Noise suppression for the precise measurement of Fabry-Perot cavity with wide tunable range

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Generation of the length etalons and measurement of length of passive Fabry-Perot cavities (FPC) [1] or their displacement[2] [3] is limited by thermal fluctuations, speed of lock-loops, the noise and linewidth of the laser source which controls the cavity length. The linewidth of the laser should be below the linewidth of the passive cavity modes. A derivative or Pound-Drever-Hall technique is commonly used for the lock to an external laser to the cavity. Typical passive cavity has plan-concave configuration with the mirror distance of 100 mm. Finesse of the cavity is usually over 2 000 and in atomic clock applications can achieve up to 300 000. Linewidth of the typical cavity then reaches between kHz and MHz which corresponds to pm to nm uncertainty in the cavity length. The measurement of displacement of the Fabry-Perot cavities thus could be made by a tunable laser with sub-kHz to sub-MHz linewidth with an optical reference laser with better or same linewidth. If the large passive cavity mirror displacement is measured then the broad tunning range of the control laser should be used. Gas lasers like He-Ne have the tuneability of only 1 GHz. The typical laser diodes have larger tunability but the linewidth of 30 MHz. Better linewidth can be achieved with external cavity laser (ECL) setup but these complex laser systems are sensitive to alignment and introduce power losses. The state-of-the-art ECLs include planar waveguide with the fiber Bragg grating and reach the linewidths under 3 kHz. Such lasers have tunability only up to 5 GHz. The DFB lasers can achieve roughly about 1 MHz linewidth corresponding to 10^{-8} relative uncertainty of measurement and 1 nm uncertainty for 100 mm long cavity. They provide wide tunable range of nms (or hundreds of GHz). Such a tunable range is very useful for precise measurement of absolute length and displacement between mirrors of FPC. The noise Fourier spectrum should be suppressed to kHz Fourier frequencies generating the low noise to the optical frequencies as well as to definition of the length of the cavity.

We present the laser diode working at 1542 nm with 2 nm (400 GHz) tunable range and noise suppression. The noise suppression is made by an unbalanced heterodyne fiber interferometer. The frequency noise in our experiment has been suppressed by -60 dBc/Hz at Fourrier frequencies of 0-10 kHz while the tunability range stayed untouched. By this method we were able to reach 10^{-10} uncertainty corresponding to 10 fm in cavity length and the tunable range of 100s of GHz corresponding to 1000s nm cavity length changes. The precision has been ensured by referencing the DFB laser optical frequency to a stabilized optical frequency comb.

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