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CALIBRATION OF FIBER OPTIC POWER METER AT 1625 NM

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Abstract – Fiber optic power responsivity scale at 1625 nm is newly established to support optical fiber communication industry. Using the absolute scale at reference level of -10 dBm and the linearity measurements, a fiber optic power meter is calibrated at 1625 nm from -60 dBm to 0 dBm. The uncertainty is less than 0.7 % (*k*=2) at -10 dBm and about 1 % in the full range.

Keywords: fiber optic power, responsivity, calibration, fiber optic power meter

1. INTRODUCTION

Fiber optic power meter (FOPM) is a key measurement instrument in fiber optics research and development for components, modules, and systems. The most common wavelength ranges of FOPM have been 1310 nm and 1550 nm, and therefore the fiber optic power responsivity scale has been established and maintained in national metrology institutes to disseminate the standard and to provide calibration services at these two wavelengths [1-3].

Recently, new demand at 1625 nm rises as the optical fiber communication systems begin to use this wavelength for monitoring system performance. This requires us to establish the fiber optic power responsivity scale at 1625 nm and expand the service capability for FOPM calibration at this new wavelength. It looks like a mere expansion of already existing facility and capability, but we believe that it is still worthwhile to report the results for audience or readers who are interested in or going to do the similar work.

In this presentation, we describe our calibration setup, capability and procedure to calibrate FOPM at 1625 nm including linearity measurement.

2. CALIBRATION SETUP FOR FOPM

2.1. Absolute Fiber Optic Power Responsivity

Our reference optical power meter for fiber optic power responsivity is an electrically calibrated pyroelectric radiometer (ECPR). The correction factor (CF) of the ECPR is obtained through comparison with a silicon trap detector which is traceable to our absolute cryogenic radiometer. The measurement setup to determine the CF of a FOPM is as shown in Fig. 1. We used a distributed-feed-back (DFB) type laser diode (LD) as an optical source for the calibration. The DFB LD was purchased from LasersCom, LLC., whose output power could be increased up to 20 mW in continuous-wave operation. The wavelength was finely controlled to be 1624.99 nm ± 0.01 nm (*k*=2) by injection current to drive the LD and temperature of the thermo-electric cooler as measured by a calibrated multi-wavelength meter. The laser output from an FC/APC type fiber connector of the LD was made to a collimated beam and re-launched into an FC/APC connector using two fiber optic collimators, respectively. An optical beam chopper of the ECPR could be moved in or out of the collimated beam path by a linear translation stage so that we can measure the output power through the ECPR and the FOPM in turn. The reference optical power level of -10 dBm was set by a variable optical attenuator (VOA). A motorized polarization controller (MPC) was used to measure the polarization dependence of the CF. Finally, a fiber optic isolator was used to prevent optical power drift due to optical interference arising between the fiber end and the various optical interfaces of the setup. Using this setup, we could determine the CF of the KRISS working standard FOPM (WS) at -10 dBm. The optical head of the KRISS WS has an integrating sphere so that polarization dependence and fiber connector effect are intrinsically low.

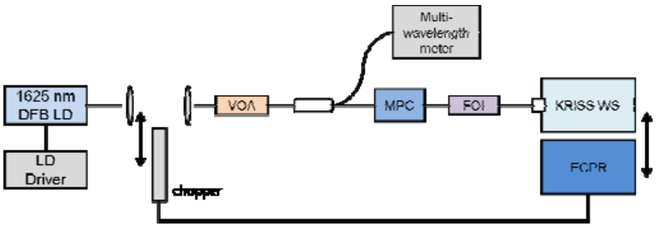

Fig. 1. Calibration setup for absolute fiber optic power responsivity at 1625 nm. ECPR, electrically calibrated pyroelectric radiometer; FOI, fiber optic isolator; MPC, motorized polarization controller; VOA, variable optical attenuator; WS, working standard.

2.2. Linearity of Fiber Optic Power Responsivity

We applied the superposition method [4] to measure the nonlinearity of the FOPM as shown in Fig. 2. Two independent laser outputs from the DFB LD’s were combined with a directional coupler after VOA1 and VOA2, and delivered to a FOPM under measurement after VOA3. The VOA1 and VOA2 could attenuate the optical power of the individual path up to 60 dB and so the optical power range to measure nonlinearity was from -65 dBm to +5 dBm using two different attenuation level of VOA3. Both VOA1 and VOA2 have shutter function so that we could measure the readout of the FOPM with single and doubled optical power. Using this setup, we could determine the nonlinearity of the KRISS linearity working standard FOPM (LWS) at all levels in the above range.

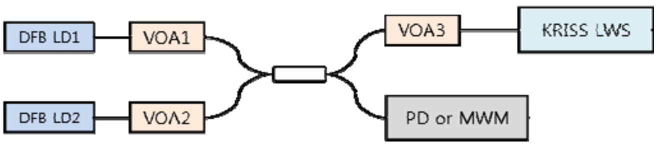

Fig. 2. Calibration setup for linearity of FOPM. LWS, linearity working standard; MWM, multi-wavelength meter; PD, photo-diode.

3. RESULTS

Calibration result of KRISS WS at a reference level of -10 dBm is summarized in Table 1. The results at 1310 nm and 1550 nm were also added in the table for comparative information. It shows a tendency that the correction factors decrease as wavelength increases.

Table 1. Calibration result of KRISS WS at reference level.

wavelength (nm)	correction factor	uncertainty*
1309.98 ± 0.01	1.0015	0.65 %
1550.00 ± 0.01	0.9884	0.64 %
1624.99 ± 0.01	0.9802	0.64 %

* *k*=2, level of confidence: approximately 95 %

At an optical power level P other than the reference level, the nonlinearity NL is defined using responsivity R and nonlinearity factor F as in (1).

$$NL(P) = \frac{R(P)}{R(P_{\mathrm{ref}})} - 1 = F(P, P_{\mathrm{ref}}) - 1 \qquad (1)$$

The nonlinearity factor F at P relative to P_0 is determined by the product of f's as in (2), where f is a ratio of readout of the doubled optical power to that of the sum of the two single optical power readouts measured using the superposition method as in (3). Here P_0 means the minimum optical power level.

$$F(P = 2^n P_0, P_0) = \prod_{i=0}^{n} f(2^i P_0) \qquad (2)$$

$$f(2^i P_0) = \frac{D(2^i P_0)}{D(2^{i-1} P_0) + D(2^{i-1} P_0)}, \quad f(P_0) = 1 \qquad (3)$$

D means the readout of KRISS WS. Each f was measured five times and the averaged value was used to calculate F in (2). Finally, the nonlinearity factor relative to the reference optical power level can be calculated by (4).

$$F(P, P_{\mathrm{ref}}) = \frac{F(P, P_0)}{F(P_{\mathrm{ref}}, P_0)} \qquad (4)$$

Fig. 3 shows the measured results of nonlinearity factor. The standard deviation of f at each level was less than 0.1 % below 0 dBm and less than 0.3 % above 0 dBm. We conclude that the nonlinearity of KRISS LWS at 1625 nm is less than 0.3 % at all optical power levels from Fig. 3.

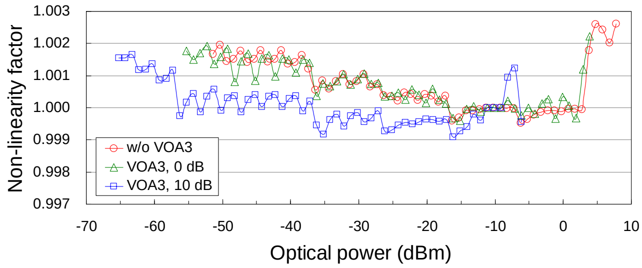

Fig. 3. Nonlinearity factors of KRISS LWS.

By comparison of a commercial FOPM as a DUT with KRISS WS and LWS, we could obtain the correction coefficient of the DUT from -60 dBm to 0 dBm with a step of 5 dB. Table 2 shows the calibration result at each optical power level with uncertainty.

Table 2. Calibration result of DUT at 1625 nm.

optical power level (dBm)	correction coefficient (dB)	uncertainty* (dB)
0	-0.028	0.043
-5	-0.026	0.043
-10	-0.026	0.043
-15	-0.025	0.043
-20	-0.024	0.043
-25	-0.022	0.043
-30	-0.024	0.043
-35	-0.023	0.043
-40	-0.025	0.043
-45	-0.026	0.043
-50	-0.029	0.043
-55	-0.029	0.043
-60	-0.028	0.043

* *k*=2, level of confidence: approximately 95 %

4. CONCLUSIONS

We constructed a calibration facility for fiber optic power meters at 1625 nm and obtained fiber optic power responsivity scale with KRISS WS and LWS using the ECPR and linearity measurements. By comparison with KRISS WS and LWS, we successfully demonstrated calibration result of a commercial FOPM from -60 dBm to 0 dBm at 1625 nm. The reported results in this presentation will be applied to disseminate the established standard to fiber optics industry for traceable measurements of fiber optic power.

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