# High resolution displacement measurement using a novel Michelson laser

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High-resolution displacement measurement techniques are widely used in gravitational wave detection, atomic force microscopy, and precision machining. Laser interferometers with traceability to the definition of the meter are suitable for displacement measurements. Among them, heterodyne interferometers have high immunity to interference, and efforts are made to achieve displacement measurements of 10 pm using fast phase detection methods[1,2]. However, the electronic and environmental noise makes the measurement resolution hard to be 10 pm or better.

Here, we propose a new scheme to trace displacement measurements to frequency measurements. The optical path configuration of the laser is similar to the Michelson interferometer, so we name it the Michelson laser, see Fig. 1(a). The light emitting from the laser gain (i.e., He-Ne tube) is divided into two beams, one acts as the reference beam (with a fixed cavity mirror), the other one acts as the measurement beam (with a movable cavity mirror), and we get two lasers after oscillation. There exists a relation between the laser cavity length L and frequency ν, $\Delta\nu/\nu = dl/L$, where Δν and dl indicate the change of ν and L, respectively. Use the frequency counter to measure the change in the beat frequency of the two laser modes, it is easy to calculate the displacement of the movable mirror. As the frequency measurement reaches a high resolution of 12 digits, this scheme has a theoretically displacement measurement resolution with an order of pm or better.

We also propose the second scheme based on the Faraday anomalous dispersion optical filter (FADOF), see Fig. 1(b). The anti-reflection coated laser diode (ARLD) acts as the gain medium, preventing the He-Ne tubes with small gain from being hard to oscillate. The polarizing beam splitter (PBS) is used for beam splitting. Two FADOFs with different transmittance peaks are placed in the two optical paths for the frequency selection. After measuring the beat frequency change of the two laser beams with different frequencies, we can calculate the displacement change of the movable mirror. This novel displacement measurement scheme is expected to achieve a pm-order or less displacement measurement resolution, and is useful in fields such as atomic interferometric gravimetry.

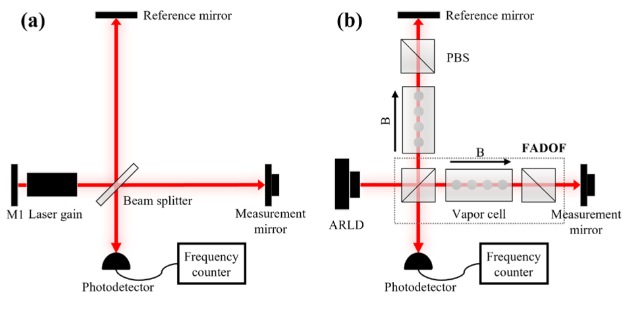


Fig. 1: Schematic of Michelson laser (a) and Michelson laser based on FADOF (b).

[1] T. D. Nguyen, "10-pm-order mechanical displacement measurements using heterodyne interferometry", Appl. Opt., vol. 59, p. 8478-8485, 2020.
[2] M.T. L. Hsu, "Subpicometer length measurement using heterodyne laser interferometry and all-digital rf phase meters", Opt. Lett., vol. 35, p. 4202-4204, 2010.