بیست و سومین کنفرانس اپتیک و فوتونیک و نهمین کنفرانس مهندسی و فناوری فوتونیک ایران
دانشگاه تربیت مدرس
۱۲-۱۴ بهمن ۱۳۹۵
23rd Iranian Conference on Optics and Photonics and 9th Conference on Photonics Engineering and Technology
Tarbiat Modares University, Tehran, Iran
January 31- February 2, 2017

طراحی و ساخت حسگر فیبر نوری باریک شده به منظور استفاده در کاربردهای زیستی

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چکیده - **این مقاله به معرفی و ساخت زیست‌حسگر بر مبنای فیبر نوری نازک شده با استفاده از اندازه‌گیری جابجایی طیف خروجی در حضور مایعات با ضرایب شکست متفاوت می‌پردازد. فیبر نوری نازک شده با طول یک سانتی‌متر و قطر کمر ۱۰ میکرون با استفاده از شعله هوا-گاز ساخته شده است. طیف‌سنجی فیبر نازک شده با استفاده از چشمه نور پهن باند و تحلیلگر طیف نوری (*OSA*)، در بازه طول موجی ۴۰ نانومتر انجام شد. در ادامه، تغییر ضریب شکست محیط اطراف فیبر نوری نازک شده بر طیف خروجی مورد بررسی قرار گرفت. آزمایش ها بر روی بافرهای زیستی انجام شده اند. می توان نشان داد که با افزایش ضریب شکست محیط اطراف میزان جابجایی طیف خروجی نیز افزایش می‌یابد. میزان حساسیت به دست آمده از مرتبه *nm/RIU* ۰/۱ است.**

کلید واژه: بافرهای زیستی ، چشمه نور پهن باند، حسگر زیستی، فیبر نوری نازک شده

Design and Fabrication of Tapered Fiber Optics Sensor for Biosensing Application

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Abstract- This article presents design and fabrication of a biosensor based on tapered fiber by measuring the output spectrum in the presence of liquids with different refractive indices. The fiber taper was made by oxy-butane torch. The spectrum is obtained using a broadband light source and an optical spectrum analyzer (OSA), in the wavelength range of 40nm. The effect of changing the refractive index on output spectrum was investigated. It is shown that by increasing the refractive index of the surrounding environment, the output spectrum is shifted and a sensitivity of the order of 0.1 nm/RIU is obtained.

Keywords: Tapered fiber, biosensor, refractive index, biological buffers

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Design and Fabrication of Tapered Fiber Optics Sensor for Biosensing Application

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1 Introduction

Today one of the most important and attractive sensors are Biosensors. Optical fibers are among devices that have been used to construct biosensors. High sensitivity, fast response time and biocompatibility are reasons, which makes optical fiber biosensors suitable for broad fields [1],[2]

One of the methods, which is used in the recent years for enhancing the sensitivity of optical fiber sensors, is tapering the fiber. Tapering optical fibers increases the evanescent field outside the fiber. In addition, the penetration deeps have inverse relationship with diameter of the fiber, i.e. as diameter of the optical fiber decreases penetration deeps increases. These factors cause the output of the signal to become very sensitive to refractive index of the surrounding medium[3][4]. In 2006 Keiu *et al* represents several simple sensitive fiber-optics-based sensors which are utilized to measure displacement, temperature and refractive-index. The latter was capable of measuring refractive index with sensitivity of 1.42×10^{-5} RIU[5]. In 2008, Leung *et al* represents a tapered optical fiber sensor, which was sensitive to Glucose concentration of 0.01 g/ml and 0.1 g/ml at wavelengths 1310 nm and 1550 nm respectively[6].

2 Fabrication of tapered optical fibre

There are some methods which are used for tapering fibers. One of the best and controllable approaches is heating and pulling. In this way, a part of the optical fiber is heated until or near the melting point. Torch[7] and CO_2 laser[8] are some of the heat sources, which are used recently. In this experiment, we used oxygen-butane gas torch.

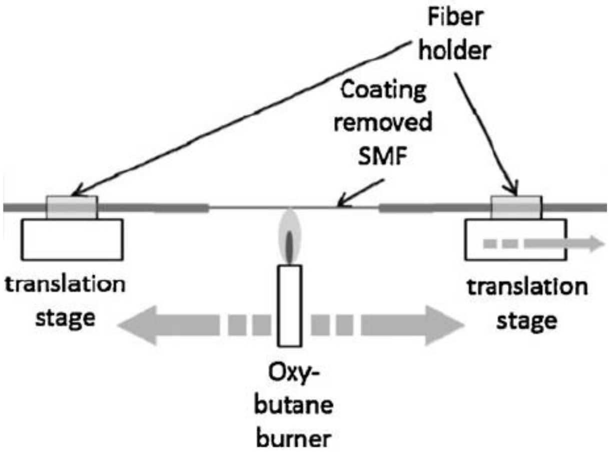

Figure 1: Fabrication of tapered optical fiber with torch**.**

As demonstrated in figure 2 optical fiber is pulled with two stepper motors with approximately 1 mm/s speed. After heating the optical fiber, the viscosity of the optical fiber is decreased and the fiber becomes soft and is pulled with two stepper motors easily.

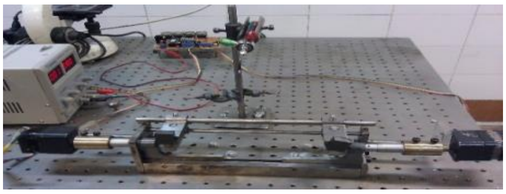

Figure 2: instrument of tapering optical fiber with torch and two stepper motor

3 Design of experimental cell

In this experiment, finding a best-performance medium for liquids is necessary, so designing a cell containing the liquid sample and tapered optical fiber is essential. This cell must have some capabilities: one of the significant capabilities is the possibility of injection and ejection of the liquid and another is protecting the cell from exposure of direct temperature change,

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evaporation and possibility of placement of cell under the microscope.

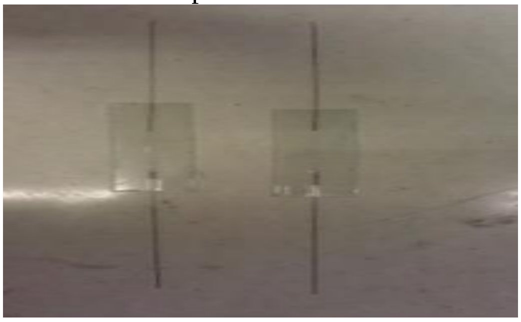

Figure 3: Experimental tapered optical fiber liquid cell

The fabricated cells as demonstrated in figure 3 consisting two microscope slides with holes that act as ingress/egress channels for sample liquid or gases. When the liquid is injected into the tiny hole of the cell, another hole ejects the air inside the cell and liquid fills the cell completely. The wall of the cell is made of two-sided glue, which after placement of the tapered optical fiber inside the slides is glued and stabled.

4 Experimental setup

As demonstrated in figure 4 the broadband light propagates inside the single mode fiber (SMF 125:8.2) from the source (super luminescent diode). The change of the refractive index causes wavelength shift in OSA. In this experiment we utilized broadband light source at the range of 1520-1560 nm.

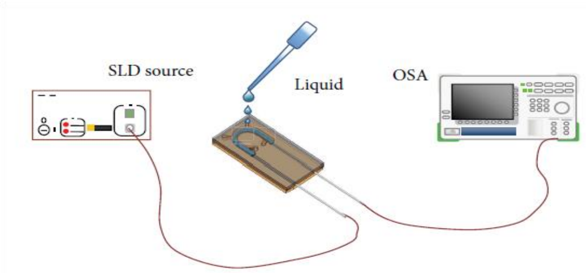

Figure 4: Refractive index measurement experimental setup

The samples that are used in this work are as follows: Phosphate-buffered saline (PBS) with refractive index of 1.3341, Sodium dodecyl sulfate (SDF) with refractive index of 1.4611 and saline-sodium citrate (SSC) with refractive index of 1.3700. Each buffer has same concentration of 10x.

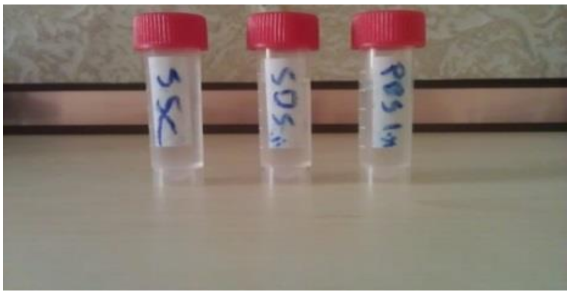

Figure 5: Three biological buffers used for measurement of refractive index change: SSC, SDS, PBS

5 Analyze of spectrum recorded

At first, the spectrum of bare tapered optical fiber (without any liquid sample) was taken. In this case, refractive index is 1.0003. Length and diameter of the waist of the optical fiber are 1 cm and 10 microns respectively.

As indicated at figure 6, the center wavelength of the bare optical fiber is 1527.7462 nm. The liquid sample (PBS) were injected and wavelength shifted to 1528.7479 at same way in figure 7 the wavelength after the injection of SDS shifted from 1528.9141 to 1530.0827 and wavelength shift interval is 1.1678.

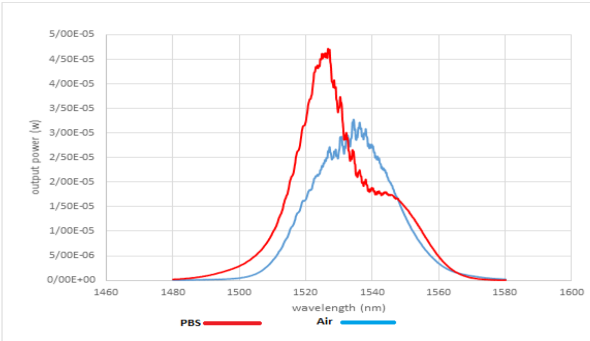

Figure 6: Output spectra for the fiber with 10-micron diameter at the presence of PBS and air.

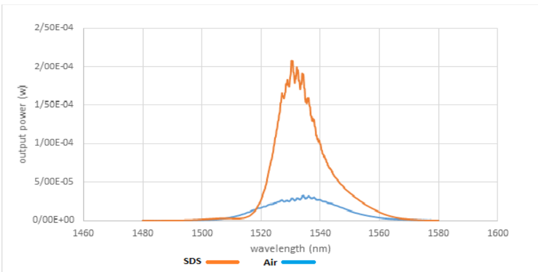

Figure 7: Output spectra for the fiber with 10-micron diameter at the presence of SDS and air.

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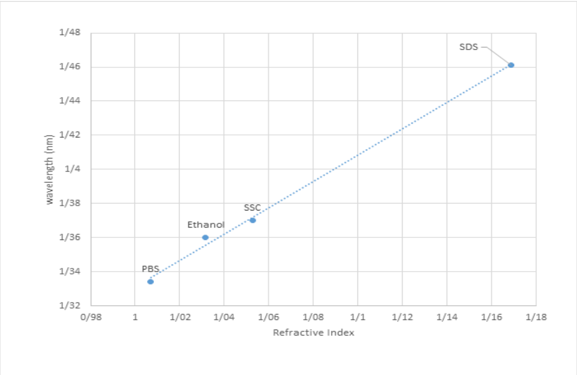

Figure 8: Relationship between refractive index and the wavelength shift at the fiber diameter of 10 microns.

As demonstrated in figure 8 the relationship between refractive index and wavelength shift is linear.

All of the procedures were repeated with another tapered optical fiber, which has 15 micrometer diameter. Figure 9 demonstrates relationship between refractive index and wavelength shift at the fiber diameter of 15 microns.

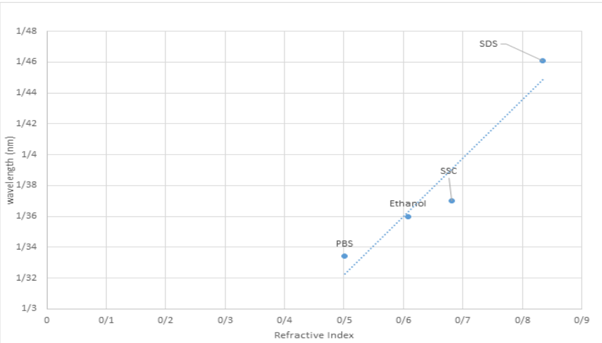

Figure 9: Relationship between refractive index and wavelength shift at fiber diameter of 15 microns.

6 Conclusion

Sensitivity of the fabricated tapered optical fiber sensors with 10 and 15 microns waist diameter are 0.7562 nm/RIU and 0.3781 nm/RIU respectively. We realized a same linear relationship between refractive index change and wavelength shift at figures 8 and 9 but the change in the diameter of the tapered optical fiber affects the sensitivity. When the diameter of tapered optical fiber sensor decreases, evanescent field intensity increases and sensitivity increases. The relationship between sensitivity and waist diameter is inverse.

7 References

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