OPTICAL PROFILING OF DIFFUSIVELY REFLECTIVE POLYETHYLENE RODS USED IN FIBER CABLES

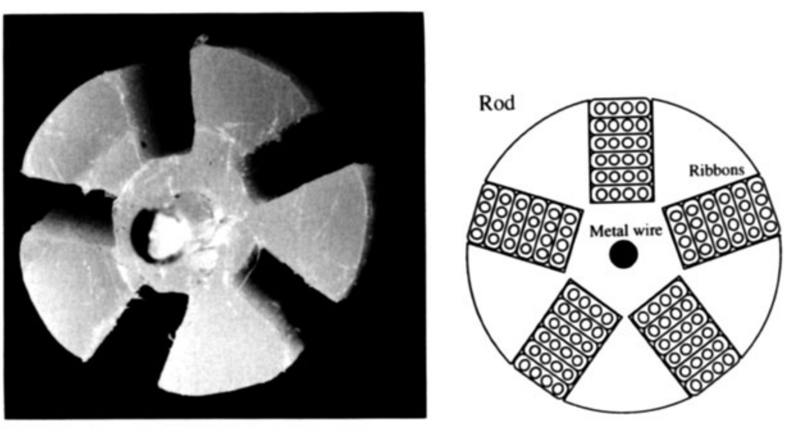
R. Vuohelainen, P. Raatikainen, J. Hietanen, M. Oksanen, and M. Luukkala
Department of Physics, P.O. Box 9 FIN-00014 University of Helsinki
Helsinki, Finland

INTRODUCTION

Optical communication has grown rapidly over recent years, increasing the demand for optical fibers. In optical cable production, separate optical fibers are often collected in the form of a ribbon before they are shielded inside a cable. Ribbons are used because they can be connected to each other more easily and quicker than a bundle of separate fibers. The ribbons do not tolerate mechanical tensions so they have to be protected by some kind of rigid structure.

In our study the supporting material was a polyethylene rod with five spiral grooves where ten ribbons of four fibers were laid on top of each other in each groove. A picture of the rod geometry is shown in Figure 1. The polyethylene rod is extruded on a metal wire that controls the mechanical strain when the cable is installed.

In the cabling process it is essential that the width of the grooves be within certain tolerance limits. To be able to control the width of the grooves during the manufacturing process they should be measured on-line just after the extrusion of the polyethylene rod, and in order to avoid deforming the rod the measurement method should be noncontacting. In



a) b)

Fig. 1. a) The cross-section profile of the rod and b) the placement of the ribbons.

this case optical methods are the most useful even though polyethylene is a translucent and diffusively reflecting material.

MEASUREMENT SYSTEM

In diffuse reflection, light penetrates a medium and subsequently reappears at the surface after partial absorption and multiple scattering within the medium, which makes measurement techniques like triangulation useless. We studied the measurement potential of several techniques based on optical fibers. Two of the techniques are schematically depicted in Figure 2. In the first one the rod is illuminated using a single fiber and the light is collected with the same fiber (Figure 2 a). The fiber is connected to a transmitter and a receiver via a Y-coupler. In the second measurement technique a bundle of fibers is used instead of a single fiber. The reflected light is collected using one fiber in the middle of the bundle and the rod is illuminated with the rest of the fibers (Figure 2 b). In both of these techniques the sensor scans over the groove pattern of the rod which yields high signal levels between the grooves and low signal levels on the grooves.

In the laboratory measurements the scanning action of the sensor was achieved by rotating a short piece of the polyethylene rod with a DC motor which could spin the rod from zero to one hundred rotations per minute. The distance between the sensor and the rod was about 1 mm. As a light source we used a 660 nm LED (Stanley H-3000). The light collected by the receiving fiber was detected by a photo diode (Hamamatsu 2386-18L) and amplified using an AC coupled amplifier. The signal was analyzed with a digital oscilloscope. The fibers used in the Y-coupler configuration had core diameters of 980 μm (plastic fiber) and 50 μm (glass fiber). In the bundle the illuminating fibers had core diameters of 100 μm and the receiving fiber had core diameter of 200 μm (glass fibers). The diameter of the bundle was 1 mm.

RESULTS

The resolution of both of the methods discussed is inversely proportional to the cross-section area of the detector fiber. In practice, the size of the detector fiber is limited by the signal to noise ratio, because the intensity of the received light drops when smaller fibers are used. When the 1 mm plastic fibers with the Y-coupler were used, the grooves could be

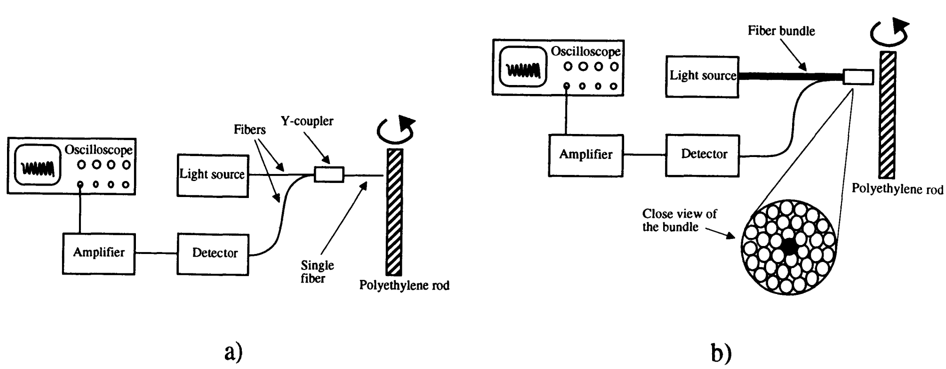


Fig. 2. a) The measurement setup with a fiber coupler and b) with a fiber bundle.

seen, but because of the large cross-section area of the detector fiber the resolution was poor. By modifying the end of the detector fiber into the shape of a rectangle of 1 mm times 0.2 mm (long side aligned with the grooves), the signal transitions became faster but much weaker. When the 50 µm glass fibers with the Y-coupler were used, the signal to noise ratio was less than one. The signal to noise ratio could have been improved by using a laser or a laser diode instead of an LED, but that would have made the measurement system considerably more complicated.

Good resolution and an acceptable signal to noise ratio with an LED light source was achieved by using the fiber bundle. Figure 3 shows a typical measurement from a polyethylene rod with five grooves. Individual grooves can be identified in the repeating signal. The rod was not totally straight, which can be seen as a periodic variation in the signal amplitude. The noise in the signal is due the roughness of the surface of the rod as shown in Figure 4.

The resolution of the sensor depends significantly on the distance between the sensor and the rod: to achieve the best resolution the distance should be kept as small as possible. In our measurements the distance had to be kept at about 1 mm because of the deviation in the rod.

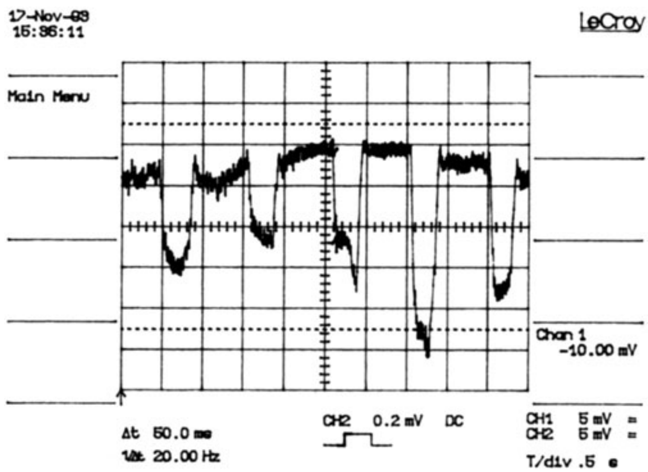


Fig. 3. The measured signal from one turn of the rod.

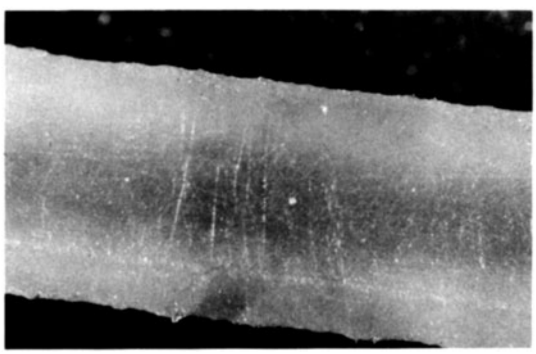


Fig. 4. Surface roughness of the polyethylene rod.

CONCLUSIONS

We have developed a simple and inexpensive method to optically measure the width of the grooves in polyethylene rods used in ribbon fiber cables.

The method is based on using a bundle of fibers as a sensor. Measurement arrangements using fiber bundles where only one fiber is used to illuminate a sample and the rest of the fibers are used as detectors are well-known in the literature. In our sensor the measurement arrangement is reversed: one fiber in the middle is used as a detector and all the other fibers are used to illuminate a sample. In this way we have been able to combine high resolution with a good signal to noise ratio.

The method described here can also be applied in optical profiling of diffusively reflecting materials in general.

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