Special Functions of Modified Optical Microfiber

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Abstract— A common optical microfiber has usually been required to have very low loss so as to satisfy the research of optical microfiber based components. On the contrary, optical microfibers with special characteristics and a little higher loss are experimentally studied in this paper, just by modifying some of the parameters related to the optical microfiber fabrication system. Some optical microfibers have high backscattering characteristic, some have a little higher absorption loss. We have fabricated a kind of OM with high backscattering and no more than 5 mm waist region length, which can be evaluated as a reflector with low reflectance. The reflection function has been demonstrated by using the OM reflector as one of the two reflectors in a Fabry-Perot interferometer. We have also controlled the size and loss of OM to enhance its optical induced thermal effect. The OM is injected with intensity-modulated 980 nm light with average light power of about several milliwatts, the optical phase in the OM at 1550 nm wavelength is measured to be modulated while the OM is inserted into a Michelson interferometer. The result show that the OM acts as a kind of optical modulating material based on the optical induced thermal effect. In conclusion, OMs have been studied to evaluate reflection function and thermal modulation function, OM will become a kind of functional fiber and have potential value on research of new OM components.

1. INTRODUCTION

Optical microfiber (OM) has been paid much attention to for its special characteristics mainly due to its small diameter [1, 2]. Optical microfiber resonator (OMR) [3, 4] with very high quality is a typical application of OM, which requires the OM has very low loss. Corresponding works on researching low loss OM had been performed by improving the OM fabrication methods. On the contrary, we have set up an OM fabrication system and tried to research some other characteristics of OM by adjusting some fabrication parameters of the system. Modified OMs with high backscattering and a little loss are achieved and some special functions such as reflection function and light induced thermal modulation function are found in the modified OM.

2. IMPROVED OPTICAL MICROFIBER FABRICATION SYSTEM

An OM fabrication system has been set up according to the modified flame brushing method introduced by Reference [2]. The heater is an electronic heating wires embedded into special ceramic, which is driven by a DC source with digital current controlling function. The heater can heat the tapering fiber with different temperature. Meanwhile, we have built a monitoring system with a laser source and a photo-detector connected with a computer so as to monitor the transmitting light power variation during the fiber tapering process, and then we can get the ultimate loss of the fabricated OM sample. What's more, another photo-detector is used to detect the backscattering light of the tapering fiber by inserting a fiber circulator after the light source. The system with monitor function is shown in Figure 1.

It can be found that the heating temperature will have relation to the loss of the fabricated OM. We can control the heating temperature with high or low value to analyze the loss variation

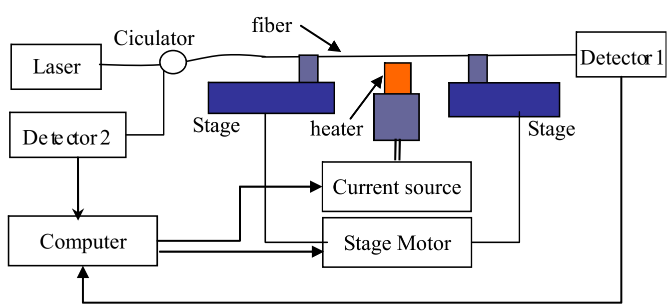


Figure 1: Schematic diagram of the OM fabrication setup with light monitoring.

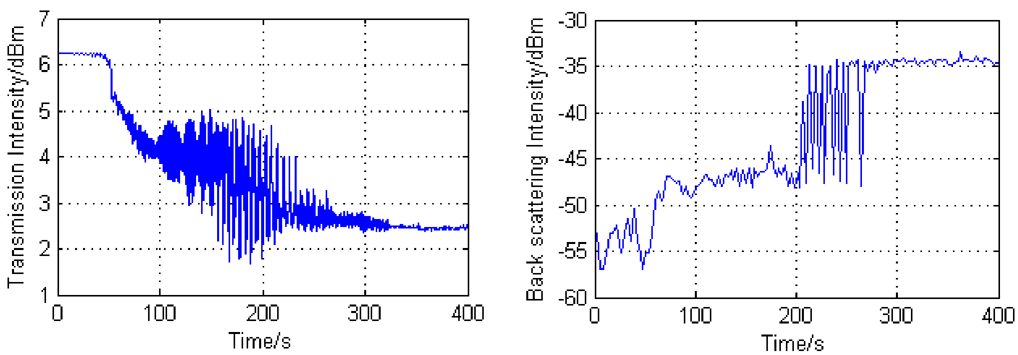
rule of the OM. The heating temperature can also be designed and controlled in the computer, which means that a heating temperature function can be designed and applied by the system. Correspondingly, special OMs with not very low loss are achieved.

3. OPTICAL MICROFIBERS WITH HIGH BACKSCATTERING AND OPTICAL MICROFIBER REFLECTOR

A telecom fiber (outer diameter $\sim 125\,\mu\text{m}$, Numerical aperture ~ 0.12) is clamped onto two motorized precision translation stages and stretched under the microheater with temperature about 1200 Celsius degree. Usually, people will pay more attentions on the transmission loss. Here, we will care about the backscattering light from the drawn optical microfiber. According to experimental results, sharp cooling of the optical microfiber can produce additional loss of the microfiber. Meanwhile, we found that the backscattering light will be raised as the result of the sharp cooling of the optical microfiber. An optical microfiber with enhanced backscattering light is fabricated.

The fabrication process is described as following steps. One end of the 8 m drawn fiber is connected to a laser (Agilent 8148A, output power ~ 10 dBm) through an optical circulator. The other end is angled to greatly decrease Fresnel reflection. Back reflected light is measured through a 3 dB optical fiber coupler with an Optical Power Meter (Lightwave 8210). Both stages and microheater shown in Figure 1 are connected to a computer. By accurately controlling the microheater's temperature, stretching speed and annealing time, we got a 10 mm waist length and $1\,\mu\text{m}$ diameter optical microfiber.

The inline monitoring light power data are plotted in Figure 2. The backscattering light power data are in Figure 2(a), the transmitting light power data are in Figure 2(b).



(a) (b)

Figure 2: (a) The transmitting light power monitoring result, (b) the back reflecting light power monitoring result.

As shown in Figure 2(a), the transmitting light power is about 2.7 dBm, and the loss of the fabricated OM is about 3.7 dB, which is not a very low loss. In Figure 2(b), we can notice that at the last part of the tapering process, the backscattering increased, while we had specially shifted the heater away from the tapering fiber with a displacement about only no more than 1 mm, while still maintaining the tapering fiber in the heating region, but the heating temperature may decrease a little. The back-reflected light is measured to be about -35 dBm, and has increased about 20 dB compared with the original back-reflected light of the fiber. In fact, the tapered OM has had backscattering function, and it is a reflector with low reflectance. The reflectance is about 41 dB, or 0.01%.

In order to identify the reflection is due to the modified special OM, we had the sample measured with a device called optical backscattering reflector (OBR), which can measure the distributed backscattering light of the fiber. We can measure the OM by just connecting the OM sample into the fiber connector of OBR. The measured result of the modified special OM is shown in Figure 3.

In Figure 3, the backscattering line at the displacement about 4200 mm is due to the OM sample. The peak at 0 mm and 7000 mm are separately due to the input fiber pigtail end and last fiber pigtail end. It can be got that the backscattering light power is about 15 dB higher than the fiber pigtail end. According to the result, we can conclude that the OM has obvious backscattering function, which is different with the common fiber.

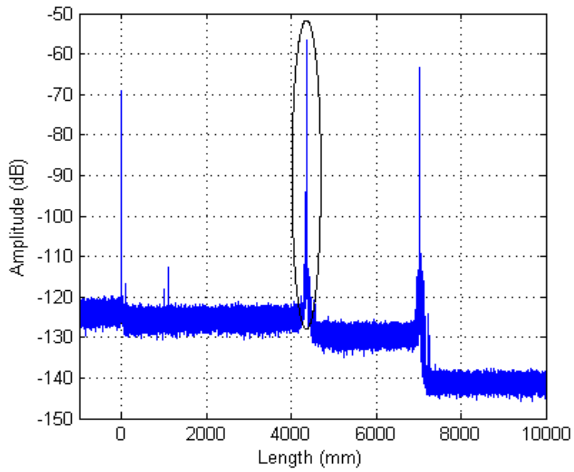


Figure 3: The distributed backscattering light of the OM sample measured with OBR.

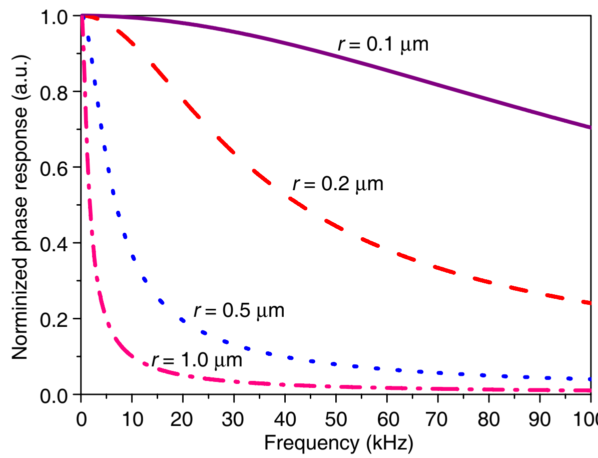


Figure 4: Calculated frequency responses of OM phase modulators with different OM radii.

We had also achieved another OM sample with stronger reflectance. The OM sample had been applied as a partial reflector in an interferometer, the work had been published by our group [5]. The result had demonstrated the OM as a real partial reflector.

4. OPTICAL INDUCED THERMAL EFFECT AND OPTICAL MICROFIBER PHASE MODULATOR WITH DIRECTLY LIGHT

We have been concerning the small diameter of the OM, only about $1 \sim 2$ micrometer for the usual OM. In Ref. [6], common fiber has been studied to produce phase modulation according to the light induced thermal effect. But the common fiber has bigger diameter so that the pump light must be very high to produce weak phase modulation. As the OM has small size, we want to produce a kind of OM to be useful on the light induced thermal modulation. We had simulated the OM phase modulation according to the fiber modulation driven by pump light. The modulation ability is shown in Figure 4 for different OM radii.

It can be seen that the smaller the radius of the OM is, the higher response the OM phase modulator will have.

Similar to the OM reflector, OM samples with a little loss have been experimentally studied for many times. OM phase modulator driven by intensity-modulated 980 nm light inserted into a phase demodulation system had been designed and experimentally studied. The setup is shown in Figure 5.

The measured phase modulation response amplitude (rad) of the OM phase modulator corre-

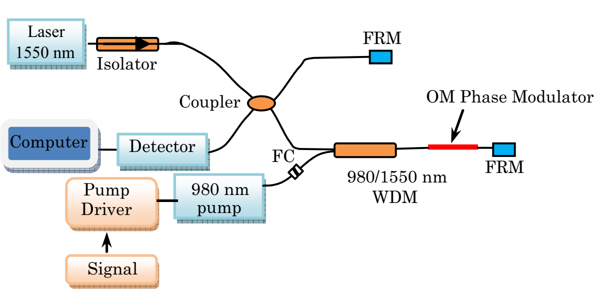


Figure 5: Schematic diagram of the OM phase modulator measurement system.

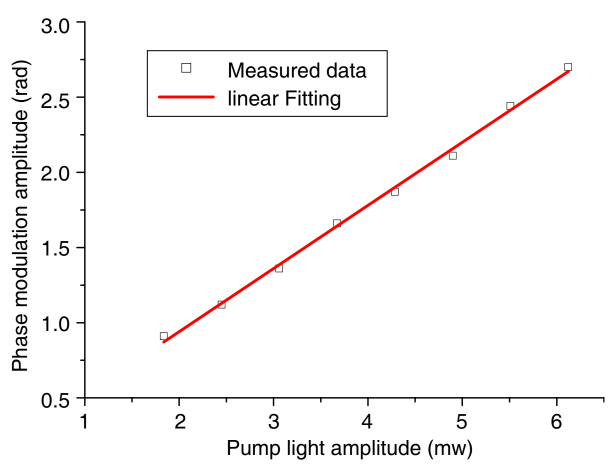


Figure 6: The phase response of the OM phase modulator with the changing pump light amplitude.

sponding to the changing average power of the intensity-modulated pump light with 1 kHz frequency are plotted in Figure 6. The linear fitting result is shown in Figure 6 in solid line. It can be seen that the OM has appeared phase modulation function and the OM modulator has good linearity for the average power of the pumped light. The detailed result of the OM phase modulator has been finished and will be published in the future by our group.

5. CONCLUSION

We have put forward to OM samples with two different special function: one is backscattering, which can be used to be partial reflector, the other is light induced thermal modulation function, which can be used as light modulator. The main property of the modified OMs is a little loss due to the thermal control during the OM fabrication process. However, the basic principle of the OMs has not been explained clearly, further works will be carried out to study the microstructure of the modified OMs.

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