Three methods for characterizing thermo-optic noise in optical cavities

Elizabeth M. Gretarsson*
College of Optical Sciences, University of Arizona, 1630E. University Blvd., Tucson, AZ 85721

Andri M. Gretarsson
Embry-Riddle Aeronautical University, 3700 Willow Creek Rd., Prescott, AZ 86301

Thermo-optic noise is likely to be the dominant noise source in next generation ultra-low noise optical cavities. We developed three measurement and analysis methods allowing us to estimate the level of coating thermo-optic noise in optical cavities, including interferometric gravitational wave detectors. We measured the shift in the broadband transmission spectra as a function of temperature for single-layer, high index coatings in order to find the thermo-optic coefficient, β_H, of a coating while assuming the thermal expansion coefficient, α_H. Our value for β_H could then be used to calculate the thermo-optic noise in any high-finesse optical cavity using coatings with the same high index layer material. We also measured the spectra as a function of temperature of a multi-layer, high-reflective coating where the material composition of the layers was similar to the coatings installed in Advanced LIGO. This method has the advantage of allowing us to calculate thermo-optic noise directly; α_H and β_H don't need to be known separately although we do need to know the value of the overall coating thermal expansion coefficient. Finally, we used lasers of different wavelengths to measure transmission changes on the band edges of a multi-layer high reflective coating. This gave measurements with high statistical precision but potentially lower systematic accuracy. To address systematic accuracy concerns, we used a constrained Monte-Carlo application of the theory of multilayer coating transmission.