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Laser Interferometer Gravitational Wave Observatory (LIGO) Project

To:	Advanced LIGO Systems Group
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Refer to:	T040008-00-D
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Subject: **Optical Loss due to Suspension Mounting Flats (Advanced LIGO)**

Summary:

Past calculations of the diffraction loss due to the finite size of the test mass mirrors treated the mirror as being perfectly circular. This did not account for the two flats polished on the barrel of the optic for the suspension attachments. If the flats are polished across the full width of the barrel, they will decrease the mirror aperture area and increase the diffraction loss. Limiting this diffraction loss component to a very small fraction of the total loss budget suggests a maximum mounting flat length of 9.5 cm.

Overlap of beam and flat area:

The geometry of the problem is shown in the figure below. The first part in estimating the optical loss due to the mirror area lost to the mounting flats is to find the fractional power of the TEM_{00} mode that lies in the lost area.

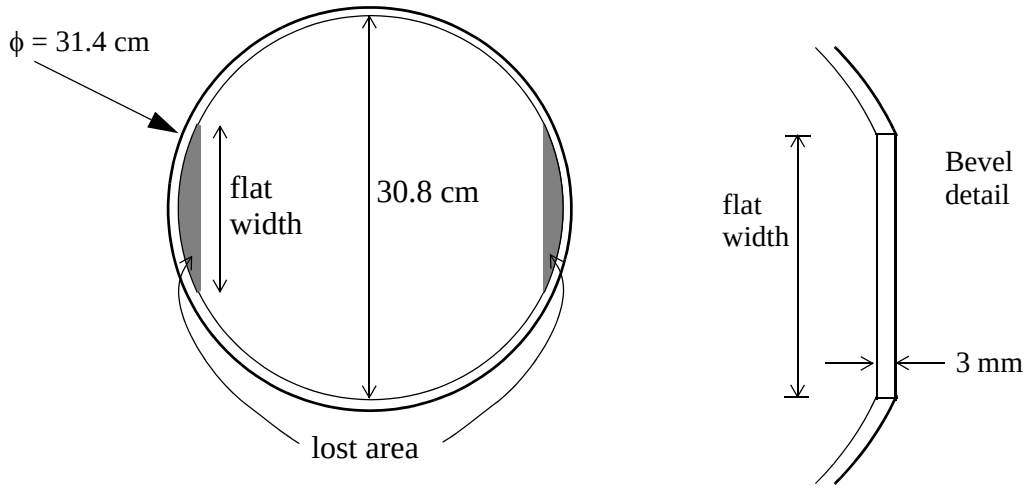

Figure 1. Geometry of the mirror substrate with suspension flats. From the substrate diameter of 31.4 cm, a 3 mm annulus is lost due to a (approximately) 2 mm-wide, 45 degree bevel. The geometrical clipping loss associated with 30.8 cm diameter circular area is 1.9 ppm.

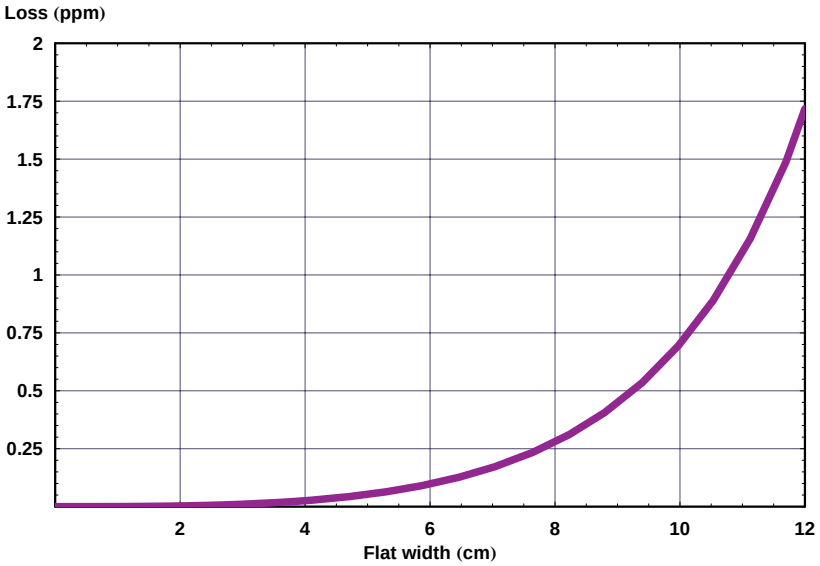

Figure 2. The fractional power in the 6.0 cm radius ($1/e^2$ intensity) TEM_{00} mode beam that falls in the mirror surface area lost to the suspension flats (shaded areas in Figure 1). The effective diffraction loss is expected to be several times larger than the loss indicated in this plot (see below).

Effective diffraction loss:

Calculations of the effective diffraction loss due to the finite circular area of the miror show that, for the (mirror radius:beam radius) ratio of Advanced LIGO, the effective aperture loss is approximately 3× larger than the geometrical clipping loss. Assuming this is true here as well, the effective loss from the area lost to the suspension flats is estimated to be 3× larger than shown in Figure 2.

Acceptable loss:

Given that the total average per mirror loss budget of 37.5 ppm will likely be difficult to meet, the loss due to the suspension flats should be limited to a small percentage of the total. I propose that the suspension flat loss be no more than 5% of the total, or no more than 1.9 ppm. This corresponds to a maximum clipping loss of 0.6 ppm, and a maximum flat width of 9.5 cm.