STABILITY OF LOW LOSS SUBSTRATES FOR COATING RESEARCH: FROM EDGE EFFECT TO AGEING.

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Abstract

Thermal noise due to multi-layer dielectric coatings limits the sensitivity in gravitational wave detectors from few tens to hundreds Hz, where first gravitational wave signals were detected and others are expected [1]. Coating thermal noise is directly related to structural dissipation inside the material [2]. In view of future upgrades of gravitational wave detectors, increasing the mechanical performances of reflective coatings, lowering loss angle (ϕ) and retaining their outstanding optical and morphological properties, is fundamental. The mechanical characterization of substrates and coatings can be performed measuring ϕ in small disk-shaped samples, on which different coatings material can be deposited. The ϕ measurements can be performed through the ring-down method, exciting the resonant mode of the sample and measuring the exponential decrease in the free oscillation amplitude. The sample has to be held by some kind of suspension or clamping, making the coupling between the two negligible: in the Gentle Nodal Suspension (GeNS) system the sample is placed in equilibrium from its centre on top of a sphere, providing a mechanically stable support [3]. GeNS allows to avoid the clamping of the samples and the contact area is minimized; its reproducibility is within 5%. GeNS is worldwide recognized as one of the most powerful tool for coating characterization. Coating loss angle can be derived by a differential measurement, of the sample before and after the coating deposition. To perform a precise coating mechanical characterization, the substrate on which it is deposited must be characterized as well and must be stable with respect to its dissipative behaviour. Mechanical losses of commercial SiO_2 substrates have a frequency dependent behaviour and are subjected to ageing. These effects compromise the accuracy or even the detectability of the coating loss angle. The source of this deterioration can be related to the ground, unpolished lateral surface [4]. The effect of spurious losses can be quantified from the loss angle separation of different classes of mode shapes, since different resonant modes store different amount of elastic energy in the barrel surface. The polishing of the samples edge reduces the amount of spurious losses and ageing effects coming from the absorption of impurities through the edge itself. We designed and assembled a facility for a CO_2 laser polishing of the substrate barrel [5], to provide a reliable heat treatment, reducing spurious losses to a negligible level. Other further treatments have been tested, with the aim of minimizing ϕ deterioration. Results of mechanical characterization of SiO_2 substrates before and after CO_2 laser polishing and thermal annealing are shown. The measurements are compared with edge losses model and other proposed models.

References

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