Development of Optical Interferometric Dilatometer

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Introduction

The goal of this project is to develop a highly sensitive dilatometer based on the FPS3010 interferometric displacement sensor produced by Attocube Systems Inc. [1]. The sensor consists of an electronics, which transmits laser light by an optical fiber into an optical electronic-free sensing head. The head is placed in front of a reflecting sample, which reflects light back into the fiber. That reflected signal is analyzed by a detector. Thus, the optical head and the sample create a Fabry-Perot resonator cavity. Therefore, alteration of the light resonant frequency represents the sample length variation if all components of the cavity are stable with respect to each other.

Experimental Results and Discussion

The displacement sensor has been tested in the magnetic fields of up to 18 T in a ^{3}He cryostat (SCM2) at temperatures 0.3-10 K and in a dilution refrigerator (SCM1) in the temperature range 45-300mK. Note that the base temperature of the dilution cryostat is about 20mK, but due to high light power produced by the laser the mixing chamber was heated up to 45 mK. An optical head had been mounted in front of an aluminum mirror in an aluminum SM05L30C 0.5” lens tube produced by Thorlabs Inc. [2]. The variation of the resonant frequency, i.e. of the distance between the mirror and the head, was measured as a function of the magnetic field (Fig. 1) or temperature, or time (Fig. 2). The observed effect of the magnetic field on the sensor signal is presented in Fig. 1. That the signal change is much larger than a few angstroms precision of the sensor announced in an Attocube brochure. It is not clear yet what is the origin of such signal change. It also was found that the signal from the sensor is very sensitive to the temperature instability. In Fig. 2 the correlation between the signals from the displacement sensor and the temperature sensors is shown. Unfortunately, announced in the sensor manual an average of the signal by the sensor electronics is not implemented yet. The averaged curves presented in Figs. 1 and 2 were obtained at a post-measurement analysis of the results.

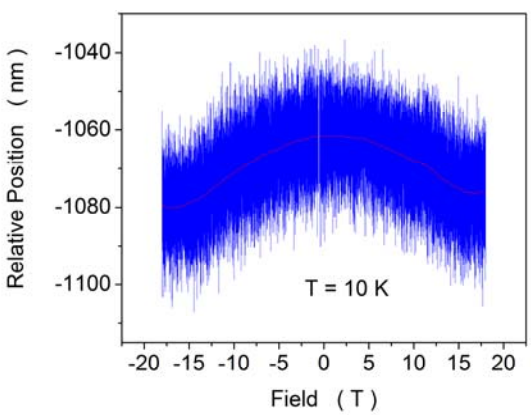

Fig.1 Effect of magnetic field on the signal from the displacement sensor. The red curve is the averaged signal.

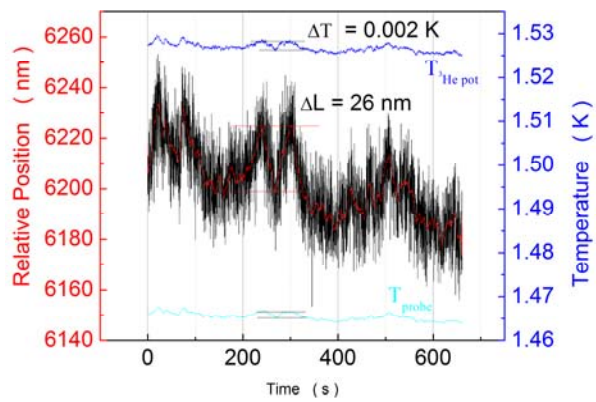

Fig. 2 Effect of temperature on the signal from the displacement sensor mounted in ^{3}He cryostat.

Conclusions

Further improvement of the dilatometer is required. In the next test two optical heads will be mounted in front of the same mirror. It is expected that analysis of the differential signal from these heads will allow compensating the change of the signal in the each of the optical paths. Also development of a procedure, which will perform signal averaging directly during an experiment, would allow significantly increase sensitivity of the dilatometer. Reduction of the light intensity transmitted into cryostat would allow perform measurements at lower temperatures.

References

[1] http://www.attocube.com/attosensorics/
[2] http://www.thorlabs.com/