# The Fiber Fuse Phenomenon in Polarization-Maintaining Fibers at 1.55 μm

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**Abstract:** The fiber fuse phenomenon was investigated in PANDA-style polarization-maintaining fibers at 1.55 μm. We present fuse velocity and threshold data, and observe different thresholds for fast- and slow-axis alignment.

**OCIS codes:** (060.2400) Fiber properties; (060.2420) Fibers, polarization-maintaining; (350.5340) Photothermal effects

## 1. Introduction

Modern communication systems with transmitters based on doped-fiber amplifiers may operate with power densities exceeding 1 MW/cm$^2$. At such powers, optical fiber is susceptible to the fiber fuse phenomenon – catastrophic destruction of the fiber core characterized by a bright visible light traveling towards the laser source [1, 2]. A fuse can initiate when defects in the fiber or dust at the fiber endface cause localized heating, and can ruin the amplifier and other components in the transmitter chain.

Previous work has yielded data on fuse velocity and initiation conditions at relatively high power densities (5-30 MW/cm$^2$), but has focused on shorter wavelengths and standard fiber [1-3]. Since many laser communication systems use controlled polarization, fuse characteristics in polarization-maintaining (PM) fiber are of great interest. We report observations of fuses in PM fiber using a 1.55-μm data-modulated communication source. The experimental results show fuse initiation in slow-axis aligned fibers at peak power densities as low as 3.7 ± 0.2 MW/cm$^2$ (1.6 W in the fiber). Furthermore, data for fast-axis aligned fibers is also presented, and shows a higher fuse threshold of 5.4 ± 0.3 MW/cm$^2$ (2.3 W in the fiber). Finally, we investigated a means for stopping fuse propagation with a directional coupler.

## 2. Experimental setup

To emulate a realistic communications source, a 1.55-μm distributed feedback laser was externally modulated with a 10-Gb/s sequence and coupled to a PM erbium-doped fiber amplifier (EDFA). After passing though a free-space isolator (ISO), the input signal was coupled to a Fujikura PM PANDA fiber (SM.15-P-8/125-UV/UV-400). The polarization alignment was adjusted via a half wave-plate using a single-polarization fiber isolator (SPFI) that was temporarily spliced to the fiber output. Fuses were initiated in a controlled manner by contacting the end of the fiber with steel fiber strippers. To determine the fuse velocity, an infrared camera (Sensors Unlimited SU320MS-1.7RT-RS170, 60 frames per second) recorded the fuse propagation. Fiber fuses were observed for both slow- and fast-axis alignment for a number of peak power densities, where these densities were estimated as $2\times(1.04\times P_{meas})/A_{mode}$.

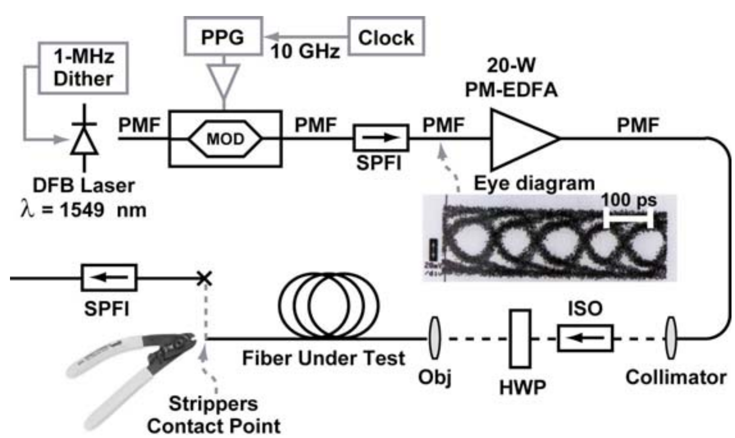


Fig. 1. Schematic of fiber fuse experimental setup.

## 3. Results and discussion

Velocity measurements for sustained fuse propagation are shown in Fig. 2. Each data point represents a fuse that propagated until the EDFA was turned off or until the fuse had propagated along the entire length of the fiber. The data illustrates the similar velocities for slow- and fast-axis alignment over a range of powers. Ranges for the fuse initiation threshold are also shown in Fig. 2; we observe the threshold for fast-axis alignment to be ~44% higher than that for slow-axis alignment. We hypothesize that the threshold difference results from the asymmetric stress distribution within the fiber. The slow axis is under greater tensile stress, causing the $SiO_2$ and $GeO_2$ to dissociate at a lower temperature for excitations oriented along the slow axis; thus, fuse propagation initiates at lower powers.

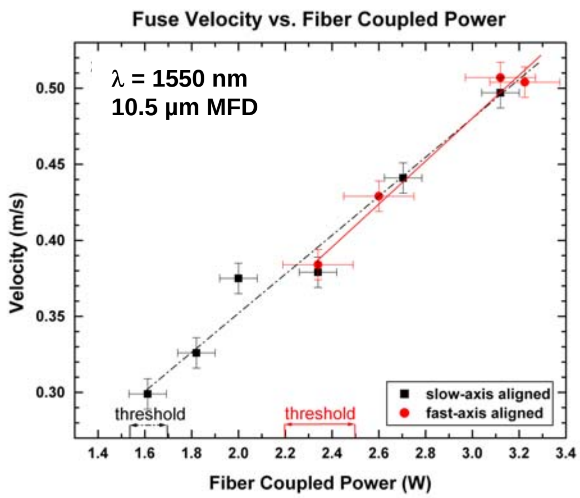


Fig. 2. Measured fuse velocities and estimates for slow- and fast-axis aligned fuse thresholds.

A limited amount of recent work [4-6] shows fuse data for SMF-28 and $SiO_2$-$GeO_2$ fibers at 1480 nm. Atkins *et al.* reported that for SMF-28 fiber with a 1480-nm source, ~2 MW/cm$^2$ were needed to sustain fuse propagation, and fuse velocities spanned ~0.32-0.69 m/s for power densities from ~2.7-5.7 MW/cm$^2$. These velocity and threshold ranges are comparable with our data for PM fiber at 1.55 µm.

To investigate techniques for mitigating fiber fuse damage [7], we also propagated a fuse into the primary port of a biconic 99/1 PM coupler. For slow-axis alignment with a peak power density of 6.7 MW/cm$^2$ (2.9 W in the fiber), the fuse propagated into the coupler and terminated immediately; the expanded mode in the tapered region reduced the power density below the threshold necessary to support fuse propagation.

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