

## PORTABLE POLYMER OPTICAL FIBRE CLEAVER

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**Abstract:** Polymer optical fibre (POF) is a growing technology in short distance telecommunication due to its flexibility, easy connectorization, and lower cost than the mostly deployed silica optical fibre (SOF) technology. Microstructured POFs (mPOFs) have particular promising potential applications in the sensors and telecommunications field, they could specially help to reduce losses in polymer fibres by using hollow-core fibres. However, mPOFs are intrinsically more difficult to cut due to the cladding hole structure and it becomes necessary to have a high quality polymer optical cleaver. In the well-known hot-blade cutting process, fibre and blade are heated, which requires electrical components and increases cost. A new method has recently been published to cut POF without the need for heating the blade/fibre, therefore electronically devices are not required if it is used a proper mechanical system. In this paper, we present a passive and portable polymer optical cleaver implemented with a mechanical system formed by a constant force spring and a damper.

**Key words:** POF, Polymer optical fiber, Polymer optical cleaver, cleaver, mPOF

### 1. Introduction

Photonic crystal fibers (PCF) are single material fibers with a specific holes pattern in the cladding to allow guidance of light; the first example was made by knight et. al. in 1996 [1]

The flexibility in design allowed by the microstructured geometry allows the manufacture of fibers with properties unachievable with step-index fibers, such as air guidance [2], endlessly single mode operation [3], larger or smaller modal area [4,5], etc... This has suggested a variety of applications including fiber lasers, nonlinear active fibers or biological sensing [6].

Polymer optical fiber (POF) technology has advanced rapidly in recent years and it is expected that it will form an integral part of datacom networks. They offer a broader bandwidth, easier installment replacement for copper cables [7]. In contrast to a glass optical fiber a thick POF will remain mechanically flexible, which, in combination with a large core, offers easy and inexpensive connectivity of fibers during installation. Despite these achievements, POF has not yet achieved widespread deployment; some of the technical reasons behind this are large modal dispersion, as a consequence of multimode operation, and the higher losses than silica fiber.

Polymer PCFs, commonly known as microstructured polymer optical fibers (mPOFs), were firstly made by M.A. Van Eijkelenborg et. al. in 2001 [8]. The variety of possibilities of mPOF can help to overcome the aforementioned problems. On the one hand, polymer hollow-core fiber can be implemented to reduce losses significantly; the first example of this kind of fiber was reported by Argyros et. al. [9] and according to their theoretical calculations [10] losses can be as small as 50 dB/km in PMMA based fibers, comparable to the CYTOP fibers [11].

Furthermore, fabricating an mPOF with proper control of the pitch and hole size in the hole array allows fibers with a large modal area working in single mode operation to be fabricated[4].

However, mPOF are intrinsically difficult to cleave due to the hole array, therefore present and future commercial applications will require the development of a portable high-quality polymer optical cleaver. So far, several methods have been implemented to cleave mPOF [12-14], but none of them is well suited to the creation of a portable device. In the most commonly used and effective approach, fiber and blade are heated close to the glass transition temperature of the polymer, and then, the blade cleaves the fiber with a controlled speed [13,14]; this method requires the assembly of a POF cleaver

with several electronic components (temperature and motor controller, heater, stepper motor, power supply) which make it expensive not electrically passive and hence hardly portable for outdoor applications. Recently, we have published a new method to cleave POF [15] at room temperature. The method is based on the time-temperature equivalence principle of polymers [16] which allows the heating of the blade and fiber to be replaced by a slow cleave. In this method, an end-face free of crazing is achieved by increasing the process of cleaving longer than a certain time, which is characteristic of each polymer. Allowing sufficient time for the cut enables the stress in the cutting tip to relax, preventing crazing.

Figure 1 shows the cleaver used in our previous work [15], where the fiber was sawed rather than chopped (we use the word chop to describe the case when the blade cuts the fiber by being moved in a direction at 90° to the blade edge). For the purposes of a detailed study, a translation stage was used to move the blade at different controlled constant velocities. The smaller the blade angle the higher the sawing time for a constant speed of the blade. An illustrative scheme is shown in fig. 2, which defines the blade angle  $\alpha$ . According to [15], high quality PMMA cleaving was accomplished with relatively high blade velocities (0.1-1 mm/s) using blade angles from 1 to 5 degrees.

In this work, we present an electrical passive and portable POF cleaver, where the correct range of velocities can be achieved by using a simple mechanical system composed of a constant force spring and a damper.

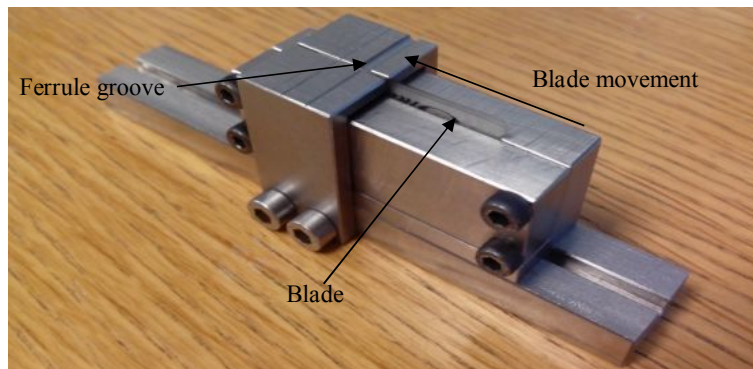


Figure 1: Fibre and blade positioning in the polymer optical cleaver

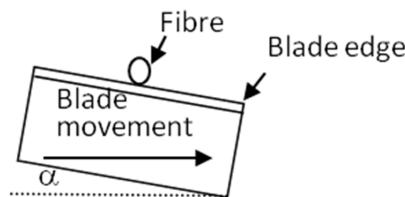


Figure 2: Transversal section of the cleave process

## 2. Cleaver fabrication

In order to make the cleaver portable, it was mounted onto a mechanical system composed of a constant force spring and a damper as showed figure 3.

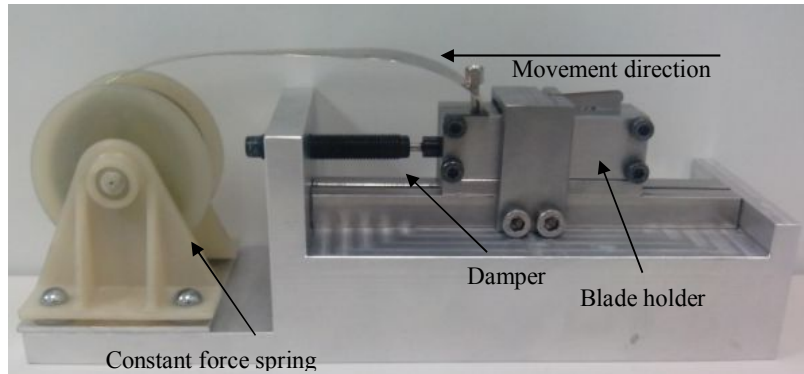


Figure 3: Full Polymer optical cleaver

In figure 3, the constant force spring pulls the blade holder and the damper dampens this movement. The constantly damped mechanical system is driven by the following differential equation:

$$\frac{d^2x}{dt^2} + \frac{b}{m} \cdot \frac{dx}{dt} - \frac{F_{SF}}{m} = 0 \quad (1)$$

where  $x$  is the position of the blade,  $F_{SF}$  is the difference between  $F_S$  (spring force) and  $F_F$  (friction force of the blade holder),  $b$  is the damping coefficient of the spring,  $t$  is the time and  $m$  is the mass of the blade holder. The solution of this equation gives the velocity of the blade as:

$$v(t) = \frac{F_{SF}}{b} \cdot \left( 1 - e^{-\frac{b \cdot t}{m}} \right) \quad (2)$$

where  $v$  is the blade velocity. Using our system parameters, for times over a few milliseconds,  $t \gg \frac{m}{b}$ , the velocity is approximately constant and is given by the following expression:

$$v = \frac{F_{MR}}{b} \quad (3)$$

The spring was provided by Spiroflex and pulls with a constant force of 7,8 N. The damper was provided by Ace Controls Inc (model HB-12-10) and according to our experiments the  $b$  coefficient can be modified from 300 to 25000 N/m/s. For the minimum value, the damper can travel a distance 7.5 mm while a length of 5 mm is covered when set to its maximum value.

Three minor additional modifications were done to improve the cleaving process. Firstly, the fiber being cleaved was only held from one side unlike in [15] where it was clamped either side of the cutting point. Figure 4 shows both situations and typical results. In Figure 4(a) the fiber is held from two sides and the fiber is sawed in the middle. This creates axial stress in the fiber and consequently produces an end-facet with an end-crack, as can be seen in figure 4(c). This crack is observed in all the cuts in [15] and represents a region where part of the fiber has been torn away by the cleaving process. In contrast, in Figure 4(b) the fiber is only held from one side avoiding the stress and therefore it is free of such cracks, as shown in figure 4(d). Secondly, a new groove was included in the blade holder to allow cutting the fiber when it has been mounted inside a connector ferrule, as shown in figure 1.

Finally, a modified blade with one almost flat-side, as shown in figure 5, is employed in the cleaver. The flat-side of the blade is placed as close as possible to the clamping point of the fiber in figure 4 (b) in order to increase the stiffness of the fiber section between the blade and the clamping point, as is discussed in [15].

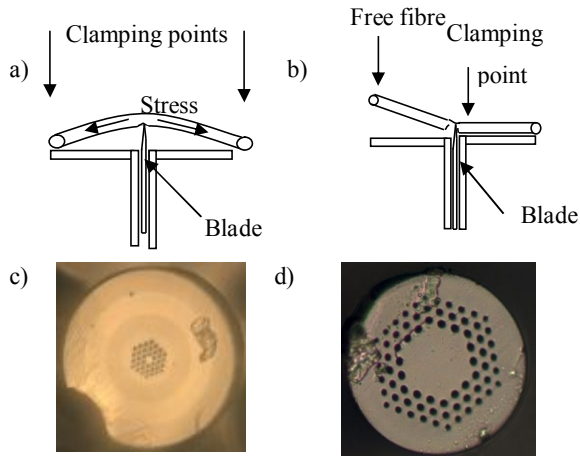


Figure 4: (a) Schematic with two sides fibre holding. (b) Schematic with one side fibre holding. (c) End-face cleave using scheme (a). (d) End-face cleave using scheme (b).

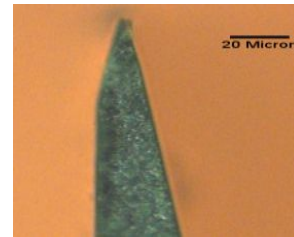


Figure 5: Photograph of the blade tip

### 3. Cleaving demonstration

A multimode microstructure polymer optical fibre (mPOF) based on PMMA was manufactured at Denmark Technical University (DTU), by using a fabrication procedure analogous to [15]. These fibre was used to perform a full characterization of the portable POF cleaver under different cutting times and angles.

The multimode fibre is depicted in figure 6. As it was demonstrated in [15], the end-face is free of crazes for enough long cutting times.

t (s)	2 degree	t (s)	3 degree	t (s)	4 degree	t (s)	5 degree
10.9		6.8		5.6		4.5	
8.8		7.5		3.8		1.3	
2.6		2.0		1.2		0.4	

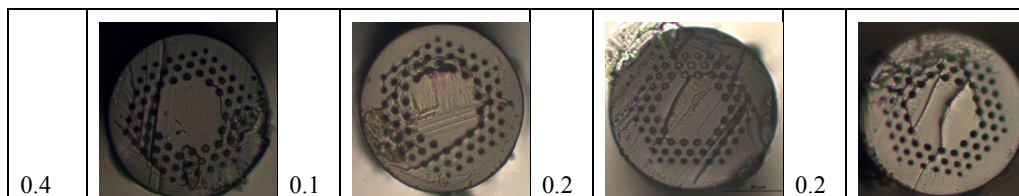


Table 1 Cleaving demonstration with multimode fiber.

### 3. Conclusions

In conclusion, we have described the construction and testing of the first high quality passive and portable polymer optical fiber cleaver. The device has been satisfactorily characterized by using a multimode microstructured polymer optical fiber which, in general, are difficult to cut.

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