LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

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LIGO-T1000147-v1 *LIGO* 3/17/10

TGG Crystal Wedge Angle for aLIGO Output Faraday Isolator

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1 Introduction

The purpose of this note is to determine the acceptable minimum wedge angle on the Output Faraday Isolator TGG crystal surfaces that will not cause excessive back-scattered light noise.

2 Analysis

2.1 Surface Roughness

The TGG crystal wedge surface is assumed to have a micro roughness <20-40 nm. This is considered a super-polished surface.

2.2 BRDF

We will use the measured BRDF of the initial LIGO pathfinder optic S/N 2 polished by CSIRO to estimate the scattering of the super-polished TGG crystal.

The BRDF of S/N 2 is described by the following analytical expression:

BRDF, sr^-1; CSIRO, surface 2, S/N 2

$$BRDF_1(\theta) := \frac{2755.12}{\left(1 + 8.5078710^8 \cdot \theta^2\right)^{1.23597}}$$

which describes the fractional scattering per solid angle at an angle θ from a beam at normal incidence to the surface.

If the surface is tilted, this same expression will describe the scattering at an angle measured relative to the specular reflection direction.

The back-scattered BRDF at small incidence angles on the tilted surface will be estimated as the BRDF at twice the incidence angle

For a 0.5 deg wedged TGG surface, the backscatter BRDF will be calculated at an angle of 1.0 deg.

BRDF_Faraday, sr^-1 @ 0.5 deg

$$BRDF_1(\theta) = 5.612 \times 10^{-4}$$

2.3 Scattered Light Noise

The scattered light noise of the suspended optical surfaces of the Faraday Isolator, mounted to the HAM ISI platform, is calculated by assuming all the 9 scattering surfaces of the Faraday input side have a BRDF = 0.005 sr^-1. This meets the Thermal Noise requirement, as shown in Figure 1.

Even if the BRDF of the TGG crystal were ten times larger, e.g. BRDF = 0.005 sr^-1, it would only contribute 0.11 of the scattering noise and is a negligible scattering source.

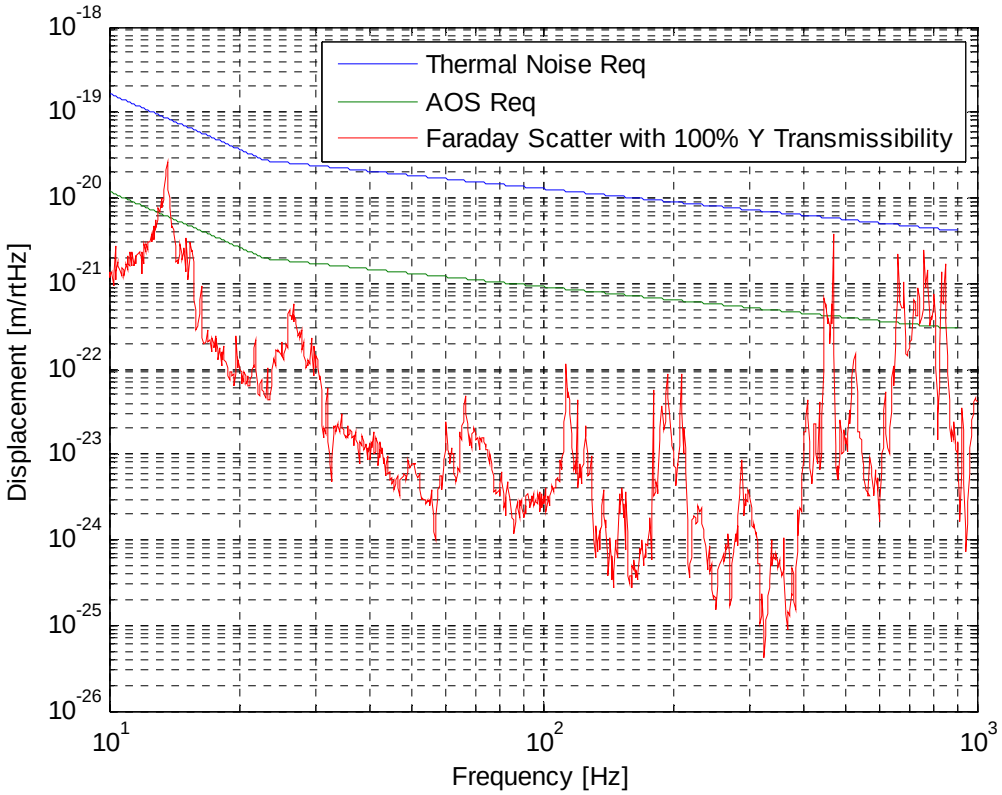

Figure 1: Displacement Noise of Output Faraday Isolator, with 0.5 deg TGG Crystal

3 Conclusion

The specification of the TGG crystal will be revised to allow a wedge angle of 0.5 deg. However, the orientation of the wedge angle should be marked so that it can be oriented in the horizontal plane, which will allow vertical pitching of the Faraday assembly to avoid glints from the input wedged plates.

A micro roughness specification will be added: rms micro roughness not to exceed 40 nm RMS.

4 References

T980027-00 Baffling Requirements for the 4K and 2K IFO

L1000120 Mike Burda EOT e-mail micro roughness of TGG

E980131 Output Faraday Isolator, 20 mm Specification

T0900269-v3 AOS SLC PDD

Note: the calculations for Output Faraday Isolator scattering were originally done for 5 surfaces with a BRDF of 4.9E-6 per surface. In figure 1, the calculations were revised using N=9 and BRDF = 0.005, using the actual measured transmissibility of the OFI suspension prototype.