Bi-filar pendulum mode Q factor for silicate bonded pendulum

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Abstract. An all fused silica pendulum with record $Q$ factor fabricated using the technique of hydroxide-catalysis bonding is described. Possible sources of loss which limited the measured $Q$ are discussed.

INTRODUCTION

Thermal fluctuations of the mirror surface position in an interferometric gravitational wave detector are one of the principle limits to interferometer sensitivity. In order to reduce these fluctuations it is necessary to reduce the dissipation in the relevant modes of the mirror’s suspension. Fused silica is a good material for the test masses (mirrors) and their suspension fibers because of the low mechanical losses of this material. The highest quality factors of pendulum and violin modes of suspensions have been obtained for monolithic fused silica pendulums with suspension fibers attached to the test masses and support structure by welding. Welding excludes the additional losses often associated with clamps. Experiments in Moscow (1) and at Glasgow (2) have demonstrated loss factors of $(1 \pm 0.3) \times 10^{-10}$ for pendulums suspended by fused silica fibers with welded attachments. Improvements of the technique for fabricating monolithic fused silica pendulums and more perfect experimental set-up allowed the Moscow group to achieve the quality factor $Q \approx 1.7 \times 10^8$ for the torsional mode of a 2 kg bifilar pendulum, whose loss properties are similar to those of the simple pendulum mode.

An alternative method of attaching the fused silica suspension fibers to the test masses - hydroxide-catalysis bonding - was investigated at Glasgow (3). This method is more convenient for jointing suspension fibers to large test masses. Measurements give an estimate of the excess loss of $(3 \pm 1) \times 10^{-9}$ associated with a hydroxide-catalysis bonded area of $0.8 \text{ cm}^2$ for the fundamental modes of fused quartz test masses (3). This paper describes a pendulum with record $Q$ factor fabricated using hydroxide-catalysis bonding technique.
METHOD AND RESULTS

A 0.5 kg fused quartz cylinder was suspended by two fused silica fibers of length 24 cm and diameter ~ 0.2 mm. In previous all-welded pendulums the fibers were welded to small bumps carved in a cylinder. In the pendulum described here the fibers were welded to the fused quartz cones which were attached to the cylinder using hydroxide-catalysis bonding. One can find a detailed description of this technique in [3]. The top ends of the suspension fibers were welded to a fused silica disk which was attached via an indium gasket to the cover of a vacuum chamber fastened rigidly to a concrete wall. The chamber was then evacuated to a pressure of ~ 1x10^-7 Torr. The construction was baked at 100-150 deg C for about 6 hours. The torsional mode of the bi-filar pendulum, with a resonant frequency of 1.17 Hz, was excited using a mechanical pusher. An optical sensor was used to monitor the amplitude of angular motion. Free decay of the amplitude is shown in Fig.1. The $Q$ factor was found to be 2.3x10^8 +/- 10%.

This measured $Q$ can be compared with the expected $Q \approx 1x10^9$, obtained from calculations based on the pendulum dilution factor and the measured loss angle of $\phi \approx 1.4x10^{-7}$ for the fused silica fibers. The discrepancy may be explained by incomplete elimination of possible sources of excess loss such as recoil losses, contact losses in indium gasket at mounting point, fiber surface contamination and others. But it is important that at achieved level of $Q$ we did not see losses associated with hydroxide-catalysis bonding.

REFERENCES