Shutter Array

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History and actual status

The Micro Shutter Array (MSA) was developed for the successor of Hubble : James Webb Space Telescope (JWST)

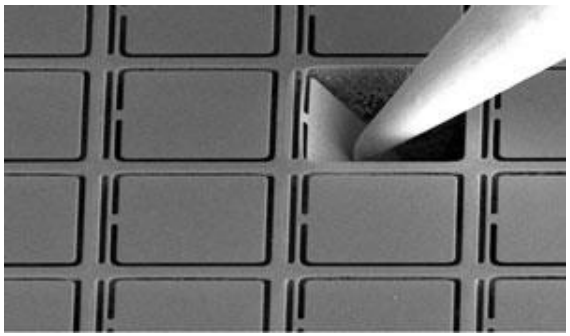
1989
First studies for a new telescope

2000
First specifications

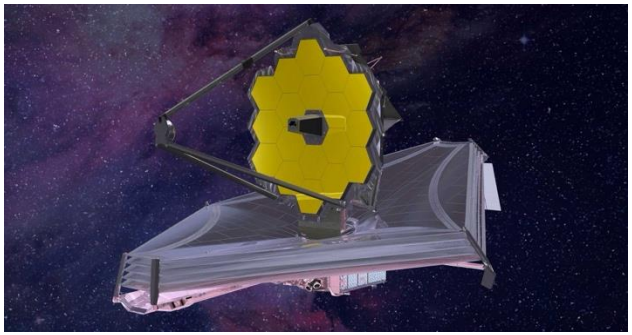
2004
Start of mirror and instrument production

2011
Mirrors completed

2021
Launch !
ESA & Ariane 5



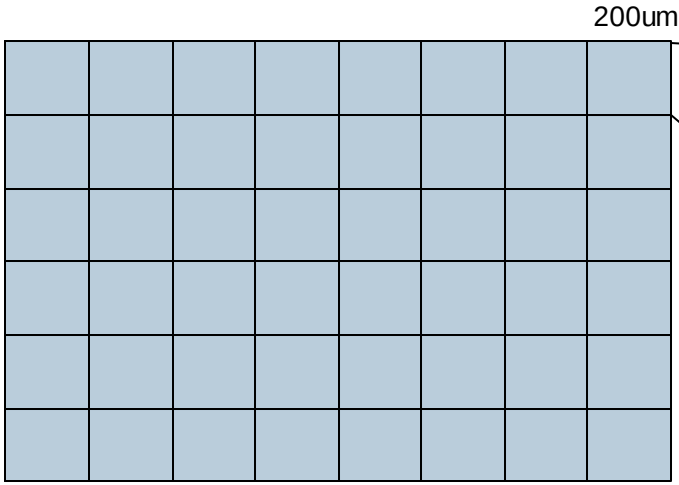
From NASA [9]

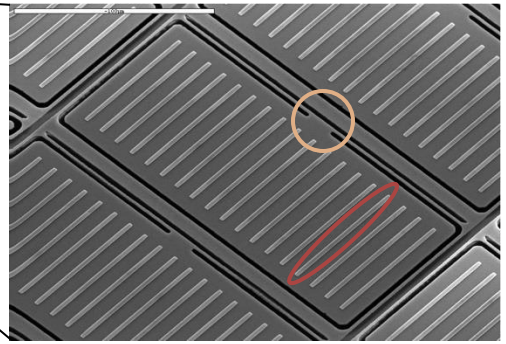


From NASA [9]

MEMS operation principle

The only user is, for now, the JWST



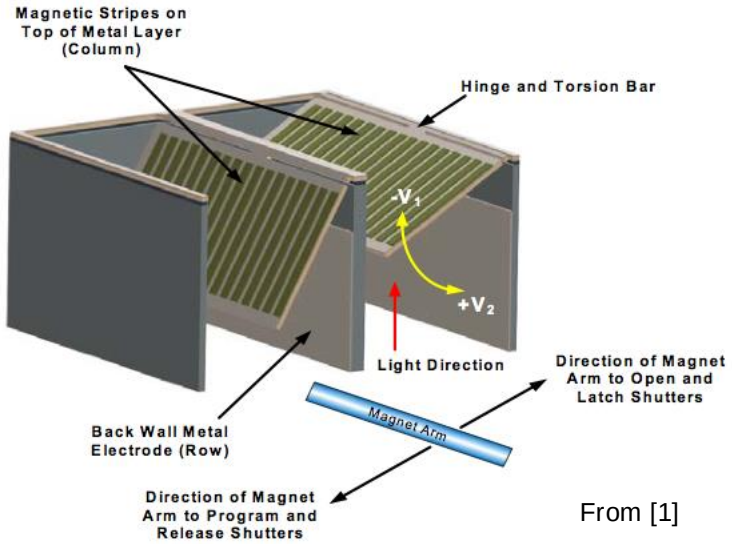


From NASA [9]

Torsional spring
Magnetic thin film

A shield covers the space between the shutter and the frame (not shown here).

- A magnet sweeps the rows, inducing a small movement in the shutters
- A 40V bias is used to fully open the shutters
- The desired shutters are kept at 20V while the bias is progressively reduced for the others
- To gently release the shutters to their resting position, the magnet sweeps back, synchronized with the voltage

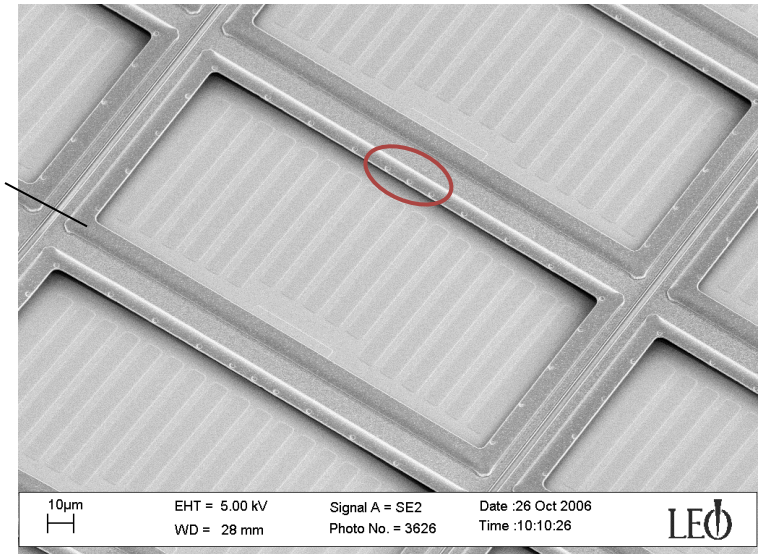


From [1]

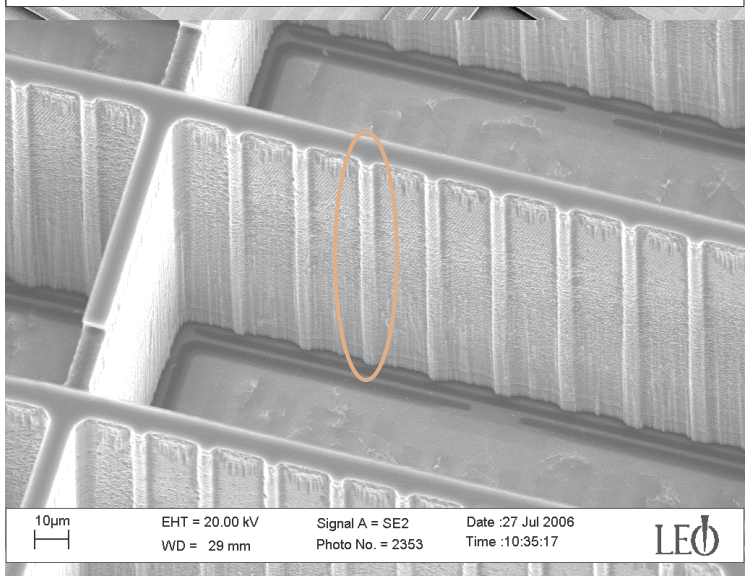
Approximately 250 000 shutters

MEMS implementation

- The shutters (silicon nitride) are patterned using bulk micromachining
  → to block the light
- The magnetic bands (cobalt-iron) are deposited and patterned with thin-film deposition
  → to enhance the reaction to the magnet
- Bumps and ribs are fabricated with Deep Reactive Ion Etching (DRIE)
  → to avoid sticktion



From [3]



From [3]

Characteristics

In space, a lot of constraints must be satisfied

Requirements

- All the shutters can be individually activated
- 100 objects can be observed at the same time
- It must cover a 3,4’ x 3,4’ field of view
- Contrast > 2000
- It must operate for 9.4 x 10^4 cycles with minimal failures
- 35K to 300K temperature range
- + volume, mass and radiation constraints

Performances

- 14% of the shutters are malfunctioning today
- 50 - 200 objects can be observed at the same time
- Wavelength 0.7— 5.3 um
- Contrast > 10000
- Spectral resolution : 100 / 1000 / 2700 depending on the mode
- A full open/close cycle takes ~ 90s

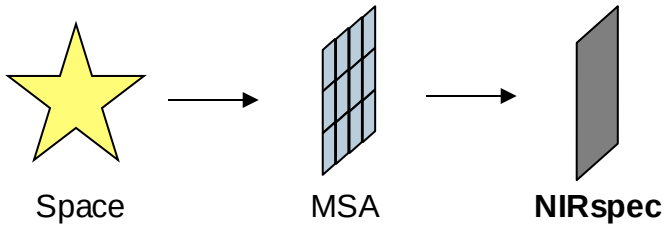
Packaging and systems integration

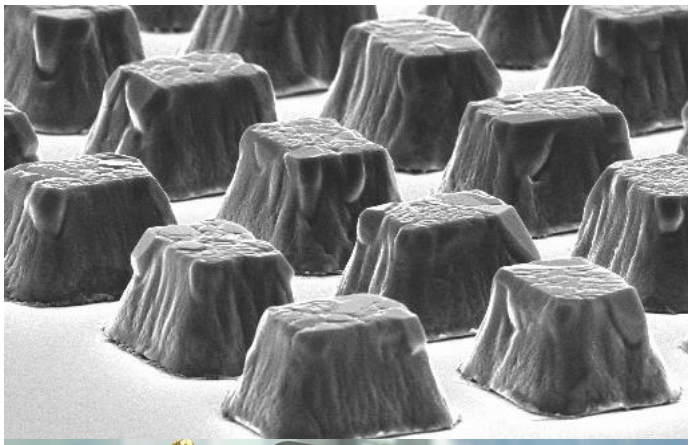
As mechanical support and electrical paths, *indium bumps* are patterned on the substrate with a lift-off process. (180 000 bumps for each MSA)

“The bonding between a MSA and a substrate is conducted using a novel single-sided indium flip-chip bonding technology.” [3]

To integrate the MSA, five ASIC multiplexer/address chips, twenty capacitors, two temperature sensors, several resistors and the interconnexions are required.

Once through the MSA, the light goes towards the NIRspec (Near Infrared spectrometer) for analysis.





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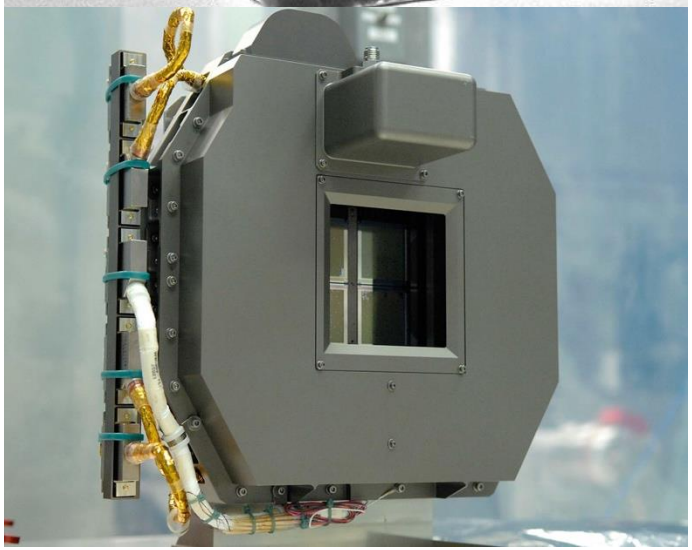

From NASA [9]

Products and current applications

This technology is still in the research stage

MSA development is closely linked to the field of astronomy and all the actual users are telescopes. They are currently developed by NASA and ESA at Goddard Space Flight Center.

Future missions like Large UltraViolet Optical InfraRed surveyor (LUVOIR), Habitable Exoplanet surveyor(HabEx) and the Cosmic Evolution Through UV Spectroscopy (CETUS) mission are planning on using such shutters.

Today, NGSMA (Next Generation SMA) is under research at NASA, trying to eliminate the magnetic actuation aspect to make the array more simple, scalable and robust.

References

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