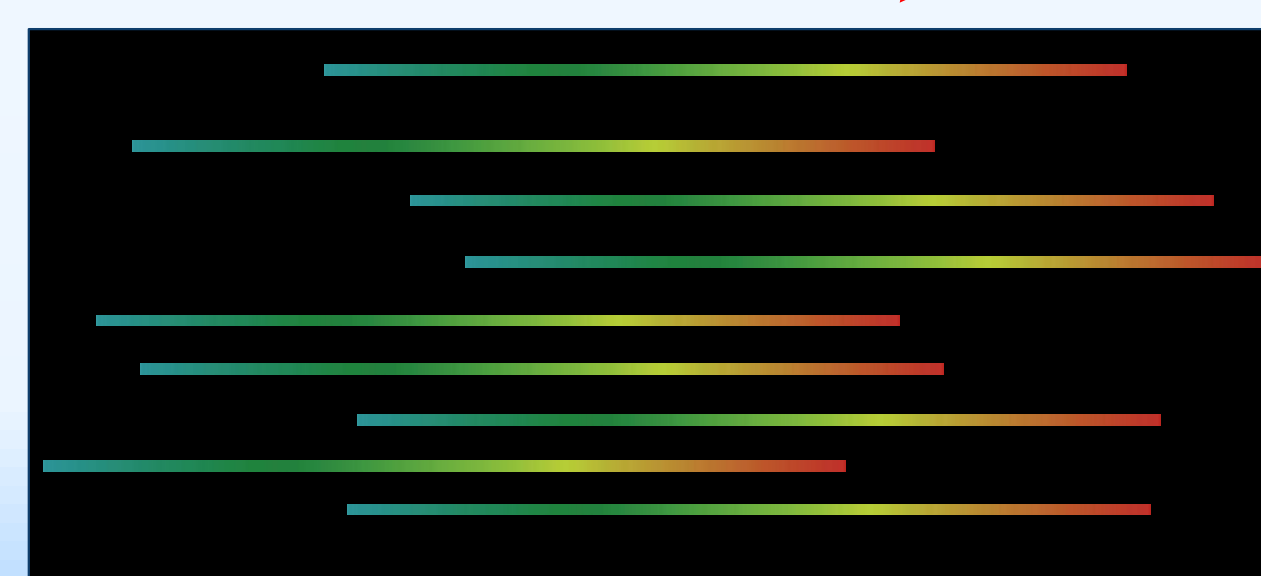
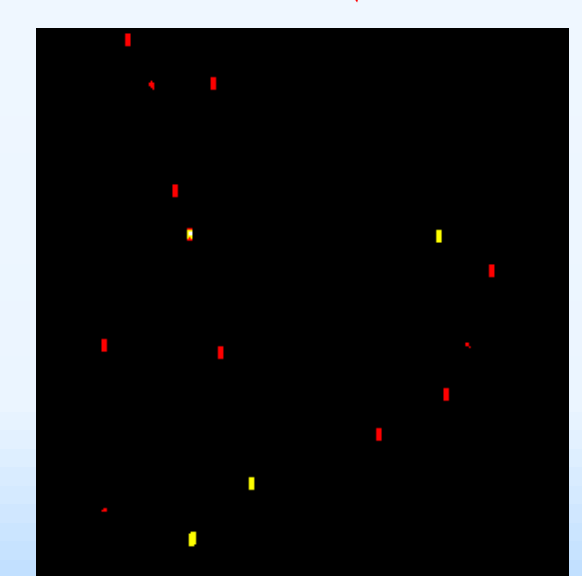
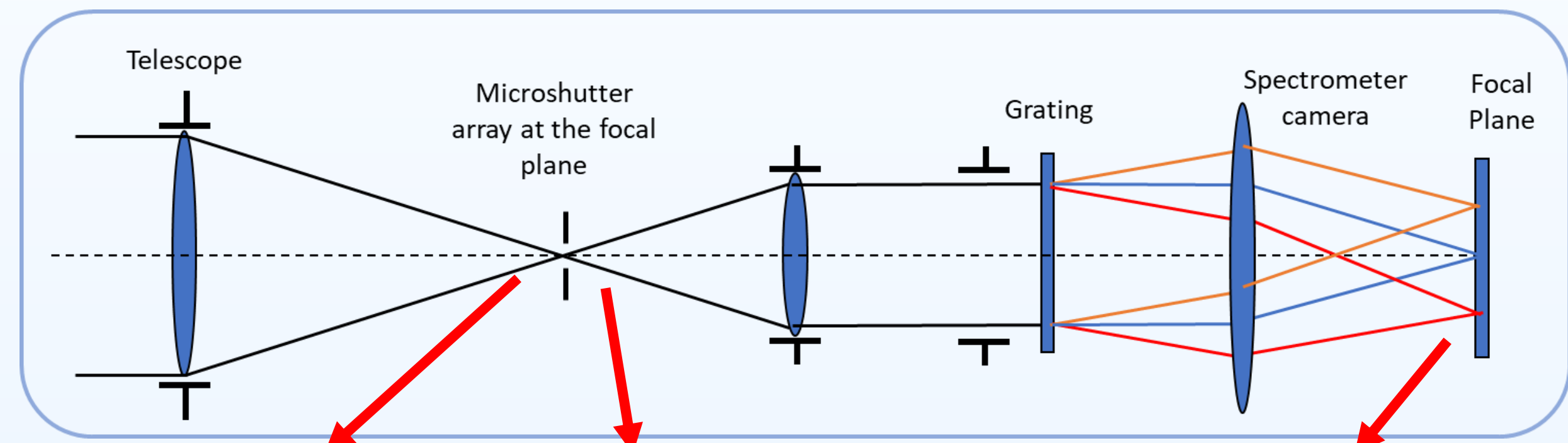


# Next-Generation MicroShutter Array for HWO UV Multi-Object Spectrograph

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## Motivation

The main target for the Next-Gen MicroShutter Arrays (NGMSA) is the *HWO Ultraviolet MOS spectrograph* which is considered a primary instrument for the mission. The science drivers for the mission are being defined at this time by the HWO Project Office and call for the ability to take multiple spectra in sparsely populated fields and across both extended objects and point-like targets, ranging in context from cosmological targets, to regions of star formation across galaxies, to individual resolved extended objects to solar system targets. A MSA functions as a programmable field slit mask to select multiple astronomical targets to obtain their spectra simultaneously, thus increasing the efficiency of spectrometer. Each micro-shutter is similar in size to a human hair and can be commanded opened or closed to match the position of sparsely distributed sources in the telescope focal plane.



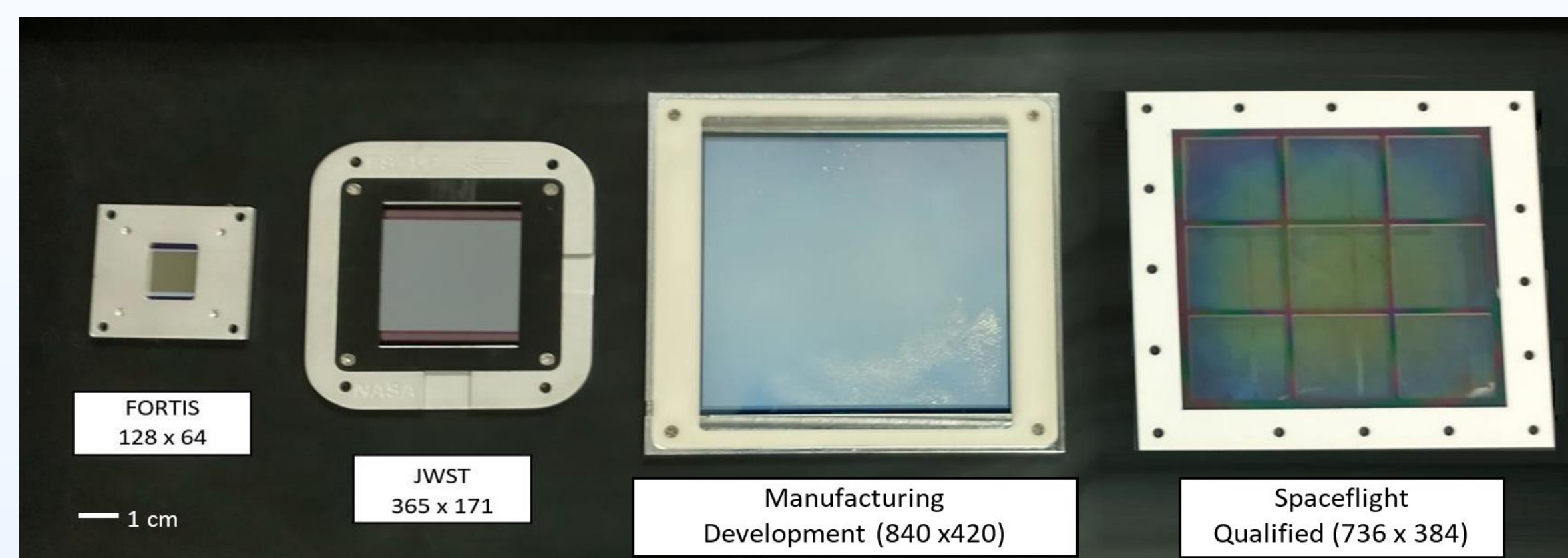
Telescope image at the focal plane

Image masked out by the microshutter array

Spectra produced by MOS

## Microshutter Arrays: JWST vs. HWO

Built upon the successful microshutter arrays on the JWST NIRSpec, the NGMSA technology transforms this paradigm by eliminating magnetic actuation dependencies, thereby creating a *scalable architecture* amenable to substantially larger formats while simultaneously *reducing mass requirements and eliminating both external mechanical complexity and life-limited macroscopic components*. This technological advancement was demonstrated through the successful operation of a 64x128 array during Far-ultraviolet Off Rowland-Circle for Imaging and Spectroscopy (FORTIS) sounding rocket flights in both 2019 and 2024.



The NGMSA is scalable to meet different application needs. Our pilot (FORTIS) and JWST formats are shown on the left. A concept and manufacturing development array is shown in the center; we also produced a ruggedized design of an array mounted on a ceramic carrier with a supporting grid that has been demonstrated through test to general environmental verification standard (GEVS) vibration levels for evolved expendable launch vehicle (EELV) launch, shown on the right.

## Why NGMSA?

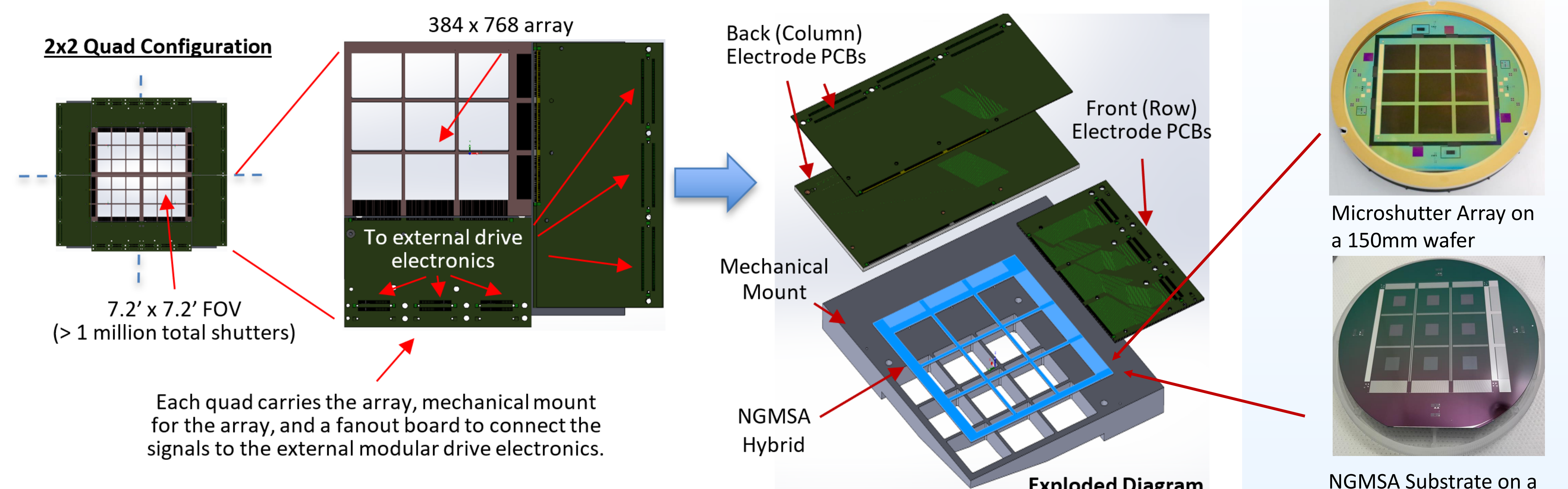
1. Random access of the individual pixels in large format single module
2. UV performance verification: high contrast optical blocking with  $10^5$  and higher in FORTIS
3. MEMS devices: fully electrically actuated with no flying magnets used in JWST MSA with >100x smaller time constant
4. Long lifetime for the operation thanks to no macro mechanisms
5. Scalable larger format arrays – suitable for two side butttable quads for increased field of view
6. Modular design of the integrated array module
7. Can be customized for applications in UV, visible and infrared spectrum
8. Improved operation reliability through anti-stiction treatment

Attribute	Spec/Attribute Value
FOV	> 7.2' x 7.2' for 2 x 2 butted arrays
Pixel Numbers	384 x 768 (294k shutters) each quad; > 1 million for 2 x 2 butted arrays
Fill Factor	50% - 60%
Contrast	> 100,000
Source Multiplexing	> 256 objects simultaneously

## References

1. Rigby, J., et al. (2023). "The Science Performance of JWST as Characterized in Commissioning." PASP, 135, 048001.
2. Kim, K., et al. (2024). "Technological Developments of NexGen Micro-Shutter Array (NGMSA) for the Future Habitable Worlds Observatory (HWO) Flagship Mission." Proc. SPIE 13100, Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation VI, 131001N.
3. Kuttyrev, A., et al. (2023). "Scalable microshutter focal plane masks for UV, visible, and infrared spectroscopy." Proc. SPIE 12678, UV, X-Ray, and Gamma-Ray Space Instrumentation for Astronomy XXIII, 126780Q.
4. Mitchell, O. H., et al. (2023). "An enhanced contrast evaluation testbed for next-generation microshutter arrays." Proc. SPIE 12678, UV, X-Ray, and Gamma-Ray Space Instrumentation for Astronomy XXIII, 126780V.

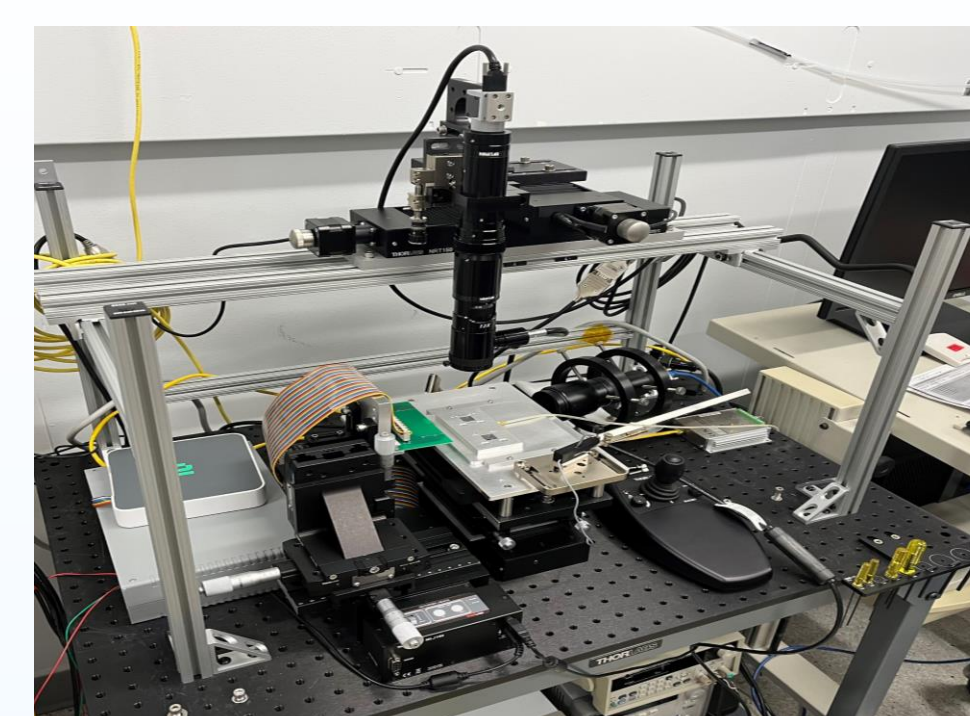
## Development of NGMSA Hardware for TRL-5 Demonstration



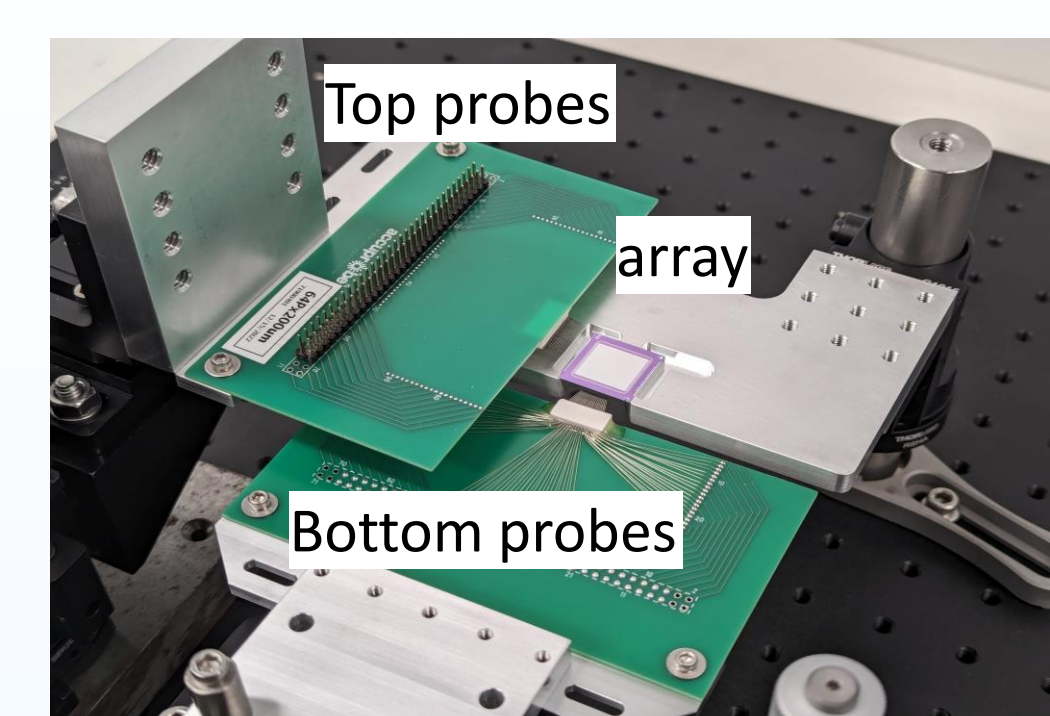
Each quad carries the array, mechanical mount for the array, and a fanout board to connect the signals to the external modular drive electronics.

A two-side butttable entirely electrically-actuated NGMSA quad will be demonstrated for TRL-5 as a multi-object selector with  $> 10^5$  UV contrast through a series of tests demonstrating HWO requirements are met in a relevant environment. This TRL-5 demonstration hardware includes an NGMSA assembly (an array hybridized with a substrate) and PCB fanout boards, all supported by an array mechanical mount. An auxiliary set of drive electronics, not part of the TRL-5 hardware, will be used for array actuation. The current 150 mm large format NGMSA fabrication process, evolved from the established 100 mm JWST MSA manufacturing, functions as a critical pathfinder for producing the large-format arrays for the HWO instrument.

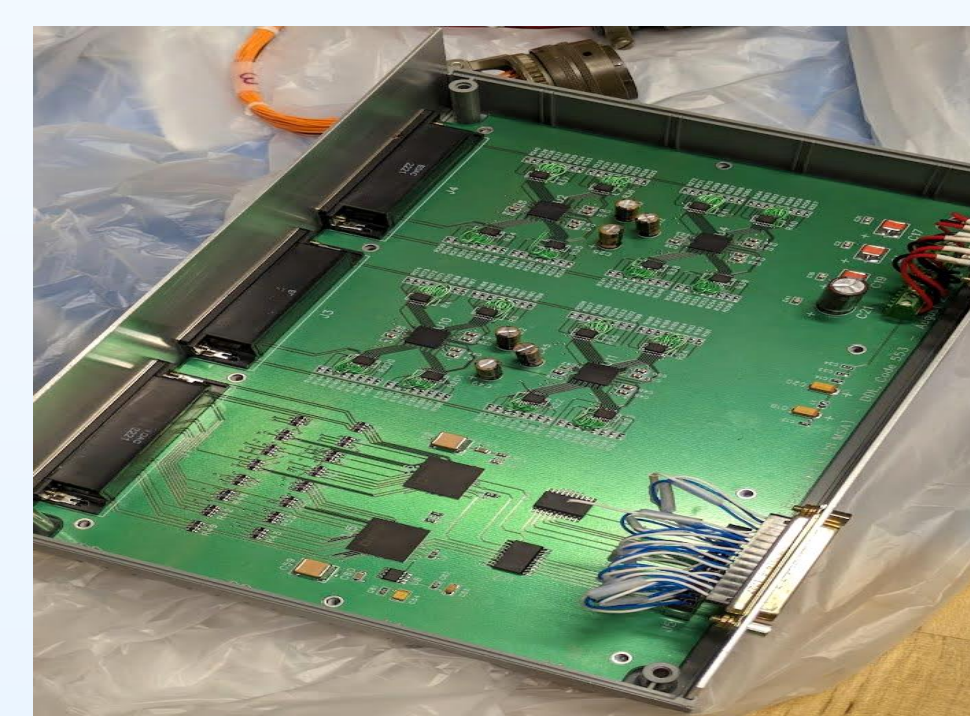
## Development of Testing Apparatus



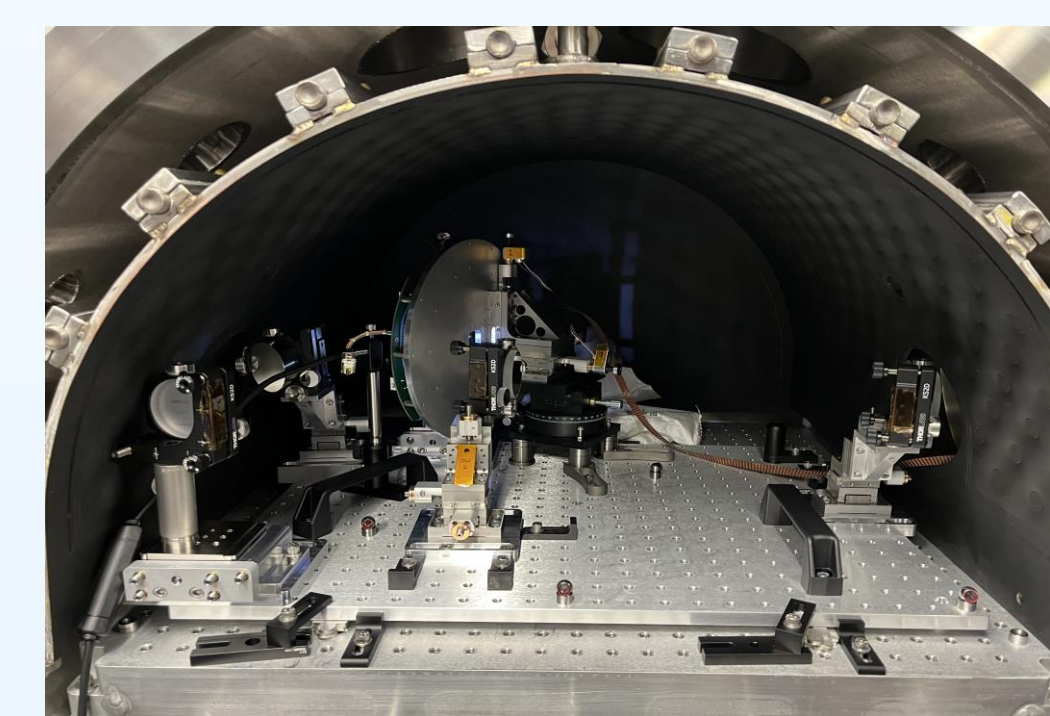
We developed an array actuation system which is capable to screen an array at the die level prior to the packaging process.



Based on the actuation system, we are developing a dual-side probing system that will enable 2D addressing of the arrays prior to packaging.

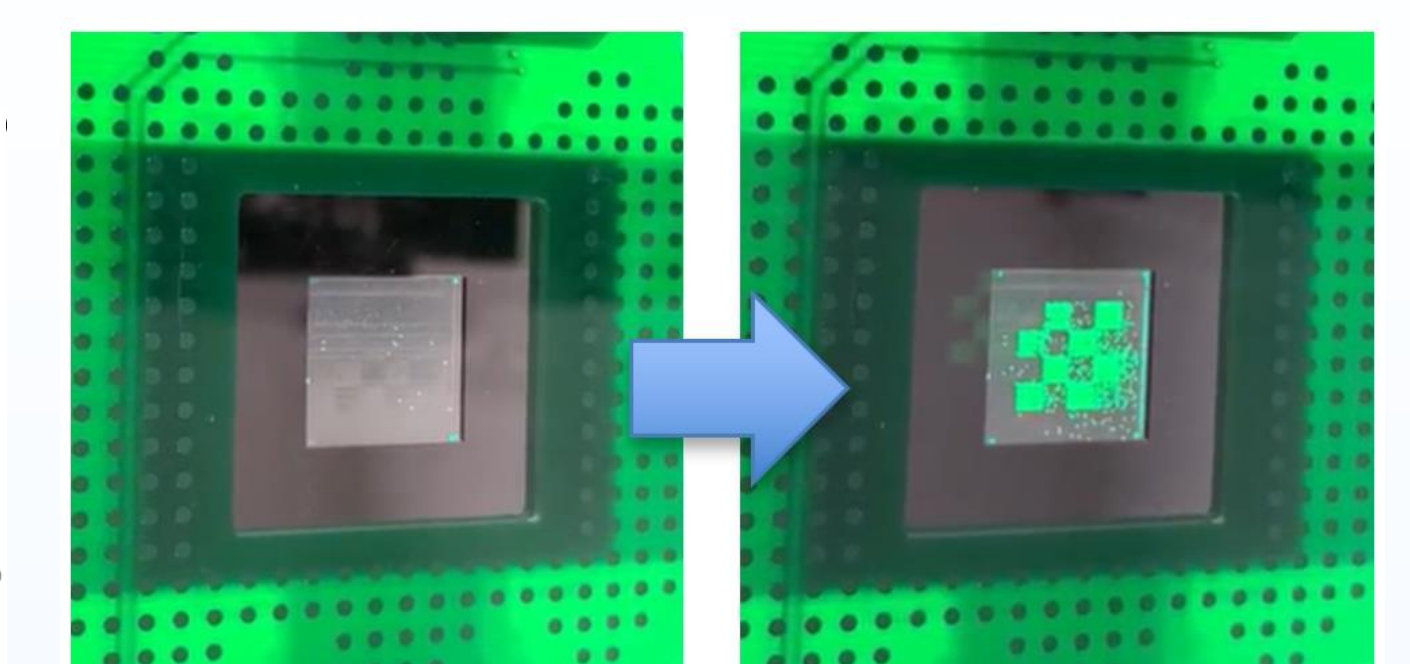
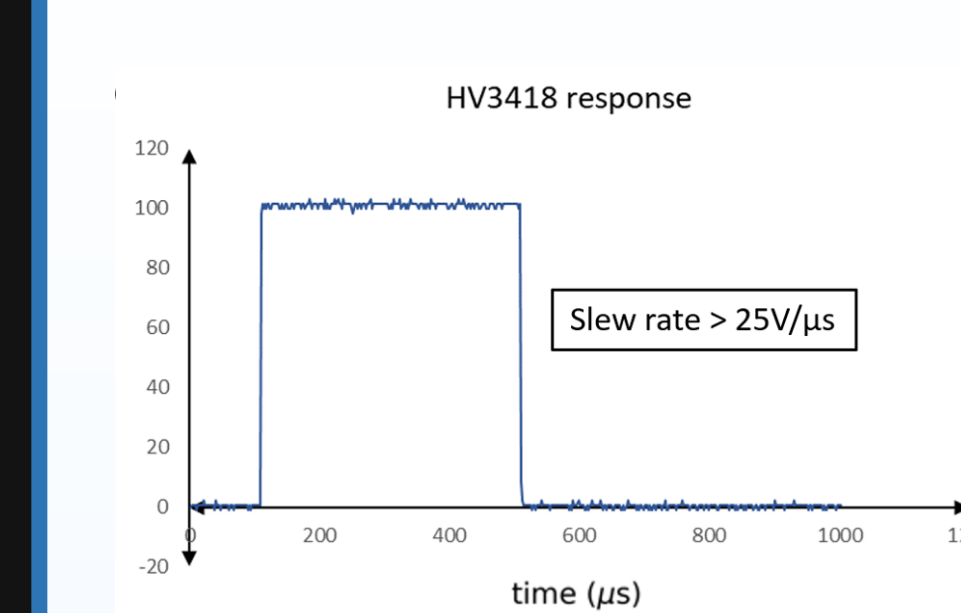


We designed a compact electronic module for array actuation, which can easily scale up to accommodate larger array sizes.

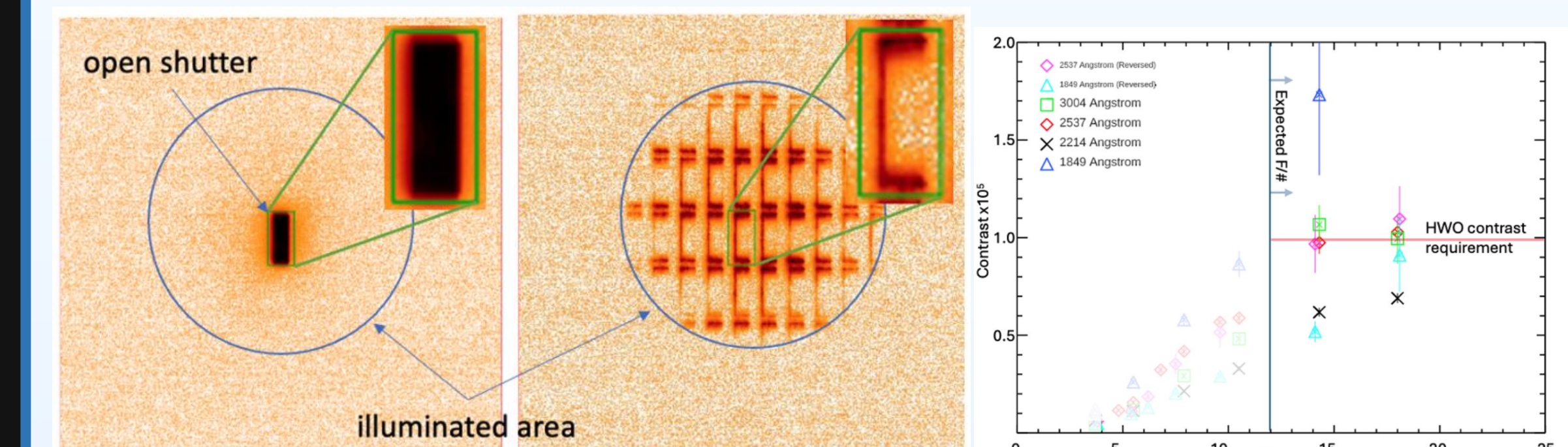


The vacuum chamber interior showing UV contrast experiment insert platen. Also shown are chamber shroud and plumbing for thermal control.

## Performance Characterization



Commercial off-the-shelf ICs are used for the array actuation for pre-Phase A development. The time domain response of HV3418 with  $> 25V/\mu s$  slew rate was found to be adequate for the shutter actuation. The right figures show the 2D-addressing of an NGMSA testing device using the HV-3418 and HV-2801 driver chips with the -40V to 80V operation voltage range.



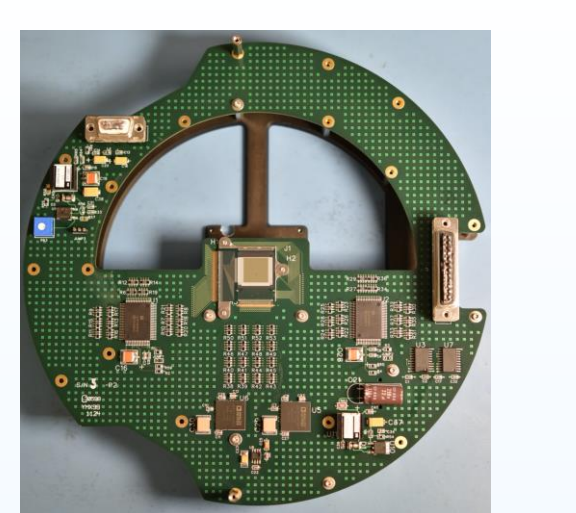
Contrast measurement done at the JHU FUV setup on the FORTIS array shows the contrast level relation to wavelength. Our aim is to increase the contrast to  $> 10^5$  levels at the low  $f/\#$  range to advance device performance. The results at the faster beam are shaded out to emphasize the measurements at the relevant beam speeds expected for HWO.

## Conclusion and Path Forward

1. The primary goal of the NGMSA project at the current stage is the refinement and optimization of all the steps in the fabrication of the microshutter arrays and the integration of the components into a fully functional device. The operation of the shutters will be studied to determine the sensitivity of actuation parameters to fabrication tolerances.
2. The current NGMSA has been shown to have UV contrast of approximately 50,000:1 for optical systems with focal ratios larger than F/10.
3. NGMSA in the small format flown on FORTIS and Off-Axis FORTIS sounding rockets has provided much-needed assessment of flight performance, but they need to scale up to meet the large format requirements for HWO.
4. Large format arrays are currently in development under the auspices of NASA SAT program. Yield, high contrast, and the number of functional shutters are key metrics. Our experience has shown that process improvements are not always directly transferable between different wafer sizes- specifically, from 100mm for small-format arrays to 150mm for large-format arrays. Multiple cycles of process refinement are necessary to improve the yield.

Subsystems	Entry TRL (2023)	Current Asserted TRL	Target TRL by 2029
Overall System	3	3	4
Microshutters	4	4	5
Drive Electronics	3	3	4

5. The Technology Management Board of the Physics of the Cosmos/Cosmic Origins Program Office assessed our current TRL as 3 (drive electronics) and 4 (shutter array) and approved our TRL-5 maturation plan. Our group also submitted a TRL elevation to the HWO Technology Maturation Project Office. The plan is to bring the technology to TRL 5 by FY2029.
6. The rad-hardness of drive electronics will be developed during Phases A-C according to the HWO TMPO schedule plan.
7. We are confident that our NGMSA technology (excluding drive electronics) will achieve TRL-5 before March 2029.



FORTIS "Big-D" NGMSA Module for 2026 flight

## Acknowledgements

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