Microshutter arrays for JWST - programmable field masks.

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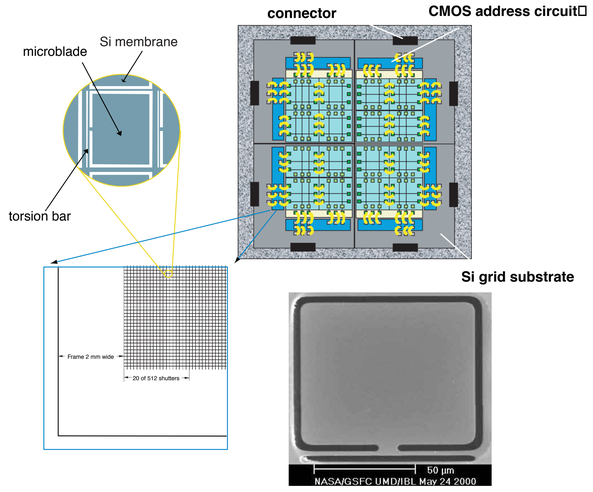
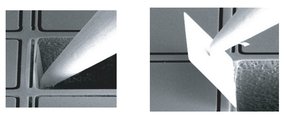
http://bram.gsfc.nasa.gov/ms_webpage/ms_main.html

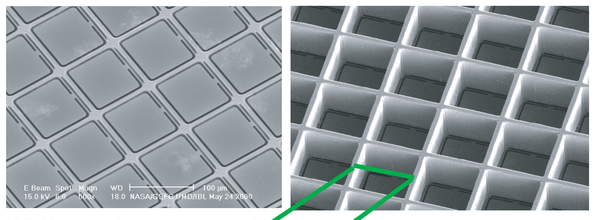
Microshutter array concept



Single shutter scanning electron microscope image and layout of a 2048 by 2048 microshutter array. 512 by 512 (~ 100x100 micron shutter pitch) shutter arrays are arranged in a mosaic. Four 512x512 element shutter arrays and their addressing electronics are assembled on a common substrate to form a quadrant assembly. Four quadrants are integrated into the magnet transport mechanism to form the complete mosaic of shutter arrays giving a 2048x2048 array of shutters. Expanded views show the corner of the mosaic and a single microshutter outline. The shutter array layout is currently being changed to accommodate 100x200 micron shutter pitch requirement by JWST.

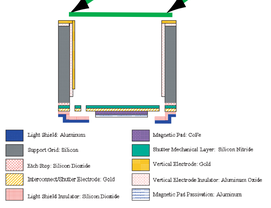
SEM images of photolithographically fabricated shutters flipped out of the plane by a micromanipulator.



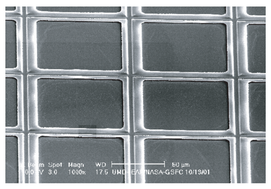


SEM images of the photolithographically produced 128x128 microshutter array. Image on the left side shows the front surface of the shutter array, the image on the right is the backside of the shutter array with the support structure.

Cross section of the unit cell

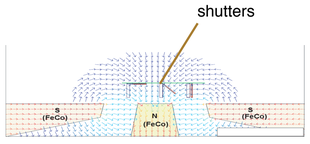


LIghtshields



Principle of magnetic actuation

- magnetic coating of the shutters has to be magnetized.
- shutters have to be rotated out of the plane of the array.
- the shutters have to be moved to proximity of the vertical walls.
- the overall force on the array frame must be small.

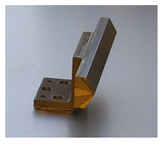


We have designed a special tri-pole magnet. It is swept along the array. The interaction of the magnetic field with the shutter coating produces torque that rotates the shutters out of the plane. When the shutters reach the proximity of the wall, a voltage applied between the shutter and the frame wall attracts it and holds the shutter in vertical position.

Magnets:

we have designed and built a tri-pole electromagnet and permanent magnet for microshutter actuation:

electromagnet **permanent magnet**

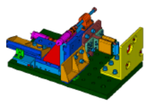


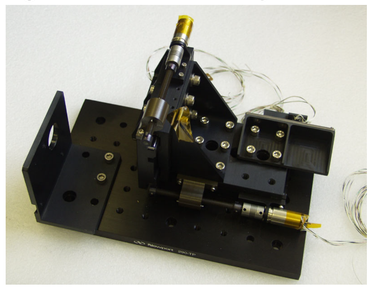
The Near Infrared Spectrometer (NIRSpec) is a key instrument for carrying out the primary science of the James Webb Space Telescope (JWST). It is critical for obtaining spectra of faint distant galaxies to calibrate photometric redshifts, which will be used to find "first light", the first generation of galaxies to form after the Big Bang. This instrument is being developed by the European Space Agency as part of their contribution to JWST. While this spectrometer will be of great scientific value for many projected investigations, its design is largely driven by its ability to carry out this early universe research. The most critical design requirements are that the instrument must have the highest possible instantaneous sensitivity, and must measure as many candidate objects simultaneously as possible. In order to meet these requirements simultaneously, the NIRSpec team has chosen to build a multi-object spectrograph with a programmable slit mask.

Our team at the NASA Goddard Space Flight Center (GSFC) is developing two-dimensional microshutter arrays to be used as programmable aperture masks for the NIRSpec. The system consists of Silicon Nitride shutters on a low filling factor Si support frame (see figures at left). The shutters, coated with a CoFe film, are opened by scanning a magnet across the array. They are latched electrostatically, and released under address control to produce the desired slit pattern.

In this poster, we describe the shutter operation, design, and fabrication. The fabrication process is being refined, and we expect it to be complete by Apr. 2003. We plan to demonstrate a fully qualified 128 x 64 array by the end of 2003. The flight version of the microshutter array must be delivered to ESA in early 2006.

Functional cryogenic testing of the shutter array





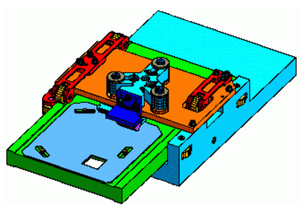
A new 2D magnet translation stage with position sensors has been built.

It will accommodate both the electromagnet and permanent magnet. The electromagnet coil has been rewound with superconducting wire. With the new superconducting coil microshutter lifetest will be possible at cryogenic temperatures.

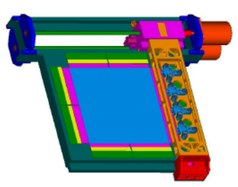
Permanent magnet was built according to our design. Actuation tests of the shutter demonstrated that the torque produced by the magnet is close to the expected from the model.

512x256 array translation stage

To perform functional, optical and life tests on 128x128 arrays and ultimately on 512x256 arrays we have designed a shutter translation stage. For packaging reasons the magnet is fixed and the shutter array is movable. This stage will be used for laboratory testing of the shutters and for the Rapid Infrared Visible Multi object Spectrograph (RIVMOS). It accommodates a board with the microshutter array and SuperTex HV583 high voltage shift registers for a full 2D addressing of the array.



Flight transport mechanism development progress

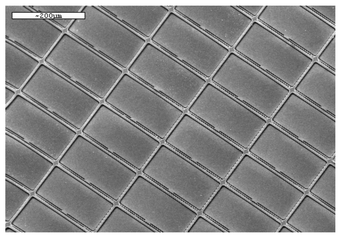


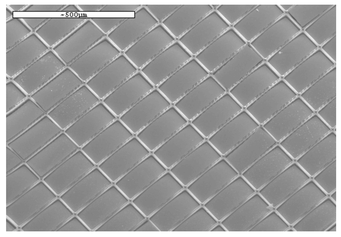
- **Can accommodate mosaic of a 2048 x 1024 microshutter arrays with 100 x 200 µm rectangular shutter panels**
- **Electromechanical interfaces being worked with European teams**
- **Negotiations trading power dissipation for speed of magnet arm motion are under way**
- **Current design includes redundancy in lead screw actuator**

Fabrication of 128x64 arrays with the light shield - next milestone

Our next step is to fabricate 128x64 shutter arrays with 100x200 microns. Until now all the arrays fabricated had 100x100 microns pitch. To make arrays compliant with the new JWST requirements a series of 32x16 shutter arrays with 100x200 microns pitch have been made to test:

- **torsion bar width and strength:** the actuation of the shutters by the magnet did not cause any in-plane movement or torsion bar deformation, indicating the torsion bars are stiff enough.
- **bowing of shutters introduced by Co-Fe only:** slight bowing about 8 microns. More tests on CoFe and Al-(Co-Fe)-Al layers will be carried out to eliminate bowing
- **Co-Fe adhesion to SiN:** the arrays showed a good adhesion between Co-Fe and SiN.

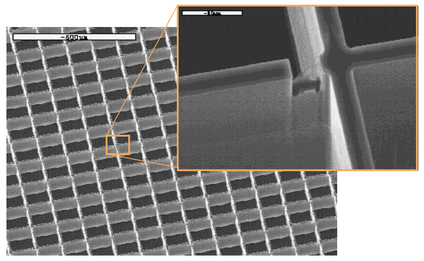


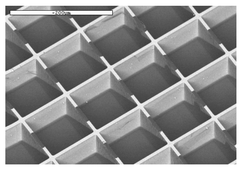


First samples of the shutter array with 100x200 microns pitch (left) with 200 nm thick CoFe layer (right). CoFe layer caused slight bowing. Further tests with a different deposition process will be done to eliminate the bowing.

Back electrodes: double DRIE approach

New tests for back-electrode processing – double DRIE approach: both shadow-mask back electrodes and the back-up plan, saw-diced back electrodes, require high flatness of shutter array. In order to processing back electrodes in wafer level instead of chip level, we designed and are testing a new processing procedure called Double DRIE. It utilizes a two-step patterning, oxide patterning and silicon patterning, before a two-step DRIE etching. From the double DRIE, back-etched silicon frame is formed with grooves similar to saw-dicing lines (technique we used before) for back-electrode delineation during angle metal deposition. The tests on Si wafers have been done and looked very promising.





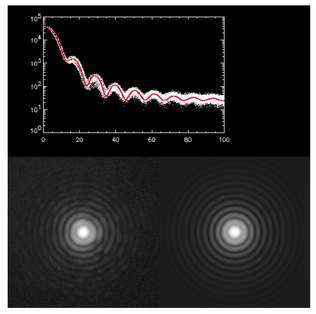
Samples of the back electrodes produced with a shadow mask. Gold electrodes are light colored. Dark spaces between them are gaps on the Si frame left uncoated. These areas were protected by the shadow mask during the deposition. The deposition is done at 45 degrees to produce a coating on the wall only.

The advantages of the new approach are:

- Ease of fabrication in wafer level
- Elimination of saw dicing debris
- Elimination of mechanical damage from saw dicing

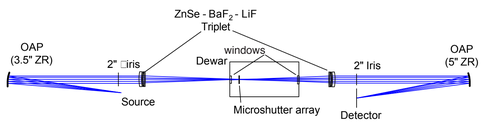
Optical testing and analysis

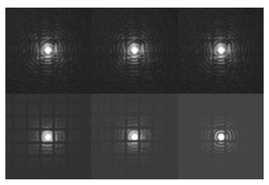
We continue our study of the effects of the shutter structure on the optical performance of the spectrometer. Issues of the diffraction, vignetting and sampling are considered. The efforts are directed toward finding the optimal slit configuration and observing strategy that would maximize the instrument performance over its whole spectral range..



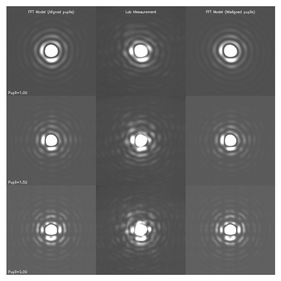
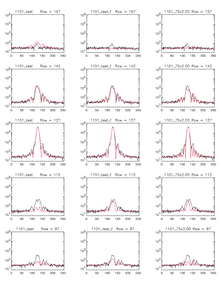
The figure shows a point spread function of the optical system without the shutter array in the beam (image on the left), and model defocused model beam (on the right). The plot above shows both beams plotted as a function of the radial coordinate: lab data in white, FFT model in red. The best fit was calculated by minimizing χ-squared for a set of beams with different Zernike defocus coefficients. This demonstrates that the FFT model can accurately represent even aberrated optics.

Optical test setup layout





Above: images of the point source acquired with the optical test setup in the lab (upper row) and modeled using Fourier optics approach. Below: sample slices through the observed (black) and model (red) 0.75" beams (F/45). These tests will allow assesment of microshutter optical performance and provide an input to the design and fabrication of the microshutter array.



Comparison of the images acquired with the microshutter optical test setup with the Fourier optics models allowed us to develop tools for analysis of the shutter performance. The result of the Fourier optics analysis without and with different axial misalignment (col 1 and 3) allowed us to qualitatively reproduce the imaging pattern and obtain the relative coordinates of the point source with the respect to the microshutter array. Second column represents the images obtained in the lab. Different rows show different F/#: F/60, F/45 and F/30 respectively.