Fiber fuse terminator consisting of a step-index multimode fiber spliced with SMFs

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Abstract: We have realized a fiber fuse terminator consisting of a commercially available short length of step-index multimode fiber, spliced with conventional SMFs. The fabricated fiber fuse terminator suppressed the fiber fuse propagation when the input power was 6 W, at a wavelength of 1.55 μm.

Keywords: fiber fuse, high power, fiber fuse terminator, step-index multimode fiber

Classification: Optical Fiber for Communications

References


1 Introduction

Fiber fuse is a phenomenon whereby an optical discharge propagates toward a light source resulting in the catastrophic destruction of the optical fiber [1, 2]. Once initiated, the fiber fuse continues to propagate until the input power is reduced below the fuse-propagation threshold power. The propagation threshold of a fiber fuse is as low as 1.2–1.4 W for conventional fiber, used in high capacity optical communication. Therefore, this fiber fuse phenomenon is likely to pose a real danger for optical communication systems.

Several approaches have been proposed for avoiding the catastrophic damage caused by a fiber fuse. One approach is to include a device that can rapidly detect a fiber fuse by monitoring the light back-reflected from the fiber fuse, and then terminate it by shutting down the light source [3]. Other approaches include the use of passive fiber fuse terminators with a tapered fiber [4], a mode field radius transformer [5], a thermally diffused expanded core (TEC) fiber [6], and a graded-index multimode fiber (GIF) [7]. Termination of the fiber fuse, by using these fiber fuse terminators, was demonstrated for an input power of approximately 2 W. Meanwhile, it was reported that the fuse propagation threshold in photonic crystal fiber (PCF) [8] and hole-assisted fiber (HAF) [9] can be much higher than that of conventional single-mode fiber (SMF) in the optical communication band.

In this letter, we realized a fiber fuse terminator consisting of a commercially available short length of step-index multimode fiber (SIF); which has a larger fundamental mode field diameter (MFD) than that of GIF. We observed that the fabricated fiber fuse terminator suppressed the fiber fuse propagation when the input power was 6 W at a wavelength of 1.55 \( \mu \text{m} \) [10]. Furthermore, we measured the transmission spectrum of the fabricated fiber fuse terminator.

2 Structure of a fiber fuse terminator and its fabrication

Our proposed fiber fuse terminator consists of a commercially available short length of SIF, spliced with conventional SMFs. The MFD of the SMF was 10.2 \( \mu \text{m} \) at a wavelength of 1.55 \( \mu \text{m} \). The core diameter and fundamental MFD of the SIF were 50 and 38 \( \mu \text{m} \), respectively. Here we used the value of the fundamental MFD of the SIF described in ref. [11]. When the light is launched from the SMF into the SIF, fundamental mode (LP\(_{01}\)) and higher modes, LP\(_{02}\) and LP\(_{03}\), are considered to be excited [11]. We can expect that the fiber fuse terminator consisting of the SIF can terminate the fiber fuse propagation for a high power input over 2 W. This is because the fiber fuse propagation threshold is proportional to the MFD, and the fundamental MFD of the SIF was as high as 38 \( \mu \text{m} \).

Next, we fabricated the fiber fuse terminator in the manner described below:
1) The SIF was fusion spliced with the SMF.
2) We cleaved the SIF to the target length. We decided the SIF target length according to simulation results [11] on the transmission of the device which has the same structure as that of our device. The simulation results show that when the SIF length was about 10.2 mm, transmission was higher than 0.95. Therefore, we decided the target length of the SIF as 10.2 mm. We cleaved the SIF to the target length by sight, using a fiber cleaver.
3) The cleaved SIF was fusion spliced with the SMF. We measured the transmission of the fiber fuse terminator at a wavelength of 1.55 μm by using a continuous wave (CW) light source and an optical power meter.

3 Results and discussion

3.1 Transmission characteristics of the fabricated fiber fuse terminator

Figure 1 shows the relationship between the measured transmission of the fabricated fiber fuse terminator and the SIF length. The maximum transmission of 0.9 was achieved for a SIF length of approximately 10.1 mm, as shown in Fig. 1. Measurements were made at a wavelength of 1.55 μm. On both sides of the transmission peak, at 10.1 mm, the transmission rapidly decreases. This is similar to the simulation results near the transmission peak at approximately 10.2 mm. The accurate length of the SIF was measured with a digital microscope. The resolution of the SIF length measurement was approximately 0.1 mm. Therefore, we consider the SIF length of the measured transmission peak to be roughly the same as that of the transmission peak in the simulation [11].

![Fig. 1. The measured transmission of the fabricated fiber fuse terminator.](image)

Figure 2 shows the transmission spectrum through the fiber fuse terminator when the SIF length was about 10.1 mm. The transmission spectrum was measured by using a white-light source and an optical spectrum analyzer. Transmission of about 0.9 was obtained between the wavelength of 1.530 and 1.555 μm, as shown in Fig. 2.
3.2 Terminating fiber fuse in the fiber fuse terminator
We confirmed the fiber fuse termination in the fabricated fiber fuse terminator by using a CW fiber laser at a wavelength of 1.55 \( \mu \)m, when the input power was 6 W. A fiber fuse was initiated by heating with an arc discharge, provided by a fusion splicer. Figure 3 shows a photograph of the termination point of the fiber fuse in the SIF; observed with a microscope. In the figure, the fiber fuse propagated from right to left, and terminated roughly 2.9 mm from the splice point between the output end of the SIF and the SMF. The observed termination point corresponds to the calculated low transmission region around 7.0–7.5 mm in the simulation [11]. This was identified by considering the difference between the SIF length and the distance of the fiber fuse termination point from the splice point: 10.1 mm – 2.9 mm = 7.2 mm. We observed the formation of a large void near the termination point in the SIF, as shown in Fig. 3. We demonstrated fiber fuse termination at an input power of 6 W. This was 3 times larger than the, so far, reported power of 2 W in fiber fuse terminators with a tapered fiber, a TEC fiber, and a GIF.

4 Conclusion
We fabricated a fiber fuse terminator consisting of a commercially available step-index multimode fiber, spliced with SMFs. We measured the transmission spectrum of the fiber fuse terminator and obtained the transmission of about 0.9 between the wavelength of 1.530 and 1.555 \( \mu \)m. We demonstrated fiber fuse termination for the input power of 6 W. This was 3 times larger than the, so far, reported power of 2 W in fiber fuse terminators with a tapered fiber, a TEC fiber, and a GIF.
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