**Near-Field Characterization of Multimode Optical Fibers**

With the help of some of the LabVIEW control program features, including camera nonlinearity and centroid calculation, the system has been a useful and efficient tool for analyzing multimode fibers and devices.

- M. Oliviero, PHOTONLAB - POLITECNICO DI TORINO

**Author(s):**
M. Oliviero - PHOTONLAB - POLITECNICO DI TORINO
G. Perrone - PHOTONLAB - POLITECNICO DI TORINO

A recent challenge in optical communications is the widespread use of optical fibers in local area networks and short-range data transmissions using multimode fibers and related devices. We developed an automated system for precise power distribution analysis using modal power distribution (MPD), which is the power distribution among the various modes in an MMF, and encircled flux (EF) characteristic parameters. The setup, which includes an LED source, a camera, and a frame grabber controlled by LabVIEW, provides a real-time analysis of the near-field pattern of a multimode fiber and conducts a quick computation of the parameters. The system has become essential for quick fiber inspection as well as thorough and exhaustive characterization of devices such as mode controllers and mode scramblers.

Optical fibers have implemented the tremendous development of modern telecommunications and data exchange. While well-established in transoceanic links, the use of optical fibers for short-range data transmissions, also known as “last mile” connections, is still in the early stages of development. Different techniques and standards are entering the optical communication market; however, the general trend seems to implement multimode fibers (MMFs) for short links and local/metropolitan area networks. In an MMF, the light propagating into the fiber is the superposition of several electromagnetic field configurations called “propagation modes,” each carrying a share of the total power transmitted through the fiber. In comparison to single-mode fibers in which only one field configuration can propagate, MMFs exhibit a number of advantages including the large tolerance to misalignment, easy installation, and availability of low-cost transmitters and receivers. The main challenge with using MMF is that the information carried by the optical signal may be corrupted during its propagation if the optical power is incorrectly distributed among the propagation modes. The MPD plays a particularly important role in the fiber performance in local area networks (LANs). The MPD in a LAN fiber system also has a critical effect on the available bandwidth, particularly for gigabit Ethernet transmission. In addition to MPD, a quantitative measure of the light distribution in an MMF is given by the EF. Both MPD and EF can be computed from the near-field pattern.

Using the PCI-1409 frame grabber, LabVIEW software, and the libraries from the new vision module, we set up a test bench to quickly and easily measure these quantities.

**Setup for Mode Profile Measurements**

The setup for MMF characterization, as shown in Figure 1, consists of an LED source centered at the fiber operating wavelength, usually in the near infrared at either 850 or 1,300 nm, which we can directly connect to the fiber system under test or through a mode controller. In the latter case, the measurement is the analysis of the mode controller performance, which should work to distribute power among the modes in a controlled fashion. We used a 40X microscope objective designed to...
yield low attenuation in the infrared spectrum to magnify the near-field image on the MMF facet. We mounted the MMF and the microscope objective on piezo-driven micropositioners for precise alignment, and placed a vidicon camera at a fixed distance from the objective. The PCI-1409 image acquisition board digitizes the near-field pattern grabbed by the camera and LabVIEW records and processes the data.

**Near-Field Pattern Analysis**

As shown in Figure 2, the LabVIEW user interface controls the near-field pattern acquisition and processes the image. To compute the MPD and EF, we have to locate the centroid of the near-field pattern by evaluating the first-order moment using the built-in function of the NI Vision Development Module for straightforward calculation of the centroid. We adjust the minimum/maximum levels of the frame grabber analog-to-digital converter via software so that the image intensity uses all of the 256 levels available. Starting from the centroid coordinates, the near-field profiles along the x/y axes are extracted and processed, as shown in Figure 3. The nonlinear response of the vidicon camera is taken into account by numerical compensation. If the source exciting the fiber produces a lot of noise, the near-field pattern will suffer from intensity flickering; the latter can be compensated by multiple averaging of the near-field profiles.

Figures 4 and 5 show examples of MPD and EF measurements, which we calculated according to the Telecommunication Industries Association (TIA) guideline, of an MMF excited with an LED source at 850 nm through a commercial mode controller. Both measurements are within the standard-recommended template and meet the specifications.

We made several measurements with this setup, analyzing multimode fibers, mode controllers, and mode scramblers, which produced reliable and reproducible results. We expect the described test bench to become a turnkey setup for optical fiber and optical fiber component characterization.

We developed a test bench for fast and quick characterization of the power distribution of multimode fibers and devices. The system acquires the near-field pattern of an optical fiber/device using a PCI-1409 image acquisition board and computes some characterization parameters such as modal power distribution and encircled flux. With the help of some of the LabVIEW control program features, including compensation of the camera nonlinearity and centroid calculation, the system has been a useful and efficient tool for analyzing multimode fibers and devices.

**Author Information:**
M. Oliviero
PHOTONLAB - POLITECNICO DI TORINO
massimo.olivero@polito.it
LabVIEW Screenshot of the Image Acquisition and Centroid Calculation

LabVIEW Screenshot of Camera Correction, Averaging, and XY Cuts
The red lines represent the standard limits in an example of an MPD graph.