Dual Cavity Refractivity measurements using a single Laser

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Abstract: We present a method for measuring refractivity-based pressure changes using a dual Fabry-Perot cavity utilizing a single laser with off-set sideband locking to the second cavity. Preliminary data illustrate the utility of the technique.
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1. Introduction

Recently it has been shown that refractivity-based pressure measurements can be performed to very high precision.[1-3] However traceability remains tied to the mercury manometer. A major aim is to move away from traceability via mechanical measurements of pressure (manometer based on fluid density, local gravity, and column height or piston gauge force per unit area) and to achieve traceability through quantum properties of nature. Extremely accurate quantum chemical calculations of the refractive index of helium enables this transition.[4] To facilitate the wide spread adoption of quantum-based pressure standards through the use of the NIST Fixed Length Optical Cavity (FLOC), we have tested an approach that requires a single laser operating at telecom wavelengths. A single laser approach will lower the cost of the overall system significantly by removing multiple costly components such as a second laser and a high-speed photodiode along with the needed support electronics.

The methodology of offset sideband locking is applied to the NIST FLOC, in which the single laser operating at 1542 nm is split, half of the power is used to stabilize the laser to the reference cavity and the other half is coupled to a broad bandwidth low V_π electo-optic modulator (EOM) which is separately locked to the measurement cavity of the FLOC. The EOM on the measurement cavity is driven by an RF source on the order of a gigahertz and a second frequency required for PDH lock. Both dual-side band and electronic side-band methods were tested, following the methodology set out by Thorpe et al.[5]

2. Experimental

A detailed design of the FLOC is described elsewhere[3], here the layout for single laser operation is presented. Thus far, the best results were obtained using the electronic side-band method which is illustrated in Fig. 1.

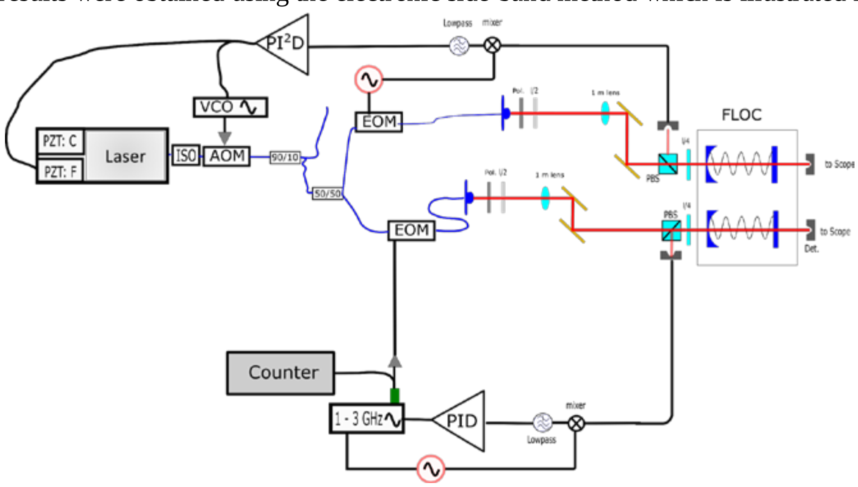

Fig. 1. Optical layout

A high-speed photodiode measuring the beat frequency between the reference cavity and measurement cavity is not needed since the difference in frequency is measured directly with a counter. As described in earlier publications it is the beat note or frequency difference between the reference cavity and the measurement cavity that is measured to determine the pressure in the measurement cavity. With the method presented here, the frequency difference is measured directly by the tuning frequency input to the EOM. A major limitation here is high noise content of the high frequency voltage-controlled oscillators (VCO). For this work a high-performance microwave synthesizer was used to tune the EOM, alternatively a low cost Direct-Digital-Synthesis (DDS) device with fast analog control could be used. To maintain lock to the measurement cavity all that is needed is a low bandwidth correction signal since the laser is pre-stabilized to the reference cavity. The error signal from the measurement cavity is digitized and a low bandwidth PID servo in software was used to feedback directly to the microwave synthesizer via remote interface.

3. Results

Preliminary results are illustrated in Fig. 2. The top panel of Fig. 2 shows the frequency stability of the lock signal on the measurement cavity and the lower panel illustrates the Allan deviation. The Allan deviation is constant at about 2 kHz over the measurement time scale (4 minutes).

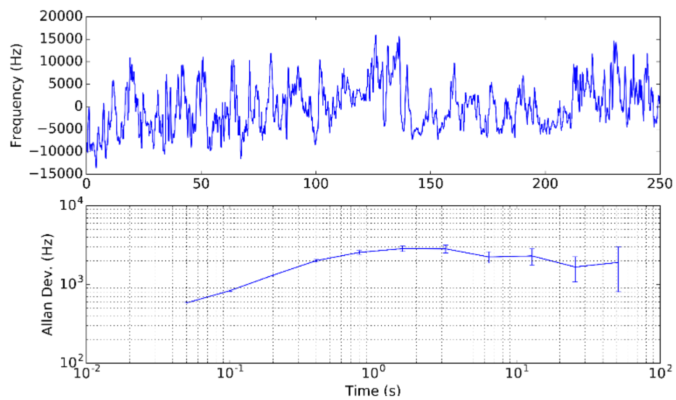

Fig. 2. Frequency stability and Allan deviation

4. Summary

The Allan deviation sets both the minimum detectable pressure and the pressure resolution. The 15 cm FLOC the frequency shift at 1542 nm is about 510 kHz/Pa for N_2, with an Allan deviation of 2 kHz this translates to 4 mPa. The preliminary data using the single near IR laser with offset-locking methods looks very promising. The major source of noise for this experiment is thought to be arising from the laser source. Thorpe et al.[5] concluded that the offset-locking methodology did not contribute to instability in the lock.

3. References

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