INTERLABORATORY COMPARISON OF FAR-FIELD METHODS FOR DETERMINING MODE FIELD DIAMETER USING BOTH GAUSSIAN AND PETERMANN DEFINITIONS

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In a previous interlaboratory comparison of measurement methods for mode field diameter (MFD) of single-mode optical fiber, participants assumed a Gaussian mode-field distribution [1]. Those results indicated good agreement (0.15 μm, one standard deviation) among the various methods for dispersion unshifted fibers at 1300 nm. The Gaussian distribution was a good assumption since 1300 nm was close to the cut-off wavelength. At 1550 nm, however, the Gaussian assumption is not valid, and significant offsets (0.7 μm) were observed between the one-dimensional far-field scan (FF) method and variable aperture far-field (VAFF) method. This is of concern, since these two methods are among the most widely used for routine MFD measurements. Anderson and Kilmer have shown that the "Petermann 2" definition, based on a second moment, gives good consistency among various measurement methods [2] [3]. Moreover, in those situations where mode profiles are not approximately Gaussian, the Petermann definition gives better prediction of splice loss than does the Gaussian.

This paper describes an interlaboratory comparison which includes the Petermann as well as the Gaussian definition and also considers measurements on dispersion shifted single-mode fibers. Participants in the comparison are members of the Electronic Industries Association and include most of the major fiber and cable manufacturers in North America.

Six single-mode fibers representing five different manufacturers were measured by the participants. Two fibers were dispersion shifted, while the remaining four were dispersion unshifted.

Seven participants used the FF method, in which laser diodes are used as sources and MFD is determined by acquiring the one-dimensional far-field radiation pattern. Five participants used the VAFF method, in which MFD is determined by measuring the relative power passing through a series of far-field apertures. Here, the source generally consists of a tungsten lamp and a monochromator. Details of the FF and VAFF methods can be found in EIA-FOTP 164 and EIA-FOTP 167, respectively.

Common to all methods were a test fiber length of 2.0 ± 0.2 m, a single 50 mm diameter loop to strip out possible second-order mode power, and, when necessary, some type of cladding-mode stripper.

Participants closely followed the guidelines of FOTPs 164 and 167. The FOTPs contain specific curve-fitting instructions for the Gaussian MFDs. Petermann MFDs were determined from far-field integrals without specification of a particular curve-fitting routine.

The results of the comparison are grouped into three categories: 1300 nm dispersion unshifted, 1550 nm dispersion unshifted, and dispersion shifted. This division seems quite natural when the average offsets between FF and VAFF methods are examined. For fibers in the same category, the relative offsets are approximately the same, without exception; relative offsets between FF and VAFF methods are given in Table 1 (small corrections have been made for variations in source wavelengths). The offsets are less for the Petermann definition for all fiber categories.

For unshifted fibers at 1300 nm, using the Gaussian definition, the results of the previous interlaboratory comparison were verified. An average standard deviation of 0.17 μm was observed, with only a small offset between average VAFF and FF results. The Petermann results did improve on this though, giving almost no offset and an average standard deviation of 0.11 μm, Fig. 1.

For the same fibers at 1550 nm, substantial offsets were observed between VAFF and FF results for the Gaussian definition. Petermann results gave significant improvement, reducing offsets to almost zero and giving an average standard deviation of 0.11 μm, as opposed to 0.32 μm for Gaussian, Fig 2.

With dispersion shifted fibers, the Gaussian results gave the largest offsets of all. Petermann results seemed to improve upon this, but only slightly. The average standard deviation was 0.5 μm for Gaussian and 0.35 μm for Petermann, Fig 3. The Petermann results of one VAFF participant were consistently within the range of FF Petermann results. We suspect the large VAFF/FF offsets are related to the small MFDs of dispersion shifted fiber. Smaller MFDs translate to more power at larger far-field angles. If the VAFF optics and associated detector do not have sufficiently uniform collection for large enough NA, then the measured far-field pattern will be truncated; this translates into a larger measured MFD. We believe, therefore, that the discrepancies observed for this fiber category have more to do with experimental apparatus than with the Petermann definition; this is currently being investigated.

REFERENCES

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Table 1. Average offset values, in μm, between VAFF and FF results, for the three categories of comparison fibers.

Category	Offset Between VAFF and FF Methods, μm (Ave. VAFF − Ave. FF)	
	Petermann	Gaussian
1300 nm Dispersion Unshifted	0.04	0.28
1550 nm Dispersion Unshifted	0.05	0.59
1300&1550nm Dispersion Shifted	0.52	0.92

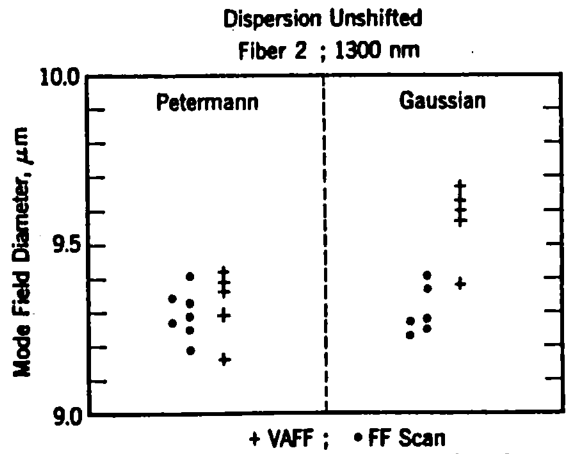

Fig. 1. Typical result for dispersion unshifted fibers at 1300 nm.

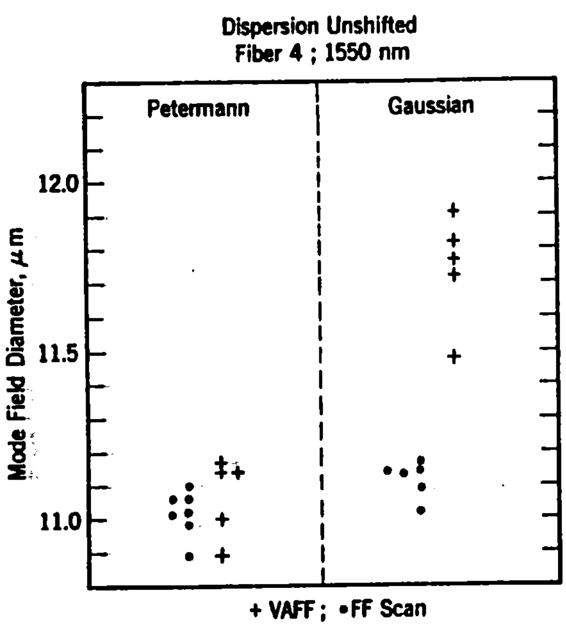

Fig. 2. Typical result for dispersion unshifted fibers at 1550 nm.

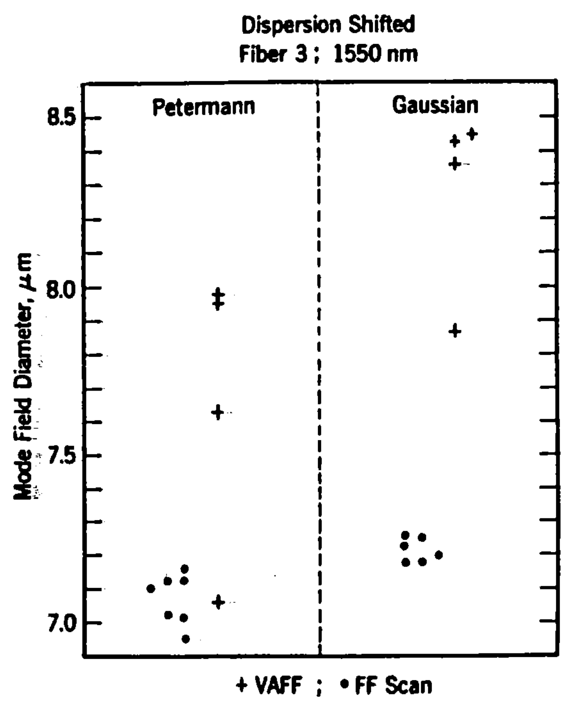

Fig. 3. Typical result for dispersion shifted fibers.