Temperature control design of a 30-cm-long high-finesse optical cavity for an enhanced middle- and long-term stability

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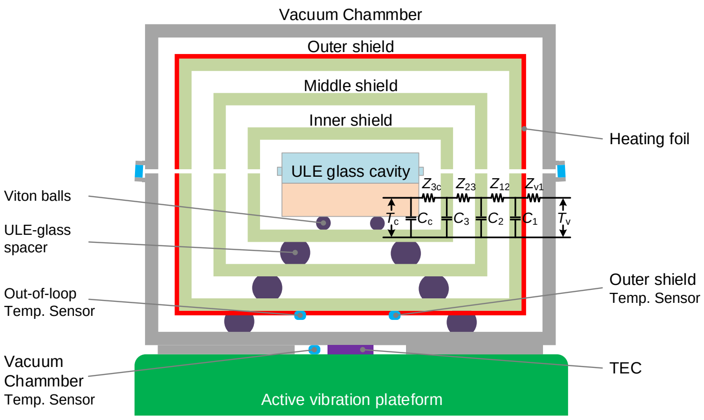
Abstract: Due to excellent temporal coherence, ultra-stable laser (USL) based on high-finesse Fabry-Pérot cavity made of ultra-low expansion (ULE) meaterials acts as a crucial role in many cutting-edge research fields of optical atomic clock [1], ultra-stable microwave signal generation [2], coherent optical frequency transfer [3], and so on. Although ULE meaterial is adopted in the system, precise temperature control is demanded to keep the high-finesse cavity at zero-expansion temperature. The stability of temperature control is usually on mK level at 1 s. The dominate limitations of the fraction frequency stability of USL beyond 10 s include middle- and long-term (10 s~1000 s) temperature control, residue amplitude modulation of electro-optic modulator [4], optical power fluctuation coupled into cavity [5], and the aging of high-finesse cavity.

Here we focus on the temperature control system of our ultra-stable laser assembling a 30-cm long ULE-glass cavity. Figure 1 shows the schematic of the design. Active temperature control is achieved by regulating the thermo-electric cooler (TEC) under the vacuum chamber and heating foil glued on the outer thermal shield, while passive temperature control is by the other two layers of thermal shield. The analyzed time constant of the inside optical ULE-glass cavity is approximately 11.5 days. Experientially, this low-pass temperature filtering supports a frequency stability below 3×10^{-16} within 1000 s. The experimental test is ongoing.



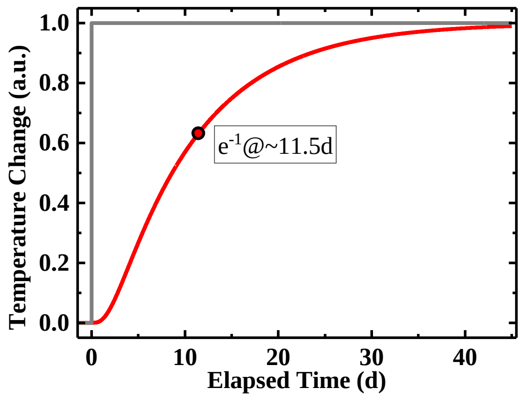


Fig. 1 Simplfied schematic of the ULE-glass Fabry-Pérot cavity assembly in vacuum. The temperature step response shows the time constant is approximately 11.5 days.

References

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