BIPM Capacity Building & Knowledge Transfer Programme

2021 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Knowledge transfer on gauge block interferometry as an NMI's primary standard for length and dimensional measurement.
Description	This project aims to establish the participant's knowledge and expertise in interferometry to develop systems and standards to address high-level traceability needs of local industries.
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Motivation & Introduction

As a de-facto National Metrology Institute (NMI) of the Philippines, we aim to provide the metrological traceability needed by the industry. However, the Length Standards Section of the National Metrology Laboratory (NML) of the Philippines' facility is limited for the calibration service of grade 0, 1, and 2 gauge blocks by mechanical comparison only.

Interferometry is known long ago for measurement needs with higher accuracy requirements. Yet, the technology is not available in the Philippines, forcing the industry to send their higher standards to other NMI abroad with higher calibration costs, risk of damaged standards from possible mishandling during shipment, suffers for longer turn-around time, additional costs for duties and taxes, and foreign exchange fluctuations. This triggers the need for us to upgrade so we can able to support and ease the burden of the industry relative to their measurement requirements. Thus, NML plans to set up a facility for laser interferometry as the Philippines metrological standards for length and dimensional measurement.

This project aims to help us equipped with the skills required, experience, and technical know-how to set up facilities for the calibration of high-level grade gauge blocks using interferometer and able to compute, formulate its uncertainty of measurement.

Research

My project revolves around the 1983 definition of a metre (m) as the length of the path traveled by light in a vacuum during a time interval of 1/299 792 458 of a second.

$$\text{Distance} = \text{Velocity x time} = \text{C x } \frac{1}{\text{C}} = \left(\frac{\text{m}}{\text{s}}\right) \text{ x } \frac{\text{m}}{\left(\frac{\text{m}}{\text{s}}\right)} = 1 \text{ m}$$

To realize this definition, light amplification by stimulated emission of radiation or laser can be used. The laser has to be stabilized so that it can be locked to a certain frequency with a corresponding wavelength which in turn, will be used for the measurement of distance. He-Ne laser for instance uses an Iodine cell for the stabilization process, locked to the Frequency of 473 612 353 602 000 Hz with the wavelength in vacuum of 632.991 212 58 nm. The wavelength of the laser is calculated by using velocity of light in vacuum (299 792 458 m/s) and measured frequency of the related locked laser. The frequency of the stabilized laser is measured by beat technique and or the comb systems which is stabilized by 10 MHz frequency coming from the cesium clock in Time Laboratory.

In Turkey, UME made stabilized lasers define the S.I. unit of metre (m) through interferometry as a method of measuring length or distance in terms of the wavelength of light. In the determination of length of long gauge blocks for example, three light sources with corresponding unique wavelength were used:
Nd:YAG/I_2 laser; 532 nm
He-Ne/I_2 laser; 633 nm
ECDL/Rb laser; 778 nm

Stabilized lasers are sent via fiber optics to UME-made Koster Interferometer to measure high-grade gauge blocks from a nominal length of 125 mm to 1000 mm. To better understand what an interferometer is, principles and theories had been discussed, experiments and actual measurements were performed which includes the following:

- Temperature stabilization of the Koster chamber that plays a vital role in the consistency of measurement.
- The use of Thermistors as a temperature sensor for better sensitivity.
- Optical alignment considerations of gauge block to be measured, the beam from the light source, and off-axis checking of the reflected beam from Koster's prism.
- Types of lenses involved for reducing and/or enlarging (increasing) of the laser beam diameter.
- Wringing of gauge block into the platen.
- Airy points determination.
- Intermediate checking of temperature sensors using SPRT.
- Sets up a short gauge block interferometer and simulates the shifting of fringes by moving the reference arm while the measuring arm is in a fixed position. For a short gauge block interferometer, two lasers are enough for measurement.
- Calculation of refractive index of the air inside the Koster Interferometer chamber and correction of the wavelengths of the frequency stabilized lasers. For refractive index calculation, revised Edlen's formula is used.
- Determine the exact focal length of the achromatic lens and its quality by using the shear plate. The lens is said to be of good quality if it can project sets of straight fringes.

After measurement, we proceed to the computation of uncertainty. Contributing factors to the measurement error were determined and used to formulate a mathematical model in computing the measurement uncertainty for interferometric calibration of the gauge block.

Upon playing on the values of uncertainty sources, I learned that the temperature aspect greatly affects the measurement results. This includes the uncertainty of temperature sensors and temperature stability of the chamber that should be maintained to as small as millikelvin (mK) as possible.

Apart from learning about interferometry, a webinar for the CIPM MRA process was conducted by Mr. Andy HENSON and Mr. Chingis KUANBAYEV of BIPM expounding the topics on how the measurement comparisons are coordinated following the guidelines stated in CIPM MRA-G-11, Quality management systems in CIPM MRA-G-12, and CIPM MRA-G-13 for the Calibration and measurement capabilities.

Conclusions and Future Work

With the knowledge gained from this capacity building, I planned to:
1. Impart these new learnings to my dear colleagues in the Philippines. A presentation about the measurement of gauge block length using a laser interferometer shall be conducted.
2. Prepare a project proposal for the Philippines' realization of SI unit for the metre.

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Aside from the new experience and learnings, I would like to commend the camaraderie from the UME staff, researchers, and linkages established with other colleagues coming from different NMI's through this capacity building. I am hoping for the continuation of the alike partnership and to be a gateway to more collaboration for developing a better world through the science of measurement.