Cryogenic Sapphire Optical Cavities

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The performance of cavity stabilized lasers is typically limited by thermal noise induced displacement noises in the glass ceramic optical resonators at room temperature. We are currently working on ultra-stable cryogenic optical resonators made of sapphire, aiming at a much better short-and long-term stability compared to conventional room temperature glass ceramic resonators. In parallel, we are working on replacing the current high finesse mirrors ("standard" Ta_2O_5/SiO_2 DBRs) with high-performance crystalline mirrors based on $Al_xGa_{1-x}As$ DBRs[1]. The crystalline mirrors will further reduce the influence of thermal noise by at least an order of magnitude.

We will present the status of our work on the cryogenically cooled sapphire cavity system, with an estimated thermal noise limited frequency stability of a few 10^{-17} (standard coating) and of a few 10^{-18} (crystalline coating), respectively. In a next step, these resonators will be used in a high-precision experiment to test Lorentz invariance within the 10^{-20} to 10^{-21} regime.

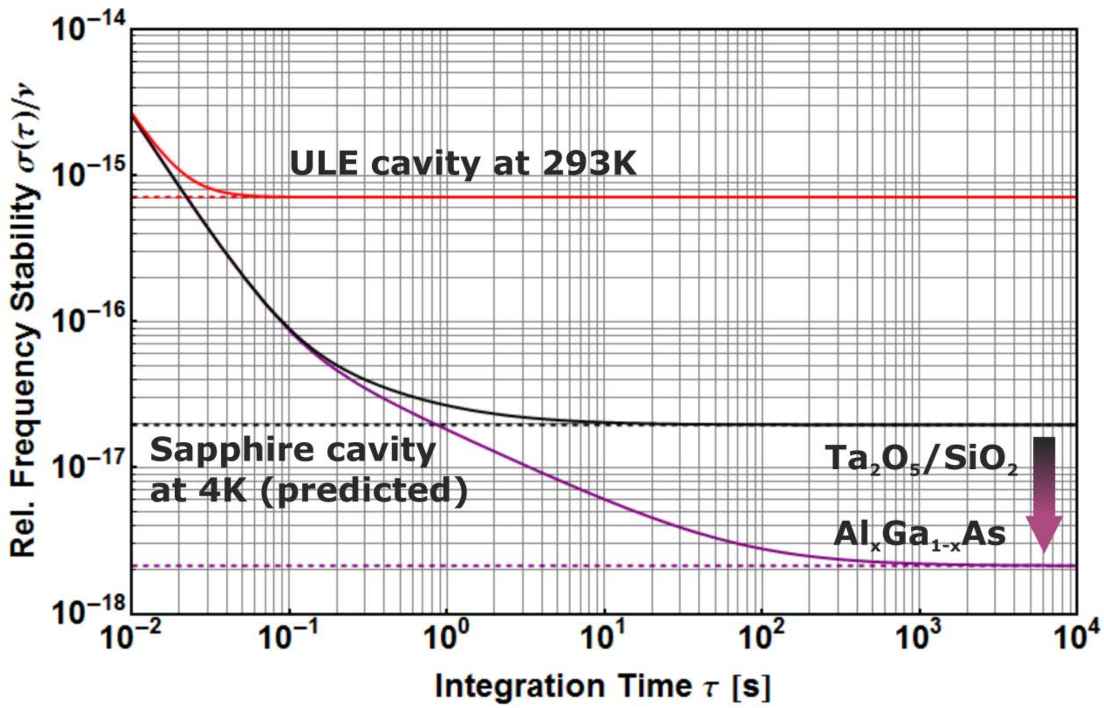

Fig. 1: Comparison of the predicted relative frequency stability of the cryogenic optical resonators operated at 4 Kelvin (black line: standard coating, purple line: crystalline coating) with the typical stability of an ULE room temperature cavity with the same length (red line). The dashed lines indicate the theoretical thermal noise limits at the operating temperatures.

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[1] G.D. Cole *et al.* "Tenfold reduction of Brownian noise in high-reflectivity optical coatings", Nature Photonics 7, 644–650 (2013).