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Fabrication and characterization of 2 × 2 microfiber coupler

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A 2x2 microfiber coupler is demonstrated by laterally fusing and tapering two optical fibers using a flame-brushing technique. The coupler has an overlapping length of 40mm with a uniform waist of around 5 µm to achieve various coupling ratios. The coupler is also succesfully packaged using a perspex and some adhesive polymer to avoid temporal loss instability to the device. The throughput loss of the 50:50 microfiber coupler is quite acceptable which is around 8 dB between port 1 and port 3.

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1. Introduction

Over the past two decades, a single mode fiber (SMF) coupler has been one of the most important fiber optic devices in telecommunications. The coupler is used as an optical fiber junction to combine and split the optical signal/power for optical switch, tunable filter and modulator [1-3]. Recently, microfibers have attracted considerable interests as they exhibit a number of exciting properties such as large evanescent field, strong confinement, easy configurability and high robustness [4-8]. These properties are advantageous for a wide range of applications including high-sensitivity optical sensors, nonlinear optics, atom trapping, micro/nano-scale photonic devices and for evanescent coupling to planar waveguides or microcavities. For instance, Jung et. al. demonstrated that sub-wavelength optical microwires can be used as an efficient element for higher-order mode filtering in multimode waveguides, creating effectively an endless single mode operation in conventional optical fibers [9]. The stable and low-loss single-mode operation obtained both at short wavelengths and over a wide spectral range is suitable for applications in high performance fiber lasers, sensors, photolithography, and optical coherence tomography (OCT) systems. However, single-mode output from a single fiber strand is not sufficient to fulfill all technical demands within these fields making the development of multi-port devices an important requirement.

In this paper, a fused-type bi-conical 2×2 coupler is fabricated and characterized. The microfiber couplers with various splitting ratios are succesfully fabricated by laterally fusing and tapering two optical fibers using a flame-brushing technique. The fabricated coupler is packaged using a perspex and some adhesive polymer to protect from any exposures to dust and moisture that can cause temporal loss instability to the device. The performance of the fabricated devices at two different coupling ratios are compared and presented.

2. Fabrication of microfiber coupler

A microfiber coupler is made by laterally fusing and tapering two optical fibers as shown in Fig. 1. In this experiment, a standard telecom optical fiber (Corning SMF-28) was used to make a low noise microfiber coupler with the aid of the well-established flame-brushing technique [10]. In the fabrication process, two fibers are brought into close proximity after the protective plastic jacket is removed. Then, both fibers are twisted at two different locations to make ovelapping contact. Then, while heated by a torch, the fibers are fused and stretched. The longitudinal profile of the conical transition tapers was achieved by reliable control of the hot zone and precise movement of the translation stages. During the tapering process, the coupling ratio is being monitored in real time by using a 1550 nm light source and power meters. The heating and pulling processes are stopped at the moment of achieving the desired coupling ratio.

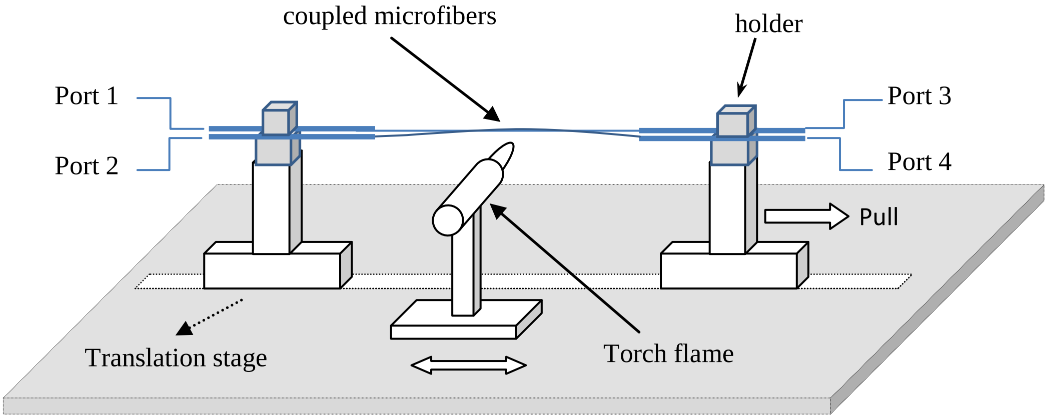

Fig. 1. Fabrication setup for microfiber coupler.

The fabricated microfiber coupler is then packaged by saving the coupling structure inside cavity of air. This packaging does not use any low refractive polymer, and thus the effective refractive index is equal to ~1 which is much lower than if it is packaged by using a polymer. This help in strengthening the light confinement in the device. At first, a few pieces of perspex sheet designed in rectangular shape are prepared. The fabricated coupler is hanged in between two earlier prepared perspex sheets. Four other perspex sheets are used to create an air gap and to close the microfiber coupler area. All perspex are fixed using a special adhesive polymer which is then cured using a UV lamp. Fig. 2 shows the packaged 2x2 microfiber coupler which is protected from any exposures to dust and moisture that can cause temporal loss instability to the device. The output power from the port 3 of the coupler is monitored for 50 days and the result is shown in Fig. 3. It is observed that the power fluctuating is less than 1dB for 50 days, which indicates that this technique is suitable for temporary measure in handling the microfiber coupler.

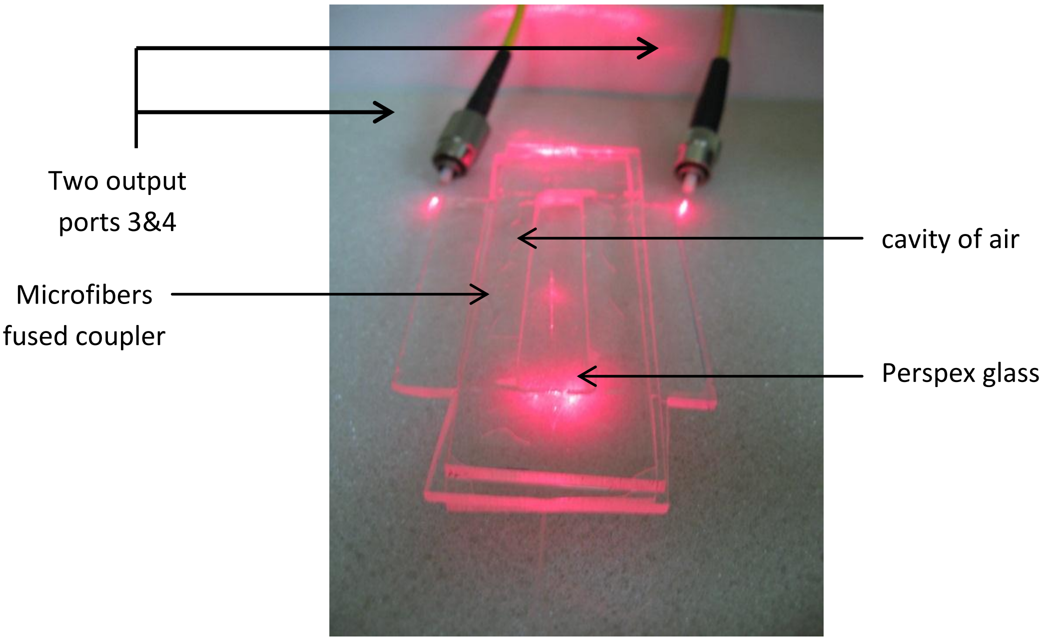

Fig. 2. The snap shot of real image for the packaged 2x2 microfiber coupler. The red laser is injected from one of the input port to help us to identify the coupling region.

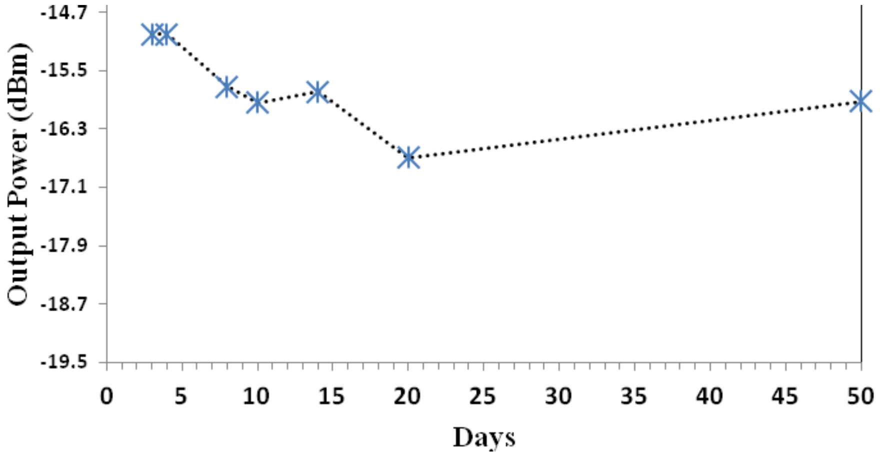

Fig. 3. The output power from the microfibers coupler recorded during 50 days, which shows a power variation of less than 1 dB.

3. Result and discussion

When two SMFs are brought in close proximity in air and tapered, they form a microfiber coupler. Fig. 4 shows the schematic diagram of the fabricated 2 × 2 microfiber coupler, which has the lengths of tapered region and uniform waist of 70 mm and 40 mm, respectively. The waist diameter of the coupling region is measured to be around 5 µm by a measurement microscope as shown in the inset of Fig. 4. An Erbium amplified spontaneous emission (ASE) source is used to couple light into one of the ports of the microfiber-based coupler, and the output spectrum is measured by an optical spectrum analyzer (OSA) from the output ports. Figs. 5(a) and 4(b) show the spectral response of the two output ports of the coupler when the ASE is injected from port 1 and port 2 respectively. As shown in these figures, an equal splitting of the output power into the two output ports is obtained, resulting in a 50:50 coupler. However, a slight spectral oscillation and amplitude modulation is also observed due to the polarization effect. The throughput loss of the coupler is quite acceptable which is around 8 dB between port 1 and port 3.

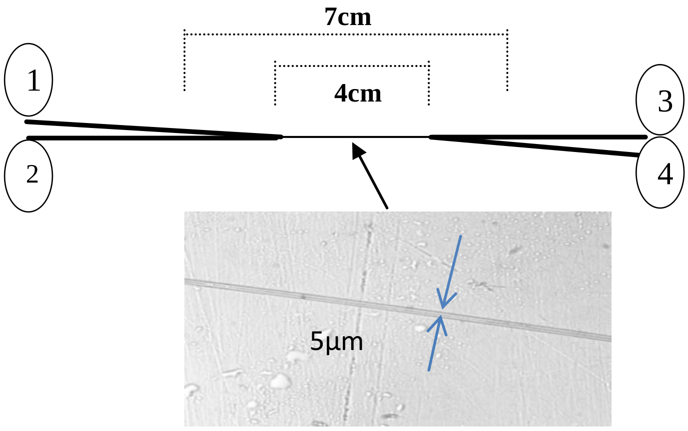

Fig. 4. Schematic diagram of the fabricated 2 x 2 microfiber coupler. Inset shows microscope image of the coupling region.

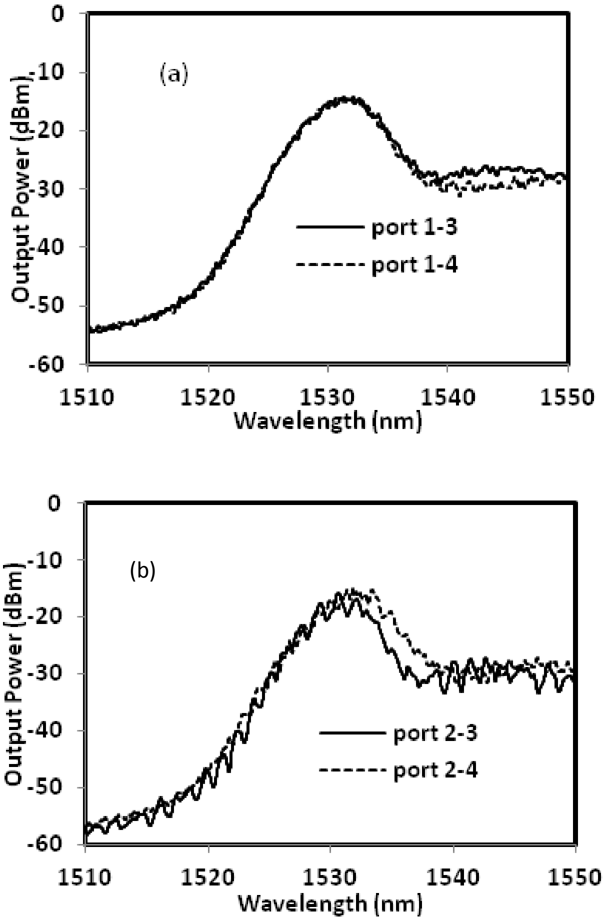

Fig. 5. Output spectra from the two output ports of the fabricated coupler when the ASE is injected from (a) port 1 and (b) port 2.

Fig. 6(a) and (b) show the output spectra from the two output ports of another fabricated microfiber coupler when the ASE is injected from port 1 and port 2, respectively. As seen in the figures, the coupler shows an unequal splitting of the output power when the ASE is injected from different port. The splitting ratios of 64:36 and 52: 48 are obtained when the input power is injected from ports 1 and 2, respectively. This is most probably to the unequality in the diameters of the two coupled microfibers. The loss characteristic and the coupling ratio of both fabricated fibers are summarized in Table 1. This coupler has a broad range of single-mode optical operation in two output ports and is directly applicable to the high performance fiber lasers, fiber sensors, optical coherence tomography (OCT) and fiber test & measurement systems.

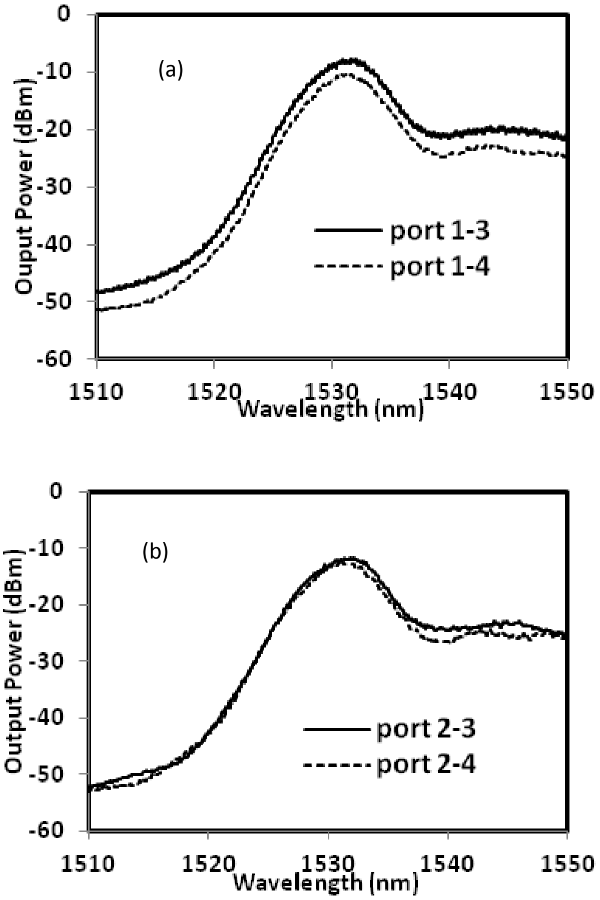

Fig. 6. Output spectra from the two output ports of a coupler with unequal splitting when the ASE is injected from (a) port 1 and (b) port 2.

Table 1. Summary of loss and coupling characteristics of the fabricated microfiber couplers.

Characteristics	Coupler 1		Coupler 2	
	Port 1-3	Port 1-4	Port 1-3	Port 1-4
Throughput loss	-8 dB	-9 dB	-1.5 dB	-5.7 dB
Tap loss	-8 dB	-9 dB	-4 dB	-6 dB
Excess loss	-4.2 dB	-4.5 dB	-2.7 dB	-3.6 dB
Coupling ratio	50:50	50:50	64:36	52:48

4. Conclusion

A microfiber coupler device is successfully fabricated to generate two output resonance spectra. It is obtained by laterally fusing and tapering two optical fibers using a flame-brushing technique. The coupler is also succesfully packaged using a perspex and some adhesive polymer to avoid temporal loss instability to the device. The coupler has the tapering region of 70 mm and an overlapping length of 40mm with a uniform waist of around 5 µm to achieve a splitting ratio of around 50:50. The throughput loss of the 50:50 microfiber coupler is obtained at around 8 dB between port 1 and port 3.

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