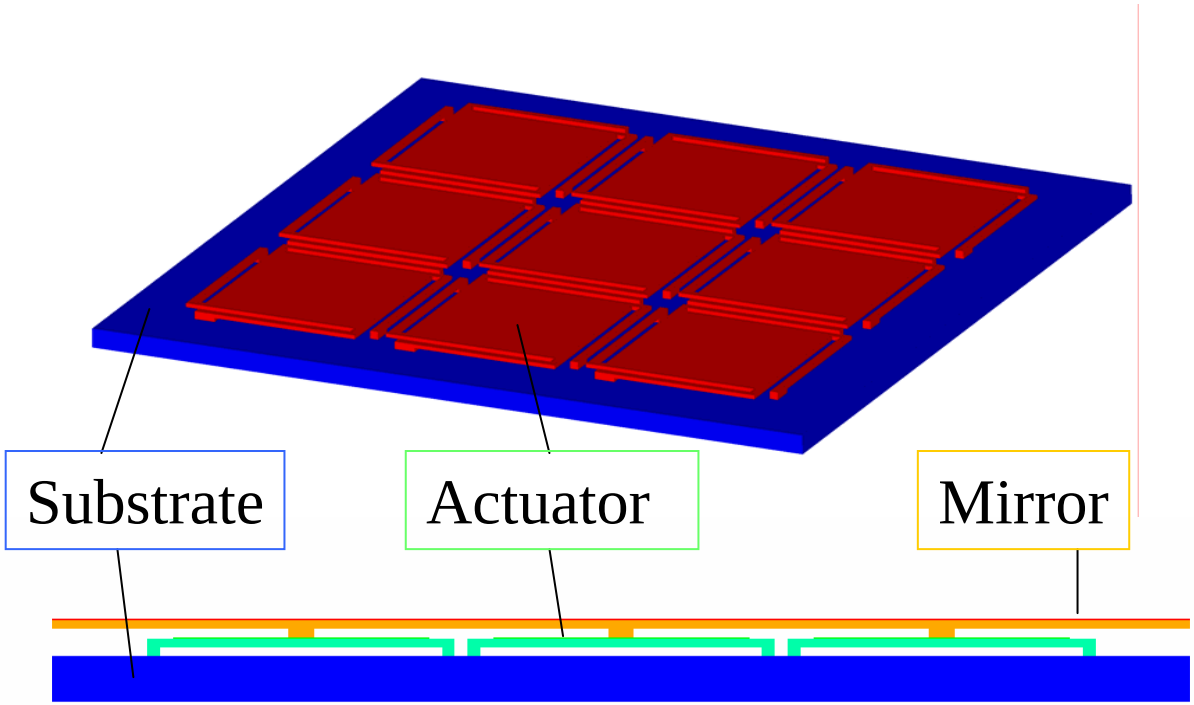


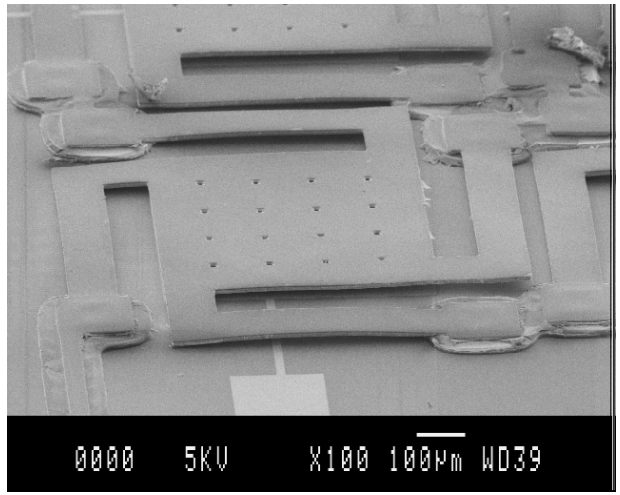


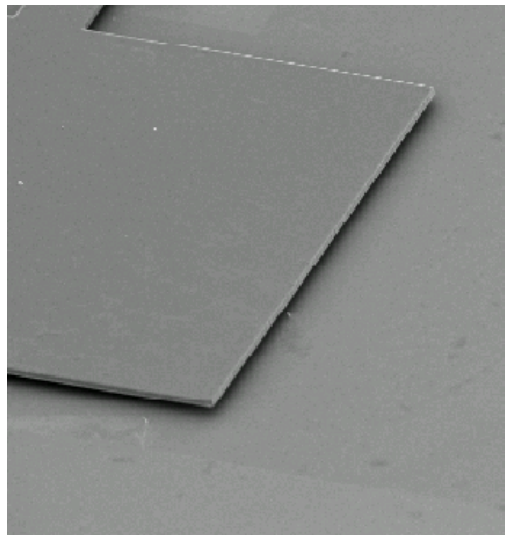


MDM architecture

- Collaboration LAM-LAAS since 2001
- New materials : polymers
- Original process

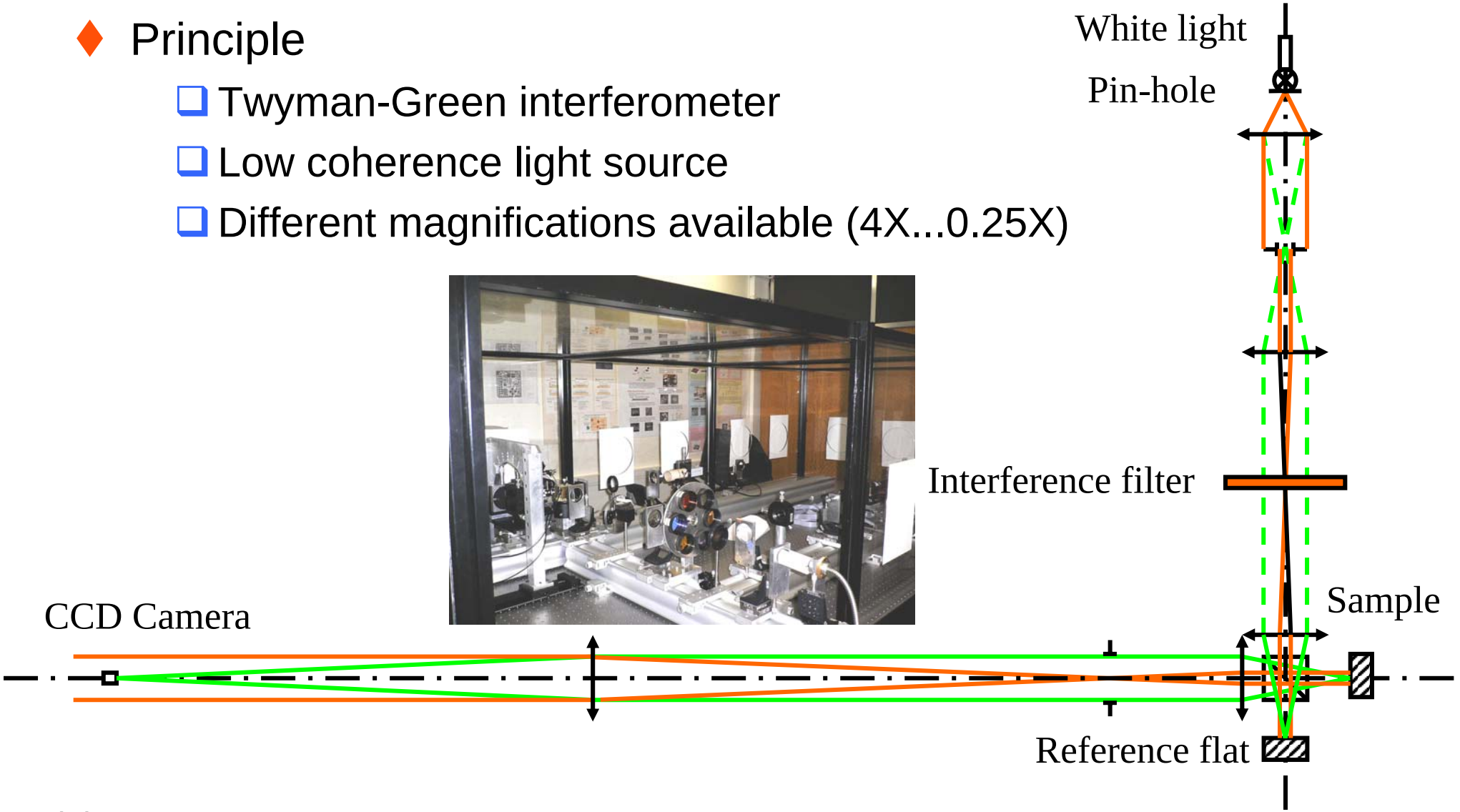






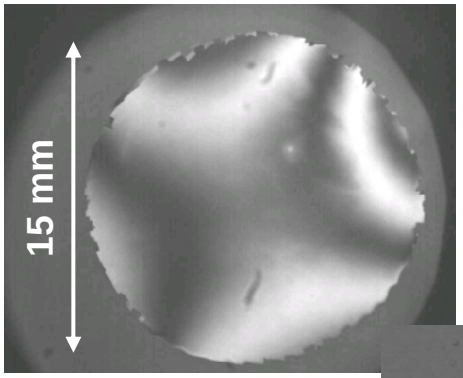
MOEMS characterization bench

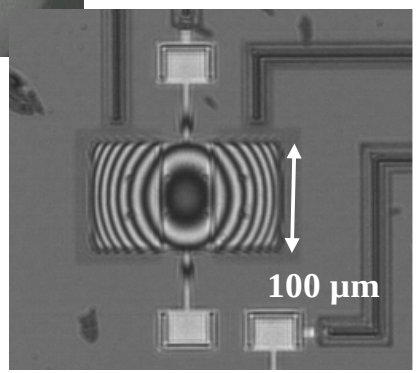
- Principle
  - Twyman-Green interferometer
  - Low coherence light source
  - Different magnifications available (4X...0.25X)



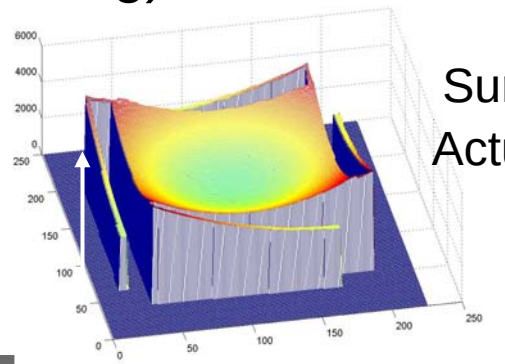
Surface measurement and actuation

- Measurement capabilities
  - Surface measurement (phase-shift, two wavelengths)
  - Actuation measurement **(resolution < 1nm)**
  - Dynamical measurement (time-averaged interferometry)
  - Probe tips (chip level testing)

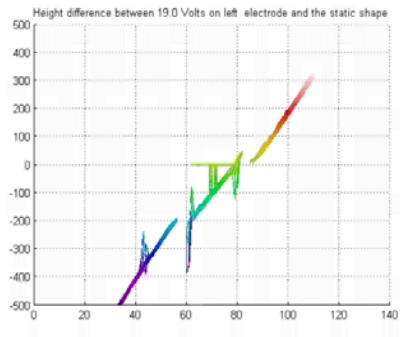


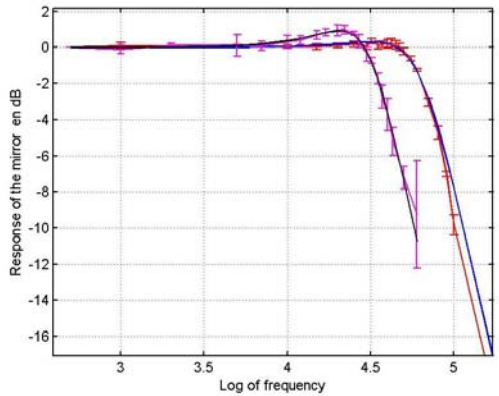


Imagery



Surface,
Actuation





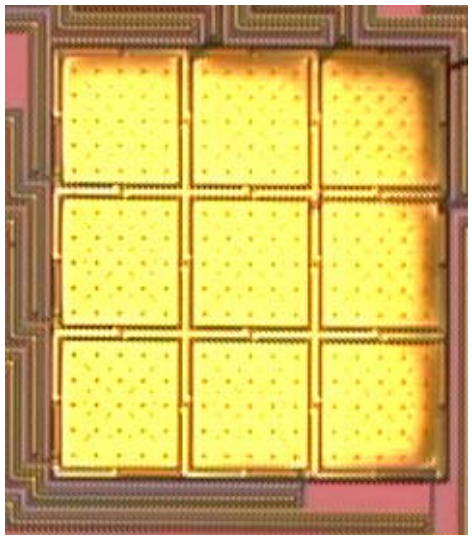
Dynamical
response

MDM prototype

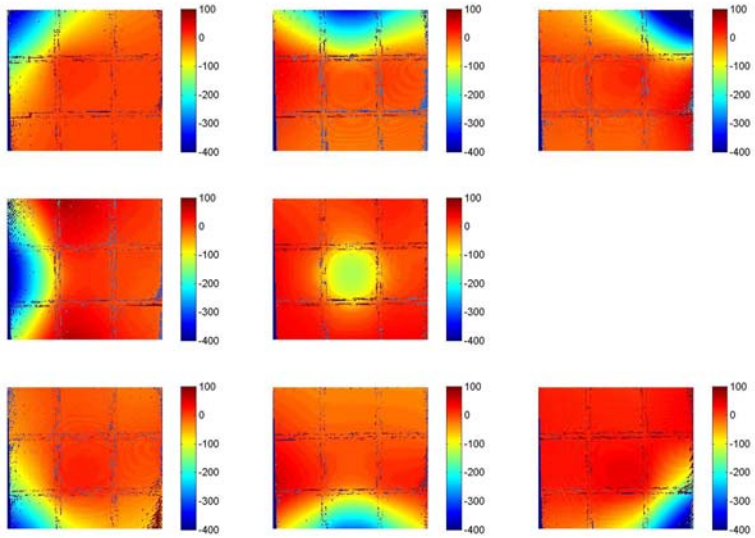
- First prototype of an MDM designed by LAM-LAAS, realized in the Memscap foundry (US)

  Material : Poly-Silicon

600 µm



Mirror with 9 actuators

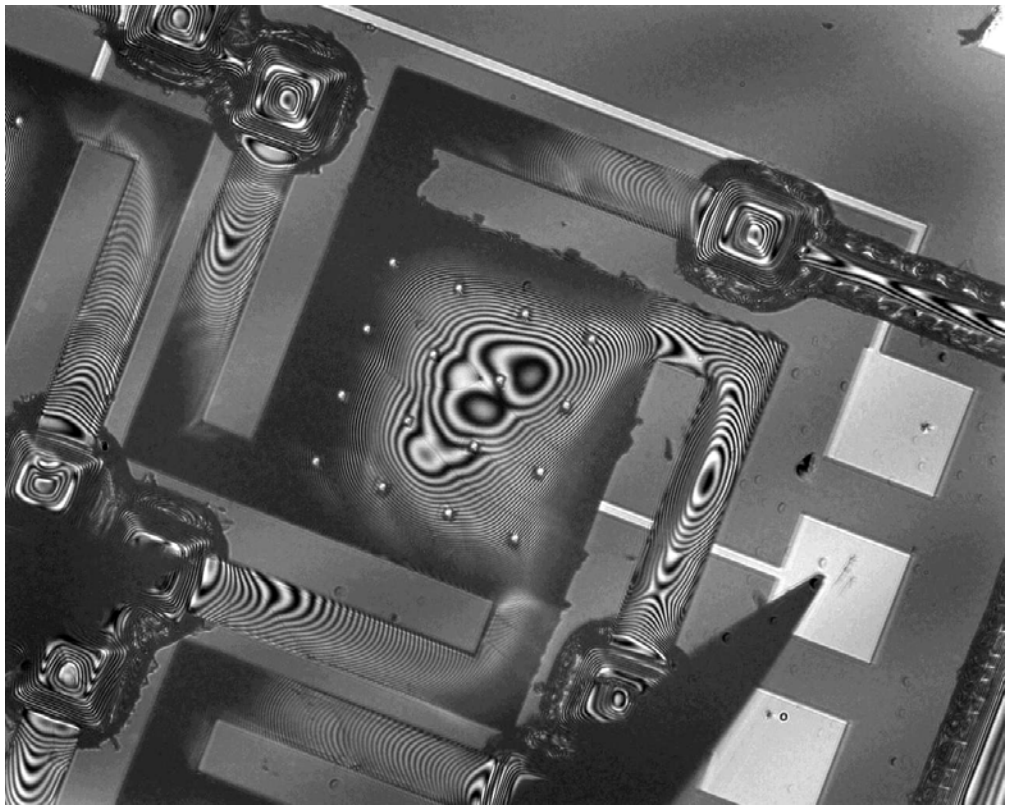


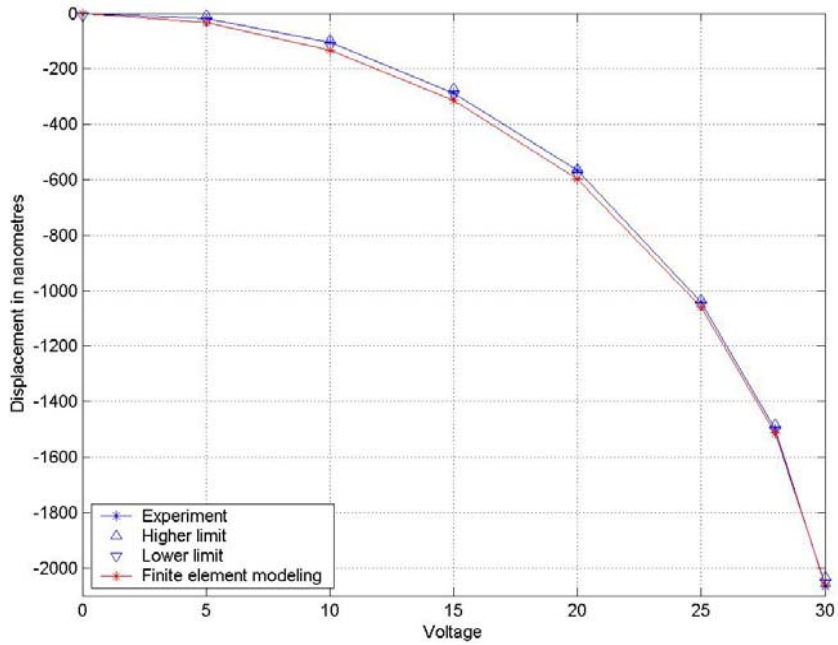
Influence function at 25V

For a larger stroke with a low driving voltage: change material

Polymer actuators

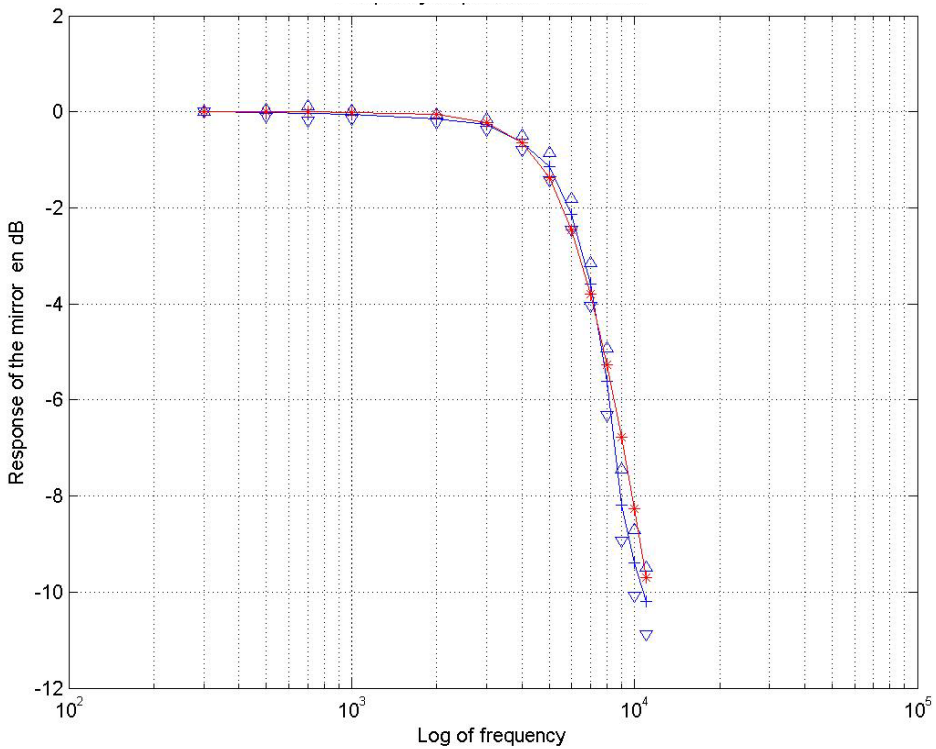
- First polymer actuators realized
- Piston stroke: **2µm at 30V**

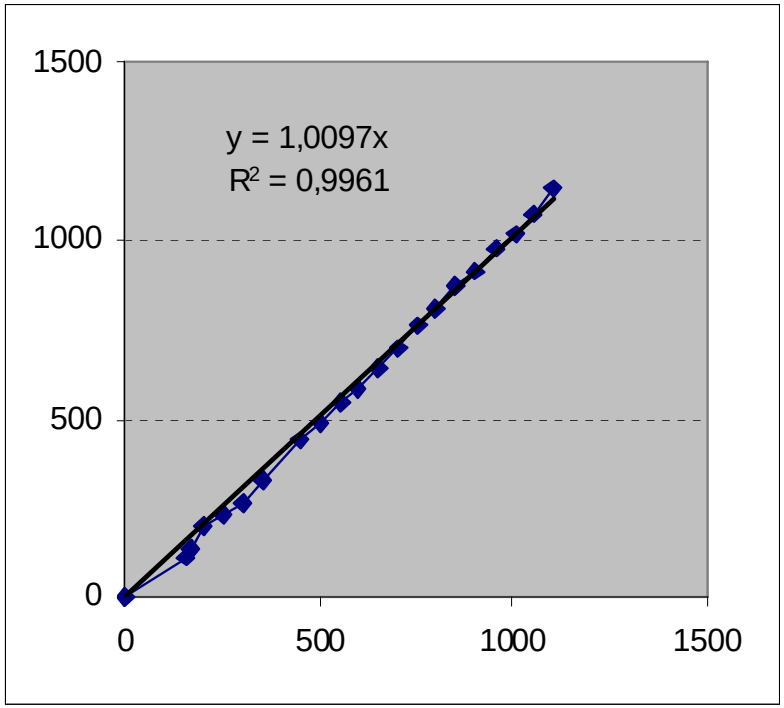




Polymer actuators

- Dynamical response: resonance frequency at 6.5 kHz
- Linearized actuation with a 14 bits dedicated electronics

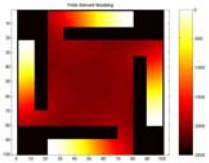




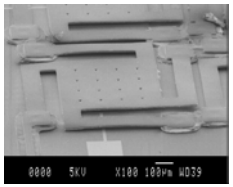
See also Liotard et al., LAM-LAAS paper at SPIE MOEMS conf. 2006, San Jose

MOEMS deformable mirror

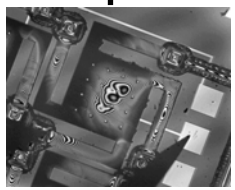
Actuator



Design

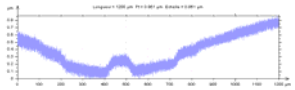


Realization

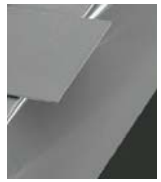


Characterization

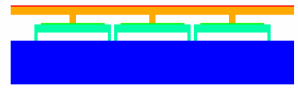
Mirror



Characterization

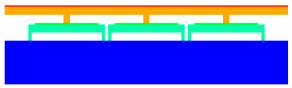


Realization



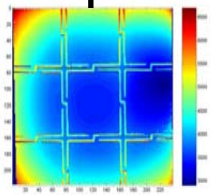
Design

Actuators + Mirror



Design

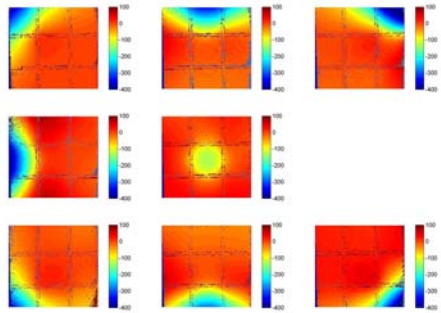
Realization



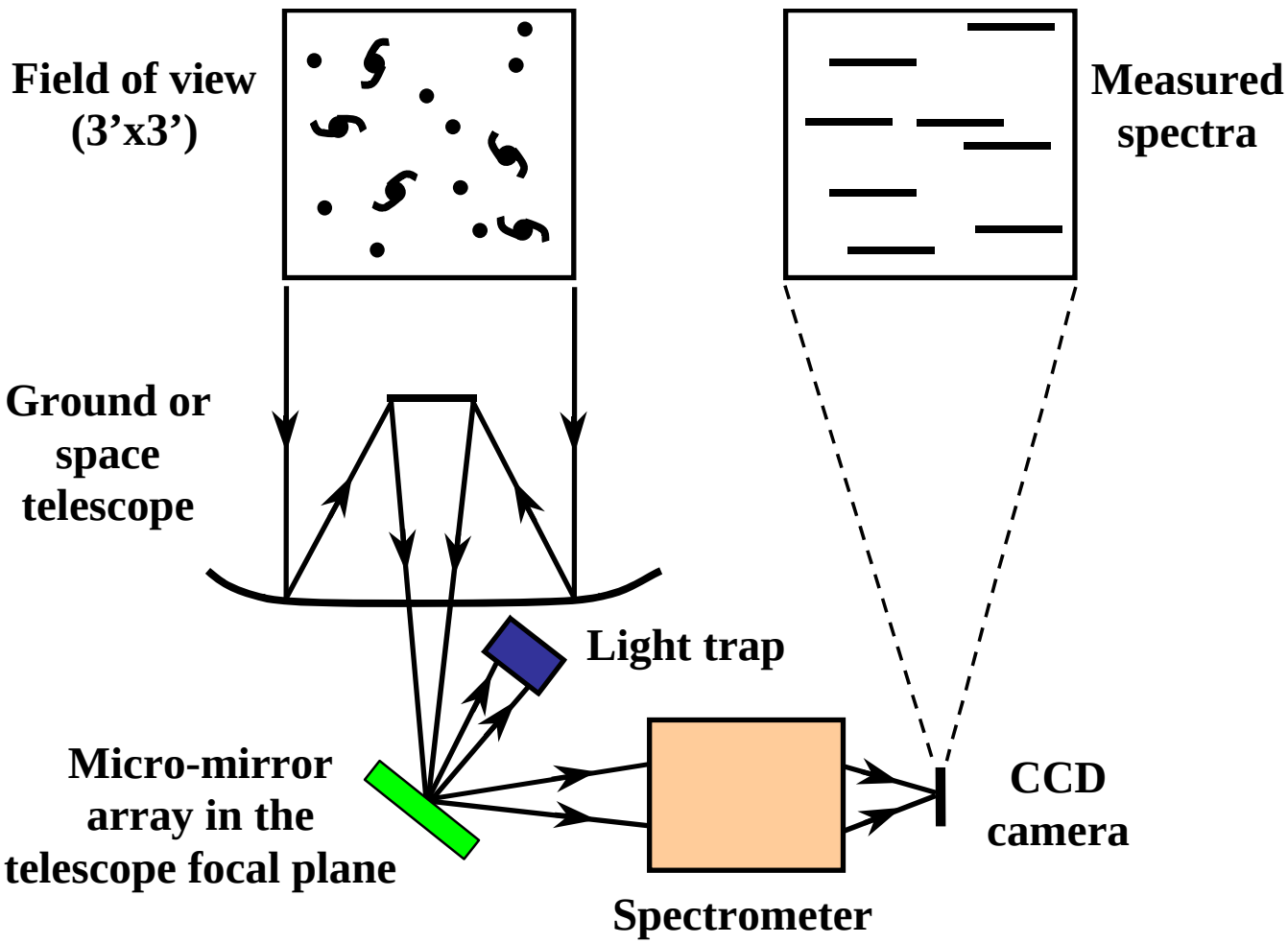
Characterization

MDM prototype

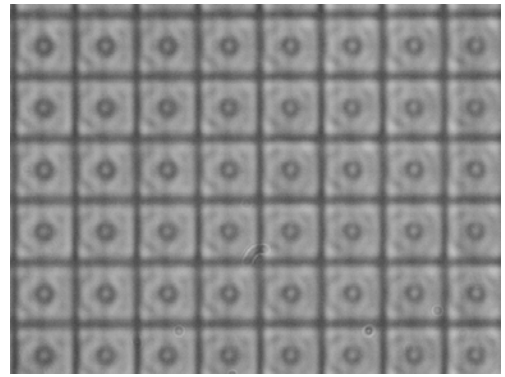
+



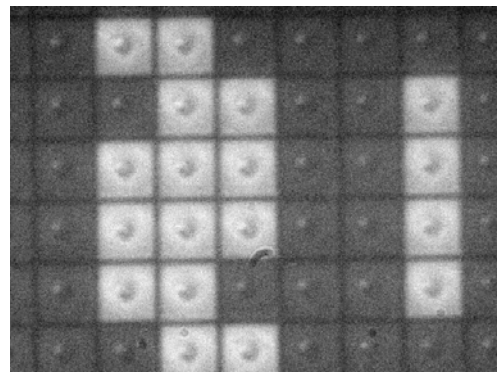
Multi-Object Spectrograph



Park position

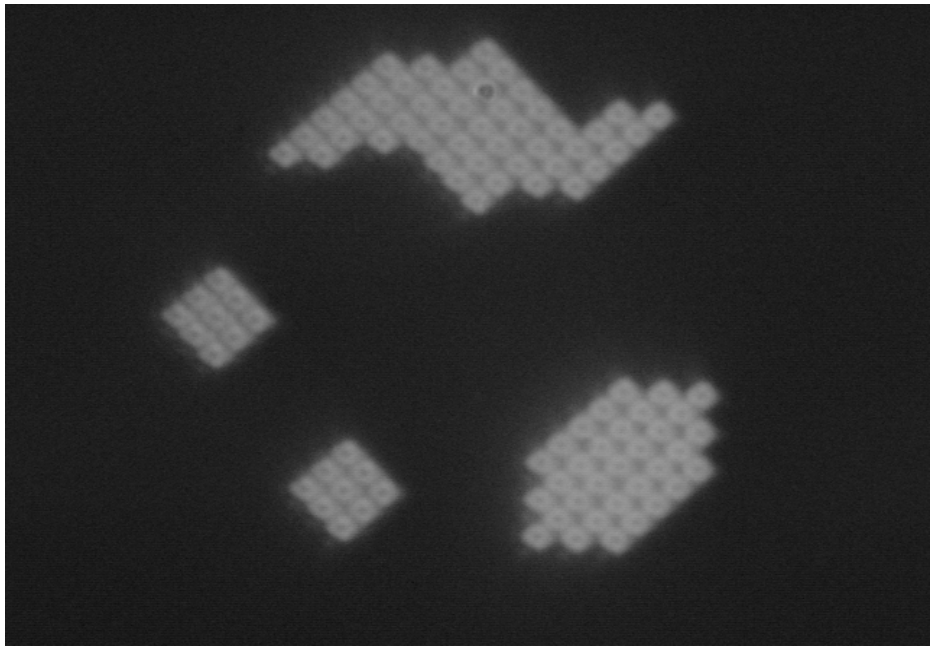


20 µm

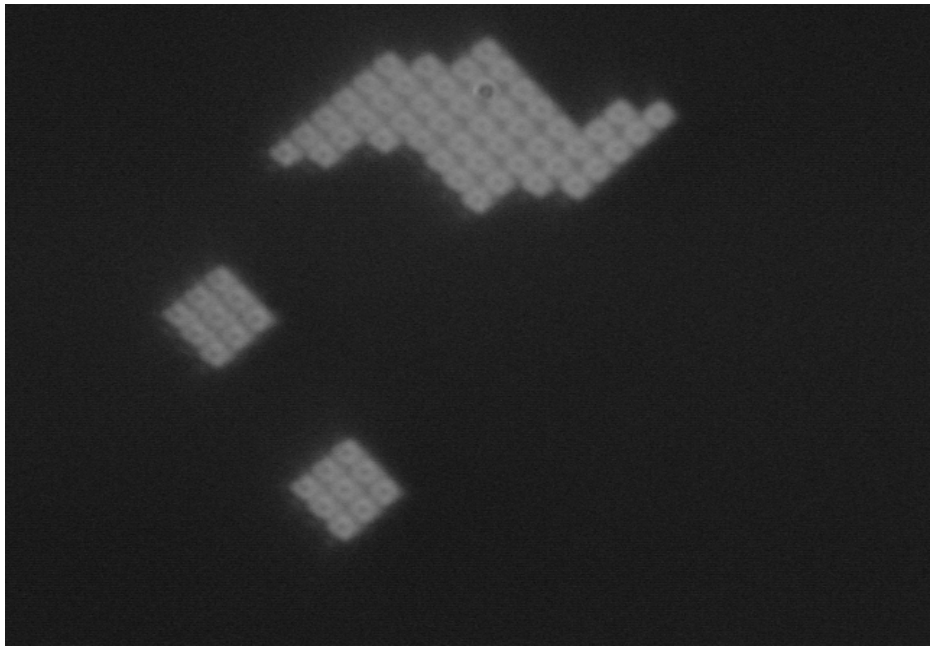


In action

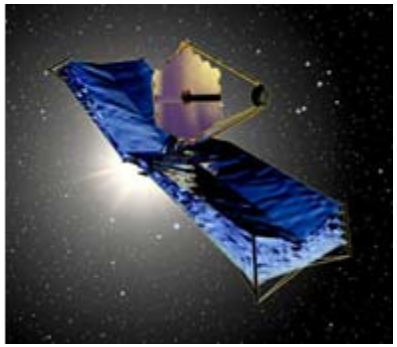
Object selection



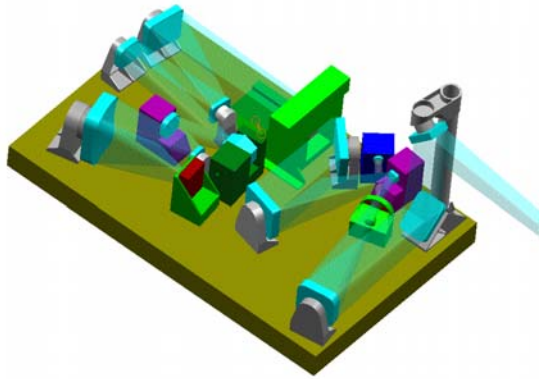
Object selection



JWST's NIRSpec



- Visible + NIR Camera
- **Multi-Object NIR Spectrograph**
  - **0.6 - 5 µm**
  - **FOV : 3' x 3' (sampling 0,1")**
  - **R = 100 et R = 1000**
- MIR Camera / Spectrograph



ESA pre-phase A, phase A and phase B1 studies

Instrument simulation

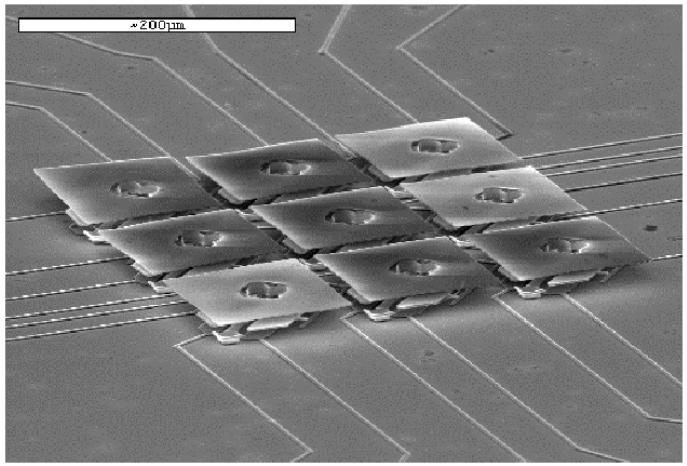
- **Tool box**
  - **Photometry**
  - **Instrument design impact**
  - **Encircled energy**

MOEMS slit masks

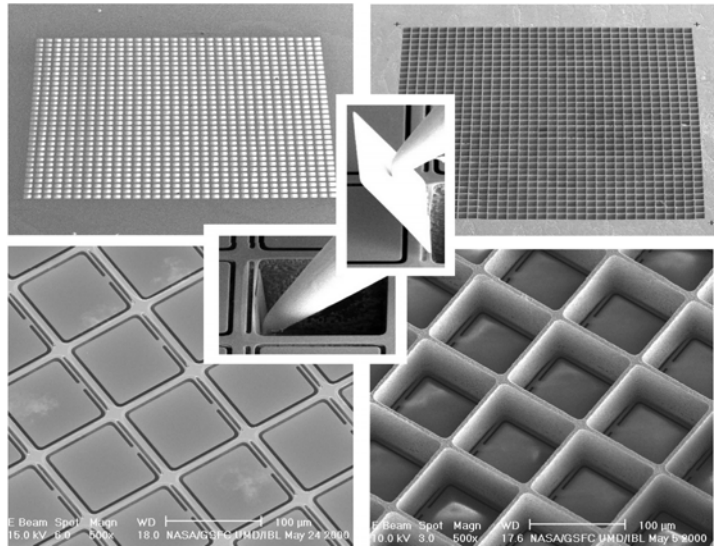
- **Characterization**
  - **Surface quality**
  - **Contrast**
  - **Operability**

MOEMS developments

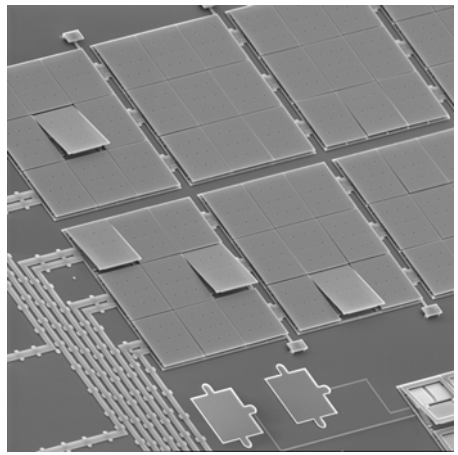
- NASA-GSFC Micro-mirrors



- NASA-GSFC Micro-shutters



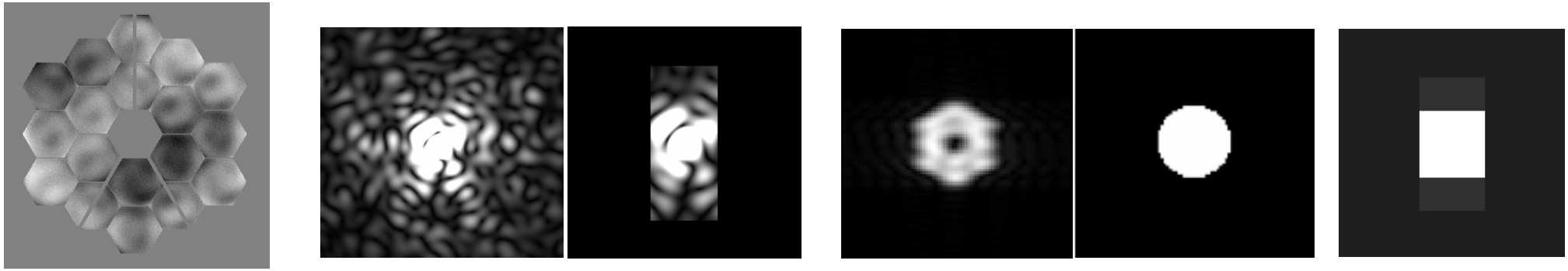
- Sandia Labs Micro-mirrors



Programmable slit modeling

- Fourier model

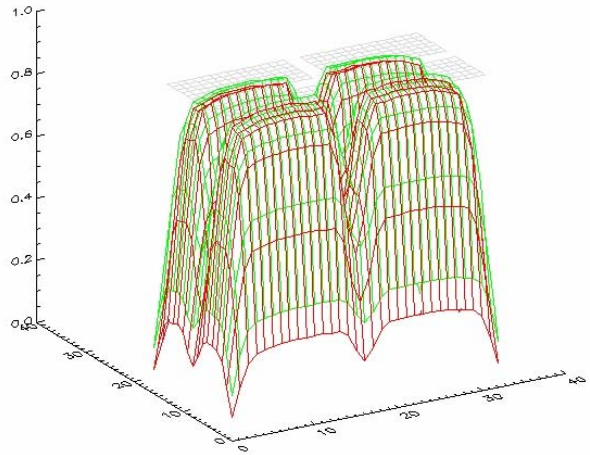
Telescope (JWST) Field Pupil Detector

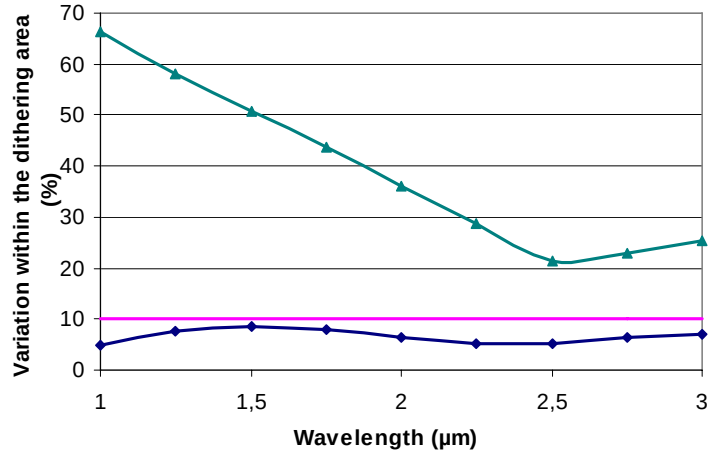


- Spectral photometric variation modeling

Geometrical effect

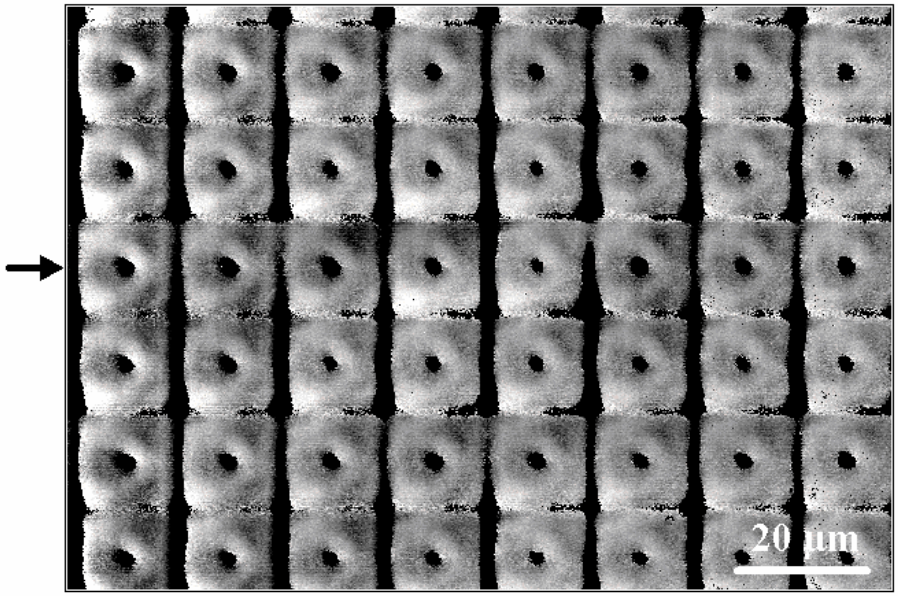
Diffraction effect

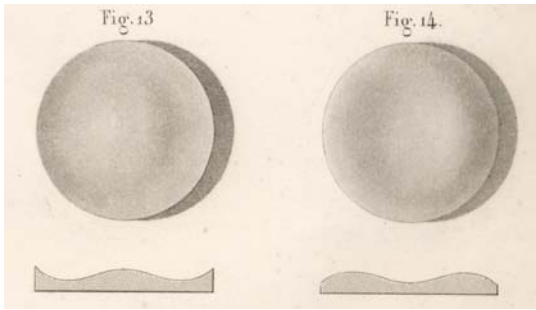


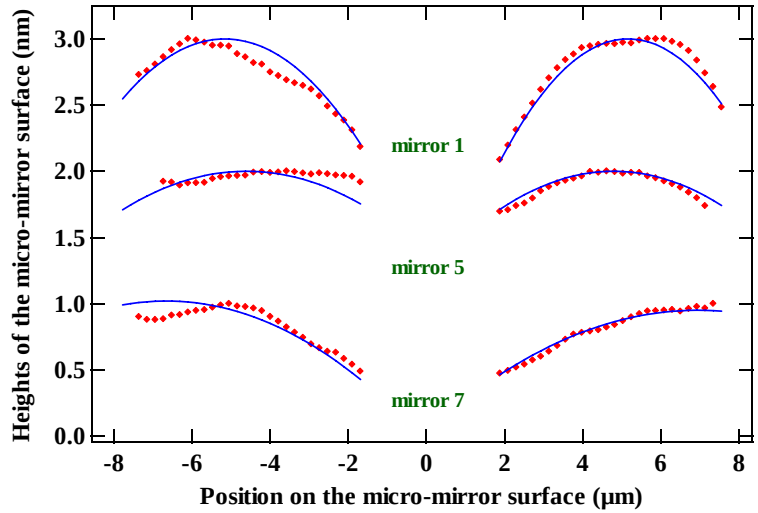


Surface measurement

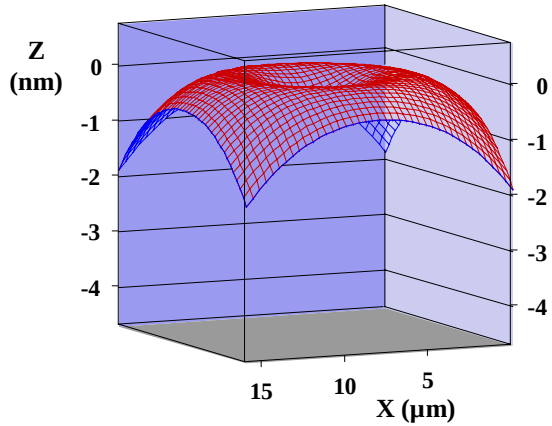
- Micro knife-edge test







"palm-tree" shape



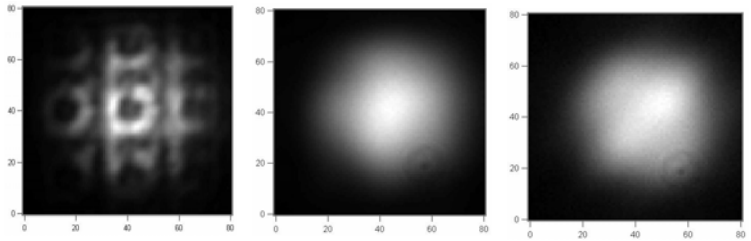
Characterization bench

- Characterization bench

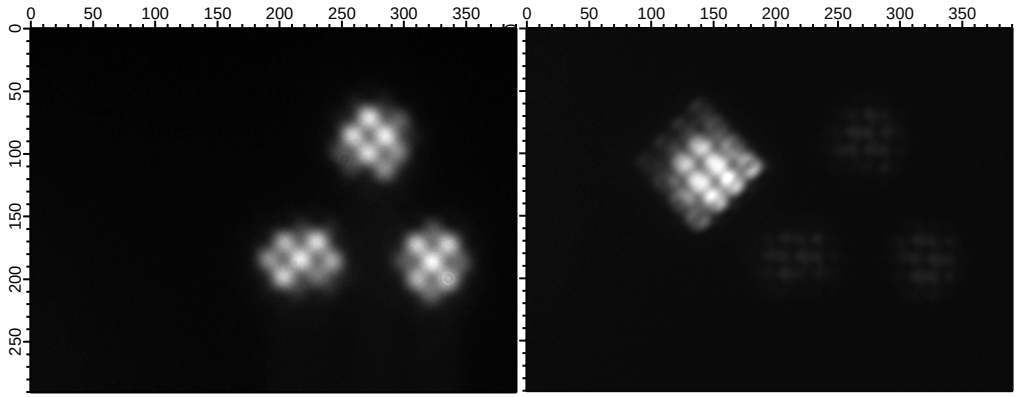
Vacuum and cryo test facility
(down to 30K) under development

- Images F_{IN}=F/20

F/2 F/17 ON F/17 OFF

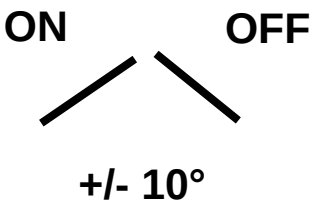


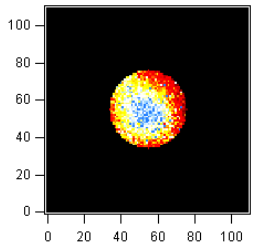
- Field simulator



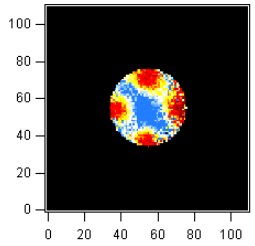
Contrast measurements

- Micro-mirrors

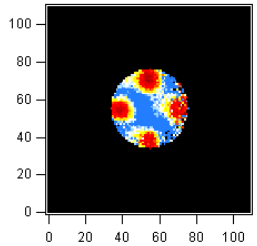




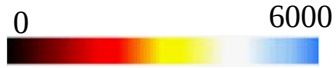
F/34



F/34 +50%



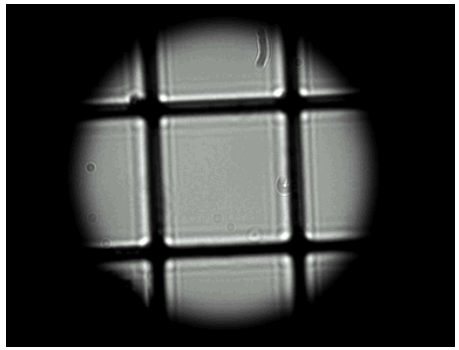
F/34 +100%

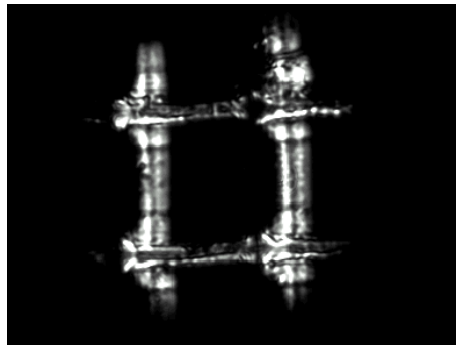


Effective Contrast > 3000

- Micro-shutters

OPEN



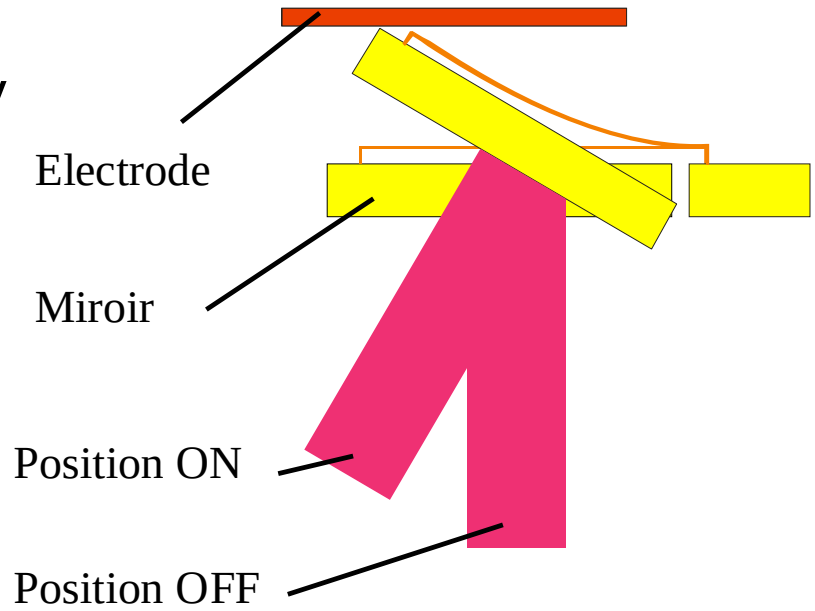


CLOSED

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

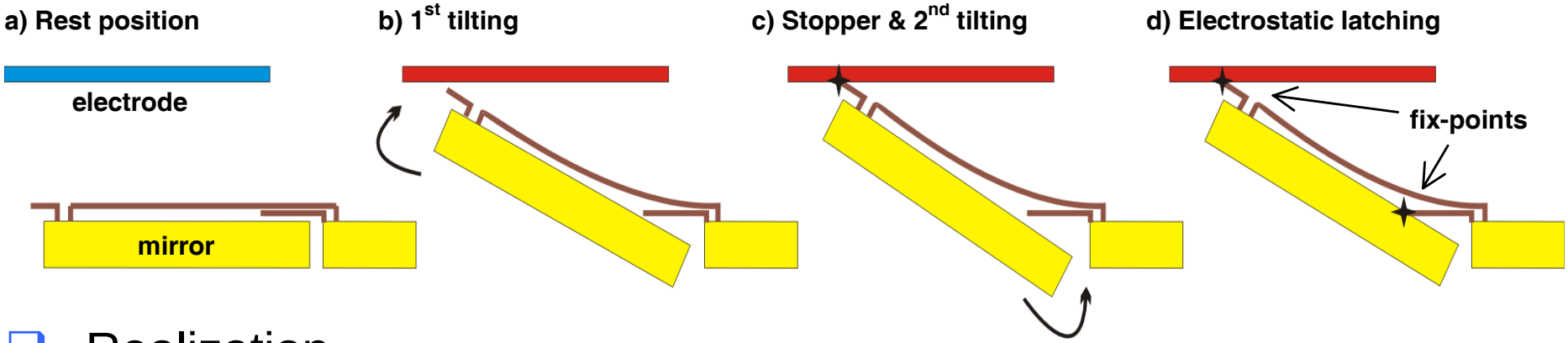
Programmable slit developments

- 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

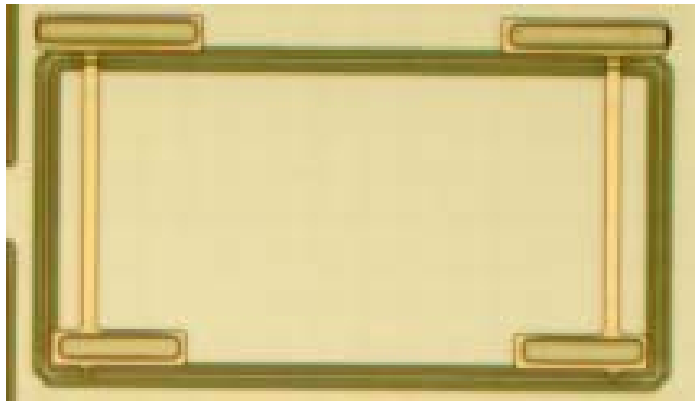


Programmable slit developments

Principle



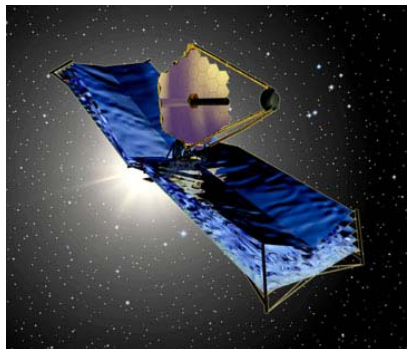
Realization



See also Waldis et al., IMT-LAM paper at SPIE MOEMS conf. 2006, San Jose

Projects

- Programmable slits
  - JRA Smart Focal Planes 2004-2007
  - JWST (NGST) 2011



- Micro-deformable mirrors
  - JRA Adaptive Optics 2004-2007
  - VLT 2nd generation (FALCON) 2004-
  - OWL 2015-2020

OPTICON

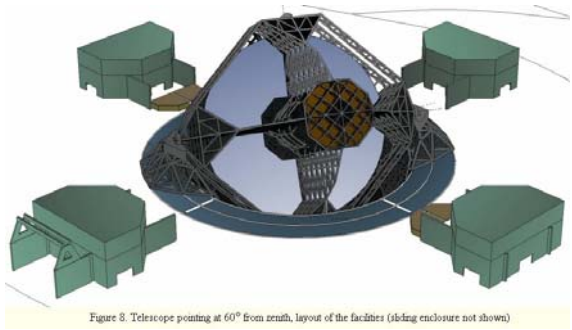
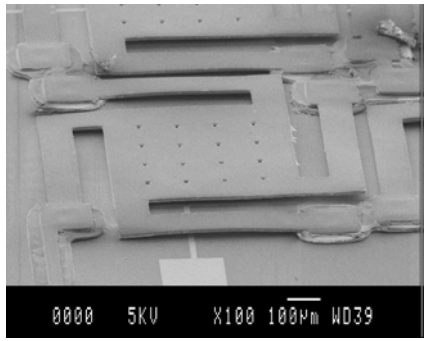
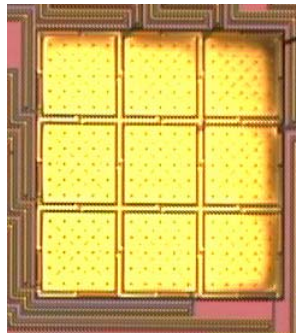


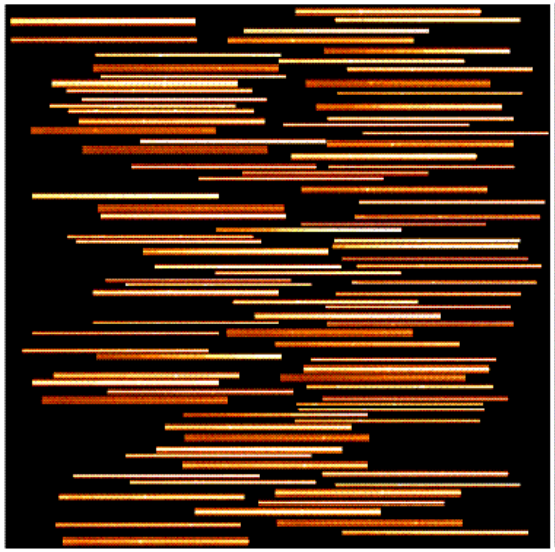
Figure 8. Telescope pointing at 60° from zenith, layout of the facilities (sliding enclosure not shown)

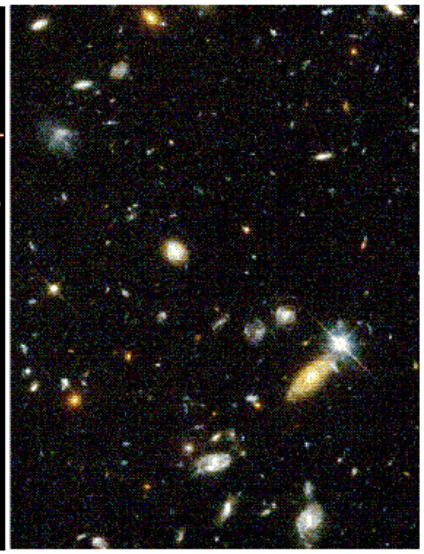
- ESA study on MOEMS Delta space qualification methodology
  - Study driven by Alcatel Alenia Space March 2005 – end 2006
  - LAM expertise for Earth and Space Observation

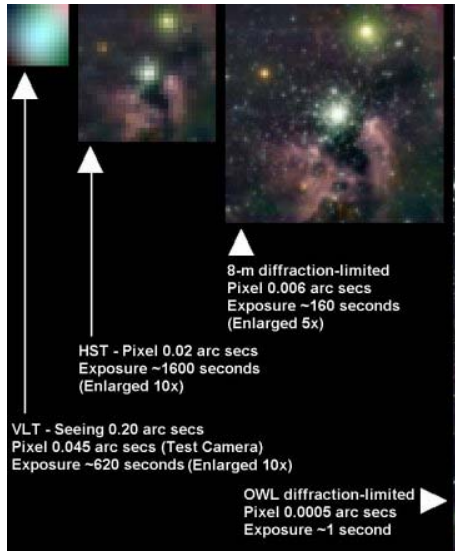
MOEMS for astronomy

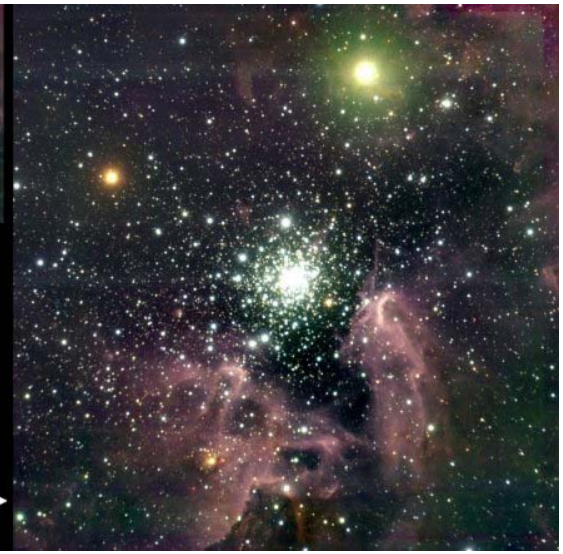












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