
 Consultative Committee for Length – CCL

Discussion Group on Line Scales – DG7

14-15 June 2018

DG7 report to CCL, 2018

BIMP HQ, Sèvres

DG7 membership

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Discussions

The technical discussions undertaken in the period since the last CCL meeting in 2015, concentrated on the planning of a 2D grid plate comparison and the issue of optical size metrology of structures (bidirectional optical measurements). In addition, international comparisons for MRA purposes were prepared and organised.

Comparison activities

In February 2012 the final report about the results of **EURAMET.L-K7.2006** (Pilot: B. Acko, MIRS, 100 mm line scales, 31 participants; 2 loops in parallel) was published on the KCDB website and Metrologia. The Executive Report was distributed as well.

Currently the line scale comparison **APMP.L-K7-2014** using a 500 mm scale is running. The comparison, piloted by KRISS, was started in April 2015 and the circulation of the transfer standard (owned by KRISS, manufactured by Mitutoyo using a low thermal expansion substrate material (Clearceram)) is expected to be finished at the end of 2016. There are 15 NMIs participating, mostly from APMP with the addition of 1 lab from AFRIMETS, and 2 labs from EURAMET and SIM each. **SIM-L-K7.2016** is a bilateral line scale comparison between INTI and INRIM which is currently running and scheduled to finish until the end of 2018.

The next **CCL-K7** comparison on line scales is scheduled to start in 2018/2019. This comparison currently is under preparation. In addition, a separate EURAMET supplementary comparison with **stage micrometers** is planned, piloted by BEV.

Other planned activities are comparison measurements on line, cross and circular features on 2D optical masks, being important for **optical CMM** and optical measuring microscopes including **x-y-position, size and roundness** (according to EN ISO 10360:7) of **features on transparent substrates** (masks, plates).

(Remark: The topic of bidirectional optical measurements (width (CD), diameter) of 2D-structures and the development of an infrastructure for optical CD measurements (linescales, opt. CMM) has been addressed in

research project proposals within the EURAMET EMRP/EMPIR metrology research programmes (SIBS Call 2012, SRT s11; IND call 2014, SRT i07; IND call 2017 SRTi02), which, however, were not selected for funding.)

Recent published papers

There is no special conference which deals with the DG 7 issues only, but at conferences like e.g. the Macroscale in 2011, 2014 and 2017 some contributions on line scale related research work were presented and published. The following list of papers (2008-2017) in the field of line scale metrology and metrology on 2D optical plates and photomasks has been generated by scanning the publication lists of CCL members and does not claim to be complete. In particular, a larger effort of research is performed in metrology for lithography applications, including dimensional metrology. These lithography related topics are partly dealt with in the WG-N and not fully covered here.

G Dai, K Hahm, H Bosse, R Dixon: Comparison of line width calibration using critical dimension atomic force microscopes between PTB and NIST. *Meas. Sci. Technol.* 28 065010 (12 pp) (2017)

C Weichert, H Bosse, J Flügge, R Köning, P Köchert, A Wiegmann, H Kunzmann: *Implementation of straightness measurements at the nanometer comparator*; CIRP Annals: 65 (2016), 1, 507 – 510

D Bergmann, B Bodermann, H Bosse, E Buhr, G Dai, R G Dixon, W Häßler-Grohne, K Hahm, M Wurm: *Photomask linewidth comparison by PTB and NIST*; Scanning Microscopies 2015; (Proceedings of SPIE 9636): (2015), 96360S-1 - 96360S -14

J Flügge, R Köning, E Schötka, C Weichert, P Köchert, H Bosse, H Kunzmann: *Improved measurement performance of the Physikalisch-Technische Bundesanstalt nanometer comparator by integration of a new Zerodur sample carriage*; Optical Engineering: 53 (2014), 12, 122404-1 - 122404-5

H Bosse, B Bodermann, G Dai, J Flügge, C G Frase, W Häßler-Grohne, P Köchert, R Köning, C Weichert: *Challenges in nanometrology: high precision measurement of position and size*; 58th IWK, Ilmenau Scientific Colloquium: Proceedings: (2014), [USB-Stick] file name: ml_2218.pdf, 15 p.

B Bodermann, R Köning, D Bergmann, W Häßler-Grohne, J Flügge, H Bosse: *The road towards accurate optical width measurements at the industrial level*; Fringe 2013: 7th International Workshop on Advanced Optical Imaging and Metrology: (2014), 35 – 41

G Dai, M Heidelmann, C Kübel, R Prang, J Flügge, H Bosse: Reference nanodimensional metrology by scanning transmission electron microscopy. *Meas. Sci. Technol.* 24, 085001 (2013)

R Köning, Ch Weichert, B Przebierala, J Flügge, W Haessler-Grohne, H Bosse: *Implementing registration measurements on photomasks at the Nanometer Comparator*; *Meas. Sci. Technol.* 23 (2012) 094010 (9pp)

A Lassila: *MIKES fibre-coupled differential dynamic line scale interferometer*; *Meas. Sci. Technol.* 23 (2012) 094011 (10pp)

A I Mares, R H Bergmans: *Evaluation of an optical coordinate measuring machine for measuring grated structures*; *Meas. Sci. Technol.* 23 (2012) 094012 (7pp)

J Unkuri, A Rantanen, J Manninen, V-P Esala and A Lassila: *Interferometric 30 m bench for calibrations of 1D scales and optical distance measuring instruments*; *Meas. Sci. Technol.* 23 (2012) 094017 (8pp)

C Weichert, P Köchert, R Köning, J Flügge, B Andreas, U Kuetgens, A Yacoot: *A heterodyne interferometer with periodic nonlinearities smaller than ± 10 pm*; *Meas. Sci. Technol.* 23 (2012) 094005 (7pp)

F Meli: *Calibration of Photomasks for Optical Coordinate Metrology*; Macroscale 2011 proceedings (online)

R Köning, B Bodermann, D Bergmann, E Buhr, W Häßler-Grohne, J Flügge and H Bosse: *Towards traceable bidirectional optical size measurements for optical coordinate measuring machine metrology*; Macroscale 2011 proceedings (online)

G Wimmer, K Karovic, V Witkovsky, R Köning: *Confidence interval for the distance of two micro/nano structures and its applications in dimensional metrology*; Proceedings of Measurement 2011, 8th International Conference on Measurement, Smolenice, 27-30, April, 2011, Slovakia

R Köning, G Wimmer, K Karovic, V Witkovsky: *Estimating the standard uncertainty contribution of the straight-line fit algorithm used to determine the position and the width of a graduation line*, Metrologia 49 (2012) 169–179

J Flügge, R Schödel, R Köning, Rainer; H Bosse: *Long term stability of Suprasil line scales and gauge blocks*; Proceedings of the 10th International Conference of the European Society for Precision Engineering and Nanotechnology. Vol. 1: (2010)

C Weichert, M Stavridis, M Walzel, C Elster, A Wiegmann, M Schulz, R Köning, J Flügge, R Tutsch: *A model based approach to reference-free straightness measurement at the Nanometer Comparator*; Modeling aspects in optical metrology II; (Proceedings of SPIE: 7390): (2009), 739000-1 - 739000-10

H Bosse, J Flügge, Jens; R Köning, C G Frase, W Häßler-Grohne, A Just, R D Geckeler: *Dimensionelle Metrologie an ebenen Substraten mit Mikro- und Nanostrukturen = Dimensional metrology on plane substrates with micro- and nanostructures*; Technisches Messen: 76 (2009), 2, 54 – 64

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J E Decker, A G Steele, H Bosse, R J Douglas: *Analysing redundancy in a line scale comparison using Monte Carlo methods*; Measurement Science and Technology: 19 (2008), 6, 064005-1 - 064005-6

I Tiemann, C Spaeth, G Wallner, G Metz, W Israel, Y Yamaro, T Shimomura, T Kubo, T Wakasa, T Morosawa, R Köning, J Flügge, H Bosse: *An international length comparison using vacuum comparators and a photoelectric incremental encoder as transfer standard*; Precision Engineering: 32 (2008), 1, 1 – 6

B Bodermann, D Bergmann, E Buhr, W Häßler-Grohne, H Bosse, J Potzick, R Dixson, R Quintanilha, M Stocker, A Vldar, G N Orji: *Results of an international photomask linewidth comparison of NIST and PTB*; Proceedings of SPIE on CD-ROM: 7488; (2009), 74881H-1 - 74881H-14

M Pisani, A Yacoot, P Balling, N Bancone, C Birlíkseven, M Çelik, J Flügge, R Hamid, P Köchert, P Kren, U Kuetgens, A Lassila, G B Picotto, E Sahin, J Seppä, M Tedaldi and C Weichert: *Comparison of the performance of the next generation of optical interferometers*, Metrologia, 49 (2012) 455

J Seppä, V Korpelainen, M Merimaa, G B Picotto and A Lassila: *A method for linearization of a laser interferometer down to the picometre level with a capacitive sensor*, Meas. Sci. Technol. 22 (2011) 094027

Z X Chao, S S Ong, S L Tan: *Improvement of measuring accuracy of an optical CMM*, icOPEN2011, Physics Procedia 19 (2011) 122-128

A I Mares, R H Bergmans, G W L Kotte, R R Tromp: *Traceability of the F25 vision system for calibration of grated structures with submicron accuracy*, Proc. SPIE, Vol. 7390, 739004 (2009)

A Takahashi, N Miwa: *An experimental verification of the compensation of length change of line scales caused by ambient air pressure*, Meas. Sci. Technol. 21 (2010) 045305

A Takahashi: *Long-term dimensional stability and longitudinal uniformity of line scales made of glass ceramics*, Meas. Sci. Technol. 21 (2010) 105301

A Takahashi, Y Takigawa and N Miwa: *Error contributor of defocus and quadratic caustic in line scale measurement*, Meas. Sci. Technol. 22 (2011) 015302

M Druzovec, B Acko T Welzer: *Simulation of line scale contamination in calibration uncertainty model*, Int J Sumul Model 7 (2008) 113-123

R Koops, A Mares, J Nieuwenkamp: *A new standard for line scale calibrations in the Netherlands*, Mikroniek 4 (2010) 5-12

S Kausinis, A Barakauskas, R Barauskas, A Jaktas, A Kasparaitis: *Reducing dynamically-induced deviations for line scale calibration in non-ideal measurement situation*, Proc. XIX IMEKO World Congress, Sep. 2009, Lisbon Portugal), ISBN 978-963-88410-0-1, 1971-1974

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Potential topics for DG discussions

There seem to be several trends, also visible in the recent research papers (order is not indicating priority):

1. Setting up an infrastructure for improved traceability chain for high precision optical size reference measurements on well defined structures (like e.g. photomasks) to optical CMM measurements on different type of measurement objects;
2. Extending the analysis of line scale comparisons with respect to condensed measurement results to be used for linking, where possible. An example of a condensed measurement result is the deviation from nominal length, determined over all measured line positions of a line scale;
3. Extending the measurement capabilities of high precision line scale comparators, e.g. for determination of straightness or roundness deviations of features; standards with graduations calibrated for position *and* straightness may be valuable references for industrial 2D comparators as well as the recently developed 1.5D length encoder systems;
4. Calibration of length encoders in addition to classical line scales, maybe also using a length encoder system as a transfer standard for DG 7 comparison measurements;
5. Take into account the application of interferometers as well as graduated standards and scale-based measurement systems for calibration and position feedback purposes in measurement instrumentation as well as manufacturing equipment, like e.g. lithography wafer scanners and machine tools and analyse the requirements from these applications on calibration aspects of graduated scales at the NMI and accredited laboratory level;
6. Customers are asking frequently also line width and from edge to edge distances with line scale calibration. These would be useful for calibration of vision CMMs.

Other notes

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Harald Bosse, DG7 moderator

10. April 2018