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Photon Calibrator DRR & CDR: Response to Reviewers' Report

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Conceptual Design

- Reviewers' comment: "*Given our experience with the iLIGO photon calibrators, we don't think it is worthwhile to do any significant re-design for AdL; we should just plan on using the iLIGO calibrators, probably with a few upgrades*."
- Agreed. The main difference between initial and Advanced LIGO Photon Calibrators is in the preliminary qualifications used to guarantee the accuracy of the calibration; the actual design and operation will be very similar.

- Reviewers' comment: "*Presumably the lasers will need to be replaced for AdL, but we don't find much motivation to go to a higher power (2W) version. Since some time has been spent in working out the kinks with the 0.5 W lasers, let's stick with them*."
- Agreed. Given the recommended calibration line SNR requirement a ½W laser is more than sufficient.

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- Reviewers' comment: "*For a list of potential upgrades to the current hardware, proposed by the folks who have been working with them, see*: http://www.ligo.caltech.edu/docs/T/T070094-00.pdf"
- These potential upgrades are for the most part incorporated into the CDD, although in much less detail.

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- Reviewers' comment: "*Is there really any evidence that the coating absorption could be 100ppm at 1047 nm? This seems rather unrealistic to us, unless there is evidence we don't know about*."
- There is no evidence for this, and it does seem unrealistic, but the possibility was raised as an explanation for the discrepancy between photon calibration and official calibration and was difficult to test *in situ*. It seems prudent to require a measurement for Advanced LIGO and lay this to rest.

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- Reviewers' comment: "*Active amplitude stabilization of the Pcal laser can be deleted*."
- So long as the displacement induced by the photon calibrator off its calibration frequency is less than AdLIGO sensitivity, we agree. This appears to be true based upon the revised requirement recommended for the DRD.

- Reviewers' comment: "*Chopper wheel. We understand this is used to measure the frequency response of the photodetector. Why does this have to be included in each Pcal's bench? Why not instead calibrate the freq resp of each PD on the bench before installation*?"
- Probably it is not essential, but reflects a philosophy of allowing as much recalibration as possible after installation without having to dismantle the calibrator.

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- Reviewers' comment: "*4.3 mentions correcting nonlinearity of the AOM response in the drive signal. Why do you want to do this? As long as the fast PD is measuring the modulation, why do we care how linear the drive is?*"
- A very good point. Our desire was to guarantee that the test mass motion was as sinusoidal as possible. This is probably not necessary.

- Reviewers' comment: "*We'd like to know what the plan is for viewport use at the LHO end stations, where there are 2 ETMs. We'd like to see a drawing that shows the viewport assignments for all uses: photon cal beams; optical lever beams; cameras; Hartman sensor beams (?); ... Also indicate any in-vacuum baffling that could restrict the views*."
- This is currently a weekly topic during the AOS telecons. The precise nature of the vacuum and facility modifications in the LHO end stations is not yet determined. Our most current baseline is shown, and incorporates our need for optical access.

Design Requirements Document

- Photon Calibrator force noise requirement
  - The PC applies force to the test mass, and noise in the noise will cause displacement noise in the IFO. Thus a force noise requirement should be set.
  - It is reasonable to require that the PC force noise satisfy similar requirements as SUS actuator technical noise, since it is like an actuator.
  - The review committee suggests a requirement that the PC noise be negligible compared to the lowest possible IFO noise. Such a standard would not be very specific.

- Photon Calibrator force requirement
  - » Reviewers' comment: "*The requirement here should be expressed as a minimum calibration line SNR, given the expected detector noise curve, for a given integration time and up to a maximum frequency. We suggest the following set: SNR = 10, Integration time: 1 sec, Max frequency: 500 Hz*."
  - » We can and have expressed the requirement in this way; however, the relation of this to modulated light power is then obscure and needs clarification, which we have also added.
  - » In practice the maximum modulated light power is not frequency dependent, so will be set by a single worst case frequency. Will the maximum frequency be 500 Hz? Is there a lower limit frequency?
  - » Should we build a margin, e.g. for operation above design sensitivity before complete commissioning or for narrowband operation?

- From the DRD: “The displacement of the HR surface of the ETM caused by the Photon Calibrator shall be absolutely known to within 1%.”
  - » Reviewers’ comment: “*This is way too much to ask, and given our iLIGO experience, it seems dubious that this will ever be achievable. We suggest making it 5% or best effort (~10%), which is good enough for a check on the primary calibration*.”
  - » We feel that the iLIGO experience has shown that more attention needs to be directed toward calibration and characterization of the PC before installation. Absolute radiometric calibration has not been attempted. Mirror and viewport reflectivities and absorptions were not adequately characterized before installation. There is no thermal control. Such techniques are relatively inexpensive and simple and should be used if they offer improved accuracy at the percent level.