COOMET Supplementary Comparison on

Polarization mode dispersion in Optical Fiber

COOMET.PR-S9

(COOMET project # 688/RU/16)

Technical Protocol

(Final version. Corrected on 09 August 2017)

2016

Moscow

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1. Introduction

1.0 The original Final version of this Technical Protocol dated 14 September 2016, was approved and published in KCDB in 2016. However, later, when measurements were already started, two participants, CENAM (Mexico) and NMISA (South Africa), declared that they would be not able to carry out measurements due to some unexpected technical reasons; therefore, they requested withdrawing them from the participant list. Other hand, METAS (Switzerland) expressed its interest in the comparison and asked including it in the participant list. These changes have been discussed and agreed by all the participants. The current version fixes these changes in the participant list. All other details remain unchanged.

1.1. The aim of this comparison is to access the equivalence of the polarization mode dispersion (PMD) in optical fiber among the participants and to underpin the relevant claim of the Calibration and Measurement Capability in BIPM KCDB.

1.2. This technical protocol has been prepared by VNIIOFI for supplementary comparison in the frame of the COOMET project 688/RU/16.

2. Organization

2.1. Participants

2.1.1. VNIIOFI is acting as a pilot laboratory among the participants in this international supplementary comparison.

2.1.2. KRISS (Korea), INMETRO (Brazil), METAS (Switzerland) and VNIIOFI (Russia) are the participants of the comparison.

2.1.3. All the participants must be able to demonstrate traceability to an independent realization of the quantity, or make clear the route of traceability to the quantity via another named laboratory.

2.1.4. By their declared intention to participate in this comparison, the laboratories accept the general instructions and the technical protocols written down in this document and commit themselves to follow the procedures strictly.

2.1.5. Once the protocol has been agreed, no change to the protocol may be made without prior agreement of all the participants.

2.1.6. All the participants confirmed the intention to take part in the COOMET Project.

2.2. Participant Details

	Participants	Correspondence	E-mail address Phone number	Address
1	KRISS (Korea)	Seung Kwan Kim Kee Suk Hong	skkfiber@kriss.re.kr +82-42-868-5701 hongi2011@kriss.re.kr +82-42-868-5938	Center for Photometry and Radiometry, Korea Research Institute of Standards and Science (KRISS) 267 Gajeong-Ro, Yuseong-Gu, Daejeon 3411, Republic of Korea

2	INMETRO (Brazil)	Giovanna Borghi	gbalmeida@inmetro.gov.br +55 (21) 2679-9051	National Institute of Metrology, Quality and Technology (INMETRO) Santa Alexandrina St, 416 Rio Comprido - Rio de Janeiro - RJ - Brazil Zip Code: 20261-232
3	METAS (Switzerland)	Jacques Morel	jacques.morel@metas.ch +41 58 387 0350	Time and Frequency Laboratory, Federal Institute of Metrology (METAS) Lindenweg 50, CH-3003 Bern-Wabern, Switzerland
4	VNIIOFI (Russia)	Vladimir Kravtsov Aleksei Mituirev	kravtsov-f3@vniiofi.ru +7 495 781-45-86 mak@vniiofi.ru +7 495 781-45-83	Fiber Optical Systems Metrology Laboratory, All Russian Research Institute for Optical and Physical Measurements (VNIIOFI) Ozernaya st.46, Moscow, 119361, Russia

2.3. Form of Comparison

2.3.1. The comparison will principally be carried out through calibrations of two PMD artifacts – for weak and strong mode coupling respectively. The artifact for weak mode coupling will be prepared by VNIIOFI, and the artifact for strong mode coupling will be prepared by KRISS. Each artifact will contain PM fiber sections and have two FC type receptacles, one for input and another for output for connecting to the measurement system.

2.3.2. Sequence of measurements will be:

Pilot – Participant 1 – Participant 2 – …. – Pilot.

2.3.3. The comparison will consist of one round. Each participant will have two month period for measurements and then must send the artifacts to the next participant right away so that the artifacts can be delivered to the next participant within one month after finish of measurements. The participant should immediately report to the pilot lab when the problem happens to delay the predetermined schedule.

2.4. Timetable

Activity	Start Date	End Date
KRISS artifact Delivery to VNIIOFI	01 June 2016	31 July, 2016
KRISS and VNIIOFI artifact measurement at VNIIOFI	01 August, 2016	31 August, 2016
KRISS and VNIIOFI artifacts Delivery to INMETRO	01 November, 2016	30 November, 2016
KRISS and VNIIOFI artifacts measurement at INMETRO	01 December, 2016	30 January, 2017
KRISS and VNIIOFI artifacts Delivery to KRISS	01 May 2017	31 May, 2017
KRISS and VNIIOFI artifacts measurement at KRISS	01 June, 2017	31 July, 2017
KRISS and VNIIOFI artifacts Delivery to METAS	01. August, 2017	31. August, 2017
KRISS and VNIIOFI artifacts measurement at METAS	01 September, 2017	31 October, 2017
KRISS and VNIIOFI artifact Delivery to VNIIOFI	01 November, 2017	31 November, 2017

KRISS and VNIIOFI artifact second measurement at VNIIOFI	01 December, 2017	31 January, 2018
KRISS artifact Return to KRISS	01 February, 2018	28 February, 2018
Distribution of Pre-Draft A data	01 February, 2018	15 April, 2018
Distribution Draft A	31 June, 2018	

Each participant should submit measurements results (report) to the pilot within two months after completion of its measurements.

When all measurements are completed, the participants will be given a deadline date for submitting the results, and if they do not meet the deadline, they might be disqualified.

2.5. Handling Artifacts

2.5.1. The PMD artifacts should be examined immediately upon receipt. However, care should be taken to ensure that the artifacts have sufficient time to acclimatize to the room environment thus preventing any condensation, etc. The condition of the artifacts and the associated package should be noted and communicated to the coordinator of the pilot lab if there is anything abnormal found.

2.5.2. Before comparison measurements the FC connectors should be inspected visually or, if possible, with a microscope. The photographs should be taken for record. The same inspection procedure should be made after completion of the measurements before packaging the artifact for delivery to the next participant.

2.5.3. Care must be taken to maintain the FC connector clean at all times. Cleaning of the connectors **MUST** be done every time before connecting the artifacts to a facility for measurements using standard fiber optic connector cleaning methods.

2.5.4. If a participant detects any damage or meets any problem that potentially can affect the comparison measurements, the participant should immediately report this to the pilot lab by e-mail. If the artifact is decided to be repaired, the participant will deliver the artifact to the owner of the artifact (KRISS or VNIIOFI). Because repairing artifact can affect its characteristics, the comparison has to be repeated with the repaired artifacts.

2.5.5. When the comparison measurements are completed, the artifacts should be repackaged in their original container. Please ensure that the content of the package is complete by checking the packing list that was delivered together with the artifacts. The original packaging container should be used unless it is significantly damaged. Please inform the coordinator if the participant decides to make a new container.

2.5.6. The participant should inform the contact person of the next participant and the coordinator of the pilot lab of the delivery schedule when the artifact package is ready to be sent.

2.6. Transportation of Artifacts

2.6.1. It is important that the artifact should be transported in a manner such that they will not be lost, damaged or handled by un-authorized persons. The artifacts should be packaged in a container that is suitably robust to protect the artifacts from being deformed or damaged during transportation.

2.6.2. Transportation is at each participating lab's responsibility and cost. Each participating lab should cover the cost for its own measurements, one-way transportation including insurance, customs clearance, and any expense to be occurred in its own country.

Choice of transportation method is up to each participating lab.

3. Description of Artifacts

3.1. KRISS Artifact

3.1.1. The KRISS artifact was fabricated by using multiple sections of PM fiber, arc-fusion spliced with random orientation of birefringent axis. The PMD coefficient of the used PM fiber was 1.5 ps/m. The physical length of each PM fiber section was made to be about 47 mm so that the artifact could have a PMD of about 0.5 ps with the number of sections of 50. After the two ends of the resultant fiber were spliced with FC/PC connectors for input and output port, it was placed in a circular groove with a diameter of 17.5 cm in a metal case with dimension of 20 cm (L) × 24 cm (W) × 2 cm (H) and fixed with silicone glue to minimize applied stress during curing, and finally covered with a metal plate with a thickness of 1.5 mm. The outer and inner look of the KRISS artifact are shown in the figure 3-1-1.

Fig. 3-1-1. Photograph of the KRISS artifact.

3.2. VNIIOFI Artifact

3.2.1. The VNIIOFI artifact consist of two sections of PM fiber with PMD values 0,3 and 5 ps for weak couple mode regime. Sections are packaged in a metal case designed to contain the fiber securely and safely as shown in Fig. 3-2-1. Two patch-cables of approximate length L = 0,1 m are fitted with FC/APC connectors and are fusion-spliced at both fibre ends. The internal structure of the VNIIOFI artefact is shown in the figure 3-2-1.

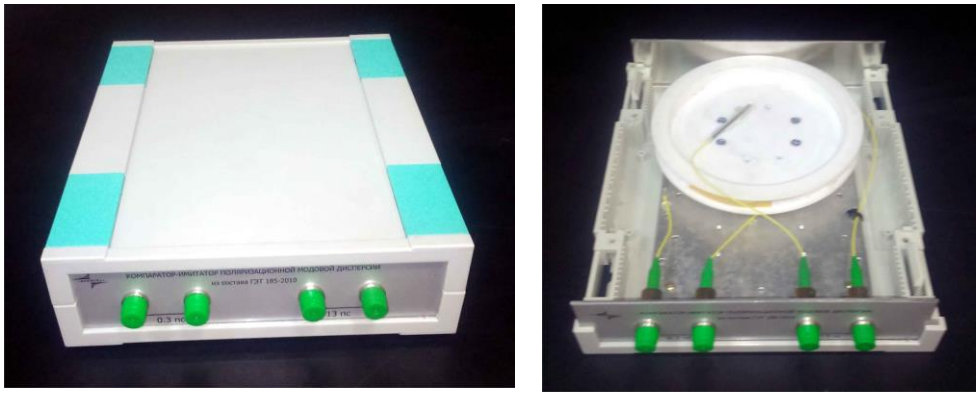

Fig. 3-2-1. Photograph of the VNIIOFI artifact.

4. Measurement Instructions

4.1. Traceability

4.1.1. Temperature measurement should be made using the International Temperature Scale of 1990 (ITS-90).

4.1.2. Electrical measurements should be independently traceable to the latest realization of the Ampere and Volt.

4.1.3. Time or frequency measurements should be independently traceable to the latest realization of time and frequency.

4.2. Measurand

4.2.1. The measurand is the average differential group delay (PMD) in the unit of picoseconds of each artifact within the wavelength range from 1520 to 1570 nm at the temperature of 23 °C.

4.2.2. Correction of temperature mismatch should be made and the corresponding uncertainty should be included in the uncertainty budget. The exact temperature of the laboratory during the comparison measurements should be reported.

4.3. Measurement Instructions

4.3.1. Measurement setup is proposed to be based on Jones matrix eigenanalysis (JME) method

according to the IEC 60793-1-48 procedure.

4.3.2. Before connecting the artifact to the participant's measurement setup, the fiber connectors of both the artifact and the setup should be inspected for possible dust, contamination, or damages. Please refer to Section 2.5 for handling the artifacts. The artifact connectors **MUST** be cleaned every time before connecting to the setup using standard fiber optic connector cleaning methods.

4.3.3. The artifact should be connected to the participant's measurement setup as shown in Fig. 4-3-1.

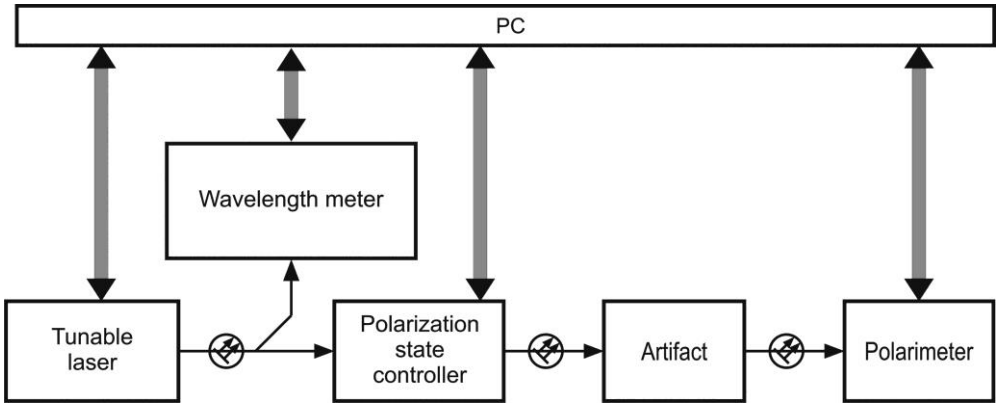

Fig. 4-3-1. Schematic diagram of measurement setup for PMD comparison.

4.3.4. The PMD measurement should be performed at the artifact temperature of 23 °C. If the actual temperature of the artifact is differ from 23 °C, it is the participant's responsibility to report the actual temperature of the artifact and to make correction to the measurement result for the temperature mismatch and to evaluate the uncertainty associated with the correction.

4.3.5. The participants should measure differential group delay (DGD) using wavelength increment $\delta\lambda$ suitable for measuring PMD values. Start wavelength is 1520 nm, stop wavelength is 1570 nm. The DGD data should be obtained every time by repeating the increment after shifting ($\Delta\lambda$) starting wavelength to appropriate value repeatedly. The measurand (PMD) should be calculated as average DGD value for all measured wavelengths.

5. Reporting Results and Uncertainty Participant's measurement report should include a description of the participant's measurement facility or a reference to a published work of the facility. Schematic diagram of the facility should be included. It would be desirable to present photograph of the facility.

5.2. The report should include the information about the traceability which the participant has established and maintained.

5.3. The report should contain a comprehensive uncertainty budget, comprising all the contributions to the total uncertainty. The uncertainty of measurements should be estimated according to the ISO Guide to the Expression of Uncertainty in Measurements.

5.4. The reported values of PMD and corresponding standard uncertainties for each artifact will be used to calculate the comparison reference value.

5.5. The participant should submit the report by e-mail in word and pdf format to the pilot **within two months** after completion of measurements. In addition, the printed report should be sent to the pilot lab by air mail. In case of any discrepancy found between the two reports, the printed one will be regarded as a definitive version and used for drafting the comparison report.

5.6. After receipt of the reports from all of the participants, the pilot lab will analyze the results, carry out Pre-Draft A procedures and prepare a Draft A report following the CCPR-G2: Guidelines for CCPR key comparison report preparation and other relevant CCPR guidelines.