Dear CQG Editor and Reviewers,

Thank you for your detailed review of our manuscript. Responses to each of the comments or suggestions are detailed below. Changes to the text of the manuscript are highlighted in red in the excerpts copied below. The reviewer's comments are in green text. Please note that we also made a slight correction in table 1 (relative uncertainty for ξ_{EL} has been corrected) along with a couple other minor changes to the text. The accompanying file, *O3b_Pcal_paper-highlighted.pdf*, is the complete updated manuscript with the revised text highlighted in red.

Best regards,
D. Bhattacharjee

No where in the manuscript is the wavelength of the laser used for calibration clearly stated. In section 3.1 it is stated that the Gold Standard sensor is calibrated at 1047 nm, presumably this is the wavelength used? Something this basic to the technique should be clearly stated.

But part of why I call this out is it impacts the power reflectivity of the HR surface of the ETM. This reflectivity is stated as being greater than 0.9999 in section 2.1. This value is a function of both wavelength and angle of incidence. No uncertainty is associated with this reflectivity, presumably because it is much lower than other uncertainties that do impact the calibration uncertainty? This should be made clearer and fully justified.

Figure 1 was updated to include a block for the "1047 nm Laser." Also, the beginning of paragraph 2 in section 2.1. text was edited as follows:

> The wavelength of the LIGO Pcal lasers is 1047 nm. Measurements of the power reflectivity of the ETMs, carried out inside the vacuum envelope when the system is vented to atmosphere and with the Pcal beams impinging on the ETM surface at their operating locations, angles of incidence, and polarizations, are limited by statistical variations. The mean of the four measurements made during the O3 observing run (one for each beam at each end station) is 1.00008[10] $\pm$ 0.0004. Calculations using the coating design parameters and measured optical losses at the 1064 nm operating wavelength of the main interferometer light predict reflectivities greater than 0.9999 at 1047 nm, consistent with the measured values. However, the anti-reflection coated

And the following footnote was added:

10 Power reflectivity of greater than 1 is, of course, unphysical.

In Section 3.1, the change in the responsivity ratio WSH/GS when moving the setup to a new building is both mysterious and somewhat concerning. Could whatever caused this change be drifting inside the end stations, and thus this should be considered a source of uncertainty in the calibration?

The second sentence in paragraph 3 of section 3.1 and was edited a follows:

different building at the LHO. The stability of the responsivity ratio between WSH and the Rx sensors at the LHO end stations (see figure 6) during the year-long O3 observing run indicates that the change in α_{WG} was caused by a change in the GS responsivity, ρ_G, alone. The exact cause of this increase in responsivity has not yet

It is true that in papers like this a referee could always ask if some phenomenon might be causing additional uncertainty, and ask that it be investigated and reported. But since this result is clearly shown in the manuscript and it is stated in the text that "The exact cause of this increase in responsivity has not yet been identified", a reader would be justified in asking for more information. What causes have been considered and ruled out? What rationale is there to believe that whatever is causing this is not changing in the end stations? A little more discussion on this would be valuable.

The third sentence in paragraph 3 of section 3.1 was edited to include the following:

been identified, but conversations with the manufacturer indicate that movement of the interior Spectralon® shell with respect to the exterior aluminium shell resulting from mechanical shock during the move between laboratories may be the cause. Design changes to address this potential movement are being implemented. The lower panel in

In section 3.2, paragraph 6 there is discussion of the main interferometer beams being offset from the geometric center of the test mass faces, and a single scalar value for this offset is given for each TM. Since the face is a two dimensional object, the single value does not specify how the beam is offset. Is the direction of the offset known, presumably it is?

Yes, the two-dimensional coordinates of the interferometer beam offsets are known, but only the magnitude of the radial offset is relevant presently because we have no information regarding the direction of the Pcal beam center of force offset. The text was amended to clarify this point as follows:

Interferometer beam position offsets are determined from angle-to-length coupling measurements for each suspended ETM. For the LHO interferometer, the offsets from center are 29 mm for the X-end ETM and 22 mm for the Y-end ETM. The uncertainty introduced by unintended rotation of the ETM, ϵ_{rot}, is proportional to the dot product of the Pcal and interferometer beam offset vectors, $\vec{a}$ and $\vec{b}$, i.e. $\epsilon_{rot} \propto |\vec{a}||\vec{b}|\cos\phi$. Because we do not know the direction of $\vec{a}$, ϕ, the angle between $\vec{a}$ and $\vec{b}$, is equally probable to be any value between -π and π. We use a *sine wave*, or *U-shaped*, probability density function [32] to estimate the variance in $\cos\phi$ and form a Type B estimate for ϵ_{rot} using the maximum estimated value for $|\vec{a}|$ and the measured values for $|\vec{b}|$ (see (2)), $\epsilon_{rot} = Mab/(\sqrt{2}I)$. The values of the relative uncertainty estimates for both the X-end

The calibration uncertainty would seem to depend on this direction through a.b in equation (2). The statement that "we do not know the magnitude or direction of the Pcal center of force displacement vector, a" makes this direction irrelevant , but it would also seem to make the magnitude irrelevant. More explanation of this, and why the magnitude of displacement is reported but not the direction, would be useful.

To form a "Type B" uncertainty that accounts for the maximum estimated magnitude of the Pcal center of force offset and the fact that the orientation is unknown, the estimate of the magnitude is required. Hopefully, the modifications in the modified paragraph above make this clearer.