OMMT1 Beam Centering Analysis Report

Evaluation using the OSEM circle, black-baffle circle, and camera parallax

September 12, 2026

Summary and Conclusions

- The center of the 92 mm-diameter OSEM circle was determined from the three visible OSEM points in the bright image. Because the camera position was unchanged, this pixel coordinate can be transferred directly to the dark image. The beam spot in the dark image nearly coincides with the OSEM-circle center.
- The nominal separation is about 0.08 pixel, corresponding to about 0.34 mm when scaled by the 92 mm OSEM circle. However, one raw pixel corresponds to about 4.1 mm, and systematic uncertainties from manual marking and image registration are larger than the nominal residual. A practical conclusion is that the beam is centered to within a few millimeters.
- Using both the apparent center offset and the radius ratio between the black-baffle circle and the OSEM circle gives an effective transverse viewpoint offset of about 89 mm. This agrees very well with the estimated installation geometry in which the camera/TCam mirror is about 90 mm below the IR beam.

1. Objective and Input Data

The primary objective is to determine whether the beam visible in the dark raw image is incident on the geometric center of the OMMT1 mirror. An intermediate objective is to test whether the apparent offset between the OSEM-center circle and the front black-baffle circle can be explained geometrically by the camera installation.

The most important condition is that the camera was not moved between the bright and dark exposures. Therefore, the OSEM center measured in the bright image can be transferred directly to the dark image at the same pixel coordinates, without applying an additional parallax correction between the two images.

Item	Adopted value / use
OSEM geometry	92 mm-diameter circle through the OSEM centers, from view B(1/2) of JGW-D1910296-0
Black baffle	90 mm aperture (45 mm radius), based on the supplied PDF and the annotated red circle
Bright raw image	Geometric reference for the OSEM LEDs and baffle position
Dark raw image	Measurement of the beam-spot position
Camera installation	Photographs, top view, and side view in the supplied PDF; the red guide-line angle was also measured

2. Identification of the OSEM Circle and Black-Baffle Circle

In the annotated image, the three blue circles indicate the visible OSEM light points and the red circle indicates the approximate black-baffle aperture. The three blue points correspond to three of the four OSEMs and uniquely determine the OSEM placement circle.

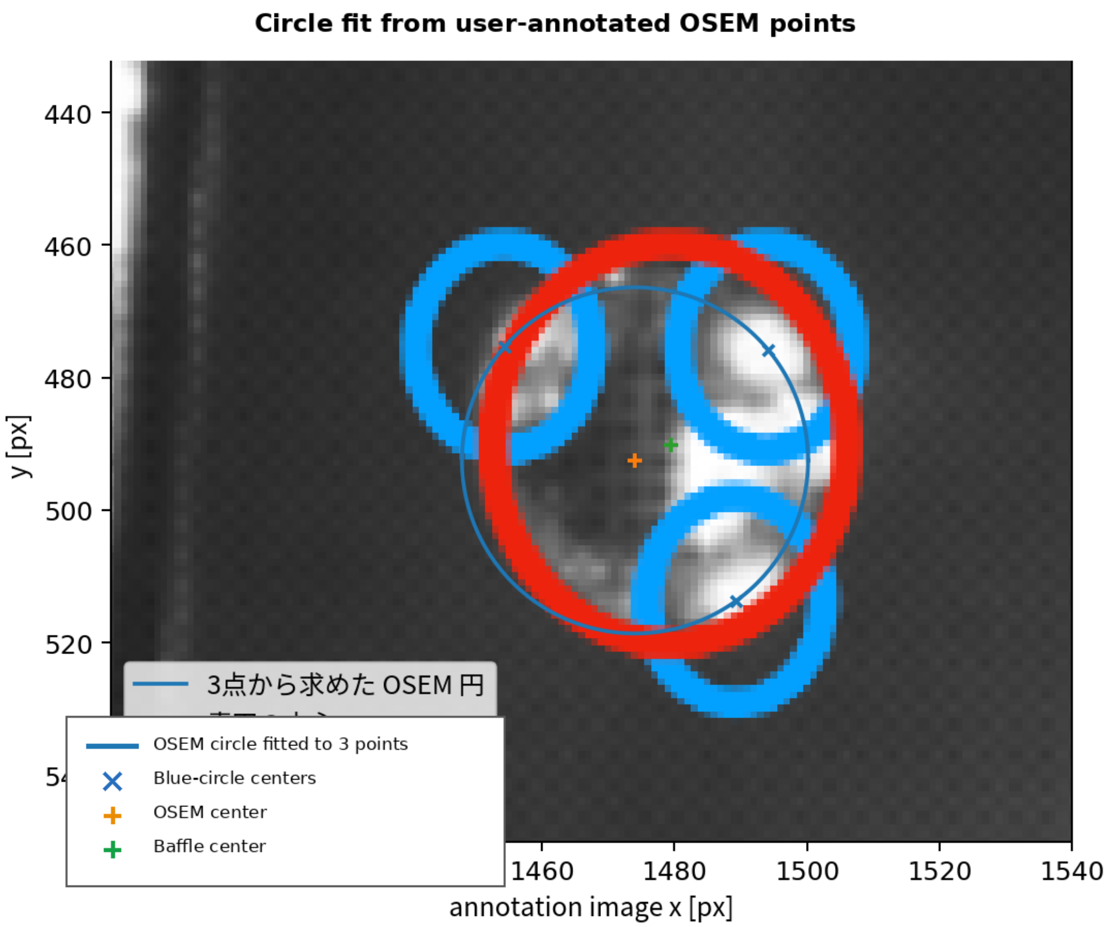

Figure 1. Centers of the three blue OSEM annotations and the fitted circle passing through them.

Quantity	Measured value
Blue OSEM point 1	(1454.36, 475.34) px
Blue OSEM point 2	(1494.09, 475.77) px
Blue OSEM point 3	(1489.27, 513.73) px
OSEM-circle center	(1474.04, 492.51) px
OSEM-circle radius	26.12 px <-> 46 mm
Baffle-circle center	(1479.39, 490.19) px
Baffle-circle radius	28.48 px <-> 45 mm
Center separation	5.83 px

3. Is the Baffle-OSEM Offset Consistent with Camera Parallax?

A simple perspective-projection model is used. The baffle plane and the OSEM/mirror plane are assumed to share the same mechanical center axis, while the effective viewpoint of the camera, including the folding mirror, is displaced transversely from that axis by H. Because image orientation can be changed by the folding mirror and camera rotation, the comparison is made using the magnitude of the center offset rather than its image-plane direction.

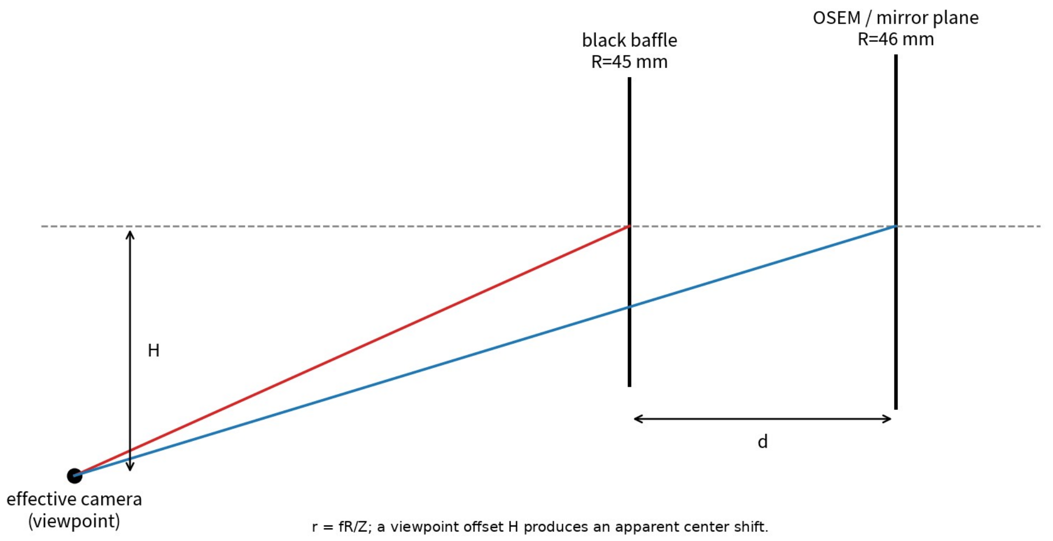

Figure 2. Perspective-projection model. Because the baffle and OSEM planes are at different depths, a common mechanical center appears at different image positions.

For a circle with projected radius r, physical radius R, distance Z from the viewpoint, and focal length f,

$$r = f R / Z$$

Therefore, denoting the baffle plane by subscript b and the OSEM plane by subscript o, the distance ratio q = Zb/Zo can be obtained from the radius ratio alone:

$$q = Zb/Zo = (ro/rb)(Rb/Ro)$$

$$q = (26.118/28.482) \times (45/46) = 0.897$$

If the image-plane separation between the two circle centers is s, the transverse viewpoint offset H is

$$H = Rb\ (s/rb) / (1 - q)$$

$$H = 45 \times (5.828/28.482) / (1 - 0.897) = 89.5 \text{ mm}$$

Key intermediate conclusion: The effective viewpoint offset inferred from the image alone is about 89 mm, in very good agreement with the approximately 90 mm offset suggested by the installation photographs and jig geometry. Thus, the apparent offset between the baffle and OSEM circles is naturally explained by parallax.

3.1 Check of the 8 deg Tilt and the 90 mm Baffle-Mirror Separation

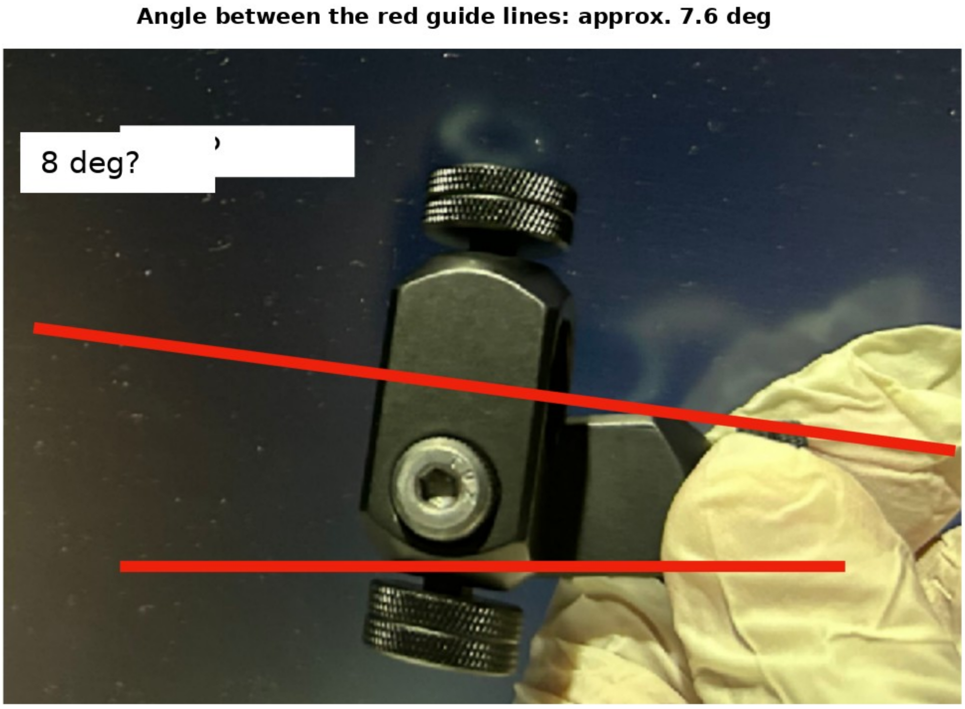

Figure 3. Image-fit angle of the red guide lines in the supplied PDF: approximately 7.61 deg.

The angular difference between the red guide lines is 7.61 deg, confirming the approximate 8 deg estimate. However, this angle is a mechanical angle of the folding-mirror/jig assembly and need not be identical to the effective camera viewing angle.

If the baffle-to-OSEM(mirror) spacing is assumed to be d = 90 mm, the radius ratio gives Zb approximately 784 mm. With H approximately 89 mm, the effective viewing angle is atan(H/Zb) approximately 6.5 deg. Conversely, if 7.61 deg is assumed to be the effective viewing angle itself, the radius ratio implies d approximately 77 mm.

The present material therefore does not establish an exact 90 mm baffle-mirror separation. A range of roughly 75-90 mm is consistent with the perspective geometry, and 90 mm remains plausible. A mechanical drawing specifying the baffle mounting position would be required for a definitive value.

3.2 Hole Position in the Top View

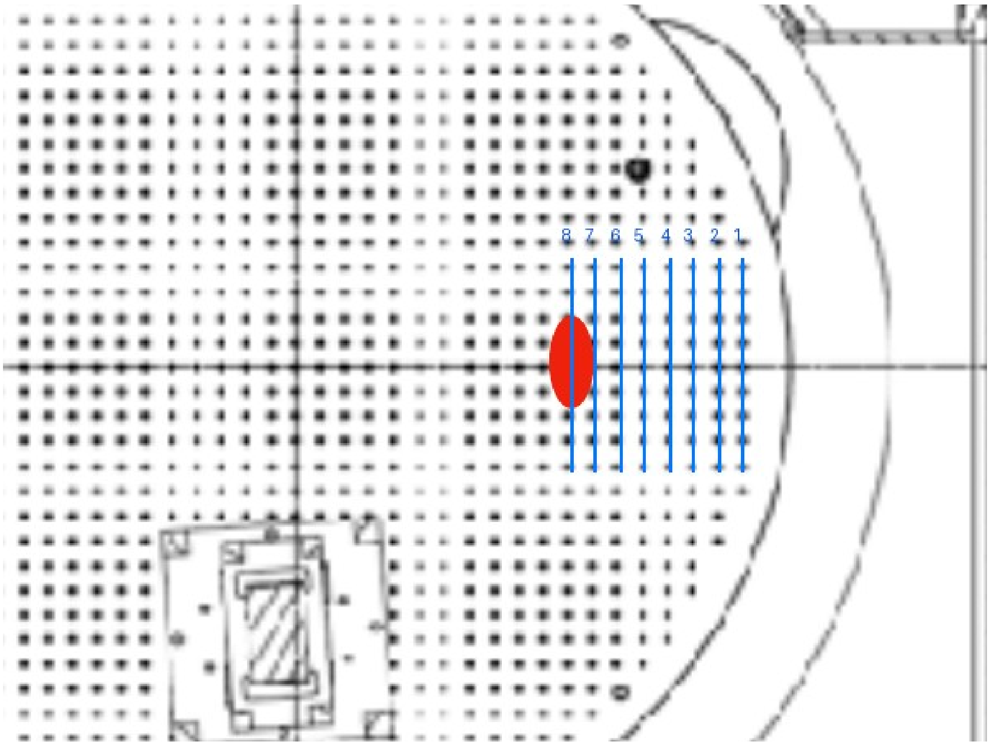

Figure 4. Red camera position in the top view and approximate hole count from the right-hand side.

In the top view, the red installation position corresponds to approximately the eighth regularly spaced hole when counted from the rightmost hole as number one. Thus, the estimate of "about eight holes from the right" is reasonable.

4. Direct Transfer of the OSEM Center from the Bright to the Dark Image

The key condition is that the camera position is identical in the bright and dark images. Therefore, it is unnecessary to infer the mirror center in the dark image from baffle parallax. The OSEM center measured directly in the bright image can simply be overlaid on the dark image using the same raw-pixel coordinates.

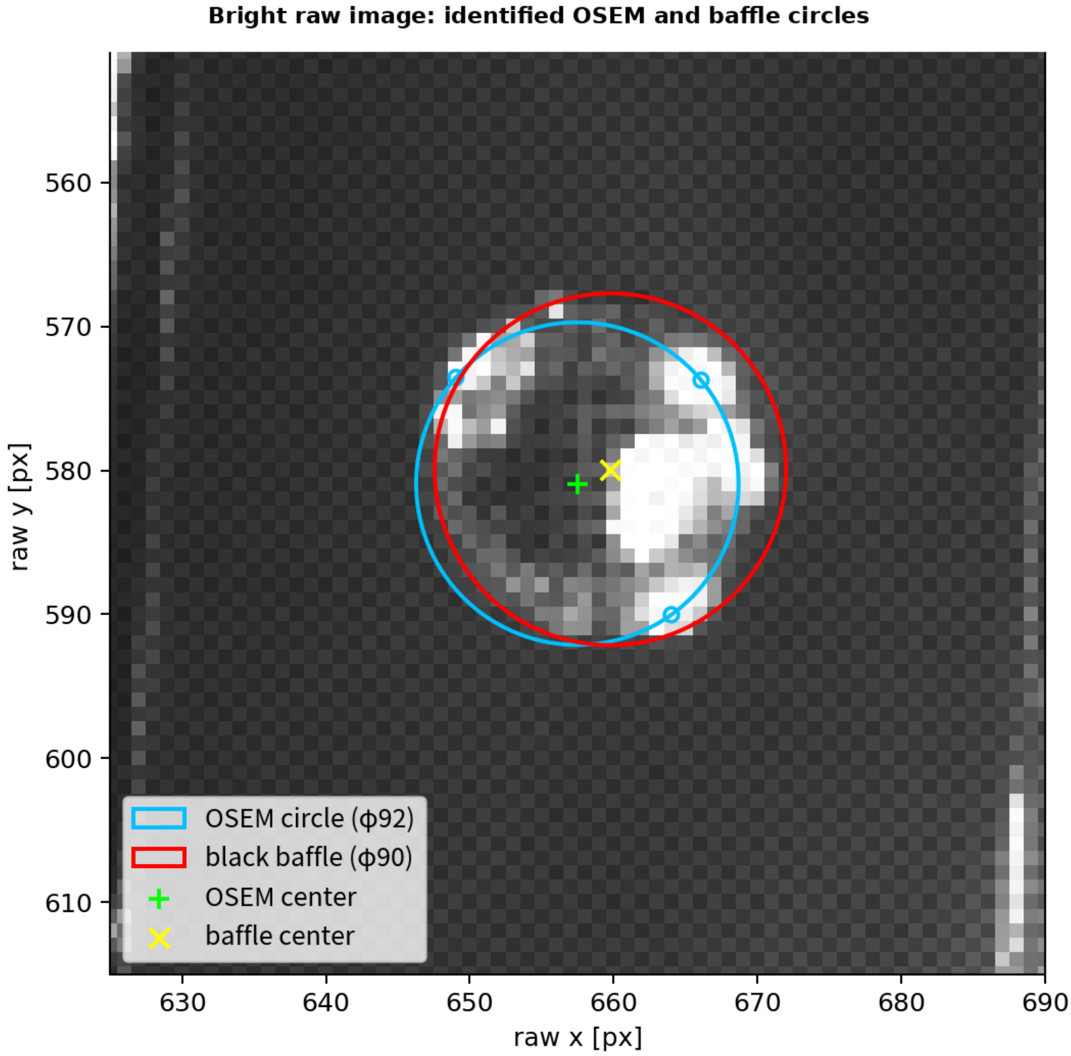

Figure 5. Bright raw image. Blue: 92 mm-diameter OSEM circle; red: 90 mm-diameter baffle circle; green: OSEM center.

The mapping from the annotated image to the raw image was determined from image features. The registration residual has a median of 0.16 raw pixel and a mean of 0.28 raw pixel. In the raw image, the OSEM center is (657.49, 580.92) pixel and the OSEM-circle radius is 11.21 pixels.

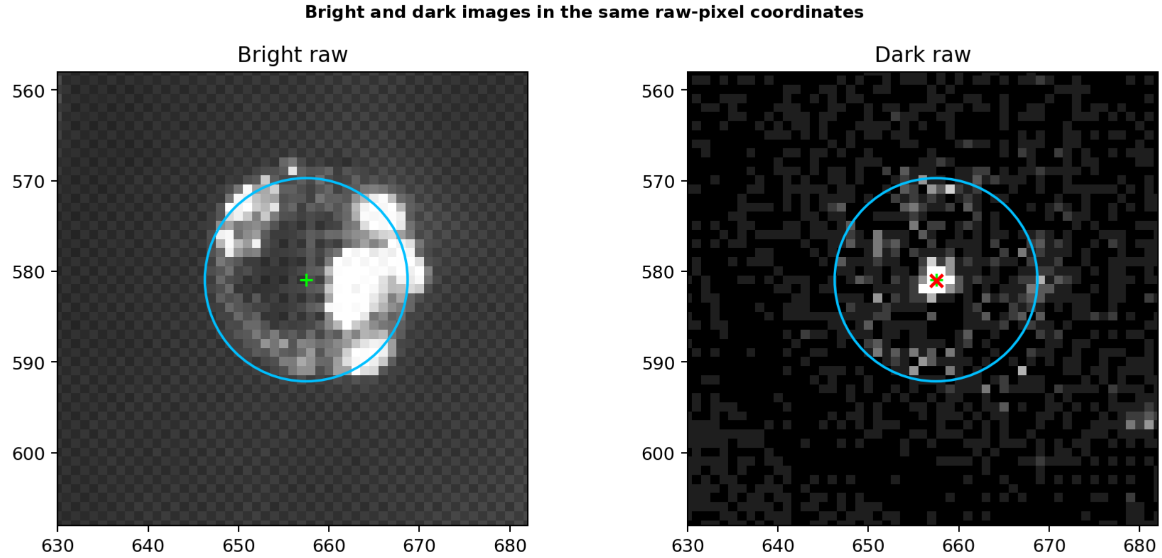

Figure 6. Bright and dark images displayed in the same pixel coordinate system. The OSEM circle and center use identical coordinates in both images.

5. Beam Position in the Dark Image

In the dark image, bright connected components near the OSEM center were extracted using multiple thresholds from 120 to 240. The beam position was defined as the mean centroid over these thresholds. The statistical variation with threshold is approximately 0.10 pixel in both x and y.

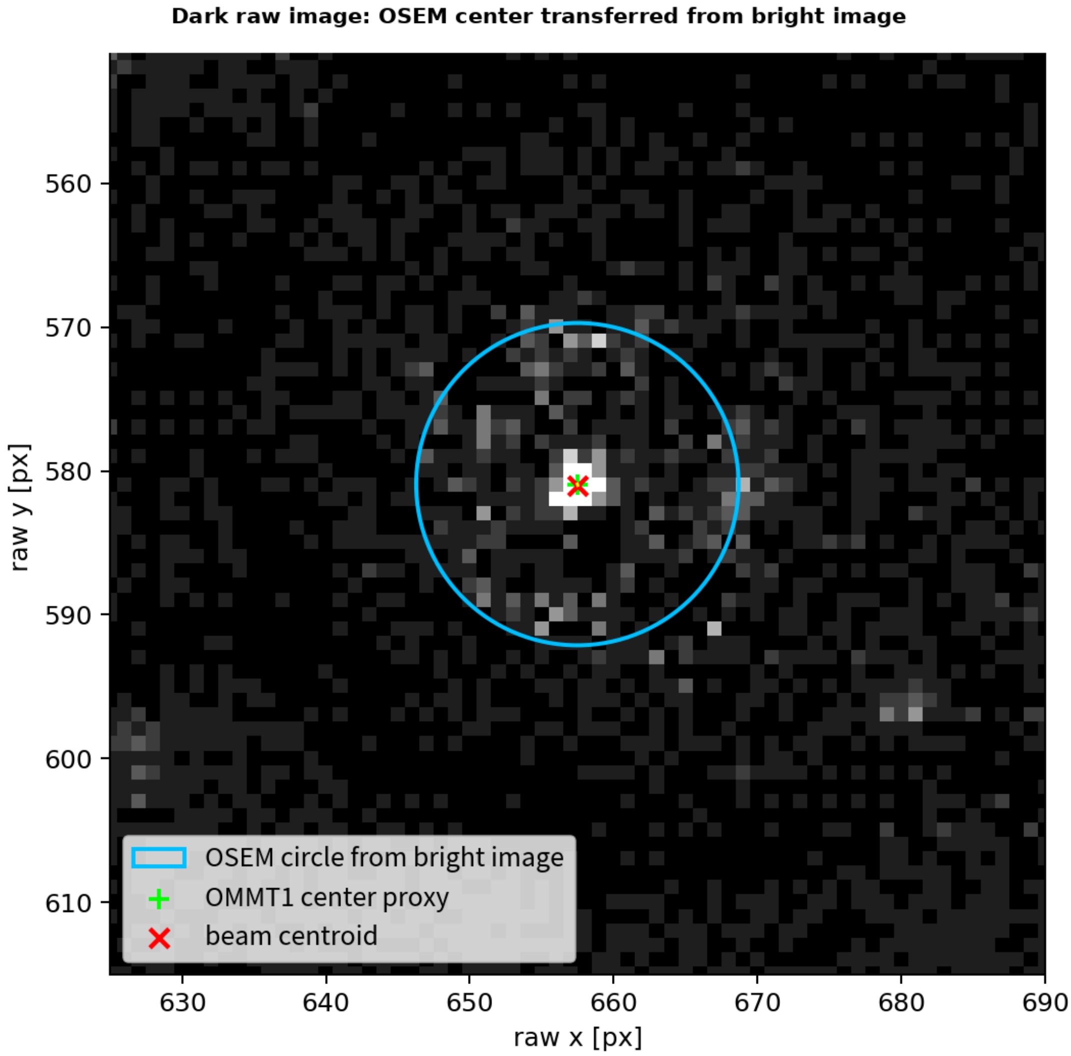

Figure 7. Direct overlay of the bright-image OSEM center onto the dark image. Green +: OSEM center; red x: beam centroid.

Quantity	Result
OSEM center	(657.489, 580.923) px
Beam centroid	(657.513, 581.001) px
Difference dx	+0.025 px -> +0.10 mm
Difference dy	+0.079 px -> +0.32 mm
2D separation	0.083 px -> 0.34 mm
Mirror-plane scale	46 mm / 11.21 px = 4.10 mm/px

The nominal beam centroid and OSEM center are nearly coincident. However, the 0.34 mm value should not be interpreted as a precision measurement. The OSEM-circle radius is only about 11 pixels in the raw image, one pixel corresponds to about 4.1 mm, and the OSEM points were identified by manual annotation.

Image-based conclusion: The beam position is consistent with the OMMT1 center. Given the image resolution and manual-marking uncertainty, the appropriate interpretation is that the beam is centered to within a few millimeters.

6. Answers to the Specific Checks

Check	Assessment	Basis
Camera/TCam-mirror vertical offset about 90 mm?	Yes	The circle-size ratio and center parallax give H approximately 89 mm; strongly consistent.
Tilted upward by about 8 deg?	Yes	Re-measurement of the red guide lines gives approximately 7.61 deg.
Approximately the 8th hole from the right in the top view?	Yes	The red position corresponds to approximately the 8th regular hole from the right.
Baffle-mirror separation 90 mm?	Uncertain	Not fixed by the available material. The image geometry naturally allows roughly 75-90 mm; 90 mm is not inconsistent.
Can the baffle-OSEM circle offset be explained by parallax?	Yes	The inferred off-axis offset H approximately 89 mm agrees with the installation estimate.
Is the beam centered on OMMT1?	Yes (within resolution)	Nominal separation 0.34 mm; practically consistent with the center to within a few millimeters.

7. Uncertainties and Possible Improvements

- The largest systematic uncertainty is that the red and blue circles are manual annotations indicating approximate locations. Although the centers of the colored outlines can be determined to sub-pixel precision, the annotation error relative to the underlying light points and aperture is larger.
- The beam centroid in the dark image has only weak threshold dependence, but the physical scale of the raw image is coarse, approximately 4.1 mm/pixel. Sub-millimeter accuracy is therefore not claimed.
- The exact axial baffle-mirror separation can be established if a mechanical drawing of the shield/baffle mounting position becomes available.

8. References

- User-supplied drawing: JGW-D1910296-0, "TAMA MC modification for new OSTM" (four OSEM holders, four OSEM bobbins, and the 92 mm diameter in view B(1/2)).
- User-supplied PDF: 380b5f14-23e8-46b1-b13a-90637ae4403c.pdf (problem statement, camera-installation photographs, 90 mm baffle, 92 mm OSEM circle, top and side views).
- User-supplied images: bright raw image, dark raw image, and the red/blue annotated image.
- KAGRA klog #37460 - the red circle corresponds to the black cover in front of OMMT1, and the TCam mirror is below the IR beam.
- KAGRA klog #37463 - bright-image observation and comparison with the OSEM-light center.
- KAGRA klog #37448 - explanation that the LIGO OSEM LEDs on OMMT1 appear bright in the IR camera.