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Measuring coating loss angle in thermoelsatic-dominated crystalline substrates for new generation gravitational wave detectors

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Coatings of materials with low optical and mechanical losses find prominent application in present terrestrial interferometric gravitational-wave detectors. The mirrors of the interferometers currently consist of fused silica substrates coated with stacks of alternating layers of amorphous silica and titania-tantala mixing. Research and development of novel materials is very active, since a major limitation to the sensitivity of the detectors in the middle-frequency range (40 - 400 Hz) is due to thermal noise within the coating, which is directly related to its mechanical loss angle. For the new generation of detectors, operating at cryogenic temperatures, crystalline substrates and coatings are also being explored; they present unique challenges with respect to the metrology of mechanical loss angle, since the loss in the sample substrates is dominated by thermoelastic dissipation.

The usual method of loss angle measurement in a coating is based on the stationarity of the substrate: the characteristics of the substrate do not depend on the presence of the film. However, the thermoelastic contribution to the dissipation in a substrate, after coating deposition, is influenced by the thermo-mechanical parameters of the film, which are generally unknown. Therefore, whenever thermoelastic loss is dominant, the loss measurements are significantly affected.

We develop a model that helps to understand the role of each material property in the thermoelasticity of layered plates, and based on this we identify three possible cases in which any coating-substrate combination could be classified. This allows an estimation of the expected change in thermoelastic loss after coating deposition, and enables the careful choice of the best sample geometry in order to minimize it, a choice that can be tailored for each specific material combination.

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