LHO Test Mass Power Scattering Calculations

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1 ITMx

Using the layout of the corner station [3], the center of the WA-1C flange (the Pcal camera used to take the images is located at VP2 in global coordinates is (37661, 0, 0) mm. The coordinates of ITMx are (5013, -200, -80) mm [4]. The D7100 was attached to a Celestron telescope. The telescope had a 6 inch aperture mask installed which was centered on the telescope, yielding an effective viewing area of 13340 mm^2 (aperture area minus the area of the secondary mirror, which has a 69mm diameter) [2]. VP2 is 30 inches (762 mm) from the centerline at an angle of 90 degrees from the vertical [5]. This places the telescope observing surface at (37661, 0, 762) mm, so the distance from ITMx is (32648, 200, 842) mm or 32659 mm. Dividing the observing area by the surface area of a sphere:

$$SA = 4\pi R^2,$$

results in a good approximation of the solid angled subtended by the camera. The radius is the distance between the test mass and camera:

$$13440mm^2/(1.34 * 10^{10}mm^2) = 1.00 * 10^{-6}steradians.$$

See aLog35327[1] for details on the images. The best estimate for the ITMx scattering power is 1.42*10^8 watts [7], so ITMx scatters approximately .0142 watts/steradian at an angle of 1.52°. Similar measurements could be used to find the distance from ITMy to its PCal camera.

2 ETMx

The ETMx global coordinates are (3999498, -200, -80), and its local coordinates are (-502, -200, -80) [4], using the center of BSC9 as the origin for the local coordinates [9]. The Pcal camera is located at the WA-1E flange in the VP6 viewport. The WA-1E flange is located at (-5652, 0, 0) mm [9]. The camera is therefore at the (-5652, 566, 509) mm because the viewport is not directly along the centerline [6]. The distance from ETMx to the camera is (-5150, 766, 589) mm, or 5240 mm. The D7100 camera is attached to a VR Nikkor 55-300 zoom lens, which was set to a focal length of 240mm, with an f-stop of f/13.

The f-stop is the focal length divided by the diameter of the aperture, so the aperture diameter is 18.46mm, yielding a viewing area of 268 mm^2. Dividing this area by the surface area of a sphere results in a good approximation of the solid angled subtended by the camera. The radius is the distance between the test mass and camera:

$$267.7mm^2/(3.45 * 10^8 mm^2) = 7.76 * 10^{-7} steradians.$$

Photos were taken on August 1st, 2017 at around 14:00:00 local time, with the interferometer locked. Power in the X-arm was stable at the time. The best estimate for the ETMx scattering power is 8.42*10^6 watts [7] (from extending the dynamic range), so ETMx scatters approximately 10.84 watts/steradian at an angle of 10.6°. Compare results with T1600085, which used photodiodes [8].

3 Data Table

Test Mass	TM Coor (mm)	Camera Coor (mm)	Camera/TM Distance (mm)	Angle (degrees)
IMTx	(5013, -200, -80)	(32648, 200, 842)	32655	1.52
ETMx	(-502, -200, -80)	(-5652, 566, 509)	5240	10.6

Test Mass	Effective Aperture Area (mm^2)	Measured Power (W)	Radiance (W/sr)
IMTx	13340	1.42*10^8	10.84
ETMx	268	8.42*10^6	.0142

References

[1] *aLog35327*. URL: `https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=35327`.

[2] *Celestron EdgeHD8 Telescope*. URL: `https://www.celestron.com/products/edgehd-8-optical-tube-assembly-cg5`.

[3] *Corner Station Vacuum Drawings*. URL: `https://lhocds.ligo-wa.caltech.edu/vac/vac_drawings/Washington/LVEA/Arrangement/5001s1.PDF`.

[4] *DCC: D0901920*. URL: `https://dcc.ligo.org/D0901920`.

[5] *DCC: D980228*. URL: `https://dcc.ligo.org/D980228`.

[6] *DCC: T1000746*. URL: `https://dcc.ligo.org/T1000746`.

[7] Christian Pluchar. *Measuring Scattering off LHO Test Masses*. URL: `https://dcc.ligo.org/G1701180-v1`.

[8] Vincent Roma. *Optical Lever and Baffle Diode Information*. URL: `https://dcc.ligo.org/LIGO-T1600085`.

[9] *XEnd Vacuum Drawings*. URL: https://lhocds.ligo-wa.caltech.edu/vac/vac_drawings/Washington/XEND/5005.pdf.