Frequency drift of cryogenic silicon cavities

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Ultrastable Fabry-Perot resonators are an important tool for a variety of precision experiments[1]. They are an indispensable component of optical clocks and a promising candidate as a flywheel oscillator for the realisation of an all-optical time scale[2]. Room temperature cavities based on low thermal expansion glasses suffer from ageing effects, leading to fractional frequency drifts of a few 10^{-16} /s. Cavities based on monocrystalline silicon at cryogenic temperatures exhibit drift rates which are three orders of magnitude smaller[3,4]. This makes them a potential substitute for H-maser and a versatile instrument for fundamental tests of physics.

We are operating several cryogenic silicon cavities at temperatures of 4 K and 124 K with conventional dielectric SiO_2/Ta_2O_5 and crystalline AlGaAs/GaAs coatings. The absolute optical frequency of all systems has been measured in comparison to Sr lattice-clocks or H-maser referenced to Cs-clocks for several years. We consistently observe a negative frequency drift which corresponds to an increase in the optical path length of the resonators opposite to the shrinking observed with ULE cavities.

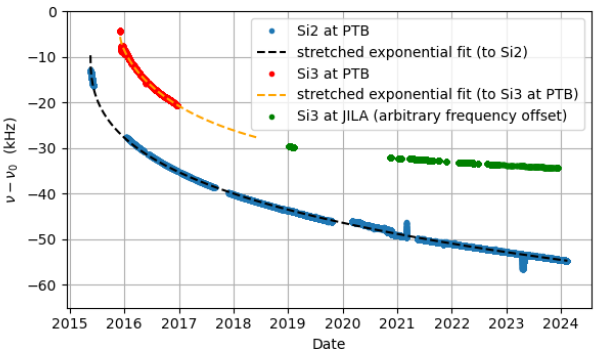

Fig. 1: Frequency drift of our two silicon cavities Si2 (at PTB in blue) and Si3 (at PTB in red, at JILA in green).

The most complete datasets have been recorded for our 21 cm silicon cavities operated at 124 K employing conventional dielectric coatings (Si2 and Si3). The long-term frequency drift of both systems can be approximated very well by stretched exponential functions. The cavities have now achieved fractional frequency drifts as small as $-1{\cdot}10^{-19}$/s. We compare the long-term drift of different silicon cavities on a time scale of several years and discuss possible mechanisms, which could potentially explain the observed drift effects.

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