National Institute of Metrology (Thailand)

APMP Comparison APMP.L-S8

Measurement of flatness of optical flat by interferometry

Technical protocol

National Institute of Metrology (Thailand), (NIMT)

Thailand, June 2015

Contents

1 Document control

Version Draft 1 Issued on 10 October 2014.

Version Draft 2 Issued on 18 November 2014.

Version Draft 3 Issued on 9 December 2014.

Version Draft 4 Issued on 22 December 2014.

Version Draft 5 Issued on 6 June 2015.

2 Introduction

The broad objective of the Asia Pacific Metrology Program (APMP) is to improve the measurement capabilities in the Asia Pacific region by sharing facilities and experience in metrology. Comparison of calibrations by different laboratories on given artifacts adds confidence in the measurement of standards and leads to international acceptance of the measurements carried out by these laboratories. This intercomparison concerns the calibration of flatness of optical flat.

Standards circulated to all laboratories consist of:

- Two (2) optical flats

Measurement conditions for each standard are described in the appropriate section of this document. If the participants cannot follow, an approximation may be made with detailed description of how the measurement conditions have varied.

3 Organization

3.1 Participants

Cooperation of all participants is essential for a successful intercomparison.

Participants are listed in Table 1. They are expected to:

- Provide correct and up to date contact and address details to the pilot laboratory.
- Have all resources and instrumentation ready by the scheduled month of measurement and commit to carry out measurements according to the schedule (Table 2).
- Ensure funds are available for onward transport of the artifacts.
- Select a suitable agent for forwarding the artifacts to the next participant and organize smooth movement through customs using appropriate documents.
- On receipt of the artifacts, inform the program pilot (by email) of receipt, any damage to the standards or the box or of any other problems or delays (Appendix B).
- Follow the instructions of measurement for each standard or specify any variation.
- Calculate a mean result and associated uncertainty.
- On completion of measurements, re-examine the condition of each standard and notify the coordination of any change (Appendix B).
- Repack the artifacts and make transport arrangements. Ensure that the set of documents are enclosed. Inform the next participant in advance. ATA Carnet will be supplied for those

countries that participate in this scheme. The schedule has been set to make efficient use of the Carnet scheme.
- Supply all results including profile image of the flatness measurements in **.bmp** or **.jpg** or other image format, calibration reports, uncertainty calculations and Appendix D summary to the pilot laboratory within 6 weeks of receipt of the artifacts.
- Agree not to discuss any measurement results prior to distribution of the draft report (after completion of all measurements).

Refer to Appendix B for a more detailed checklist of actions required.

Table 1. List of participant laboratories and their contacts.

Laboratory Code	**Contact person, Laboratory**	**Phone, Fax, email**
NIMT	Dr Jariya Buajarern National Institute of Metrology (Thailand), NIMT 3/4-5 Moo 3, Klong 5, Klong Luang, Pathumthani 12120, Thailand	+66 25775100 ext 1216 jariya@nimt.or.th
NMIJ	Dr Youichi Bitou National Metrology Institute of Japan, NMIJ National Institute of Advanced Industrial Science and Technology (AIST) Tsukuba Central 3, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, Japan	+81 298614041 y-bitou@aist.go.jp
NIM	Dr Xue Zi National Institute of Metrology, NIM Beisanhuandonglu 18, Beijing 100013, China	+86 1064524915 xuez@nim.ac.cn
NMC	Dr Liping Zhao National Metrology Centre/Agency for Science, Technology and Research , NMC, A*STAR 1 Science Park Drive, Singapore 118221	+65 62791949 zhao_liping@nmc.a-star.edu.sg
MSL	Mr Neil Swift Measurement Standards Laboratory of New Zealand, 69 Gracefield Rd, Lower Hutt 5040, New Zealand	+6449313214 neil.swift@callaghaninnovation.govt.nz
NPLI	Dr K P Chaudhary National Physical Laboratory India, Dr K S Krishnan Raod, New Delhi 110012, India	Phone: +91 11 4560 8673 / 9425 Fax: +91 11 45609310 Email: kpc@nplindia.org
NMISA	Faith Hungwe National Mterology Institute of South Africa CSIR Building 5, Meiring Naude Road Brummeria, Pretoria	+27 12 841 4936 fhungwe@nmisa.org

3.2 Schedule

The program is to commence in 2015 with measurement at the coordinating laboratory. The order for measurement is listed in Table 2. Each laboratory is expected to make all required measurement in a two week period and allow a further two week period for transferring the artifacts to the next listed laboratory. Those scheduled for December or January are allowed four weeks for measurement due to expected public holidays and a further two week period for transfer. The coordinating laboratory will make repeat measurements at the end of the schedule to check the stability of the artifacts.

Table 2. Schedule of the comparison.

Laboratory	Carnet	Starting date of measurement
NMIJ	Yes	July 2015
NMC	Yes	August 2015
NIMT	Yes	September 2015
NIM	No	October 2015
MSL	No	November 2015
NPLI	No	December 2015
NMISA	No	January 2016
NMIJ	Yes	February 2016

3.3 Reception, transportation, insurance, costs

A metal case containing 2 optical flats, is used for the transportation of the artefacts. The metal case is locked by a number type padlock for preventing accidental open of the case as shown in Fig. 1. The number to open the padlock is “129”. Upon reception of the package, each laboratory has to check that the content is complete and that there is no apparent damage on the box or any of the standards. The reception has to be confirmed immediately to the pilot with a copy to the former participant (sender), preferably using the form of Appendix A.

Figure 1 – Metal case for artefact transportation

The organization costs will be covered by the coordinating laboratory, which include the standards themselves, the cases and packaging, and the shipping costs to the next laboratory. The pilot laboratory has no insurance for any loss or damage of the standards during the circulation.

Once the measurements have been completed, the package shall be sent to the following participant. Each participating laboratory shall cover the costs of shipping and transport insurance against loss or damage. The package should be shipped with a reliable parcel service of its choice. Once the measurements have been completed, please inform the pilot laboratory and the following participant when the package leaves your installations indicating all pertinent information. If, at any point during circulation, the package is damaged, it shall be repaired by the laboratory before shipping it again.

For shipment to country with ATA carnet needed, the package is accompanied by an ATA carnet. The carnet shall always be shipped with the package, never inside the box. **Please be certain, that when receiving the package, you also receive the carnet!** After NIMT complete measurement, ATA carnet will be send to NMIJ via airmail separately to avoid lost of document.

4 Artefacts

4.1 Description of artefacts

The package contains 2 optical flats. Both optical flats are of quartz. Dimensions of both flats are given in the following table 1. The face of optical flat to be measured is indicated by arrow (↑).

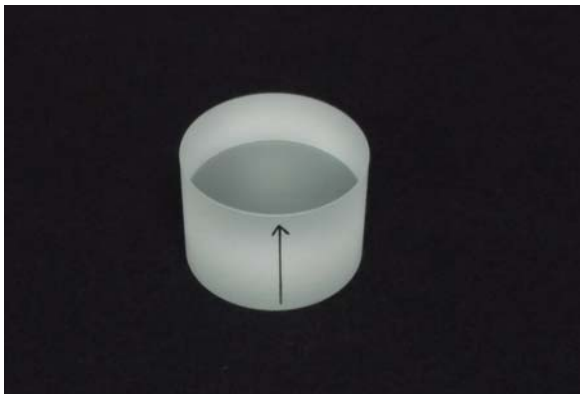


Figure 2 – Optical flat A

Figure 3 – Optical flat B

Table 3. List of artefacts.

Identification	Diameter /mm	Thickness / mm	Effective diameter / mm
A	70	50	60
B	160	50	150

5 Measuring instructions

5.1 Handling the artefact

The optical flats should only be handled by authorized persons and stored in such a way as to prevent damage. Before making the measurements, the optical flats need to be checked to verify that their measuring surfaces are not damaged and do not present severe scratches and/or cracks that may affect the measurement result. The condition of the optical flats before measurement should be registered in the form provided in appendix B. Laboratories should attempt to measure all optical flats unless there is limitation due to their equipments. No participant shall try to re-finish measuring faces by burring, lapping, stoning, or whatsoever.

No other measurements are to be attempted by the participants and the optical flats should not be used for any purpose other than described in this document. The optical flats may not be given to any party other than the participants in the comparison.

The optical flats should be examined before despatch and any change in condition during the measurement at each laboratory should be communicated to the pilot laboratory. After the measurements, ensure that the content of the package is complete before shipment. Always use the original packaging.

5.2 Traceability

Length measurements should be traceable to the latest realisation of the metre as set out in the current "*Mise en Pratique*". Temperature measurements should be made using the International Temperature Scale of 1990 (ITS-90). Detail of equipment used and measurement traceability shall be reported to the pilot using the form provided in appendix C. Orientation of flatness interferometer used should be reported and examples are presented in Figure 4 and Figure 5.

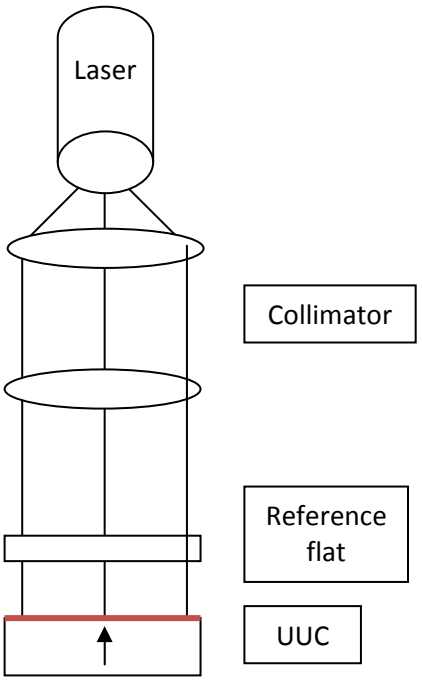


Figure 4 – Flatness interferometer: vertical orientation

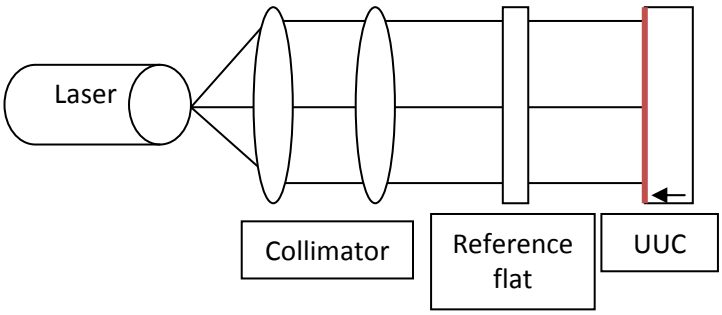


Figure 5 – Flatness interferometer: horizontal orientation

In order to perform measurement using vertical orientation flatness interferometer, both optical flats should be put on the flat base. For measurement performed using horizontal orientation flatness interferometer, optical flats should be set with no stress condition (such as setting on a v-block).

5.3 Measurands

The optical flats shall be measured based on the standard procedure that the laboratory regularly uses for this calibration service for its customers. The face of optical flat to be measured is indicated by arrow. The optical flats shall be oriented in the way that arrow sign is facing front side of the vertical orientation type interferometer system (see Fig. 4) and aligning to the bottom side for the horizontal orientation type interferometer system (see Fig. 5).

The measurand to be reported is the P-V value within an effective diameter, position of peak (P) and position of valley (V). A surface profile must be reported in any kind of image data format. The recommended format are *.jpg and *.bmp. Figure 6 is an example of image data indicating peak and valley positions.

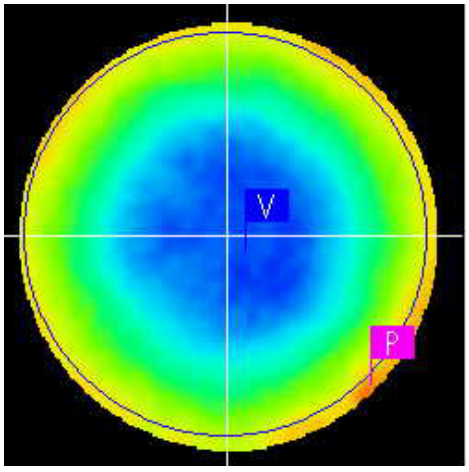


Figure 6 – Example of surface profile

5.4 Measurement uncertainty

The uncertainty of measurement shall be estimated according to the ISO Guide to the Expression of Uncertainty in Measurement. The participating laboratories are encouraged to use their usual model for the uncertainty calculation.

All measurement uncertainties shall be stated as standard uncertainties. If appropriate the corresponding effective degree of freedom might be stated by the participants. If none is given, ∞ is assumed.

6 Reporting of results

6.1 Results and standard uncertainties as reported by participants

As soon as possible after measurements have been completed, the results should be communicated to the pilot laboratory **within six weeks** at the latest.

The measurement report forms in appendix C and D of this document will be sent by e-mail (Word document) to all participating laboratories. It would be appreciated if the report forms (in particular the results sheet) could be completed by computer and sent back electronically to the pilot. In any case, the signed report must also be sent in paper form by mail or electronically as a scanned pdf document. In case of any differences, the signed forms are considered to be the definitive version.

Following receipt of all measurement reports from the participating laboratories, the pilot laboratory will analyse the results and prepare within 3 months a first draft A.1 report on the comparison. This will be circulated to the participants for comments, additions and corrections.

7 Analysis of results

7.1 Calculation of the KCRV

The key comparison reference value (KCRV) is calculated on a gauge-per-gauge basis as the weighted mean of the participant results. The check for consistency of the comparison results with their associated uncertainties will be made based on Birge ratio, the degrees of equivalence for each laboratory and each optical flat with respect to the KCRV will be evaluated using E_n values, along the lines of the *WG-MRA-KC-report-template*. If necessary, artefact instability and correlations between NMIs will be taken into account. Since there are two configuration of flatness interferometer that will be used in this comparison, measurement results from two different configurations will be analyzed separately.

7.2 Artefact instability

The instability of the optical flats must be determined in course of the comparison. For this check the measurements of the coordinator laboratory are used exclusively, not that of the other participants. Using these data a linear regression line is fitted and the slope together with its uncertainty is determined (per optical flat).

Appendix A – Reception of Standards

To:	Pilot name, pilot institute Pilot address Fax: xxx e-mail: xxx@yy		
From:	NMI: ……	Name: ……	
	Signature: ……	Date: ……	

We confirm having received the optical flats for the APMP.L-xx comparison on the date given above.

After a visual inspection:

☐ There are no apparent damages; their precise state will be reported in the form provided in Annex B/C once inspected in the laboratory along with the measurement results.

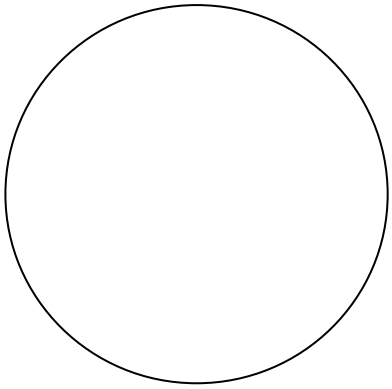
☐ We have detected severe damages putting the measurement results at risk. Please indicate the damages, specifying every detail and, if possible, include photos. If it is necessary use additional sheets to report it.

Appendix B – Conditions of Measuring Face

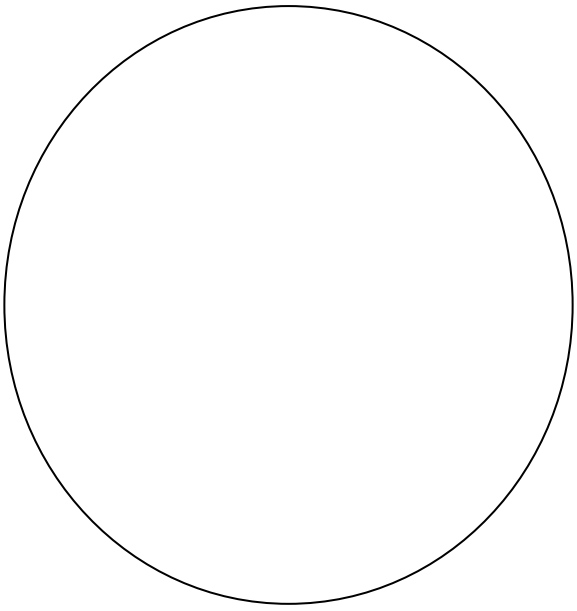
To:	Pilot name, pilot institute Pilot address Fax: xxx e-mail: xxx@yy		
From:	NMI: ……	Name: ……	
	Signature: ……	Date: ……	

After detailed inspection of the measuring faces of the optical flats these are the results. Please mark significant surface faults (scratches, indentations, corrosion, etc.).

Flat A



Flat B



Appendix C – Description of the measurement instrument

To:	Pilot name, pilot institute Pilot address Fax: xxx e-mail: xxx@yy
From:	NMI: …… Name: …… Signature: …… Date: ……

Make and type of instrument(s): .....

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.....

.....

Configuration of flatness interferometer (see 5.2): .....

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Light sources / wavelengths used: .....

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Traceability path: .....

.....

.....

Description of optical flat mounting (equipment used, etc.): .....

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Description of measuring technique (including interferometer type, orientation: vertical or horizontal, traceability, etc): .....

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CMC values and service identifiers (if applicable), and the reason why the reported uncertainty is bigger than CMC (if necessary): .....

.....

.....

(use additional pages as needed)

Appendix D – Results Report Form

To:	Pilot name, pilot institute Pilot address Fax: xxx e-mail: xxx@yy
From:	NMI: …… Name: …… Signature: …… Date: ……

Optical flat	Measured diameter / mm	Flatness (P-V) / nm	$U_{95\%}$ / nm
A			
B			

Source of uncertainty	Distribution type	Standard uncertainty / nm	Degree of freedom

(use additional pages as needed)