



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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aLIGO ISC Custom Optics Requirements

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1 Design Overview

In Advanced LIGO several ISC photo-detectors (LSC RF PD, WFSs, QPDs) are placed within the vacuum envelope, and not in in-air tables as during Initial LIGO. The driving reason for this choice is to minimize coupling of scattered light and environmental noises by relying entirely on signals produced by in-vacuum diodes for controlling the interferometer in science mode (low noise) operations.

A direct consequence of this approach is that the optical layout of the in vacuum optical tables greatly increased in complexity with respect to Initial LIGO. In order to achieve the wanted beam parameters and power levels on each diode several different types of optics (high reflectors, beam splitters of different splitting ratios, lenses, curved optics) for the main 1064 nm laser light wavelength are now placed in vacuum. Moreover, auxiliary laser light at 532 nm (green) wavelength is used to facilitate lock acquisition in Advanced LIGO, thus further increasing the number of required optic types to rout the green light in and out the arm cavities.

The result is that each Advanced LIGO interferometer has more than 100 small (1" or 2") ISC in vacuum optics total, populating HAM1, HAM3, HAM6, and the two TRANSMON tables, spanning more than 15 different coating requirements.

Only HAM1 and the TRANSMON tables accommodate optics coated for 532 nm light. 1064 nm light is (horizontally) p-polarized at the interferometer Beam-Splitter, while 532 nm light is (vertically) s-polarized, and the polarization is maintained on the in-vacuum optics tables. The only exception to this rule comes from the 1064 nm beam reflected by the interferometer and rejected by the Input Faraday (REFL path) in the vertical polarization. The polarization is changed back to horizontal right after reaching HAM1 by means of a half-waveplate.

2 General Requirements

A detailed specification document describes design requirements for each type of ISC optic purchased for use in the Advanced LIGO in-vacuum tables. Here we summarize the general guidelines which we have been following when setting requirements and during the overall purchasing process.

2.1 Substrates

The general guideline used to set the requirements when purchasing Advanced LIGO ISC optics is that fused silica **super-polished optics** should be used for 1064 nm light. This requirement is motivated by several measurements which show how the amount of light scattered by super-polished optics can be even more than two orders of magnitude lower with respect to optics with commercial polish.

It is important to point out that depending on the particular position of the optic this requirement could in principle be relaxed (for example, if an optic is used to route a low power beam onto a beam dump). However, given the large number of optics required for the three Advanced LIGO interferometers, it turned out that there was no significant cost benefit in relaxing this requirement, so only super-polished optics have been used for 1064 nm light.

For 532 nm light the impact of scattered light has been evaluated to be less important, as this laser light wavelength is only supposed to be used during lock acquisition. Super-polished optics have been purchased only when the large number of optics required for a particular type made the price for custom super-polished optics comparable to the one of commercial polished optics.

2.2 Coatings

Ion-Beam-Sputtering coatings have been selected for all the optics as they guarantee lower scatter and absorption losses with respect to other manufacturing techniques.

2.3 Purchasing process

In general, for each type of optic we could find at least one or two vendors willing to accept the job for a competitive offering price, and there was no need to revise our requirements.

The only exception comes from super-polished lenses. We could not find a single vendor able to produce super-polished lenses of the required focal length at an acceptable price. For this reason we relied on two different vendors, one producing commercial polished lenses of our required focal length, and another vendor able to re-polish the substrates to super-polished quality, and apply the AR/AR coating. The quality outcome of this apparently convoluted process had been extensively evaluated before purchasing the Advanced LIGO optics¹.

3 Optics Handling and Storage

In general, optics handling should be minimized. Optics should be removed from the original container provided by the vendor only for quality inspection and when starting the cleaning process for in vacuum use (<https://dcc.ligo.org/LIGO-E1100439>). If the optics are not placed directly in the optic holder for installation after cleaning, they should be stored in dedicated containers. For their outgassing characteristics and clean room compatibility these type of optics containers have been selected for use in Advanced LIGO: <http://www.opticspackaging.com/>. Similar containers are acceptable.

Optics must always been handled by wearing Latex gloves in a clean environment (at least class 1000 clean room or air-flow bench), both before and after cleaning.

When installing a clean optic in the optic holder for installation, the optic must always been handled by touching the edges, and never the optical surfaces.

¹ Super-polished lenses have been purchased for the H1 squeezing experiment in 2009-2010 by following this strategy. These lenses showed to produce of the order of 100 times less scattered light than lenses with commercial polish.

A better solution was not founded when approaching vendors again for purchasing Advanced LIGO ISC optics in 2011-2012.