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M. D. Rotter

D. R. Jander

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Measuring transient radiation effects in optical fibers

Mark D. Rotter and Donald R. Jander

Lawrence Livermore National Laboratory, University of California
P.O. Box 808, Livermore, California 94550

Abstract

We propose a new method for measuring transient radiation effects in optical fibers on a nanosecond timescale. The method, which incorporates a streak camera, allows more precise time resolution than other methods and has the advantage of measuring the radiation-induced attenuation as a function of wavelength and time simultaneously. By choosing different light sources and sweep speeds, radiation-induced attenuation may be measured under a variety of experimental configurations. Examples of the types of output obtained with our method are given.

Introduction

A radiation environment damages optical fibers, causing them to darken. An understanding of this darkening process is important, especially when fibers are applied in a gamma-ray detection experiment.¹ In this case, we are interested in observing damage as it occurs to the fibers in the experimental timescales. Previous methods of measuring this damage have either been limited to a single wavelength for a given dose, or to timescales longer than useful to our work.^{2,3} We describe a method that can be used to obtain data of fiber-darkening over a broad spectral range and at timescales that can vary from nanoseconds to microseconds.

Description of method

In Figure 1, we show a block diagram of our system. The source of the radiation is a Febetron Model-706 electron gun. This gun emits a 1.5-ns pulse of 400 keV (average energy) electrons. A 10-mil thick piece of aluminum at the end of the gun serves as a scatterer to ensure a uniform dose distribution over the fiber. The irradiated area is defined via the collimator. By changing the distance between the end of the gun and the fibers, the dose to the fibers can be varied by three orders of magnitude. The entire apparatus is operated at atmospheric pressure.

We used two fibers in this measurement. One fiber is connected to a xenon flashlamp. The other fiber records the amount of Cerenkov light generated in the fibers. This information is used to subtract the Cerenkov light from the data fiber. The two fibers are then attached to the fore-optics of the streak camera.

A schematic of one-half of the fore-optics is shown in Figure 2. The light from the fiber is collimated by a 54mm $f/1.8$ lens and dispersed by the 1200 lines/mm grating. The light is then collected and focused by another 54mm $f/1.8$ lens onto a stop. This stop defines the spectral range of interest. An 88mm $f/1$ lens, designed to operate at a 1:1 conjugate ratio, focuses the image at the stop onto the photocathode of the streak camera.

Figure 1. Fiber-darkening system.

Figure 2. Fore-optics system.

The other half of the fore-optics system is built in the same manner except that a fiber is placed at the step. This fiber carries light from the comb generator to provide timing calibration for the streak camera.

The streak camera is an in-house-built unit, and has an RCA streak tube with an S-20 photocathode and a fiber-optic input face. The output area of the streak tube is coupled to a 40-mm ITT micro-channel-plate image intensifier. In our streak camera, the nominal sweep length is 60 ns. By changing the internal sweep circuitry, a wide range of sweep speeds may be achieved. Figure 3 shows the fore-optics assembly and the streak camera. The rectangular box in the lower part of the photo is the optical comb generator.

We used Kodak Royal X-Pan film to record the data. In addition, a continuous density wedge, that matched the phosphor of the streak camera in spectral sensitivity, was placed on the film. This wedge was used to convert density data to intensity data. The film was developed by DK-50 developer, after which the film was read on a microdensitometer to provide a computer-compatible format for the data.

Figure 3. Photo of fore-optics assembly, streak camera, and comb generator.

Typical results

As our purpose is to describe a new method for measuring transient radiation damage in optical fibers, we give only a couple representative results. The fiber used was a Raychem pure silica core with a glass cladding. The core diameter was $125\text{ }\mu\text{m}$. In Figure 4, we show the data as it appears after it has been processed by the microdensitometer. The Cerenkov pulse and the abrupt fiber-darkening are plainly visible. For both sides, the spectral coverage is from 650 to 810 nm, with 810 nm occurring near the center of the picture. The sharp pulses running down the center of the picture come from the comb generator and are 4 ns apart.

Data analysis is performed using the many image-processing codes that exist on our CDC-7600 computers. In Figures 5 and 6, we show the induced attenuation as a function of time for low and high doses as applied to the fiber.

In Figure 5, the applied dose is 1.2 Mrad as measured by radiachromic film. The upper curve corresponds to a 10-nm wide slice centered at 675 nm; the lower curve is for a 10-nm wide slice centered at 800 nm.

In Figure 6, the applied dose is 150 krad as measured by radiachromic film. The wavelength ranges are the same as those for Figure 5.

Figure 4. Data after being digitized

Figure 5. Fiber-darkening results (high dose).

Figure 6. Fiber-darkening results (low dose).

Conclusion

We have a method for measuring transient radiation damage in optical fibers with several advantages: 1) simultaneous acquisition of transient radiation damage as a function of wavelength and time; 2) different spectral bandwidths that are easily accommodated; 3) excellent time resolution due to the streak camera; and 4) very short timescales are easy to use experimentally.

Acknowledgments

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