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Requirements and Interfaces for the ETM Transmission Monitor Suspension and Telescope

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1 Introduction

The ETM Transmission Monitor (TransMon) is an in-vacuum component that sits behind the ETM (End Test Mass) and is mounted to the BSC ISI platform. The TransMon receives the laser beam transmitted through the ETM so that this beam can be used for interferometer sensing and control. The TransMon is also used in the opposite direction, for injection of the green laser beam used in the Arm Length Stabilization (ALS) scheme. Finally, the TransMon also accommodates probe beams for the Hartman sensor that monitors the curvature of the ETM. The TransMon assembly consists of an optics platform, a suspension for that platform, a beam reducing telescope, and various opto-mechanical and opto-electronic components for beam detection and control. The assembly is split between AOS and ISC, as follows:

- Optics platform: AOS
- Suspension: AOS
- Beam reducing telescope: AOS
- Post-telescope optics and electronics for 1064 nm beam detection: ISC
- Pre-telescope optics and electronics for ALS 532 nm beam injection: ISC

This document contains the design requirements for the AOS scope of the TransMon.

2 Optics Platform

The optics platform supports both the AOS beam reducing telescope and the ISC components. Discussions between AOS and ISC have led to the following design requirements for the platform:

- One side of the platform will be used to mount the beam reducing telescope, and the other side will be used for ISC components. Beams are directed from one side to the other through a hole in the platform.
- The nominal size of the platform working surface is 70 cm x 85 cm. It can be made larger by AOS if possible (but not smaller). The ISC side of the platform should be supplied with a matrix of tapped holes: 1/4-20 on 1 inch centers, vented.
- The platform working surfaces are to be oriented horizontally, with the beam reducing telescope to be mounted on the bottom side of the platform and the ISC components on the top side.
- Other interfaces with ISC. Though their values are not specified in this document, there are some additional interfaces that must be communicated from AOS to ISC:
    - location of the beam delivered to the ISC side of the platform
    - stay-clear areas on the ISC side of the platform (for suspension attachments, e.g.)

3 TransMon Suspension

The TransMon platform must be suspended from the BSC ISI platform (rather than rigidly attached) for several reasons. First, because of the large distance between the ISI platform and the beam line, a rigid structure would have unacceptable mechanical modes (too low in frequency). Second, some additional vibration isolated is desired in order to mitigate scattered light noise due to any light scattered from the TransMon optics back into the arm cavity. Finally, ISC plans on putting two alignment sensors (quadrant photodetectors) on each TransMon, so that all eight alignment degrees-of-freedom (four in each plane) of the arm cavities can be sensed by the TransMon. To keep these alignment sensor signals from being spoiled by motion of the TransMon itself, additional isolation beyond the ISI is needed.

The following generic requirements apply to the TransMon suspension:

- All six degrees-of-freedom of the platform are to be isolated
- Suspension eigenfrequencies should be kept above 0.5 Hz, and preferrably above 0.6 Hz (if possible); this is to limit excitation of the modes, since the ISI motion increases steeply below 0.6 Hz
- All rigid-body modes should be damped, to Qs of ~10 or lower
- Internal modes of the suspension support structure should be as high as possible and damped if possible; goal for lowest eigenmode: 150 Hz or higher

Isolation. The isolation needed from the suspension is determined by the sensitivity of the ISC alignment sensors on the TransMon platform. The modeling from which the following isolation requirements are derived is shown in G0900293-v3 (slide 5):

- Above 10 Hz: isolation factor of at least 1000, nominally in all six degrees-of-freedom (see below)
- Factor of 10 isolation by 3 Hz (all DOF)
- Below 1 Hz: best effort at minimizing mode amplification and long-term stability; mode amplification would be best confined to the 1-1.5 Hz band, if possible

Note that according to G0900293, isolation from ISI motion is really only needed for the angular DOF, but we are specifying the isolation to apply in all DOF because typically a suspension does not give angular isolation without the displacement isolation as well. However, if a suspension design is found that provides the above isolation for the pitch and yaw DOF of the TransMon platform, but not for the other DOF, it may be acceptable.

Noise. From G0900293-v3, the acceptable level of TransMon platform noise above 10 Hz is a few picometers/$Hz^{1/2}$ in displacement, and a few femtoradians/$Hz^{1/2}$ in angle (the actual level shown in the plot on slide 5 is more conservative than it needs to be, by a factor of ~2-3). The isolation requirements above are consistent with this, and these noise targets can be used to evaluate other platform noise sources.

Remote position control. Remote control of the TransMon platform is not required in principal for ISC functionality. The ISC beam lines will include remotely adjustable tip-tilt mirrors to center beams on the alignment sensors. However, the trajectory of the beam delivered to the ISC beam lines by the TransMon telescope must be close enough to the design value that it is within range of the ISC tip-tilt mirrors and well-within other optical apertures. This may require remote control of some degrees-of-freedom, depending on the initial alignment tolerances and estimated drift of the suspension. A suggested criterion is: let the reduced 1064 nm beam propagate an additional 1 m past the point where it enters the ISC side of the TransMon table; at that point, given estimates of alignment errors and uncorrected drifts, the beam should be no more than a couple of mm away from its nominal transverse position, and no more than a mrad off its nominal propagation angle.

The position of the suspended TransMon platform within the BSC chamber is a controlled interface between AOS and ISC. It is defined in the Zemax model contained in D0900622-v1.

The TransMon suspension must allow for electrical cabling to be run from the ISC side of the TransMon platform up to the ISI platform. This includes providing appropriate clamping points for cabling within the suspension (cabling is provided by ISC).

4 Beam Reducing Telescope

The beam reducing telescope (BRT) must reduce the beam size so that it can be handled by 2 inch diameter, or smaller optics (at 45 deg. angle-of-incidence) on the ISC side of the platform. The BRT must be able to be adjusted so that it delivers a beam with well-known beam parameters and these beam parameters must be stable over time, with ‘well-known’ and ‘stable’ clarified in the next paragraph.

As discussed in G0900459-v2, the ISC side of the TransMon employs two alignment sensors that by design are separated in Gouy phase by 90 deg. The adjustment and stability of the BRT must be such that this Gouy phase difference does not deviate by more than 10 deg from this design value. The setup and stability of the BRT must also be such that the beam size on the alignment sensors is not more than 10% different than the design value.

Within the above constraints many BRT designs are possible. The current design, as found in D0900622-v1, appears to be adequate: it reduces the beam radius from 62 mm to 4 mm over a distance of about 3 m (output beam is at a waist). This document does not assume this is the final design. Changes may be proposed if there appear to be better design options, either on the AOS/ BRT side or the ISC side.

For expansion of the ALS green beam, the BRT design should produce an expanded green beam whose beam parameters are stable and within 10% of their design values given the design tolerances. The BRT properties are not required to be the same for the 532 nm beam and the 1064 nm beam (i.e., allowing for refractive lenses, if desired).

Additionally, the BRT must allow for convenient separation of the Hartmann sensor reference beam on the ISC side of the platform.