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Fiber fuse terminator for above 20 W input

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1. Introduction

A 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]. Since the propagation threshold of a fiber fuse (P_{th}) in conventional single-mode fibers (SMF) is as low as 1.3 W at 1480 nm, in the near future the fiber fuse phenomenon will pose a real danger to optical communication systems constructed with conventional SMF [3]. Several devices have been proposed for avoiding the catastrophic damage caused by a fiber fuse, for example, fiber fuse terminators using a tapered fiber [4] and a thermally-diffused expanded core (TEC) fiber [5] for an input power of not more than 2 W. In addition, a device has been reported that can rapidly detect a fiber fuse by monitoring the light back-reflected from the fiber fuse and terminate it by shutting down the light source [6].

Recently, it was reported that the P_{th} in hole-assisted fiber (HAF) can be much higher than that in conventional SMF [7, 8]. The propagation characteristics of the fiber fuse in HAF depend on the relationship between the diameter of an inscribed circle linking the air holes (**c**) and the diameter of the melted area (D_{melted}) [7, 8]. The melted area is caused by fiber fuse propagation and D_{melted} is assumed to be almost the same as the size of the optical discharge. When **c** is much smaller than D_{melted}, the fiber fuse does not propagate even at a maximum input power of 15.6 W [8].

In this paper, we report a compact fiber fuse terminator consisting of a short length of HAF. We confirmed the termination of a fiber fuse using a fiber fuse terminator with a 2.5 mm-length HAF when the input power was 21 W.

2. Fiber fuse terminator and experimental setup

Fiber fuse terminator

Fig.1 (a) shows the structure of our fiber fuse terminator which consists of a short length (L) of HAF spliced with conventional SMFs. We used a 2.5-2.6 mm length of HAF in this experiment. Fig. 1(b) shows a cross-section of a HAF with six air holes. The core diameter was 9 μm. The **c** and d values of the HAF were 18.6 and 9.1 μm, respectively. As shown in Fig. 1(a), our fiber fuse terminator is compact and has a simple structure with low loss. It is easy to handle and can be installed in an optical connector in the same way as a fiber fuse terminator using a TEC fiber [5].

Experimental setup

Fig. 2 shows the experimental setup. The light source used for the initiation and propagation of the fiber fuse consisted of a Raman fiber laser and an amplified ASE operating at wavelengths of 1480 and 1550 nm, respectively. Two cw lights were simultaneously multiplexed with a WDM coupler and then guided into a fiber fuse terminator. We initiated a fiber fuse with an arc discharge by heating an SMF that was spliced with the fiber fuse terminator. We examined its propagation in the HAF of the fiber fuse terminator. We also observed the dynamics of fiber fuse termination near the splice point between the HAF and SMF using a high-speed camera.

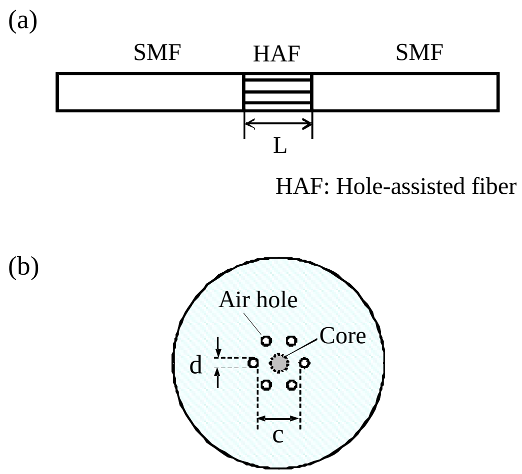

Fig. 1 (a)Structure of fiber fuse terminator and (b)cross-section of HAF.

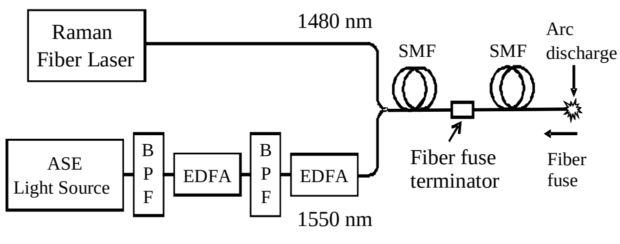

Fig. 2 Experimental setup.

3. Results and discussion

Fig. 3 shows a side view of a splice point between the HAF and SMF before and after fiber fuse propagation at a wavelength of 1550 nm. The coupled input power into the HAF was 5.5 W. The HAF length (L) was 2.6 mm. The total splice loss between the HAF and SMF was 0.1 dB. The fiber fuse terminated near the splice point between the HAF and SMF, as shown in Fig. 3. The fiber fuse penetrated 24 μm into the HAF.

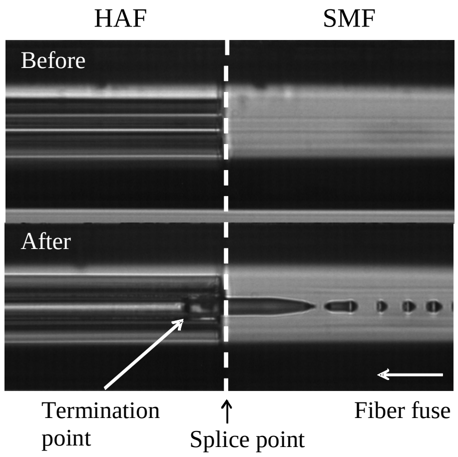

Fig. 3 Side view of a splice point between HAF and SMF before and after fiber fuse propagation at an input power of 5.5 W.

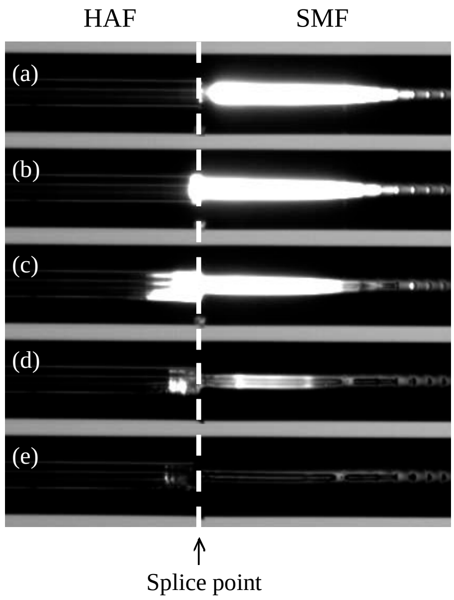

Fig. 4 Dynamics of fiber fuse termination near the splice point between HAF and SMF. The input power was 21 W. The images were obtained at 20 μs intervals.

Fig. 4 shows the dynamics of the fiber fuse termination near the splice point between the HAF and SMF. The HAF length (L) was 2.5 mm. The total input power into the HAF was 21 W. The input powers at 1480 and 1550 nm were 8 and 13 W, respectively. These images were obtained at intervals of 20 μs by using a high-speed camera operating at a speed of 10^5 fps. As shown in Fig. 4(b)-(d), the front shape of the optical discharge changed at the splice point. Since the optical discharge is considered to be a high temperature gas at a high pressure [2], its front shape shown in Fig. 4(c) indicates the jet of the high temperature gas into the air holes. Then, the optical discharge terminated. The optical discharge penetrated 65 μm into the HAF. Therefore, we found that we could terminate the fiber fuse propagation by using a fiber fuse terminator consisting of a HAF with a length of only 2.5 mm when the input power was 21 W.

The mechanism of fiber fuse termination in HAF can be explained as follows [9]. Since the diameter of the optical discharge at an input power of 21 W exceeds 23 μm [8], which is much larger than **c** in HAF, the high temperature gas reached the air holes. At the same time, the gas jet penetrated the air holes. That is, the gas expanded. This resulted in a reduction in the gas pressure. Simultaneously, the gas temperature decreased and the fiber fuse terminated.

4. Conclusion

We reported a compact and low-loss fiber fuse terminator composed of a short length of HAF. We confirmed that a fiber fuse could be terminated using a fiber fuse terminator consisting of a HAF with a length of only 2.5 mm when the input power was as high as 21 W.

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