High-power nonlinearity of optical fiber power meters

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Abstract

We have developed a system for measuring the nonlinearity of optical fiber power meters at a maximum power of 2 W. This system is based on the triplet superposition method. This system provides an accurate determination of nonlinearity of optical power meters by means of correction factors at different powers.

1. Introduction

Most users of optical power meters assume that the meter output reading is directly proportional to the optical input power. This proportionality property is called linearity, and the departure from this direct proportionality is defined as nonlinearity. Optical power meter nonlinearity is defined as the relative difference between the response at an arbitrary power and the response at the reference power:[1]

$$\Delta_{NL}(P;P_c) = \frac{R(P)}{R(P_c)} - 1, \tag{1}$$

where $R(P)=V/P$ is the response of the meter at optical power P, the subscript c indicates the calibration point, and V is the meter output reading.

While the calibration gives the true input power from the power meter output reading at the calibration point, the measurement of nonlinearity and range discontinuity, together with calibration, provides this input-output relationship at any power within the entire dynamic range of the optical power meter.

1.1. Correction factor for nonlinearity and range discontinuity

The true input power P is obtained from the power meter reading V by

$$P = \frac{V}{F_c \cdot CF}, \tag{2}$$

where $F_c = V_c/P_c$ is the calibration factor, and

$$CF = \frac{a_1[c]}{a_1[m]} \times \frac{1 + \sum_{k=2}^{n} b_k[c]V_c^{k-1}}{1 + \sum_{k=2}^{n} b_k[m]V^{k-1}}$$

$$= \frac{a_1[c]}{a_1[m]}[1 + \Delta_{NL}(V;0) - \Delta_{NL}(V_c;0)], \tag{3}$$

where CF is a correction factor due to nonlinearity and range discontinuity, *m* is a number that corresponds to a specific range of an optical power meter, a_k and b_k are coefficients. b_k is determined by measurement of nonlinearity, $a_1[c]$ is determined by calibration and $a_1[m]$ by range discontinuity. Consequently, each range of a power meter has its own correction factor. The degree of the polynomial *n* depends on the value of the data's standard deviation.

2. Measurement system and results

We have based the operation of our system on the triplet superposition method,[2-6] which relies on the principle that, for a linear power meter, the sum of meter outputs corresponding to inputs from two individual beams should equal the output when the two beams are combined and incident on the meter at the same time. The measurement system is depicted in Figure 1 and described below.
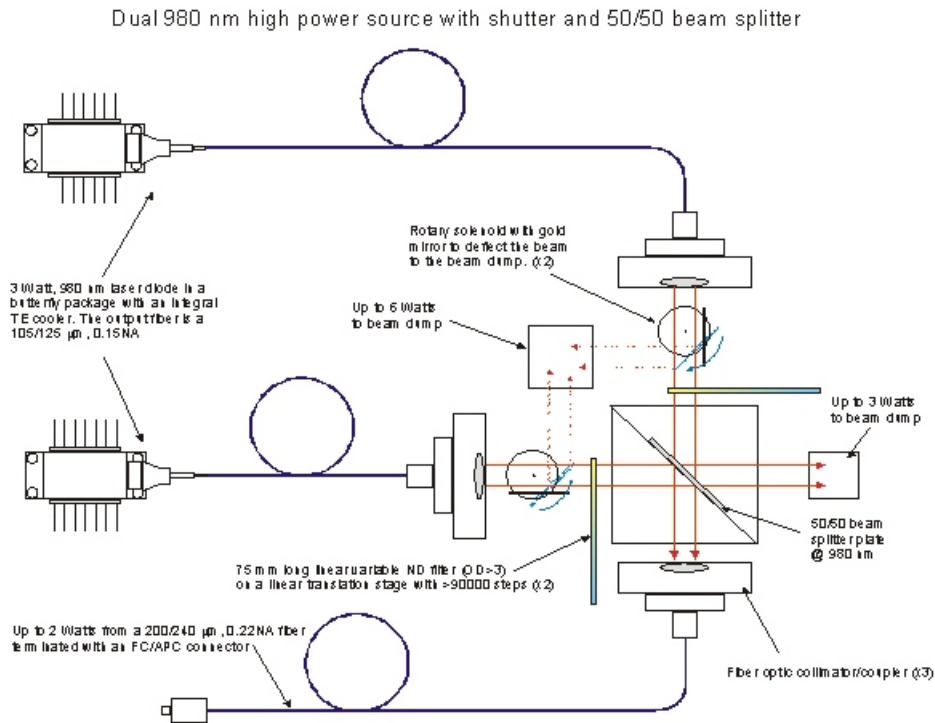

Figure 1. Measurement system.

Each source is a 980 nm laser diode in a butterfly package with an integrated thermoelectric (TE) cooler, monitor photodiode, and thermistor. The laser pigtail's core/cladding size is 105/125 μm with a numerical aperture (NA) of 0.15. The laser diode is driven in a constant-power mode with a high-power laser driver, that contains an adjustable current limit and a laser enable feature. The temperature is held constant at 23˚C by the TE cooler control module.

The output fiber of the first laser diode is aligned to a high-power collimator that produces a beam diameter of approximately 6 mm. This beam then propagates through a high-power optical shutter. The shutter is a rotary solenoid with a mirror-mounted offset onto the shaft. For safety reasons, the beam is blocked when the shutter is in the "OFF" position and is sent to a beam dump. When the shutter is activated, the mirror is removed from the optical path and enables the beam to pass through.

The beam then passes through a linear, variable neutral density filter that is 75 mm in length. The filter is variable from 0 to approximately 30 dB at 980 nm. The filter is mounted on a linear translation stage and is driven by a servo motor/encoder combination. The translation stage has its travel limit set at each end by a limit switch. The total beam travel is approximately 60 mm with a step count of >90,000. The translation stage is controlled through an RS232 port. The beam then enters the 50/50 beam splitter plate where half of the light is propagated to a second beam dump. The remaining light proceeds to the high-power output lens and gets coupled into a 200/240 μm fiber with a NA of 0.22.

The second laser transmits, via an identical system, through the 50/50 beam splitter plate at 90˚ perpendicular to the beam of the first laser. The second laser's beam is then coupled with the first laser beam into the 200/240 μm fiber with the NA of 0.22. The output of each laser at the tip of the 200/240 μm fiber is set at 1 W. The fiber is routed to the outside of the case via a 3 mm stainless-steel armored cable (for safety) and is terminated with an FC/APC connector.

The measurements are performed by taking sets of three power readings from the test power meter: (1) shutter 1 is open and shutter 2 is closed, (2) shutter 1 is closed and shutter 2 is open, and (3) both shutters are open. This sequence is then repeated at different powers.

To measure the range discontinuity (offsets between range or scale settings), readings are taken at the lower power end of each range and compared to the readings on the higher power region of the next lower range (if any) at a constant power. The calculated correction factors result from the meter nonlinearity within each range, combined with the range discontinuity.

Figure 2 depicts correction factors obtained on a high-power optical fiber power meter at 980 nm. Each data group represents a separate power range setting of the meter. The total nonlinearity of this power meter is approximately 3.5% for powers from several milliwatts to several watts.

3. Conclusion

We have designed and built a nonlinearity system that allows us to obtain correction factors for optical fiber power meters at a maximum power of 2 W at 980 nm. This system is an important tool to characterize optical fiber power meters at high powers. Similar nonlinearity systems could be built at other telecommunication wavelengths: 1310, 1480 and 1550 nm.
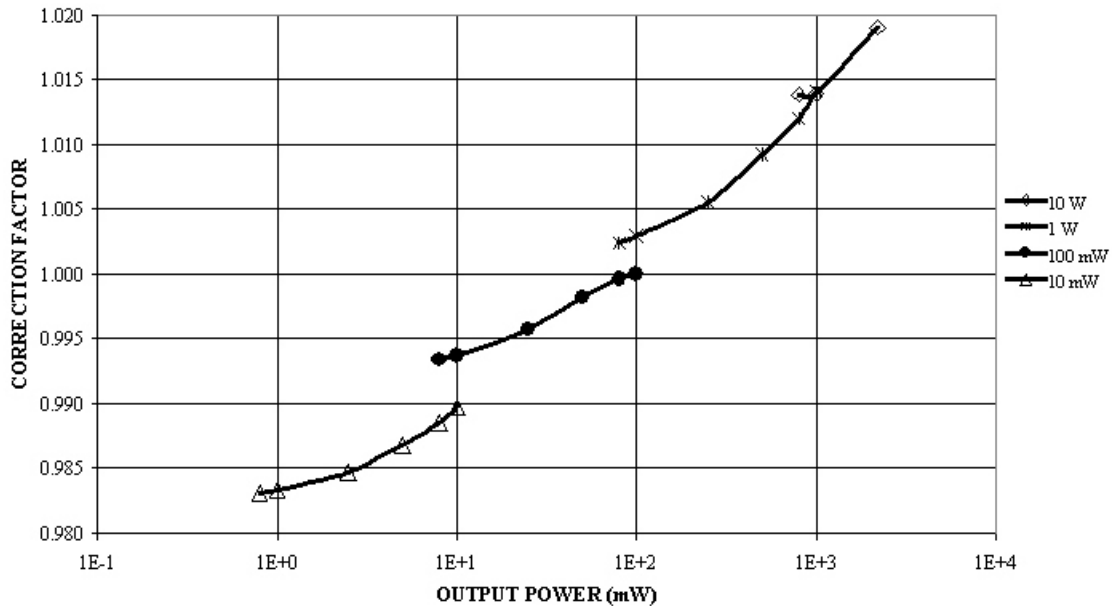
Figure 2. Correction factor vs. incident power at 980 nm.

References

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