

# Fabrication and characterisation of tapered and arc-shaped fiber for saturable absorber device in pulse fiber laser operation

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## Abstract

Pulse fiber lasers are recent developments that produce efficient pulse lasers by incorporating gain medium, saturable absorber (SA) materials and SA hosts. However, the SA hosts can be improved for stable generation pulse fiber laser. This discussion emphasizes the fabrication and characterisation of tapered and arc-shaped fiber using the flame-brushing and wheel polishing technique, respectively. Examples of using tapered fiber and arc-shaped fiber to generate Q-switched and mode-locked will be deliberated that can possibly be applied in communications, medicine and sensing.

## 1. Introduction

Ultrafast pulse laser generation in photonics has gained significant interest in fundamental science and various industries, such as telecommunications, sensing, industrial processing and medicine. Advanced optical fiber structures, notably tapered fiber and arc-shaped fiber, are pivotal as SA hosts for developing efficient pulse fiber lasers by enhancing light-SA material interaction via evanescent fields. Pulse fiber lasers utilising efficient SA hosts is important for developing high-performance fiber lasers to achieve high beam quality along with the gain medium and SA material. Common SA hosts used for pulse fiber laser generation, such as Q-switched and mode-locked fiber laser in the wavelength regions of 1.55 and 2.00  $\mu\text{m}$  include tapered fiber, arc-shaped fiber and PVA film [1]. Tapered fibers, with waists narrowed from 125 to 10  $\mu\text{m}$  using flame-brushing technique, offer strong interaction but face challenges in mechanical fragility due to its reduced diameter of the fiber (around 10  $\mu\text{m}$ ). The fabrication process involves softening the fiber and pulling a specific area of the fiber [2]. The appropriate tapered area is heated with a translation torch and the SMF is pulled to taper it to the desired scale. The torch flame is created using a combination of liquefied petroleum gas (LPG) and oxygen [2]. The objective of this experiment is to fabricate and characterise tapered fiber and arc-shaped fiber as SA hosts for possible pulse laser generation.

## 2. Results and Discussion

Tapered fibers had the characteristics of adiabaticity, evanescent field and high non-linearity for the generation of pulse lasers. Figure 1(a) shows the schematic diagram for fabrication of tapered fiber, (b) microscope image of the single mode fiber before tapering and (c) microscope image after tapering, which obtained a waist diameter of 6.29  $\mu\text{m}$ . Figure 2 demonstrates the insertion loss during the fabrication of tapered fiber with different brushing (heating) lengths of 1, 2 and 3 cm (Figure 2 a, b and c, respectively). The losses obtained were 6.35 dB, 4.22 dB and 0.11 dB for 1 cm, 2 cm and 3 cm brushing lengths, respectively. It is important to design tapered fibers with a low interaction with higher order modes by carefully controlling the taper profile and dimensions and optimising the fabrication process [3].

Arc-shaped fiber as SA hosts facilitates a direct interaction with the SA material in the pulse laser cavity while maintaining low insertion loss and high mechanical integrity. Wheel polishing technique to fabricate arc-shaped fiber includes a direct current motor, a designed polishing wheel with a diameter of 1 cm that is

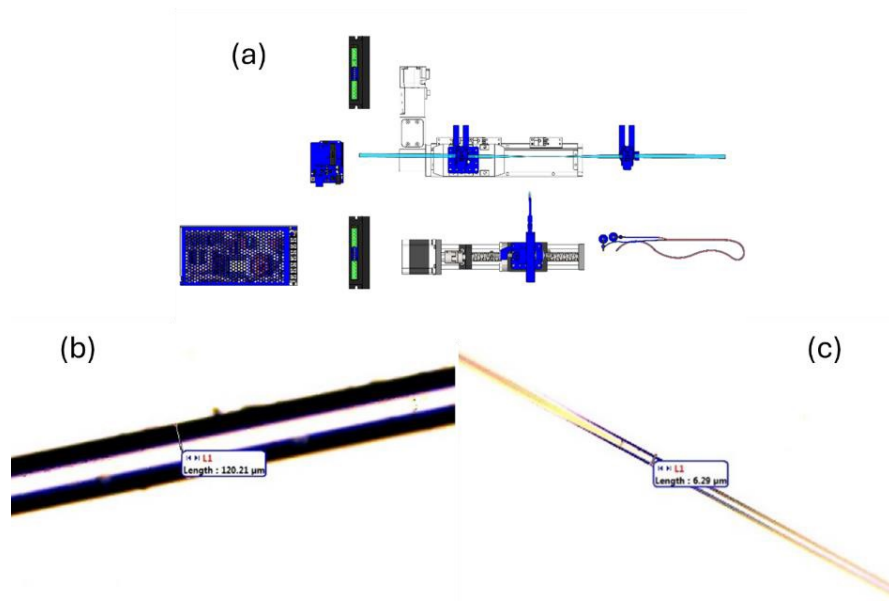


**Figure 1.** (a) Schematic diagram for fabrication of tapered fiber, (b) microscope image of the single mode fiber before tapering and (c) microscope image after tapering.

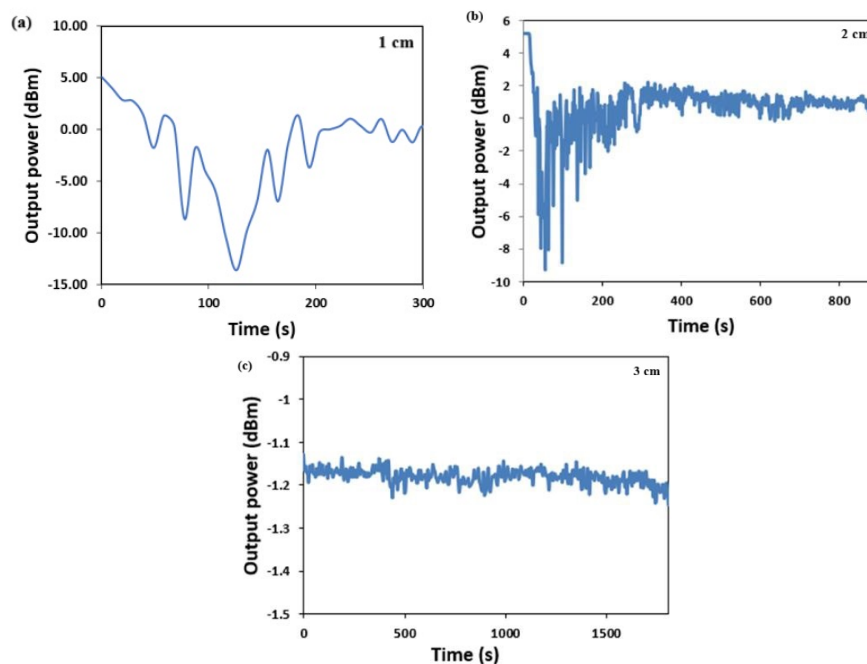


**Figure 2.** Insertion loss of fabricated tapered fiber. (a) 1 cm, (b) 2 cm and (c) 3 cm tapered fiber (brushing length (hot-zone length,  $L$ )).

covered with silicon carbide abrasive paper and a XYZ linear translation stage equipped with micrometer heads that have a resolution of 10  $\mu\text{m}$ . The stripped fiber is held in place between two fiber holders to ensure proper tension is maintained. The vertical movement of the polishing wheel is carefully regulated to guarantee consistent removal of cladding. Figure 3(a) shows the schematic diagram of arc-shaped fiber fabrication setup, while Figure 3(b) shows the physical image of designed polishing wheel and Figure 3(c) shows the insertion loss obtained after the arc-shaped fiber is fabricated with a corresponding value of 2.12 dB at wavelength of 1550 nm [4]. The inset for Figure 3(a) shows the microscope image of fabricated arc-shaped fiber. The polished part of the fiber's remained diameter around 69  $\mu\text{m}$ .

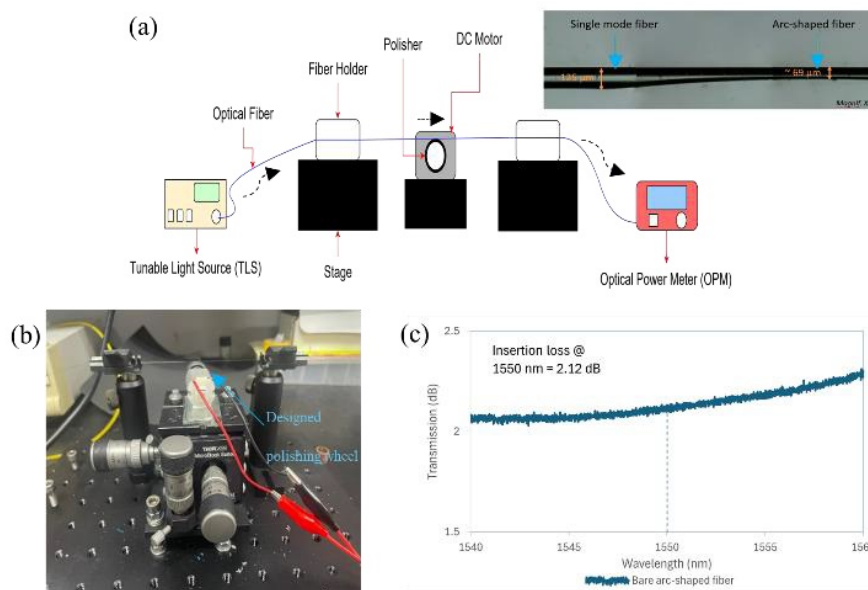


**Figure 3.** (a) Schematic diagram of arc-shaped fiber fabrication setup (inset: microscope image of fabricated arc-shaped fiber), (b) physical image of designed polishing wheel and (c) insertion loss [4].

Figure 4 shows a typical pulse fiber laser cavity setup with tapered fiber SA device [5]. It comprises the laser pump, gain medium, output coupler, polarisation controller (PC) and SA device. From the laser cavity setup, it is possible to generate mode-locked fiber laser with repetition rate, pulse width and signal-to-noise ratio measurements of 11.54 MHz, 1.77 ps and 52 dB, respectively.

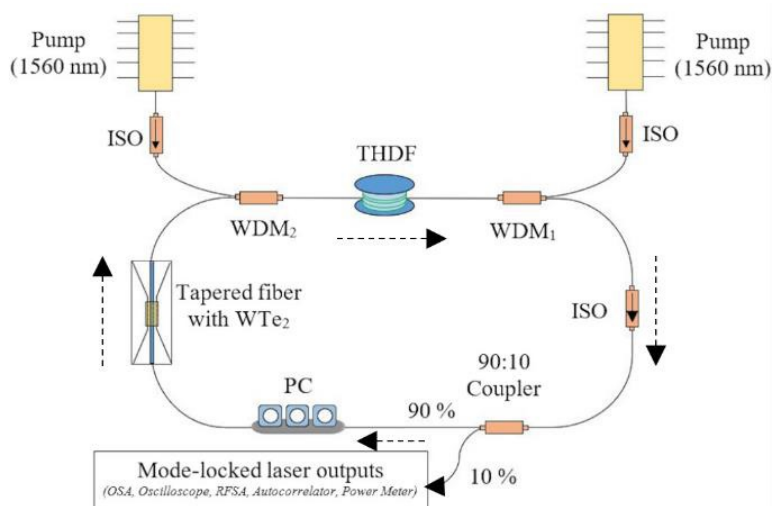


**Figure 4.** A typical pulse fiber laser cavity setup with tapered fiber SA device [5].

### 3. Conclusion

Fabricated tapered fiber and arc-shaped fiber was successfully carried with their validated characteristics with potentially used in the fiber laser cavity to generate Q-switched and mode-locked fiber lasers. Both fabricated SA hosts perform comparatively similar, however, tapered fiber has the advantage of polarisation insensitive compared to arc-shaped fiber due to the circular and symmetrical structure of the former. Appropriate SA hosts with good stability and efficiency can be applied to daily life, such as in communications, medicine and sensing.



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