CNRS
Centre National de la Recherche Scientifique

INFN
Istituto Nazionale di Fisica Nucleare

AdV - Stray Light Control: Impact of the coating ripples on the cryotrap baffles

VIR-0137A-13

J. Marque[1*], A. Chiummo[1], and R. Day[1]

[1] *EGO - European Gravitational Observatory*

Date: April 24, 2013

[*] *corresponding author:* julien.marque@ego-gw.it

VIRGO* A joint CNRS-INFN Project - EGO* the site of the VIRGO project
Via E. Amaldi, I-56021 S. Stefano a Macerata - Cascina (Pisa)
Secretariat: Telephone (39) 050 752 521 * FAX (39) 050 752 550 * Email: ego@ego-gw.it

Contents

Introduction

In order to set requirements for SLC baffles (i.e. essentially backscattering of the baffles and seismic isolation of the baffles), one needs to know first how much light impinges on the specific baffle, and secondly how much of the light back-scattered by this baffle will re-couple into the cavity. This depends on the surface defects of the mirrors. For small angle scattering in particular (paths 1a and 1b on Figure1), the requirements of the CryoBaf and MirBaf can be calculated thanks to the mirror phase maps.

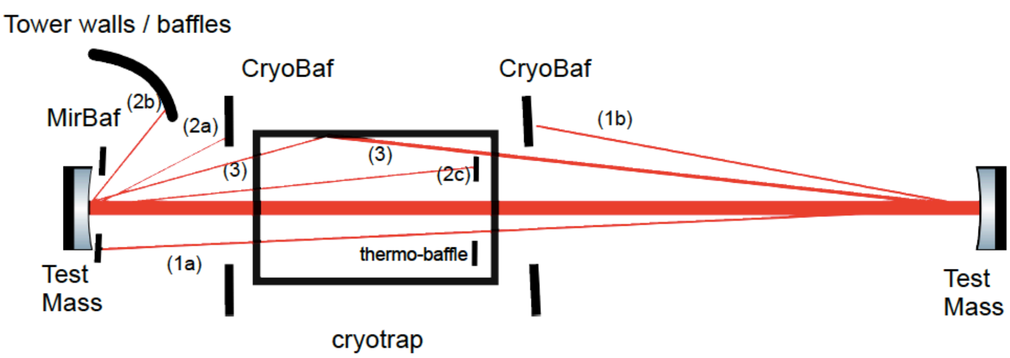
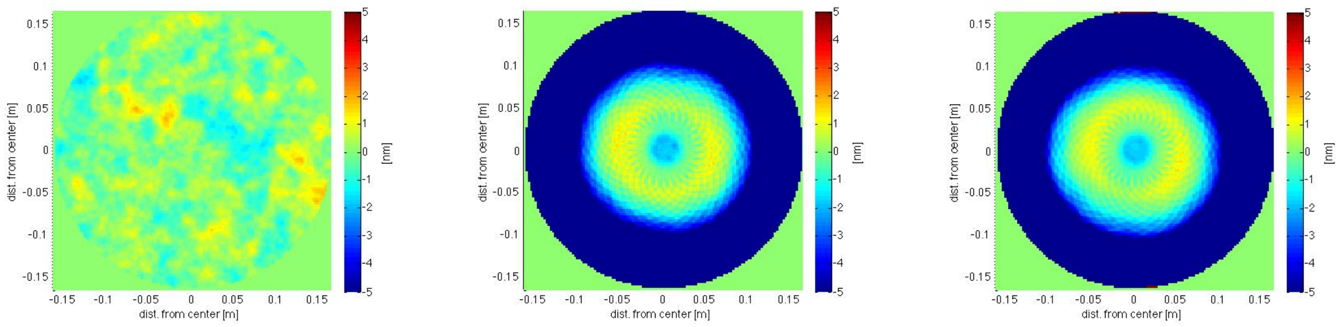


Figure 1: Re-coupling paths for scattered light (lengths not at scale). In this document we focus on path (1b).

These simulations/calculations were done in [1] for MirBaf and [2] for CryoBaf. The mirror maps were randomly generated based on the polishing requirements. Today, we know that the ETM real maps measured by LIGO differ from the ones we were expecting (the ones we randomly generated).
The randomly generated map is compared with both aLIGO ETM measured by LIGO [3] in Figure 2. The PSDs of these 3 maps are compared in Figure 3.

The measured maps are better for some spatial frequencies and worst for other ones. We will focus in this note on the study of the peak at $130m^{-1}$ which seems particularly high. Note that this peak is a feature which is known to be due to the motion during the coating deposition process [4].
The goal of this short note is to analyze the impact of the peak at $130m^{-1}$ on the CryoBaf requirement. Indeed, we expect this peak to generate an extra ring of scattered light that should impinge on the Cryotrap baffle: the diameter of the ring should be equal to λ x130x3000x2 = 830mm, while the inner and outer diameters of the Cryotrap baffle are respectively 600mm and 940mm (the inner diameter of the baffle of the tube close to the towers is 920mm while the inner and outer diameters of the mirror baffle are respectively 340mm and 600mm).



(a) (b) (c)

Figure 2: Typical expected mirror surface figure error with 0.5nm RMS (a), aLIGO measured mirror surface figure error of ETM7 (1nm RMS) (b) and ETM9 (0.9nm) (c).

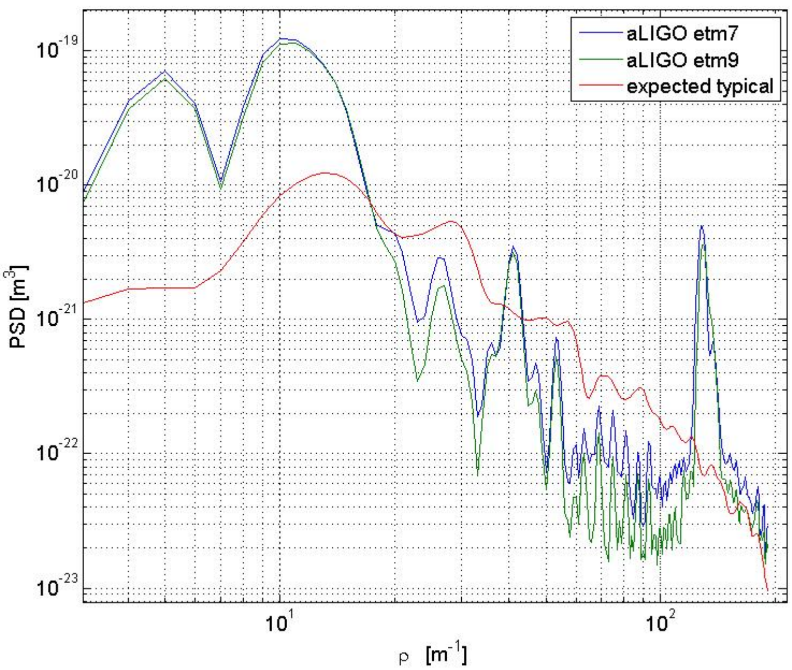


Figure 3: Measured PSD of 2 aLIGO ETM compared with a typical expected PSD in AdV that was used for calculating the requirements of SLC.

1 Simulations

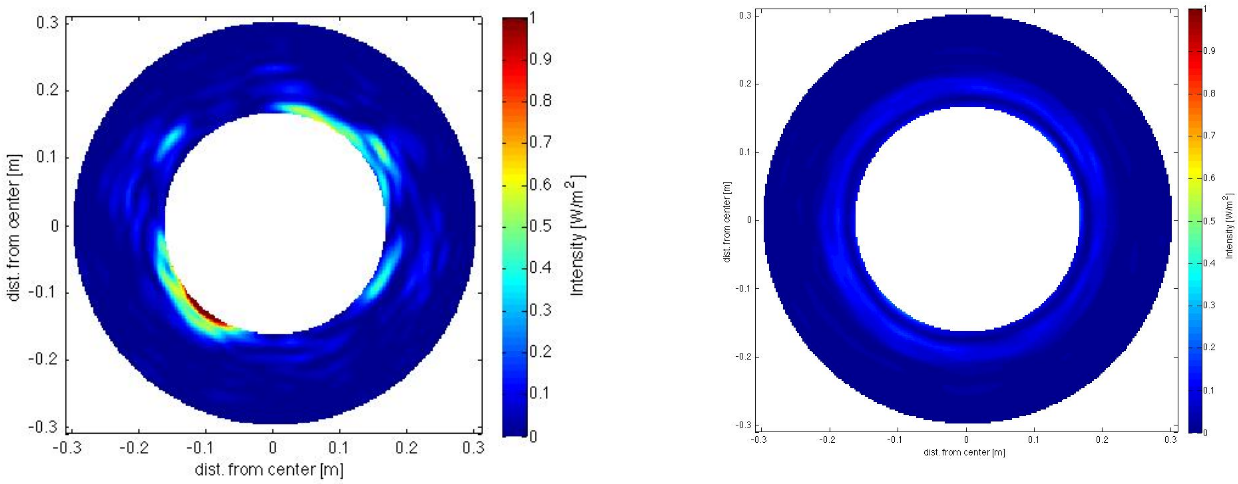
We used the FOG simulation [5] to calculate the fields impinging on the MirBaf and on the CryoBaf when the arm cavity (AdV geometry) is locked with 1W at the input in 2 cases:

- **Case1**: the input and end maps are 2 expected typical maps (randomly generated) with 0.5nm RMS (the RMS given in this document are weighted by the power distribution of the beam onto the mirrors),
- **Case2**: the input map is the measured ETM7 aLIGO map (1nm RMS), while the end map is the measured ETM9 aLIGO map (0.9nm).

It is worth stressing that all the maps were down sampled to use them in the simulations, down to a resolution of $\Delta x \sim 2.6mm$, corresponding to a maximum spatial frequency of $\rho = 1/(2\Delta x) \sim 190m^{-1}$; their residual RoC and tilt were removed before using them in the simulation. PSD plots in Figure 3 are computed after this operation.

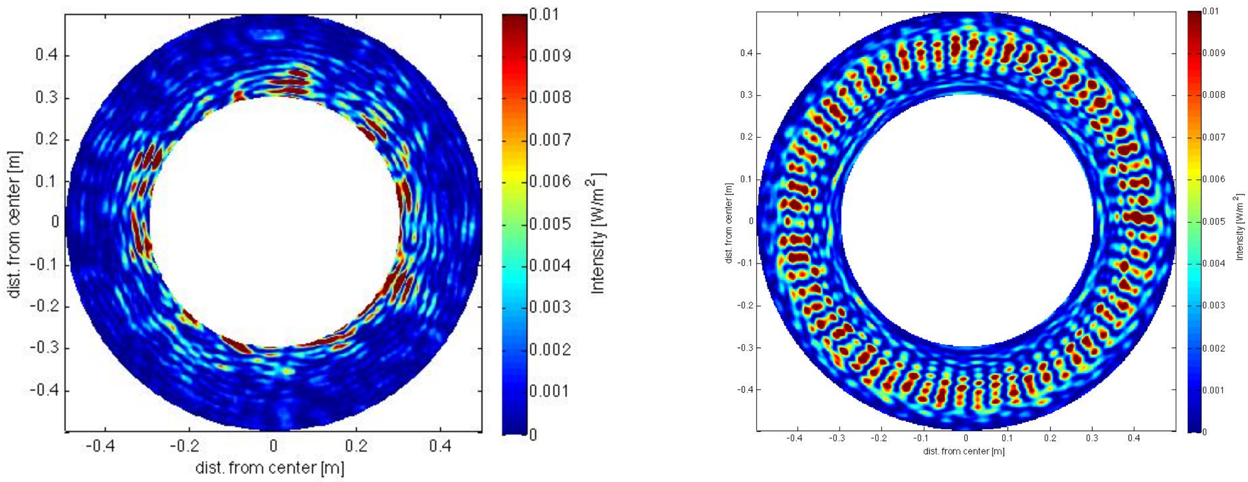
2 Results

For a 1W input power, the distribution of power onto the MirBaf and the CryoBaf at the ETM are shown in Figures 4 and 5 where the 830mm diameter ring is well visible.



(a) (b)

Figure 4: Distribution of power on mirror baffle for case1 (a) and case2 (b).



(a) (b)

Figure 5: Distribution of power on CryoBaf for case1 (a) and case2 (b).

For a 1W input power at the arm cavity, 5.7mW is caught by the EM MirBaf for real maps against 10.4mW for typical expected maps; 1.4mW is caught by the EM CryoBaf for real maps against 0.8mW for typical expected maps; 1.8mW is caught by the IM MirBaf for real maps against 3.7mW for typical expected maps; 1.3mW is caught by the IM CryoBaf for real maps against 0.4mW for typical expected maps.
The CryoBaf may be expected to be a bit more critical than expected then. But one must also take into account a quite different distribution of the light on the CryoBaf which may play a role in the final recoupling factor.
So, we repeated the same calculations done in [2] in the 2 cases in order to calculate the amount of power that is recoupled in the cavity by the Cryotrap baffles . This calculation assumes a tilt of 7 degrees of the Cryotrap baffles with respect to the beam axis as well as a certain BRDF of the Cryotrap baffle surface at this specific angle: a BRDF of 0.003 at 7 degrees is assumed.
We found that in both cases the recoupling into the arm cavity is about the same: 4e-25W for 1W at the cavity input. The recoupling is then unchanged with real maps.
One can add that, in case1, the round-trip losses are 55ppm, against 37ppm in case2. So, the real maps generate losses that fit the AdV round-trip loss budget (which is 50ppm for mirror figure error).
The total round-trip losses of the cavity will then likely be composed of:

- 25ppm due to mirror figure error at low spatial frequency (this light will be absorbed by the mirror baffle),
- 10ppm due mainly to the ripples of the coating (this light will be absorbed by the Cryotrap baffle),
- about 20ppm due to point defects [6] or even less according to recent measurements [7],
- and a few ppm of coating absorption, transmission, diffraction and scattering due to the micro-roughness of the surface.

Conclusions

The measurements of the first ETM maps of aLIGO show a specific feature in the PSD: a peak at $130m^{-1}$. We calculated that, as a consequence, using these maps in the AdV arm geometry configuration, the power impinging on the CryoBaf will be about 2 times more than expected. However, the recoupling of light into the cavity from this baffle is unchanged, meaning that the Crotrap baffle with the following characteristics will make its job: inner diameter of 600mm, outer diameter of 940mm, tilt of 7 degrees, and a BRDF of 0.003 at 7 degrees.
Note that the coating ripples have been analyzed also by our LIGO colleagues [4]. The conclusions differ due mainly to 2 differences between Virgo and LIGO:

- the arm is longer in LIGO leading to a diameter of the ring of about 1.1m against 0.83m in Virgo,
- the cavity axis is offset with respect to the tube axis by 215mm.

The contribution from the scattering of the beam tube baffles is then largely enhanced with respect to Virgo, since the minimum distance between the beam tube baffle edge and the beam axis is 310mm in LIGO (against 460mm for Virgo).

Aknowledgments

We acknowledge H. Yamamoto and J. Degallaix for useful discussions and LIGO for sharing with us the measurement of the first ETM maps.

References

[1] A. Chiummo for SLC, "Preliminary Computation of AdV arm-cavity baffle displacement noise projection", Talk at GWADW 2012, VIR-0188A-12 1

[2] A. Chiummo, J. Marque, "Calculation of displacement noise induced by the cryotrap baffle", VIR-0272A-12 1, 4

[3] G. Billingsley, "aLIGO ETM07 and ETM09 measurement for coating uniformity verification", LIGO-T1300184-v1 1

[4] P. Fritschel, H. Yamamoto, "Scattered light noise due to the ETM coating ripple", LIGO-T1300354-v2 1, 4

[5] R. Day, "A new FFT code: FOG Fast Fourier Transform Optical Simulation of Gravitational Wave Interferometers", Talk at GWADW 2012, LIGO-G1200629-v1 2

[6] H. Yamamoto, "aLIGO Core Optics and interferometer performance", LIGO-G1300398-v1 4

[7] L. Pinard, "MIR status", VIR-0162A-13 4