

Renewal of the gage-block interferometer at INRIM

R. Bellotti, M. Franco, G. B. Picotto* and M. Pometto

Istituto Nazionale di Ricerca Metrologica (INRIM), Strada delle Cacce 73, 10135 Torino, Italy

* Corresponding author: g.picotto@inrim.it

Keywords : gage block, interferometry, excess fractions, fringe analysis, metrology

Abstract

The Hilger& Watts interferometer in use at INRIM for the calibration of gage blocks up to 100 mm has been recently upgraded with stabilized He-Ne laser sources providing traceable wavelengths at 633 nm, 543 nm and 594 nm. The new set-up has been validated by an internal comparison with reference gage blocks in use for the periodical verification of the overall measuring system. The fringe order ambiguity determined with the exact fractions method by using the two wavelengths at 633 nm and 543 nm has been tested and compared with that obtained by using all the three wavelengths.

1 Introduction

Gage blocks (GBs) are popular material measures of length, still widely used to disseminate the metre unit by metrology to industrial labs [1,2]. As specified by the relevant ISO standard [3] the calibration of the highest grade of GBs is based on interferometry, by which the length of the gauge is determined from the wavelength of optical radiations traceable to the “mise en pratique” of the metre. Interferometers of Twyman-Green, Kösters and Fizeau optical designs are common for calibrating short GBs wrung to a reference plate. Use is made of the method of exact fractions applied to the interference fringe systems recorded at different wavelengths. Spectral lamps were used with the earliest instruments, thus requiring a dispersing prism to split the different colour radiations emitted by the lamps [4]. Recent instruments make use of radiations supplied by stabilized laser, which provide high contrast and low noise fringes.

2 The interferometer

The Hilger & Watts interferometer in use at INRIM relies (is based, exploits) on an earliest design [4] developed at the National Physical Laboratory. Our instrument was manufactured in the early seventies, later on in the mid/late eighties a camera-based fringe detection system and an home-made software for the analysis of the fringe systems by means of the exact fraction method have been implemented together with the insertion of the Kr lamp and of a stabilized He-Ne laser at 633 nm. The latest version of the instrument (Fig 1) fully operates with stabilized He-Ne lasers at 633 nm, 543 nm, and 594 nm. Program-driven electro-mechanical shutters are used to select the laser beam at the input of the interferometer when recording the fringe systems at the different wavelengths. To minimize the speckle noise in interference fringes the laser beam goes through a beam diffuser made of a rotating ground glass plate, by which the temporal coherence of the beam is destroyed. Compared to the original set-up the dispersing prism is no longer necessary, hence it has been

replaced by a mirror. In this way, some beam losses occurring at the reflections in the prism are avoided. Furthermore, a good luminosity of the fringes is obtained with the laser beams. Circular linear variable filter are somewhat used at the output of lasers to slightly attenuate the intensity of the radiation for better matching the luminosity of the fringe systems taken at the three wavelengths.

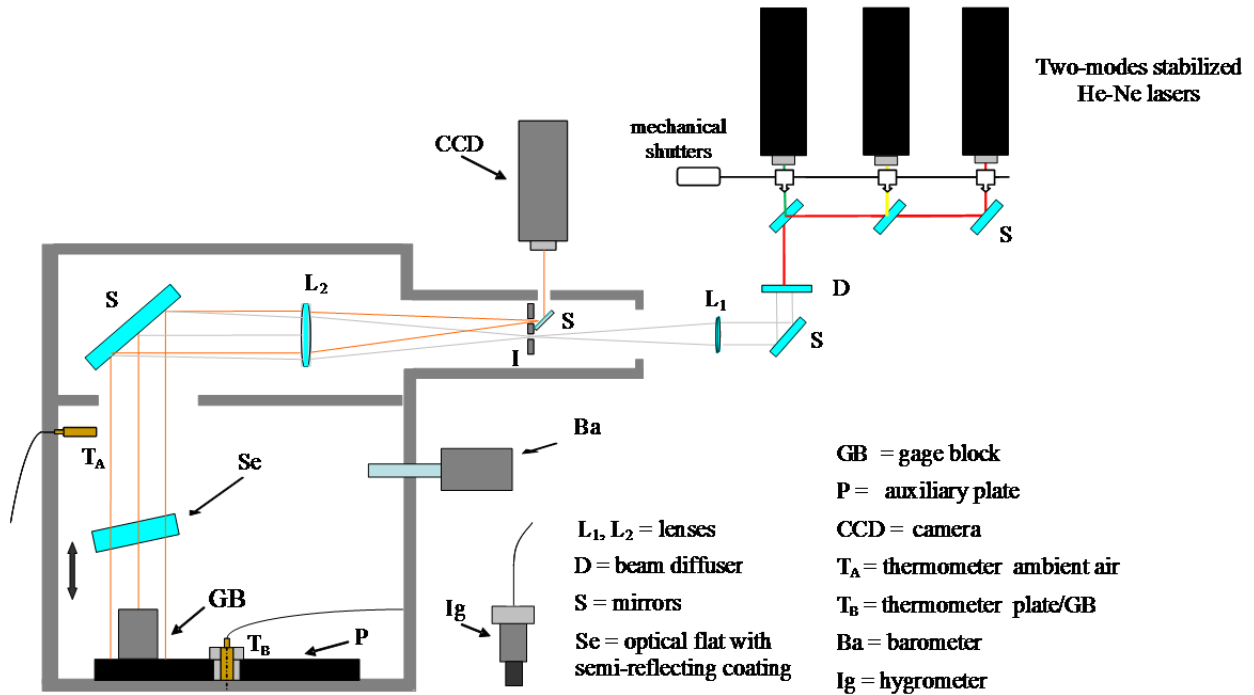


Fig. 1 Schematic of the measuring apparatus with the three stabilized He-Ne lasers at 633 nm, 594 nm and 543 nm.

As an example of fringe visibility, images of the interference fringes are shown in Fig. 2. No significant changes of contrast and luminosity is visible from the red to yellow and green laser radiations.

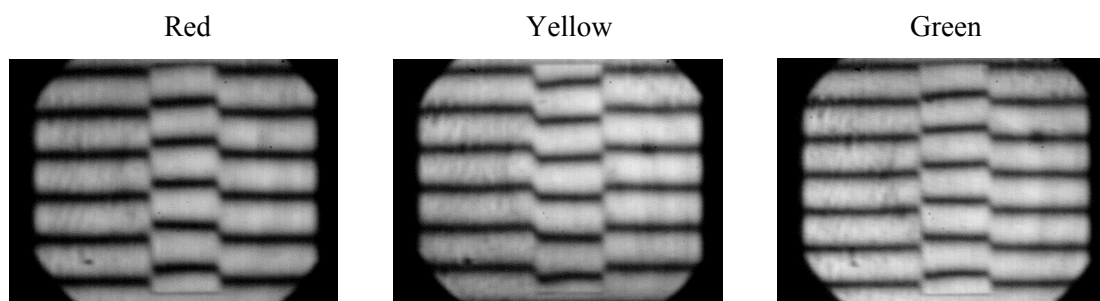


Fig. 2 Visibility of fringes at the three wavelengths

3 Fringe order ambiguity

The analysis of the interference fringes on the reference plate and on the upper face of the gage block is performed by an home-made software implementing the exact fraction method. The length of the gage block is determined from the available matches of integers and excess fractions of fringes observed at the different wavelengths, thus combined with the nominal length and grade tolerance of the gage. The higher the number of wavelengths the larger the difference in length from the available matches and possible combinations. The experimental investigation of such a “fringe order ambiguity” has been performed by means of the standard deviation associated to the length of a 100 mm nominal length GB, as determined by all the available matches of integer and excess fractions of fringes calculated using three wavelengths (red, green and yellow) and using only two wavelengths (red and green). As shown in the graph in Fig. 4, minimum values of standard deviation occur every six integer fringes with two wavelengths (633 nm and 543 nm), whereas the gap is much larger (around 30 integer fringes, not visible in the graph) for the case of the three wavelengths.

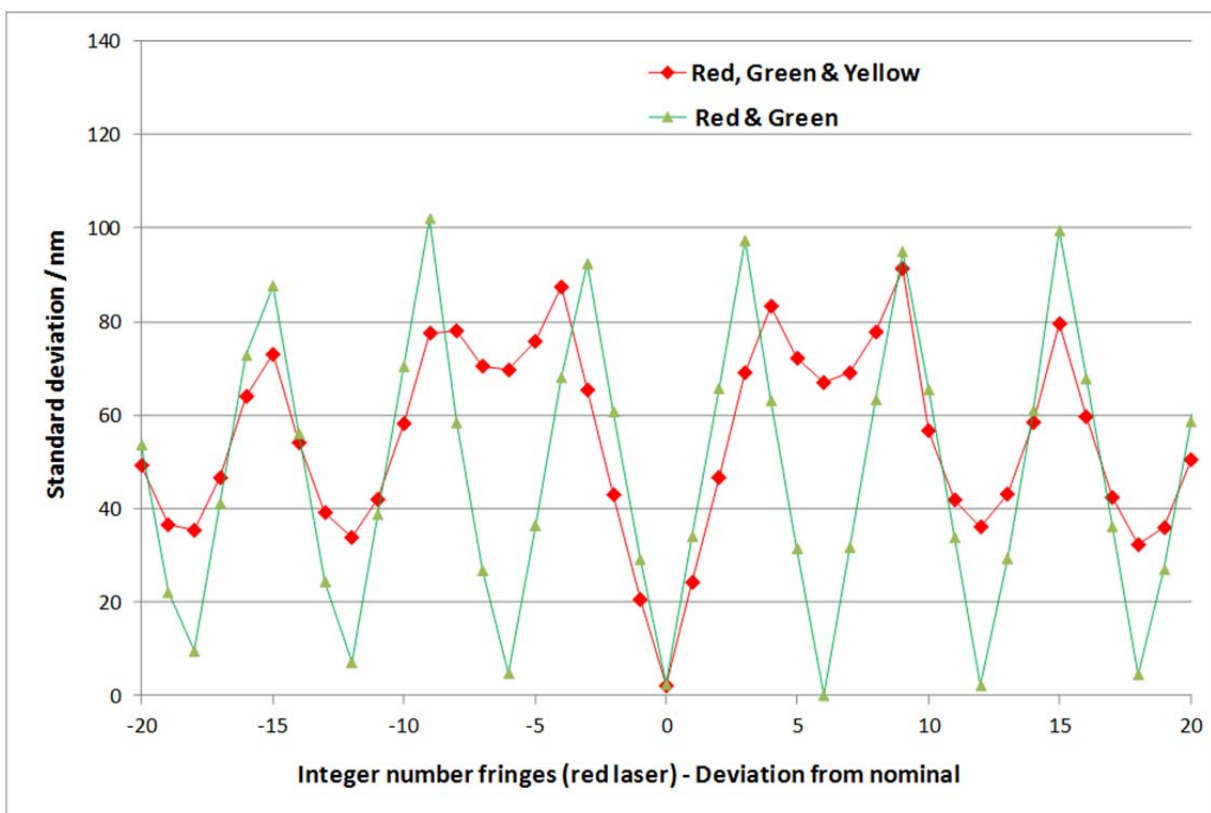


Fig. 4 Fringe order ambiguity with two- and three-wavelengths

4 Results

The validation of the new setup has been performed by an internal comparison with reference GBs in use for the periodical verification of the overall measuring system. The INRIM 1-5 reference sets including 2 mm, 4 mm, 10 mm, 60 mm, and 100 mm nominal length GBs in each set, have been used. The graphs in Fig. 5 show the results achieved today together with those of our previous calibrations of two reference gages of 10 mm, and 100 mm nominal lengths.

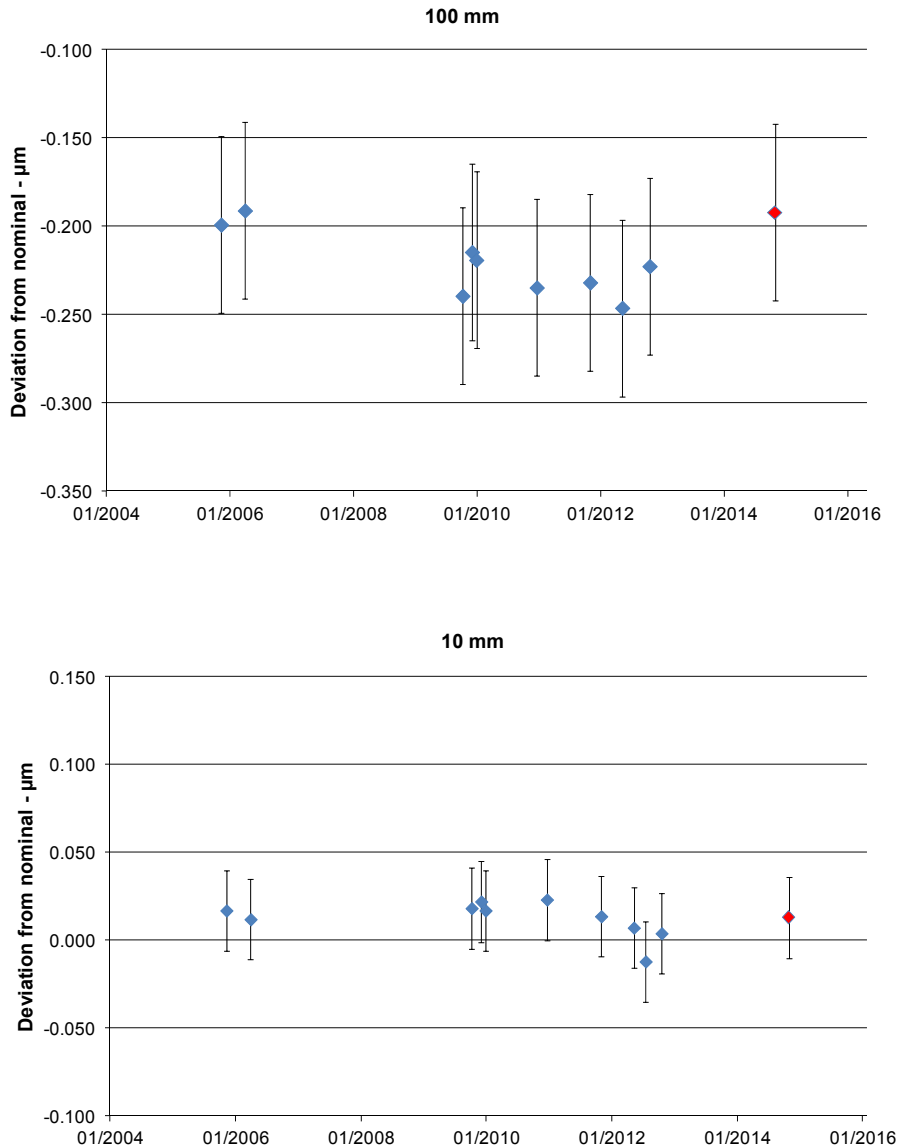


Fig. 3 Calibration of two gage blocks (100 mm and 10 mm). The graphs show the results achieved today and those since 2006

The results achieved so far with the calibration of our reference gages are in agreement with previous calibration results, the last performed in the late 2012, just before the interruption for the renewal of the interferometer. As with the previous interferometer set-up using the ^{86}Kr lamp and a He-Ne laser at 633 nm, the length of the GB is calculated from the integer and excess fraction of the red laser fringes, thus only a few minor changes have been introduced in the uncertainty budget, which has been once again proved by our internal comparison.

5 Conclusions

The Hilger& Watts interferometer in use at INRIM for the calibration of gage blocks up to 100 mm has been upgraded with stabilized He-Ne laser sources providing traceable wavelengths at 633 nm, 543 nm and 594 nm. The renewed interferometer has been successfully validated by an internal

comparison with reference gage blocks. The fringe order ambiguity resulting from the excess fractions method by using two and three wavelengths has been studied and compared. Minimum values of standard deviation of results from the two wavelengths of 633 nm and 543 nm occur every six integer fringes, whereas the gap is up to about 30 integer fringes for the case of the three wavelengths.

References

- [1] T. Doiron, *Gauge Blocks – A Zombie Technology*, J. Res. Natl. Inst. Stand. Technol. 113, 175-184 (2008)
- [2] A. Lewis et al., *Long-term study of gauge block interferometer performance and gauge block stability*, Metrologia 47, 473 (2010)
- [3] ISO3650: 1998 *Geometrical product specifications—length standards—gauge blocks*,” ISO, Geneva (1998)
- [4] D. C. Barnes and M. J. Puttock, *National Physics Laboratory interferometer*, The Engineer 196, 763-766 (1953)