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Toward a sub-kelvin cryogenic Fabry-Perot silicon cavity

We report the current development of a sub-kelvin Fabry-Perot silicon cavity. This devel-opment aims to reduce thermal noise-limited frequency instability and by this way address the cur-rent limitations of ultra-stable lasers, aiming to set the ground for the next generation of these devic-es with frequency instabilities below 1×10-17 [1]. However, silicon cavities with crystalline mirror coatings at cryogenic temperatures have shown birefringence correlated frequency fluctuations [2], [3].

Our cavity (Fig. 1) is based on a spacer made from a monocrystalline silicon with optical axis aligned to the [111] axis. The size of the cylindrical spacer is about 18 cm in length and 20 cm in diameter. Mirrors with silicon substrates and Al0.92Ga0.08As/GaAs crystalline coatings are optically contacted [4]. We measured a room-temperature finesse of 220 000 and a TEM00 mode splitting due to the birefringence of the coatings of about 250 kHz. (Fig. 2)
To operate our cavity at sub-kelvin temperatures, we use a dilution cryostat able to reach 12 mK in unloaded operation with optical windows. Calculations based on the Stefan-Boltzmann law indicate that cooling by radiation alone would take excessive times with our spacer design, of order a year. To circumvent that, we propose to decouple the mechanical support and thermal manage-ment.
We propose to measure optical characteristics of our silicon cavity with crystalline AlGaAs coatings at sub-kelvin temperatures, as well as the sensitivity of our cavity to residual temperature fluctuations in the cryostat. We will also investigate the efficiency of our cavity cooling at sub-kelvin.

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