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As Built L1 TransMon EY Telescope and Table

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1 Introduction

In this document we report on the assembly, alignment and focusing of the telescope and the mating of the telescope and optical table, for the L1 EY transmission monitor. This is the second transmission monitor to be built for L1, the first being for EX, and as such we have generally followed the same procedure as for EX. The report for the as built L1 EX Transmission Monitor is in [1]. Where we have deviated from the procedure, we have stated clearly in this document.

2 Telescope Assembly and Initial Alignment

The telescope frame was assembled as set out in [2] and suspended from the tele-alignment support bridge [3], which was mounted on an optical bench.

The procedure suggests to use two auto-collimating alignment telescopes (ACAT), one mounted at the entry aperture (ACAT1), and one mounted to the telescope at the exit aperture (ACAT2). Due to a significant horizontal offset between the alignment telescope cross-hairs, and the etchings in the secondary plate, we decided not to use the ACAT2. Instead we decided to use the laser that was initially only intended to be used for the fine alignment and telescope focusing (see next section).

The initial alignment set-up can be seen in Figure 1. A 1064nm laser source coupled to a fiber with a fiber collimator (Thorlabs F220 APC-1064) was set-up on the same optical bench. A periscope with silver coated mirrors was used to bring the beam from table height to the exit aperture.

The laser beam was aligned to the telescope frame using the etchings in the primary plate, and a dummy mass with cross hairs. The dummy mass was installed into the secondary mirror mount. The steering mirrors were tuned to center the laser beam in the etchings on the primary plate and the cross-hair etchings on the dummy mass.

Once the laser was aligned, the dummy mass was replaced with a flat dummy mirror. An iris was installed and centered on the input beam. The pitch and yaw of the secondary mirror mount was then adjusted until the reflected beam was centered in the iris.

The flat mirror was then removed and the convex off-axis parabolic secondary mirror installed. It was clocked until the forward going laser beam was centered in the vertical etching behind folding mirror 2. Folding mirror 2 was then installed, and aligned to center the laser beam on the etchings behind folding mirror 1.

The next step in the procedure was to install the primary mirror. The primary mirror mount was installed. A dummy plate with a 2" flat mirror mounted in the centre was installed into the primary mirror mount. ACAT1 was set-up in front of the entry aperture and focused to infinity. A light source was used to project a reticle pattern from ACAT1 onto the dummy mirror and back into ACAT1. ACAT1 was adjusted in pitch and yaw to line up the reticle pattern with the cross-hairs. ACAT1 was focused onto the etchings behind the primary mirror mount and then adjusted horizontally and vertically to line the cross-hairs up with the etchings. ACAT1 was now aligned to the primary plate.

The primary mirror was then installed into the mount. ACAT1 was tuned to focus on the etchings behind FM1. The primary mirror was clocked until the vertical etching and vertical cross-hair lined up. At this point the primary mirror was now correctly oriented, and we clamped it down. Folding mirror 1 (FM1) and its mirror mount were installed onto the secondary plate. This mirror was aligned to so that the cross-hairs lined up with the etchings in the primary plate.

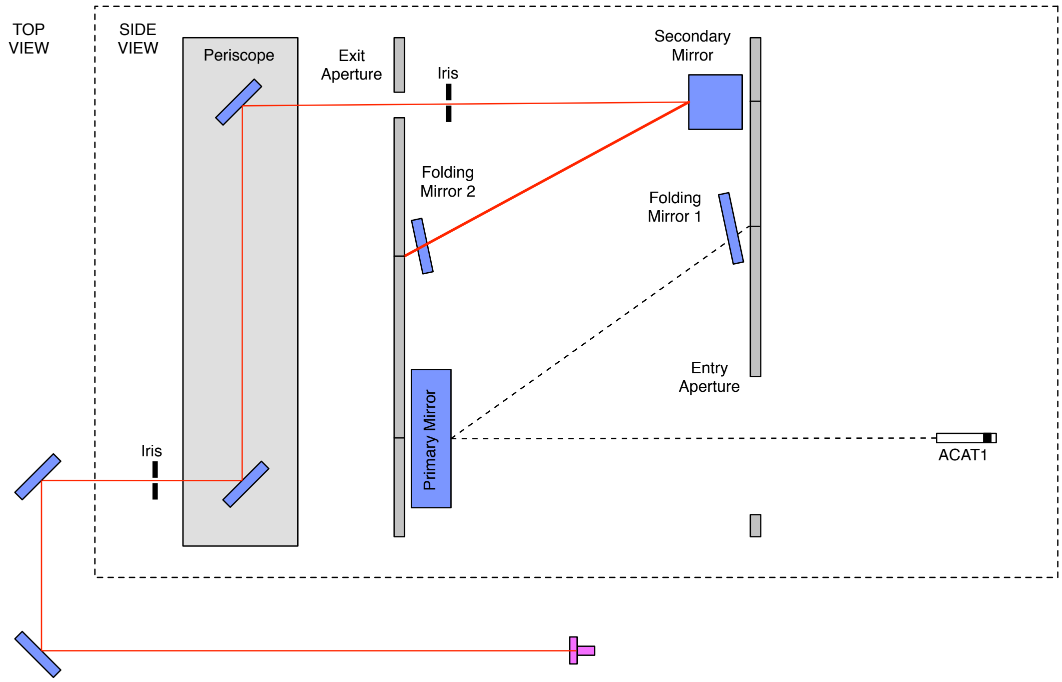

Figure 1: Set-up for the initial alignment of the mirrors in the Transmon Telescope.

A second iris was mounted to the telescope frame, with the iris aperture located between the exit aperture and the secondary mirror, and positioned so that it was centered in the laser beam. The folding mirrors were aligned so that the ACAT1 cross-hairs were centered in both irises. This completed the initial alignment of the telescope.

3 Focal Tuning and Fine Alignment

An 8" diamter flat mirror was placed between ACAT1 and the secondary plate (entry aperture). ACAT1 was tuned to infinity and a reticle pattern was projected onto the back of the mirror. The 8" mirror was tuned in pitch and yaw until the retro-reflected beam was centered in the cross-hairs. The folding mirrors were then aligned further to ensure that the reflected laser beam was centered on both irises.

The mode-master beam scanner was set-up at the return port of the beam-splitter, to catch the return beam. Figure 2 shows a diagram of the final set up for the focal tuning of the telescope.

A flipper mirror was mounted in between the periscope mirrors, to reflect the input beam back to the mode-master, to obtain the input beam parameters. The input beam had a waist radius of approximately 1.9 mm and the waist position was approximately 5 m before the secondary mirrror.

Using the matlab code from [4], it was calculated that the waist of the return beam would have a radius of 450 μm and be located between 2 and 2.5 m from the secondary mirror, when the telescope was optimally tuned. The return beam was measured with the mode-master. The matlab code was used to compare the measured beam parameters with the calculated parameters, and calculate how far the telescope was detuned from optimal. We would then tune the secondary mirror appropriately, and adjust FM2 pitch to realign the return beam to the input beam, by centering it on the back of the irises. This procedure was repeated until the return beam parameters

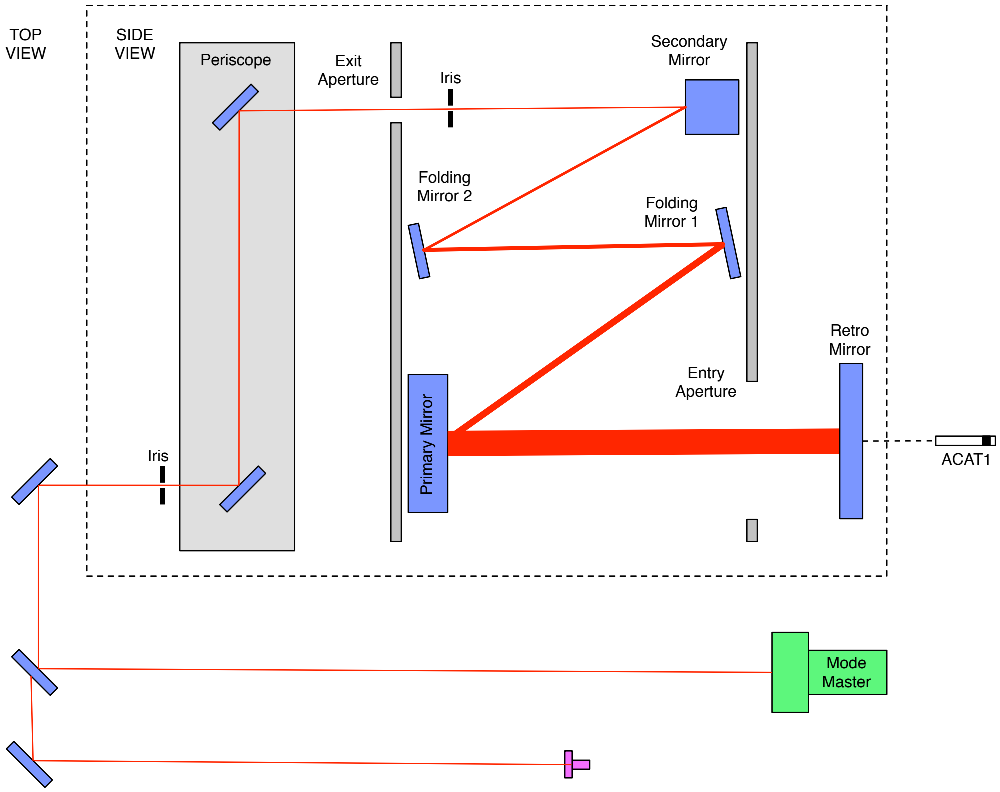

Figure 2: Set-up for measuring the mode parameters of the double passed beam.

were within the calculated tolerances. For full results, see [5]

At this point the telescope is aligned and correctly tuned.

4 Mating and Aligning the Table to the Telescope

Another iris was mounted to the telescope, this time to the secondary plate, and centered in the laser beam. The telescope was moved to the lower table, and stabilized with the stabilizing bars. The optical table [6] was mounted on top of the telescope, and the mated telescope and table were then suspended from the optical table support bridge [7]. Note that for the rest of this report we will use the mirror labeling from [6].

A green (532 nm) laser source was set-up. The green laser was fiber coupled. The output of the fiber was approximately collimated using a fiber collimator (Thorlabs F280APC-A), which gave a beam with waist radius approximately 2mm. The fiber collimator was mounted to a rotation stage that allowed us to set the declination angle to the required 21 degrees (within 0.5 degree). The green beam was shone onto the angled ALS receiving mirror (M8 in [6]) on the optical table. This mirror was adjusted in pitch and yaw, to align the beam to the next mirror. Each mirror was adjusted to steer the green beam on the table down the TransMon periscope and centered on the irises. The 8” retro-reflector was adjusted in pitch and yaw to make the return green beam pass back through the irises.

Once the input green alignment was set, the leakage green beam through the beam splitter, M3, was aligned to the QPD sled. The green beam was centered on both QPDs by adjusting M1 and

M2.

The infrared (1064nm) source was set-up with another rotation stage, and the declination angle also set to 21 degrees again. This infrared beam was shone onto infrared exiting mirror (M13 in [6]) on the table. It was aligned to the telescope using the green ghost beam from the IR beam splitter (M4). This green ghost beam was also used to align the beam-diverter mirror (M11) and M9 into the beam dump. Once the infrared beam was aligned to the telescope, the return beam was aligned to the infrared QPD sled, by adjusting M14 and M15 to centre the beam on the QPDs.

5 Cabling

The QPDs, Pico-mirrors and Beam Diverter have all been cabled up. The beam diverter was retested. The pico cables were tested with a spare pico (we didn't want to ruin our alignment), and the individual pico's were tested previously. The QPD's also give signals with incident light, these were used for alignment in the previous section.

5.1 QPDs

There are two QPD sleds on the breadboard, and each sled has two QPDs each. The cables for the two QPDs on a sled are both connected to a DB25 connector, see [8]. Both QPD sled connectors are mounted in the bracket on the primary mirror mount side. The green QPD sled is connected to the bottom connector in the bracket. The infrared QPD sled is connected to the top connector.

A QPD tester was used to check each QPD. All four quadrant diodes from each QPD were shown to be responsive, and for both QPD sleds the ordering of the QPDs is as expected, i.e. the near-field QPD was QPD1 and far-field QPD was QPD2.

5.2 Picos

There are four pico-motor driven mirror mounts on the bread-board, in the optical layout [9] these are the mirrors labelled M3, M4, M6 and M14. Each pico cable has a mighty mouse connector and four of these cables are connected to one DB25 connector, see [10].

The pico-motor connections are: J1 to lower connector in bracket on ETM side of bread-board. J2 to M3, J3 to M6, J4 to M4, J5 to M14. Each pico-motor was tested after the installation and shown to be responsive.

5.3 Beam Diverter

The beam diverter has one cable with a DB25 connector [11]. This connector is the mounted in the top connector in the bracket on the ETM side of the breadboard.

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