LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Technical Note **LIGO-T1000555-v4-D** Date: 2015/03/05

Adv. LIGO Arm Length Stabilisation - Vertex Layout Overview

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1 Introduction

The Arm Length Stabilisation system has been described in T0900144. In this note we describe the optical layout of the system in the corner station in more detail.

The major change is to relocate the critical ALS signal detection from the PSL table to ISCT1 in-air table. This is to ease commissioning efforts of the ALS system by limiting the need to access the PSL enclosure.

1.1 Supporting Documentation

- Adv. LIGO Arm Length Stabilisation Design (T0900144)
- PSL Table Layout with ALS optics (D1001944), has references to the PSL and IO-PSL layouts.
- TOP LEVEL ISC Equipment Block Diagram (D1000653)
- Advanced LIGO H1 Optical Layout (D0902838)
- List of ISC Photodetectors in Advanced LIGO (T1000264)
- H2 Input Septum Plate Port Locations (D1001665)
- Preliminary ALS installation schedule (single arm test) (E1000101)
- Arm Length Stabilisation, aLIGO Wiki page.
- Core Optics Coating Design Details, aLIGO Wiki COC Detailed Design

2 Basic Approach

In summary there is a 532 nm laser in each end-station which is directed into each arm cavity. The laser frequency if made resonant using the PDH reflection locking technique by feeding back to the laser frequency (see T0900144 for more details). The 532 nm transmitted light of both arm cavities are reflected or transmitted by the beamsplitter and directed towards the power-recycling-mirror. The second power-recycling-mirror (PR2) is made 'highly' transmissive for the 532 nm light. The transmitted light of PR2 (which comes from PR3) consist of the 1064 nm POP beam and the two 532 nm ALS beams which are co-linear (or close to). Via two steering mirrors these beams are reflected towards HAM1 (the beam shoots over the optics on HAM2, through the septum plate, D1001665).

Figure 1 provides a schematic overview of the ALS beams in the vertex. This shows that most of the critical ALS signal detection is done on ISCT1, located next to the HAM1 chamber. Previously this was located on the PSL table in the PSL enclosure. With the optics located on the ISCT1 commissioning access to the ALS readout is made easier.

In HAM1 the POP and ALS beams are separated by a dichroic. A small portion of the POP beam is directed to the viewport towards ISCT1. Also, the 532 nm ALS beams are reflected

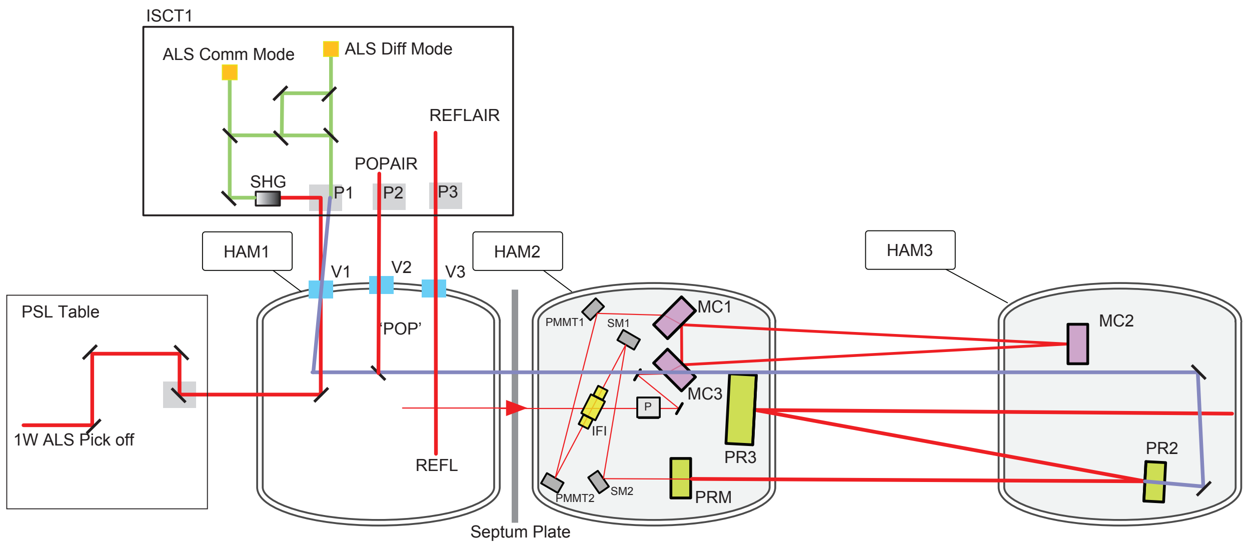

Figure 1: Vertex layout of the ALS system. P1, P2 and P3 are periscopes, 'POP' indicates the PR2 transmitted beam which contains the 1064 nm POP and two 532 nm ALS beams. V1, V2 and V3 indicate the vacuum viewports.

out of the vacuum towards ISCT1. A ∼2 ft periscope on ISCT1 will drop both beams down to a 4" beam height on the table.

3 ALS Table Layout - ISCT1 and PSL

To obtain the ALS Common Mode signal the 532 nm transmitted beam from the X-arm is combined with a 532 nm beam from the PSL. This is achieved by directing the 1 W ALS pick-off on the PSL table (just before the EOM), via a periscope into HAM1 and reflected through a viewport and periscope onto ISCT1 (see figure 1).

Figure 2 shows the ISCT1 table which holds the POP periscope and optics to separate the POP and ALS beams. The POP beam is directed to the LSC_POPAIR_A, LSC_POPAIR_B and LSC_SPOPAIR_A detectors. The REFL periscope directs the REFL beam to the LSC_REFLAIR_A and wavefront sensors ASC_REFLAIR_A and ASC_REFLAIR_B. The LSC and ASC detectors are referenced in T1000264.

The PSL periscope directs the 1 W 1064 nm beam from the PSL table towards the SHG, which provide the 532 nm local oscillator for the ALS Common Mode signals.

Figure 3 shows the PSL table with the reminder optical components for the ALS system. The 1 W pick-off is taken from the folding mirror prior the EOM which provides the main modulation sidebands for the IFO. The beam is routed around the table to one of the support legs of the periscope, which holds a folding mirror which reflects the beam into HAM1 (the exact beam path is TBD).

Also on the PSL table is the pick-off from the transmitted beam of the reference cavity. The light incident on the reference cavity if frequency upshifted by +158.8 MHz via a double pass

AOM at +79.4 MHz[1] . The the transmitted beam from the reference cavity is injected into a fiber coupled AOM to downshift (-158.8 MHz) the light to the nominal PSL frequency. The light after the fiber coupled AOM will be split in two and sent to each end-station. A chassis with the fibre coupled AOM, and amplifier and fibre couplers will be located outside the PSL enclosure (an alternative location is inside the diode room). A diagram of the AOM chassis is shown in figure 4.

The power levels for the reference cavity pick off are listed in table 1.

Table 1: Power levels of the Reference Cavity transmission pick off.

	efficiency	power [mW]
ALS pick off after Ref Cav periscope	-	8[2]
Power coupling into fiber (and output of the fiber)	70% coupling efficiency	5.6
Power after pick off	T=20%	1.1
Power into AOM	T=80%	4.5
Power after AOM	75%	3.36
Power chassis output	33% (33/33/33 fiber splitter)	1.1
Power out of the fiber in the VEA	∼63% (4km @ 0.5dB/km)	0.7

4 Optics

The ALS system uses two wavelengths, 1064 nm and 532 nm. In general only 1" diameter optics are used, with only the odd 2" diameter optics. The 2" optics will predominantly be used in the periscopes.

All in-vacuum 1064 nm mirrors will be 'super-polished', high quality HR coating. Whereas all 532 nm mirror will be high quality polished and a high quality HR coating (Precision Photonics). The polarisation on the ALS tables is 's'-polarised.

As for the lenses and their coatings, standard CVI (or Newport) lenses will be used. Due to the low powers in the ALS system, no major scatter issues will be perceived.

4.1 PSL components

Table 2 list the hardware for the components located on the PSL for the fiber coupling.

[1] email conversion with Benno Willke 24 Nov 2011: **Re: upshift?**

[2] depending on the splitting ration this value can vary between 5 mW and 8 mW.

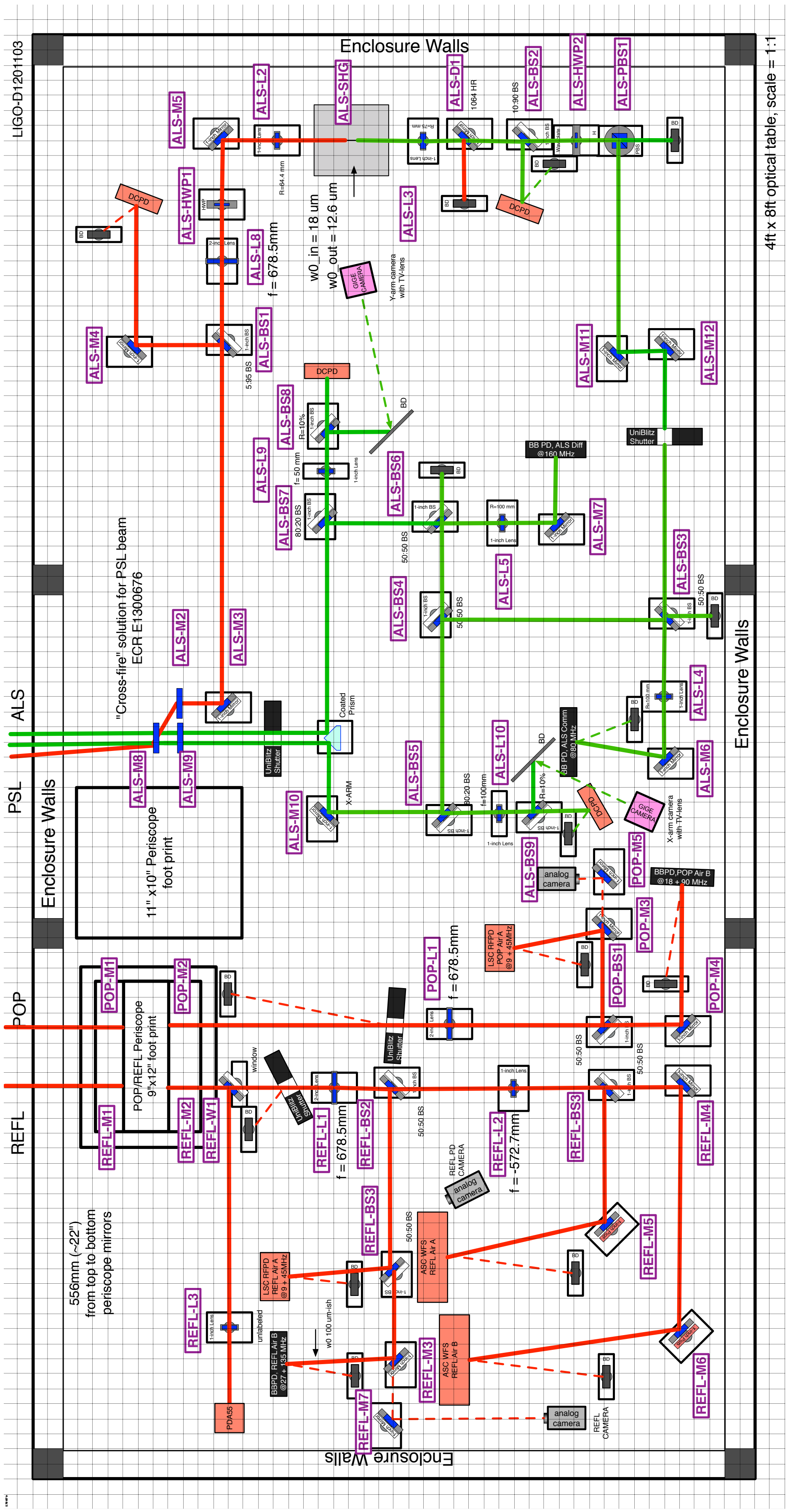

Figure 2: Proposed optical layout of the ISCT1 in-air table located next to HAM1. The LSC and ASC detectors are from D1201103

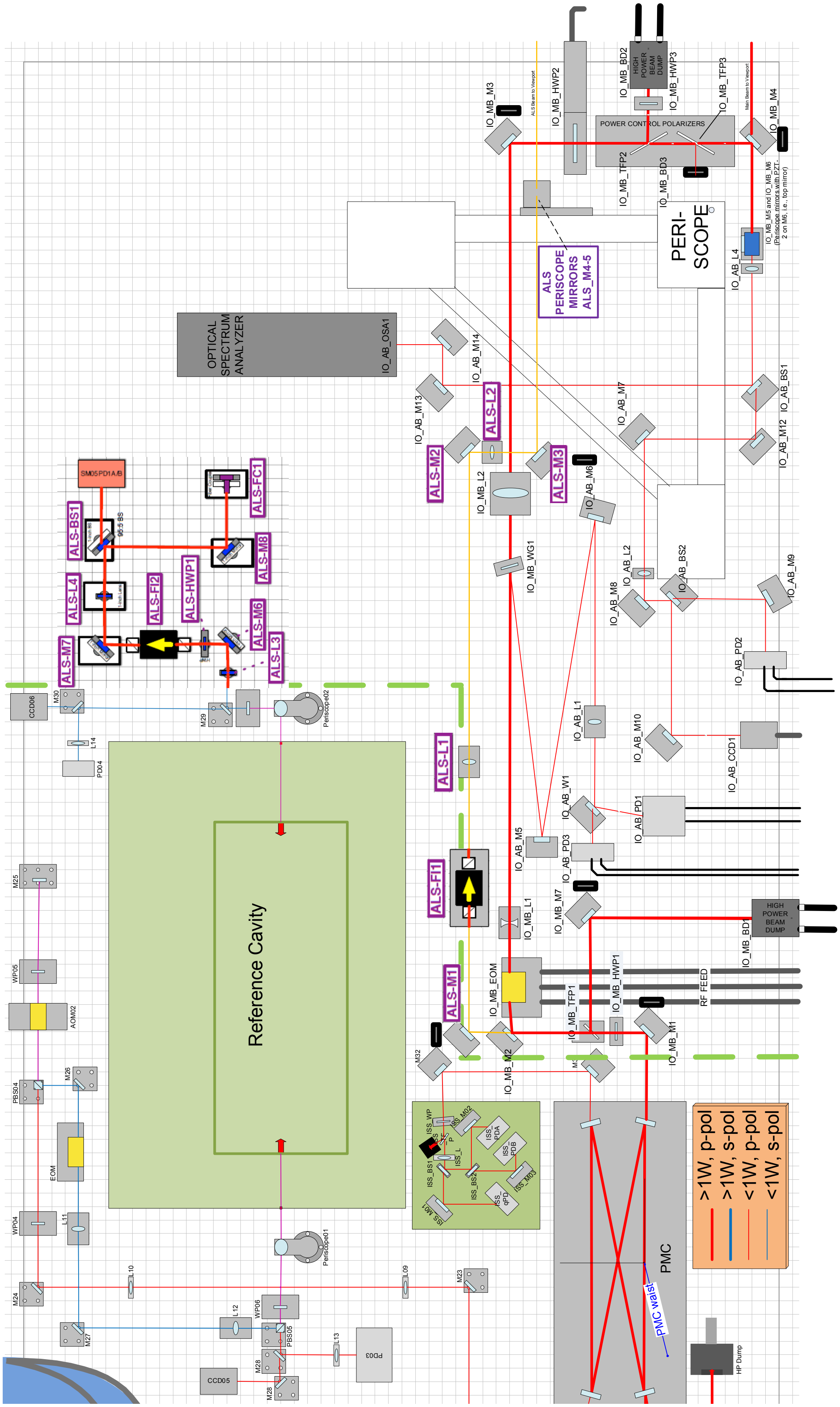

Figure 3: Modified PSL table, with the modifications for the ALS beam indicated with a 'yellow' beam. Routing of the 1 W beam prior the EOM through a periscope directed into HAM1, from D0902114

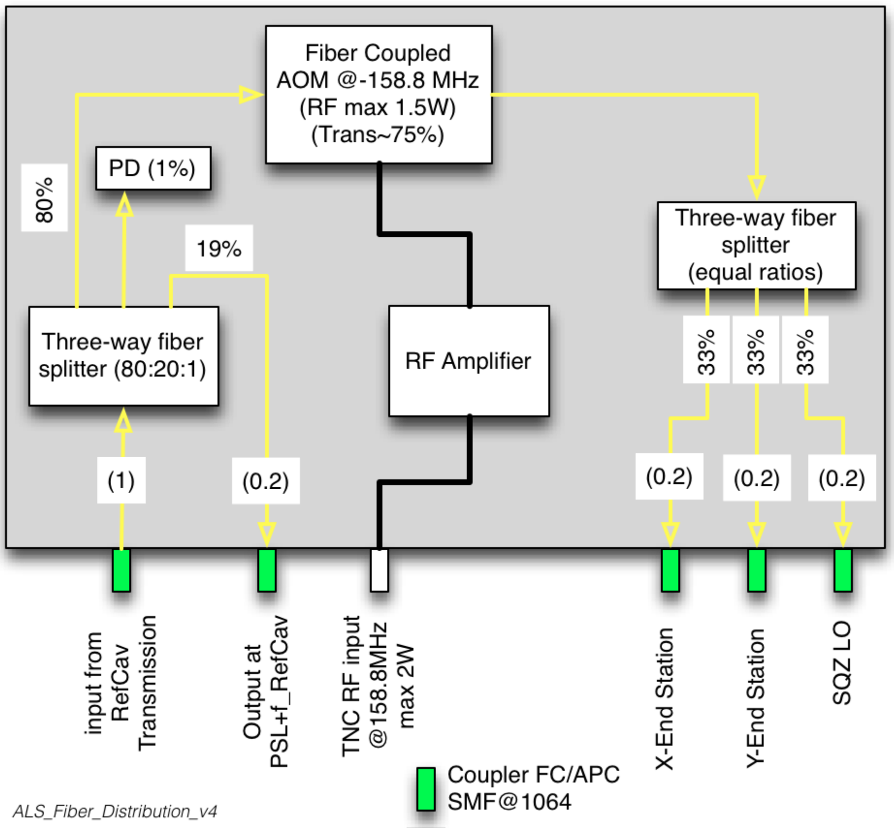

Figure 4: The ALS fiber AOM chassis. There is a single optical input, with a 20% tap-off, which goes into the fiber coupled AOM. A 1% tap-off is coupled into a photodiode to measure the relative fiber input. The AOM has approx. 75% transmission, which get split in three equal ways. All optical connections are angle-cut PC, reducing back reflections. The AOM has a 2 W maximum RF input (damage limit). It will be a 2U chassis based on the RF source, and is connected to the EtherCat concentrator for monitoring the the various signal levels.

Table 2: Hardware on the PSL table for the ALS. All parts provided by ALS/ISC, width a nominal beam height 4".

Hardware	**Qty**	**Comments**
Steering mirrors + mounts	3	HR@1064nm, ISC recycled from iLIGO
Faraday Isolator + mount	1	ISC recycled from iLIGO
Lenses + mounts	2	TBD, ISC recycled from iLIGO
Polarising Beam sampler + mount	1	ISC recycled from iLIGO
Half waveplate + mount	2	ISC recycled from iLIGO
Free space to fiber coupler + mount	1	Thorlabs coupler (ALS/ISC)
Single mode fiber (PC/APF)	1	Thorlabs single mode @1064nm (ALS/ISC)
Fiber PC connector bracket	1	Thorlabs (ALS/ISC)