BIPM Capacity Building & Knowledge Transfer Programme

2018 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Khadijeh Norouzzadeh
Description	Gauge Block Length measurement by Interferometer and Laser Stabilization
Author, NMI	Khadujeh Norouzzadeh, ISIRI-NMCI, IRAN
Mentor at TÜBİTAK UME	Dr.Damla Sendogdu, Wavelength, TUBITAK-UME, Turkey
Date	01 March 2019 to 30 Avril 2019

Motivation & Introduction

For a national metrology laboratory and holder of national standard for length, capability of performing gauge block calibration with lowest possible uncertainty, is of highest importance.
A gauge block is a length standard, defined as the perpendicular distance from a gauging point on one end of the gauge block to an axillary true plane wrung to the other end of the block, at standard reference conditions, as shown in figure 1. In this project, we intend to measure this length by interferometry method that is highest level measurement for measuring this length.

Temperature=20°C
Barometric pressure: 101 325 Pa (1 atmosphere)
Water vapor pressure: 1 333 Pa (10 mm Hg)
CO2 content: 0.03 %

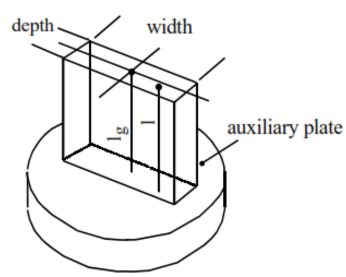

Figure 1. The length of a gauge block is the distance from the gauging point on the top surface to the plane of the platen adjacent to the wrung gauge block

Highest grade gauge blocks require best up-to-date measurements to keep up with the demands of industry and there is pressure on measurement capabilities to provide low level of uncertainty. This push for lower uncertainties, has driven the establishment of the optics-wavelength laboratory for calibration of GB at highest level, by interferometry in length area at my NMI, ISIRI-NMCI. Because ISRI-NMCI is responsible for length accuracy transfer to secondary level laboratory and in this hierarchy, to industry. Therefore, according to our plan, our project in TUBITK-UME was defined as:
1) Laser Stabilization
2) Gauge Block Length measurement by Interferometry
With the final goal of registering CMC in gauge block length measurement by interferometry in BIPM-KCDB in the future.

Research

In order to achieve our goal in length interferometry measurement, our plan divided into three main parts:

1: Time scale

We started with definition of TIME according to BIPM MeP in time & frequency laboratory. because we need to time and frequency measurements in order to increase accuracies of units involved in our plan, laser and interferometry. All time and frequency standards are referenced to a periodic event that repeats at a nearly constant rate. The atomic second defined as 9,192,631,770 periods of the radiation of the ground state hyperfine transition in cesium, is our standard for TIME definition. Then 10 MHz and 1PPS signal from resonation of atomic clocks, is used as reference sent to wavelength laboratory vis coaxial cable in femtosecond COMB for laser frequency measurement that is primary reference in length area.

2: Laser Stabilization:

Then we continued with wavelength laboratory in laser group, especially worked on Nd-YAG laser stabilization. We started with fundamental and theoretical aspects of hyperfine transition in Nd-YAG laser with an iodine cell as a reference. In such a way that, to make the atoms in laser cavity, emit with a frequency in a special transient line and special transition component in a defied ambient condition mentioned in BIPM MeP, recommended frequency.

Stabilization process according to BIPM.MeP:

- a wavelength comes from Lasers cavity
- interaction with iodine cell
- frequency detecting
- amplifying the frequencies
- frequency analyzer
- signal analysis with oscilloscope to find exact line and exact component in defied transition level
- locking the Lasers in a special frequency line (according to BIPM.MeP) by servo order to PZT.

The stabilized lasers which are used in UME KOSTER Gauge Block Interferometer:

Laser	Wavelength	Accuracy ($\Delta\nu/\nu$)	$\Delta\lambda$
UME-made ECDL/ Rb 2-photon	778 nm	6.87 E-11	5.3 E-08 nm
UME-made He-Ne/ I2 cell	633 nm	4.22 E-12	2.7 E-09 nm
Nd-YAG/ I2 cell	532 nm	9.22 E-10	4.9 E-07 nm

Absolute frequency measurement of frequency stabilized He-Ne/I2, Nd-YAG/I2 and ECDL/Rb,Cs lasers was measured by femtosecond Ti:Sa COMB (530 - 1100 nm) that is externally triggered by the 10 MHz signal of Cs atomic clock. The repetition and offset frequency of the Ti:Sa COMB system has been locked to the 10 MHz signal of Cs atomic clock.

3: Gauge block length measurement by interferometer:

"1 meter, is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second" (1983).

By the use of interferometer systems, the meter, which is the length standard, is transferred from the frequency standards (wavelength standards) to gauge blocks. The frequency stabilized lasers are the frequency standards or in other words, they are determined as wavelength standards.

In this part, we worked on:

- specifications of a gauge block interferometer by koster interferometer
  UME-made Köster Interferometer is a chamber which is designed for measuring the length of the long gauge blocks with three different stabilized lasers:
  1) the stabilized He-Ne laser locked to energy transitions of iodine molecules
  2) the stabilized Nd:YAG laser locked to energy transitions of iodine molecules
  3) the stabilized External Cavity Diode lasers (ECDL) locked to energy transitions of Cs or Rb atoms
  The lasers Stabilized in UME and transferred with fiber cables into the interferometer where the gauge block is placed. The interference fringes observed at the CCD camera are analyzed and the lengths of the gauge blocks are obtained. By using this system, the gauge blocks with lengths between 125 mm - 1000 mm are calibrated. The software for analysis of gauge block length developed in UME.
- setting up a short gauge block interferometer. We design and construct a Short Gauge Block Interferometer, which is a primary level measurement system. With the interferometric measurement method, short gauge blocks (up to 300 mm) can be measured with two stabilized lasers.
- Calibration of thermistors of koster interferometer by SPRT
- Evaluating the measurement uncertainty of gauge block by interferometry system

Conclusions and Future Work

The primary goal of our study was to measure length of gauge block with lowest uncertainty by laser as the wavelength source in laser-interferometer system. Secondly, interfrogram acquisition was substantially improved by the use of a high resolution digital camera and a quality objective. The software that was developed to acquire and analyze interferograms resulted in a significant increase in measurement resolution and consequently in improved measurement accuracy. The fact that environmental corrections are performed simultaneously with the interferogram acquisition allows further reduction in the associated measurement uncertainty. All of the factors stated above have a measurable contribution to the measurement uncertainty of calibration of gauge blocks. For that reason, we decided to quantify the performance of the interferometer by performing a complete evaluation of its measurement uncertainty according to the ISO Guide to the Expression of Uncertainty in Measurement.

Acknowledgements

I would like to express my deepest appreciation to all those who provided me the possibility to participate in this project such as BIPM and TÜBİTAK UME. A special gratitude I give to the head of physics group, Dr. Ramiz Hamid, and my advisor, Dr. Damla Sendogdu, for the continuous support of my project. Furthermore, I would also like to acknowledge with much appreciation the crucial role of the staff of wavelength Laboratory such as Mr. Cihangir Erdoganand, Mr. Cagri Seneland and Mr. Orhan Yaman for providing such a nice support and guidance and have invested quite a lot of time overseeing my progress. Last but not least, many thanks go to Mr. Andy Henson and Mr. Chingis Kuanbayev for presented the international aspects of metrology and the guidelines on participation in the mechanisms of the CIPM MRA.