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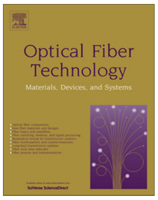

Parameter optimization of fusion splicing of photonic crystal fibers and conventional fibers to increase strength

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ABSTRACT

A splicing parameter optimization method to increase the tensile strength of splicing joint between photonic crystal fiber (PCF) and conventional fiber is demonstrated. Based on the splicing recipes provided by splicer or fiber manufacturers, the optimal values of some major splicing parameters are obtained in sequence, and a conspicuous improvement in the mechanical strength of splicing joints between PCFs and conventional fibers is validated through experiments.

1. Introduction

Since the realization of the first photonic crystal fiber (PCF) in 1996 [1], a rapidly growing interest has been seen from both academic community and industrial side [2–4]. Over the past few years PCF has re-defined what an optical fiber is, performing a range of unique optical properties that are so different from conventional fibers, including low sensitivity to temperature and radiation, lower nonlinearity, infinite single-mode propagation, and the remarkable ability of polarization maintaining [5–7]. In order to realize the full potential of PCFs, fiber assembly between PCFs and conventional fibers is always involved, which is primarily carried out by means of fusion splicing. However, splicing of dissimilar fibers poses a new set of problems on the splicing specifications. The earliest investigation of splicing holey fiber (HF) and single mode fiber (SMF) was demonstrated in 1999 [8], and since then many splicing techniques have been promoted [9–14]. Manufacturers of fusion splicers or fibers also provide customized programs for PCF splicing [15]. However, most of these publications or programs focused on minimizing the loss of fusion while the reliability of splicing is guaranteed by coating or protection sleeve, which is simple and useful in experimental research to increase the strength of splicing but not suitable in some cases of application. For example, in some optical fiber sensors the fiber coil can be small as a coin, which means that it is easy to break the fiber if the strength is not enough, and the installation of a sleeve is difficult. Consequently, a parameter optimization method based on given recipes by manufacturers to obtain high-strength fusion splices between PCFs and conventional fibers is promoted in this paper. The tensile strength of splicing joint with the optimal parameters is compared with the value under given recipes, as well as the splicing loss.

2. Parameter optimization method

Fusion splicing is a complex operation including three processes (fiber stripping, fiber cleaving and fusion splicing), and requires careful control of several variables in order to obtain a satisfactory result. Generally the fusion splicers would provide several parameters that could be altered to yield better loss and strength value. Some of the significant factors affecting the splice quality are splice power, on-duration, hot push, and splice offset.

2.1. Splice power and on-duration

Splice power defines the amount of power applied to the filament, and on-duration defines how long the filament is at full power after the fibers are pushed together. They together decide the total energy of one discharge, which should be controlled precisely to avoid excess collapse of air holes in PCF. In our investigation only splice power is studied while on-duration is constant, as the former affects the energy more directly.

2.2. Hot push

This parameter defines the distance that the right fiber is pushed in inwards. With an increase in hot push, the extent to which the fibers stuff into each other also increases, reducing the mismatch of mode field diameter (MFD) of different fibers.

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2.3. Splice offset

Splice offset adds an offset value to the position of filament, such that the filament is not centered on the gap (Fig. 1). This parameter is particularly vital in our study, as the offset of filament can protect the PCF tips from high heat, which considerably reduces the risk of severe air hole collapse.

Most commercial fusion splicers have customized programs for different combination of fibers, and some splicers and fiber manufacturers do now have recipes for PCFs. Typical splice recipes for PCFs always result in “cold” splices. In such cold splices a complete melting of the glass is avoided to preserve the holes and thereby the waveguide. Consequently, a typical splice interface between the fibers acts as a butt-coupling with physical contact.

However, only the low loss of splicing is emphasized in these recipes. The primary objective of our research is to get a high-strength splicing joint between PCFs and conventional fibers, so a parameter optimization method based on suggested recipes is promoted.

The initial values of splice power *P*, hot push *h* and splice offset *d* are determined by the values suggested by splicer or fiber manufacturers as P_0, h_0 and d_0. As splice power plays a leading role in the whole process, the first step is to find the optimal *P* with *h* and *d* fixed at h_0 and d_0. Attempts are done around the value of P_0, and the optimal *P* as P_f is obtained when the strength arrives at peak with the minimum loss. Then the same procedure is carried out to *h* and *d* consecutively while the other two parameters keep constant, and finally the optimal parameters are obtained as P_f, h_f and d_f. Following the method illustrated in Fig. 2 it is easy to accomplish a high-strength splicing between different fibers with any kind of splicer.

3. Experiment setup

To verify the optimization method proposed in Section 2, splicing between PCFs and polarization-maintained fibers (PMFs) is investigated.

3.1. Fibers

The test fibers are both supplied by Yangtze Optical Fiber and Cable Company Ltd. (YOFC). The PCF is a polarization-maintained solid-core PCF (Fig. 3(a)), and the PMF is a panda fiber (Fig. 3(b)). The suggested parameter values for splicing provided by YOFC is listed in Table 1.

3.2. Setup and process

The experiment setup is illustrated in Fig. 4. A filament fusion splicer is involved as it offers a larger degree of control in the splice process compared with most other fusion splicers. Since the working wavelength of both fibers is 1550 nm, an amplified spontaneous emission (ASE) optical source is utilized, and a dual-tunnel optical power meter (OPM) is used for power measurement. Given the insertion loss of OPM, a serial of experiments are designed to guarantee the scientificity and accuracy of the loss measurement, as shown in Fig. 5.

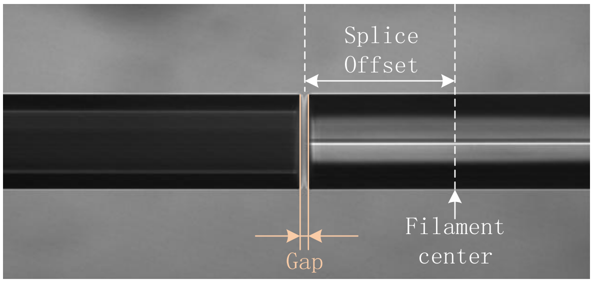

Fig. 1. Description of splice offset.

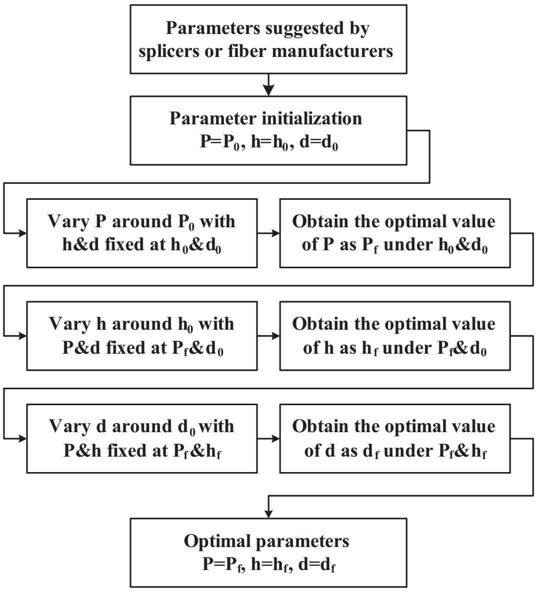

Fig. 2. Parameter optimization method diagram. *P*, *h* and *d* represent splice power, hot push and splice offset respectively.

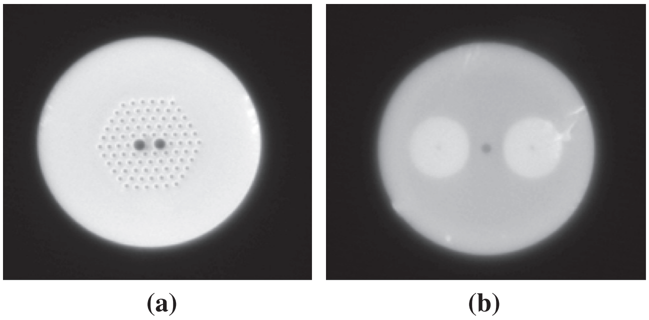

Fig. 3. End view of (a) PCF and (b) panda PMF.

Table 1
Splicing parameters suggested by YOFC.

Parameter	Unit	Value
Splice power	W	17
Hot push	μm	30
Splice offset	μm	70

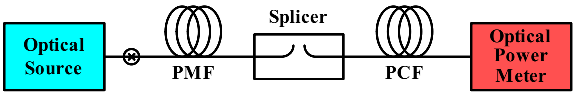

Fig. 4. Basic setup for experiment.

First, as illustrated in Fig. 5(a), the panda PMF is connected to the optical source, with the other tip directly connected to OPM using optical fiber adapter, reading a number of P_i. Then, the PMF is pinched off in the middle with both connections unchanged. Finally, as shown in Fig. 5(b), a PCF is added between the two