MIRI Coronagraphic Imaging Target Acquisition

The JWST MIRI coronographic imaging mode requires target acquisition procedures.

Introduction

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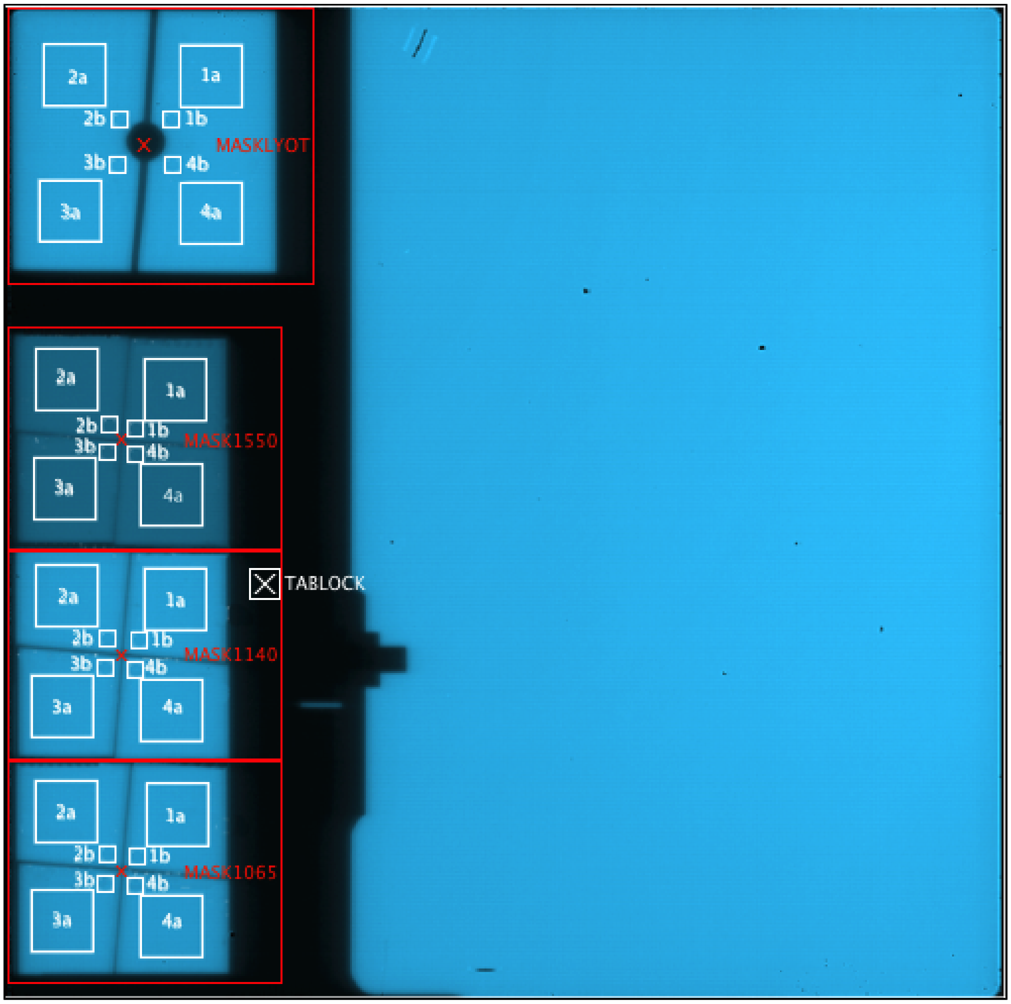
See also: MIRI Coronagraphic Recommended Strategies

MIRI coronagraphic imaging observations require precise and accurate positioning of a bright source at the location of maximum attenuation by the Lyot spot mask or 4QPMs: for the 4QPM, this is the apex between the four quadrants; for the Lyot, it is at the center of the occulting spot.

For the 4QPM, the required absolute accuracy of placing a star at the apex is 10 mas (1-σ per axis), but the ultimate positioning of the object on the mask requires a repeatable precision of 5 mas (1-σ per axis).

For the Lyot coronagraph, the pointing accuracy and precision are less stringent due to the 3 λ/D spot size. This relaxes the requirements to 22.5 mas. The neutral density filter requirements for the target acquisition have ensured that Vega can be observed in the coronagraph's subarray mode.

Figure 1. Footprints of the coronagraph masks on the MIRI imager focal plane



The 32 × 32 pixel region labeled TABLOCK is the location for placing the coronagraphic target when the telescope is initially slewed to the target. The larger four white boxes in each coronagraphic subarray indicate the initial coronagraphic target acquisition (TA) regions of interest (ROIs; 64 × 64 pixels) in each quadrant (e.g., 1a, 1b). The smaller four white boxes, closer to the center of each coronagraphic subarray, indicate the second coronagraphic TA ROIs in each quadrant (e.g., 1b, 2b). Reference points are indicated by a cross. The background image is a flight model flood-illuminated image taken in F1065C during cryo-vacuum testing.

Two effects make the TA process complex:

1. For the 4QPM coronagraphs, the phase mask can distort the image of a star close to its center and undermine the accuracy of the centroid determination.
2. The detector arrays have latent images that could mimic planets or other exciting astronomical phenomena if the centroiding process leaves them close to the target star.

These effects would make adequate TA very difficult at the nominal JWST offsetting accuracy specifications described above. Fortunately, it is projected that small angle offsets up to 20" are expected to be accurate to 5 mas (1σ per axis). Simulations of the centering accuracy on the coronagraph using the projected performance and a fiducial distance of 2" from the coronagraph center indicate a scatter of ~7 mas (rms) and average centering errors of 2–4 mas. The details depend on the particular strategy, i.e., whether one utilizes a single position for target acquisition, or uses multiple acquisitions to acquire additional information about the pointing (see MIRI Coronagraphic Recommended Strategies). None of the strategies quite reaches the desired centering performance for the 4QPM coronagraphs (the Lyot is much more relaxed in this area), so further optimization is expected during commissioning.

There are four acquisition filters available for MIRI TA: ***F560W***, ***F1000W***, ***F1500W*** and a neutral density filter ***FND*** [1] (which is needed for TA in the case of very bright sources, especially in the case of the 4QPMs; see MIRI Coronagraphic Recommended Strategies).

Due to the fact that spacecraft roll orientations are very restricted, the observer is allowed to select which of the four locations within the coronagraphic subarray to perform the target acquisition (TA). They will also have the option to repeat the entire observation, but with the TA performed within a region of the subarray that is diagonally opposed to the original TA (i.e,. a ***SECOND EXPOSURE***). This ability ensures that the observer can mitigate against the effect of latency due to the acquisition of successive images.

Software processing requirements for the target acquisition image include a flat field of the 64 × 64 pixel region of interest (ROI) surrounding the coronagraph sweet spots of which there will be 16 in the baseline strategy. A centroiding algorithm for the targets in the sweet spots is outlined in Lajoie et al. (2014a). These exposures will be normally short; therefore, cosmic rays should not be an issue.

[1] ***Bold italics*** font style is used to indicate parameters, parameter values, and/or special requirements that are set in the APT GUI.

Lyot coronagraph target acquisition

> *Main article: MIRI Coronagraph Masks*
> *See also: JWST High-Contrast Imaging Optics*

For Lyot coronagraphy, the point source will be placed in one of the four target acquisition ROIs in the Lyot coronagraphic field of view (MASKLYOT a.k.a. LYOT, 304 × 320 pixels). The readout times for each subarray in ***FAST*** mode is 0.240 s. Given the brightness of some sources, it is possible that the target acquisition will leave a latent image in the TA region of interest, which will persist in the science image.

To mitigate confusing the latent image with a nearby faint source, it will be optimal to take two coronagraphic observations: one with target acquisition using the 1st ROI and one with target acquisition using a second 2nd ROI that is diagonally opposed to the first one. Any latent images will be different between the two coronagraphic observations, allowing for discrimination of faint sources and these latent images. Discrimination is possible since the observations taken with the 1st target acquisition region will not have latent images in the 2nd target acquisition region because the latent images are variable in time; that is, the latent images in the 1st ROI will have decayed by the time the 2nd ROI target acquisition observations are performed.

The goal is to have the ROIs located as close to the center of the Lyot spot (radius = 2.4''; Renouf 2006) as possible without being affected by any edge effects. The accuracy of spacecraft small angle maneuvers from 2" –20" is expected to be <~4–6 mas (Lajoie et al. 2014a).

4QPM target acquisition

Main article: MIRI Coronagraph Masks
See also: JWST High-Contrast Imaging Optics

There are several possible strategies for 4QPM TA, which are discussed in detail by Lajoie et al. (2012, 2013, 2014a, 2014b). The baseline approach is described as follows on the assumption that offset slew accuracy is consistent with NASA's pre-launch estimates.

First, the target is initially placed at a *fiducial location* within one of the four quadrants. An exposure is obtained, a centroid is found for the target, and the offset necessary to move the target to the optimal location at the center of the coronagraph is calculated. The observatory then makes a small angle maneuver (SAM) to place the target at the center of the apex of the 4QPM. For 4QPM coronagraphy, there are specific readout subarrays defined for each mask (MASK1550, MASK114, and MASK1065).

In scenarios where the potential contribution of latent images in the science observations poses serious concerns for the coronagraph science goals, a ***SECOND EXPOSURE*** can be performed. Here, the target acquisition (followed by a science exposure) will be repeated in the quadrant diagonally opposed to the quadrant in which the initial TA was performed. This allows for discrimination between latent images and faint sources because the latents are variable in time: the 1st observation will not not have latents present in the ROI of the 2nd TA and latents in the 1st TA ROI will have decayed by the time the 2nd TA observation is completed.

References

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