Characterization of DNA Optical Microfiber Devices Fabricated by Drawing

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Abstract: We demonstrate the characterization of DNA optical microfiber devices fabricated by manually drawing. The strength, flexibility and optical loss are experimentally investigated. DNA optical microfiber devices are expected to be used as optical biosensors.

OCIS codes: (160.1435) Biomaterials; (130.3990) Micro-optical devices; (060.2370) Fiber optics sensors

1. Introduction

The applications of DNA in photonics and optoelectronics have attracted intensive attentions during recent years [1-3]. This is because the DNA-lipid complex has the property of thermal and optical stability [4], and DNA complexed with cationic surfactant cetyltrimethylammonium chloride (CTMA) has more efficient photoluminescence and lasing characteristics compared with conventional materials [1,4-6]. There is a growing need to fabricate optical fiber based on DNA materials for micro-photonic devices, of which the key requirements are enough strength, good flexibility and low optical loss. DNA microfibers were recently fabricated by electrospinning and solvent evaporating [7,8]. Up to date, DNA optical microfibers have not been reported yet. In general, the method to fabricate optical microfibers by directly drawing is faster, simpler, and more cost-effective, which has the capability of fabricating prototype micro-photonic devices and easily interconnecting into mechanically flexible three-dimensional structures [9,10]. This method was used to fabricate polymer microfibers/nanofibers for optical fibers and gas sensors [9,10].

In this paper, we demonstrate the characterization of DNA optical microfiber devices fabricated by simply drawing the DNA-CTMA solution. The fabricated DNA optical microfibers have better uniformity and smoothness, and can be directly patterned into suspended strand compared with those fabricated by solvent evaporating and electrospinning.

2. DNA optical microfibers

DNA-lipid complex was homemade by mixing salmon DNA (sigma-Aldrich) and CTMA (Mw =320, sigma-Aldrich) solution, which is similar with the method described in [4]. DNA optical microfibers were fabricated at room temperature by directly drawing from DNA-CTMA solution. Using this technique, we could fabricate the DNA optical microfibers with diameters down to several micrometers and lengths up to tens of centimeters.

To study the surface properties of DNA optical microfibers, atomic force microscopy (AFM) and scanning electron microscope (SEM) tests were employed, respectively. The AFM image of 500-nm length is depicted in Fig. 1(a), which shows the average surface roughness less than 2.39 nm with the peak-to-peak value less than 5 nm. Before complete solidification, the DNA optical microfiber was stuck on another DNA microfiber and bended by micromanipulation. The SEM image of the above-mentioned structure is shown in Fig. 1(b), which validates strong strength and excellent flexibility of the as-fabricated DNA optical microfibers.

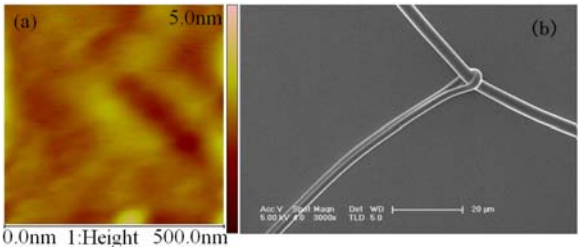

Fig. 1. (a) AFM and (b) SEM images of the as-fabricated DNA microfibers.

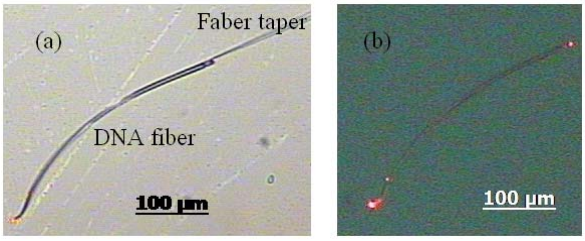

Fig. 2. Microscope images of the light transmission at 632.8 nm under the (a) brightfield and (b) darkfield illumination.

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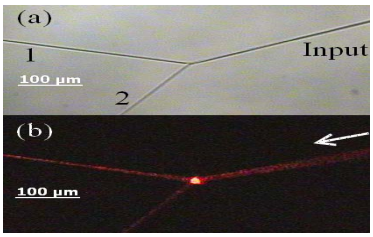

Fig. 3. Microscope images of 1x2 suspended splitter at 632.8 nm under the (a) brightfield and (b) darkfield illumination.

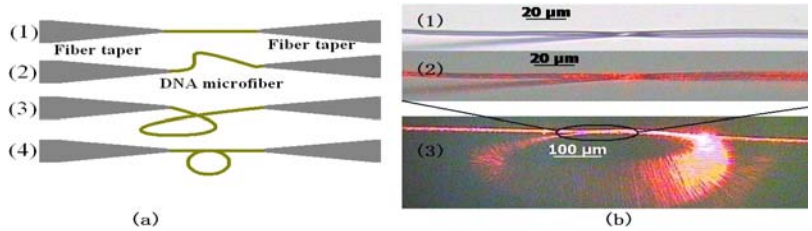

Fig. 4. (a) Schematic of DNA MLR fabrication with four steps (1-4). (b) Microscope image of DNA MLR light transmission at 632.8 nm. The bottom subplot is the entire view and the top two subplots are the magnified views.

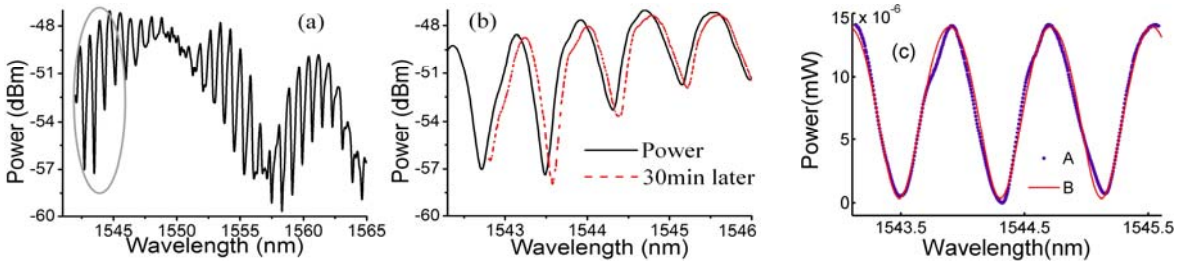

Fig. 5 (a) Transmission spectrum of the DNA MLR. (b) Magnified spectra measured with half-an-hour interval. (c) Loss estimation by the least-squares fitting. A, the experiment data; B, the fitting result.

Light transmission at 632.8 nm and 1550 nm wavelengths were both studied. Figure 2 illustrates an example at 632.8 nm, indicating good light transmission with a total loss (coupling loss and transmission loss) of ~12 dB. At 1550 nm, the total loss was measured to be ~10 dB.

3. DNA microfiber splitter and microfiber loop resonator

By twisting two separate DNA optical microfibers, we fabricated DNA optical microfiber splitter, which is one of key devices in micro-photonics. When 632.8 nm red light was launched into the splitter, the splitting effect was clearly observed (see Fig. 3). The splitting ratio was measured to be approximately 57: 43.

As schematically shown in Fig. 4 (a), the DNA MLR could be fabricated by four micromanipulation steps. The loop was formed by the electrostatic and van der Walls attraction. The microscope images of the DNA MLR with 632.8 nm light launched are depicted in Fig. 4(b). The microfiber's diameter of the DNA MLR is estimated to be ~2.8 μm.

Additionally, we studied the resonance properties of the DNA MLR at 1550nm wavelength. The transmission spectrum is shown in Fig. 5(a). The stability of the DNA MLR resonance was testified, and two examples of the spectra with half-an-hour interval are given in Fig. 5 (b). The results show that the resonance curve drift slightly, which is possibly due to the fluctuation of ambient temperature.

The free space range (FSR) of the DNA MLR is evaluated to be ~0.8169 nm. According to the definition of the FSR, i.e., $FSR=\lambda^2/(n_{eff}L)$ with n_{eff} the refractive index of DNA-lipid complex (1.482), L the MLR circumference, and λ the resonance wavelength (1543.5 nm), the MLR circumference is calculated to be ~1.97 mm. In order to estimate the optical loss of the MLR, we referred to the method described in [11]. As shown in Fig. 5(c), the fitting result is in good agreement with the experiment data. The optical loss is estimated to be ~6 dB/mm.

4. Conclusions

We have experimentally characterized the fabricated DNA optical fibers with diameters of several micrometers, DNA microfiber splitter and DNA MLR. The DNA optical microfibers have reasonably low optical loss and good optical transmission at both 632.8 nm and 1550 nm wavelengths. The DNA MLR was preliminarily fabricated with diameter of ~1.97 mm and optical loss of ~6 dB/mm. It is expected that the simple drawing method may be a good way for custom fabrication of DNA prototype micro-photonic devices. Thanks to good biocompatibility of DNA, DNA optical microfiber devices are potential candidates in applications to optical biosensors.

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