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LETTER

Optical power delivery with suppressed fiber fuse in standard single mode fiber at a wavelength of 1064 nm

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Abstract We confirm the suppression of both fiber-fuse propagation and initiation in standard single mode fibers (SMFs) by using optical pulses with a pulse period of 7.5 μs, for an average input power of 2.0 W and wavelength of 1064 nm. Using the same optical pulses, we demonstrated optical power delivery with a suppressed fiber fuse in a 1.1 km SMF.

Keywords: fiber fuse, suppression, power over fiber

Classification: Fiber-optic transmission for communications

1. Introduction

The development of wireless communication systems, such as 5G systems, has increased the interest in remote power supplies that use optical fibers in remote antenna units. Recently, the transmission of a 10 W light at a wavelength of 1064 nm over a 1 km standard single-mode fiber (SMF) was reported [1]. However, input powers that exceed a few watts are associated with the risk of SMF damage owing to the fiber fuse phenomenon. Fiber fuse is a phenomenon in which an optical discharge propagates toward a light source [2, 3] and several approaches have been proposed to avoid the resulting damage. These include the use of passive fiber-fuse terminators [4] and an active device that rapidly detects the fiber fuse and terminates it by shutting down the light source [5]. The termination of fiber-fuse propagation using optical pulses in dispersion-shifted fibers has recently been reported [6]. In this letter, we report the demonstration of optical power delivery and fiber-fuse termination in a 1.1 km SMF at 2.0 W of input power using optical pulses at a wavelength of 1064 nm, which was previously presented at IEICE ICETC 2023 [7][1].

2. Termination of fiber fuse using optical pulses

The experimental setup shown in Fig. 1 was used to investigate the termination of fiber fuse propagation in an SMF using optical pulses. Rectangular optical pulses were generated using an acousto-optic (AO) modulator driven by a function generator (FG) and an amplified spontaneous emission (ASE) light source with a bandpass filter with a center wavelength and bandwidth of 1064 nm and 3 nm, respectively. The pulse duty ratio was 0.5. The optical pulses were amplified using an ytterbium-doped fiber amplifier (YDFA) coupled to an SMF. The mode field diameter of the fundamental mode in the SMF was 8 μm at a wavelength of 1.06 μm. The output of the AO modulator was continuous-wave (CW) light when the output of the function generator was turned off. Fiber fuse was initiated for the CW input light when the SMF was heated by an arc discharge provided by a fusion splicer. As the fuse propagated through the SMF, the input light was transformed into rectangular optical pulses at time $t=t_1$ by turning on the FG output. We changed the pulse period and determined whether the fuse terminated when the input light was transformed from CW to optical pulses.

Figure 2 shows the minimum pulse period required for fuse termination versus the average input power. The average input powers were 1.4, 1.6, 1.8, and 2.0 W. The minimum

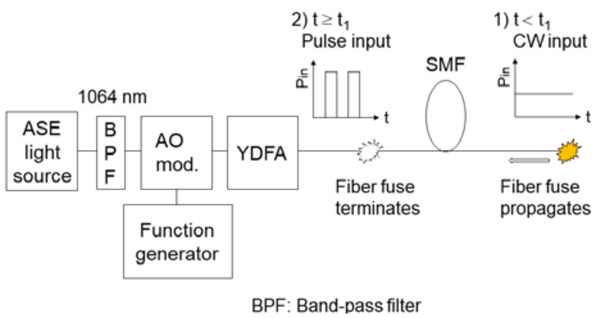

Fig. 1 Experimental setup for fiber fuse termination.

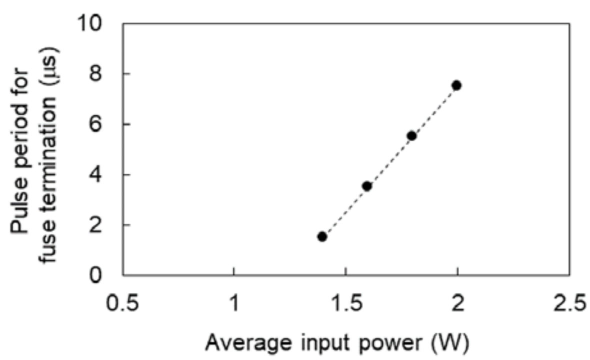

Fig. 2 Minimum pulse period required for fiber fuse termination.

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[1] In this letter, the suppression characteristics of fuse initiation is newly examined and we add detailed experimental results on the optical power delivery.

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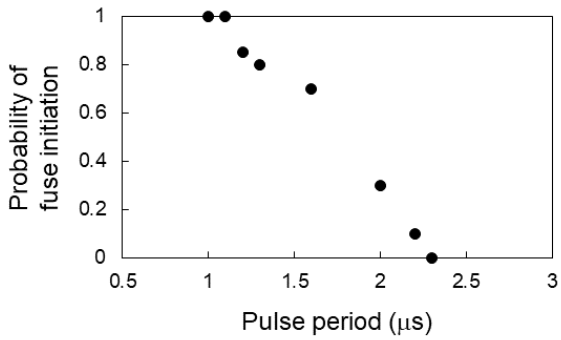

Fig. 3 Probability of fuse initiation as a function of the pulse period for an average input power of 2.0 W.

pulse period required for fiber-fuse termination increased linearly with the input power. The x-intercept of the fitted line was close to the fuse propagation threshold of 1.1 W for the CW input light. When the average input power was 2.0 W, the fiber fuse was terminated by an optical pulse period of 7.5 μs.

We also measured the probability of fiber fuse initiation as a function of the pulse period when the input power was 2.0 W. The pulsed light source was the same as that shown in Fig. 1. The fiber fuse was initiated by heating the SMF using the arc discharge provided by the fusion splicer. The initiation was tested ten times for each pulse period, and the probability of fuse initiation was determined. Figure 3 shows the pulse period dependence of the initiation probability. When the pulse period was 1.1 μs, the fiber fuse was initiated in all ten trials. Thus, the initiation probability was 1 for a pulse period of 1.1 μs. When the pulse period was increased to 2.3 μs, fiber fuse initiation was not observed. Thus, the fiber fuse initiation in the SMF was suppressed at a pulse period of 2.3 μs when the input power was 2.0 W. Therefore, no fiber fuse initiation was observed at a pulse period of 7.5 μs, which was the minimum pulse period required for the fiber fuse termination for the 2.0 W average input power.

3. Optical power delivery with suppressed fiber fuse

Using a 2.0 W optical pulse with a pulse period of 7.5 μs which can terminate fiber fuse propagation, we demonstrated optical power delivery with a suppressed fiber fuse in a 1.1 km SMF. The experimental setup is shown in Fig. 4. The optical pulse source was the same as that shown in Fig. 1. An amplified optical pulse with a pulse period of 7.5 μs was passed through the SMF and the output optical power was 1.66 W. The output pulse passing through a multimode fiber (MMF) patch code was injected into a commercially available photovoltaic power converter (PPC) to achieve electric power. We used the MMF patch code with a core diameter of 105 μm, because the optical-electrical conversion efficiency of the PPC was optimized for the input light from the MMF.

Figure 5 shows the PPC output voltages (a) without and (b) with a capacitor with a capacitance of 10 μF. As shown in Fig. 5(a), ripples are observed in the output voltage because the light input to the PPC is an optical pulse. However, ripples are negligible when the capacitor is used, as shown in Fig. 5(b). Figures 6 (a) and (b) show the I-V curve and

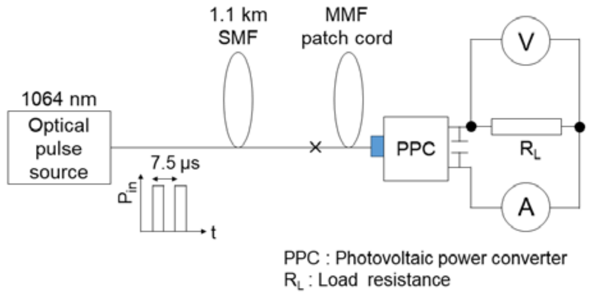

Fig. 4 Experimental setup for the optical power delivery.

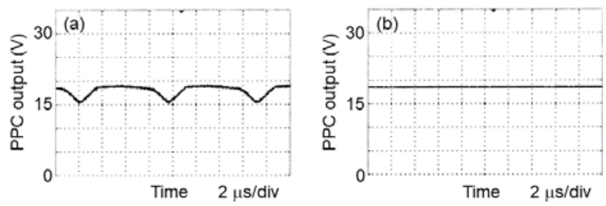

Fig. 5 PPC output voltages (a) without and (b)with a capacitor.

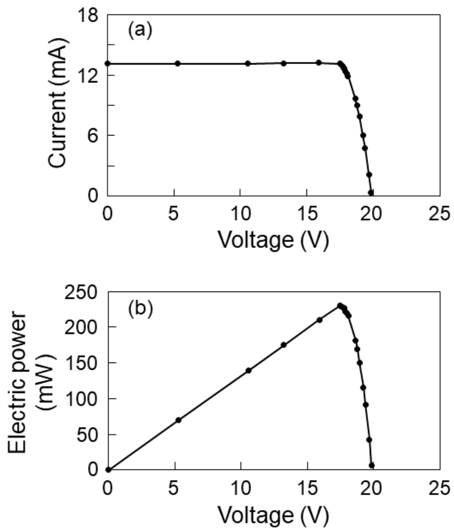

Fig. 6 Measured (a) I-V and (b) P-V curves.

P-V curves, respectively, measured by the PPC, which operates efficiently in the wavelength range 915–980 nm. We achieved an electric power of 230 mW and optical-electrical conversion efficiency of 14%. Higher conversion efficiency could be achieved using a PPC that operates efficiently at a wavelength of 1064 nm [8]. Thus, we demonstrated optical power delivery with suppressed fiber fuse in a 1.1 km SMF at a wavelength of 1064 nm.

4. Conclusion

We confirmed fiber-fuse termination in the SMF using optical pulses with a period of 7.5 μs, an input power of 2.0 W, and a wavelength of 1064 nm. We used the same optical pulses to demonstrate optical power delivery with suppressed fiber fuse in a 1.1 km SMF.

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