Vibration sensitivity optimization of a 30-cm-long high-finesse optical reference cavity by multi-body modelling

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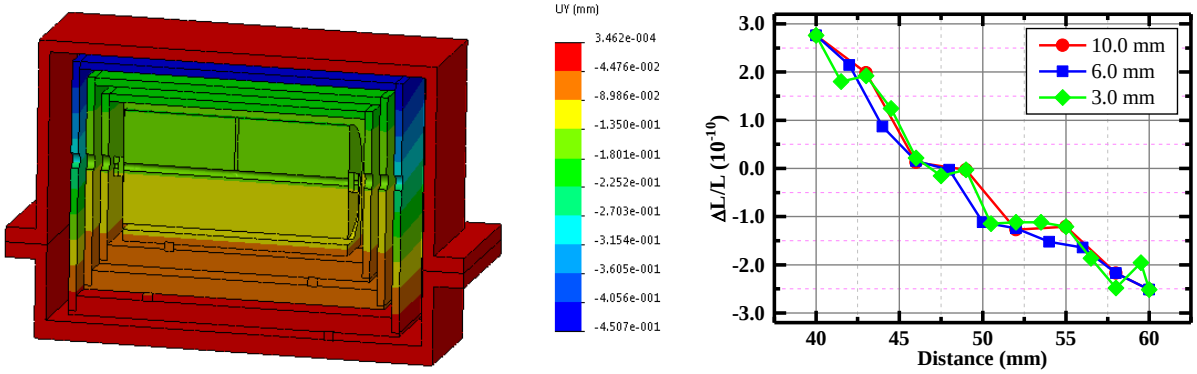
Abstract: Ultra-stable laser is fundamental apparatus utilized in diverse applications ranging from fundamental scientific researches to industrial applications. The performance metrics of the stabilized laser, namely absolute linewidth and fractional frequency stability, is fundamentally restricted by its thermal noise limit of the cavity.

Among many methods of reducing the thermal noise limit, increasing the length of the cavity spacer is remarkably effective. However, the longer the length of an optical reference cavity is, the more difficult and tedious the optimization of vibration sensitivity becomes. Previous investigations by researchers, such as S. Häfner *et al.* [1] and Li Jin *et al.* [2], have yielded instructional results on the vibration sensitivity of the high-finesse optical reference cavity beyond 30 cm via single-body modelling. To date, multi-body modelling involving the whole cavity assembly is still unexplored.

In the paper, we applied multi-body modelling to numerically analyse the vibration sensitivity of a 30-cm-long high-finesse optical reference cavity. The displacement along the axis of optical reference cavity can be calculated in Fig. 2(a). The vibration sensitivity of the optical reference cavity is ploted in Fig. 2(b). The vibration sensitivity reaches a null value when the distance between the holding hemisphere of the optical reference cavity and the near end of the cavity spacer is approximately 48.5 mm. Up to the present, the experimental test is ongoing.



(a) (b)

Figure 2 Numerical calculation of the vibration sensitivity of the whole optical cavity assembly. (a) The displacement along the axis. (b) The vibration sensitivity of the cavity assembly. The red, dot line denotes the diameter of the Viton hemispheres is 10 mm, while the red, square line is 6 mm, and the green, diamond line is 3 mm.

References

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[2] L. Jin, Yanyi Jiang, Yuan Yao, Hongfu Yu, Z. Bi, and Longsheng Ma. Laser frequency instability of 2×10^{-16} by stabilizing to 30-cm-long Fabry-Pérot cavities at 578 nm. Optics Express, 26: 18699 (2018).