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Selective detection of labeled DNA using an air-clad photonic crystal fiber

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Abstract: Demonstration of selective detection of fluorophore labeled DNA by hybridization inside the air holes of a photonic crystal fiber. A laser exposes the fiber from the side and the emitted fluorescence tunnels into the core.

OCIS codes: (060.2370) Fiber optics sensors, (170.6280) Spectroscopy, fluorescence and luminescence

1. Introduction

The air holes of a Photonic Crystal Fiber (PCF) [1] makes it possible to position various samples in close proximity to light guided through the fiber without reducing the thickness and robustness of the fiber. The evanescent field of the guided modes penetrates of into the air holes [2], and evanescent-wave sensing in PCFs has been demonstrated [3,4]. Here we present a new approach for the selective detection of fluorophore-labeled DNA in aqueous solutions using an air-clad PCF. The biomolecules are hybridized to a sensing layer immobilized inside the air holes. Illuminating the fiber from the side with a line shaped laser beam excites the fluorophores, and the emitted fluorescence is collected in the high numerical aperture fiber core and guided to a spectrometer. The method does not require removal of the fiber cladding and coating.

2. Experiments

The sensing layer is immobilized on the glass surface inside the air holes by using a conventional Streptavidin-Biotin procedure [5]. A single-strand DNA-Oligo with the complementary nucleotide sequence relative to that the device should detect is attached to the Biotin. If the sample contains DNA with the correct nucleotide sequence, these will hybridize to the immobilized complementary strand, while DNA with other nucleotide sequences are flushed out during subsequent washes. Prior to the measurements, the fiber is emptied with air. To demonstrate the method we used DNA-Oligo labeled with Cy5, which has excitation and emission spectra that peaks around 650nm and 670nm, respectively.

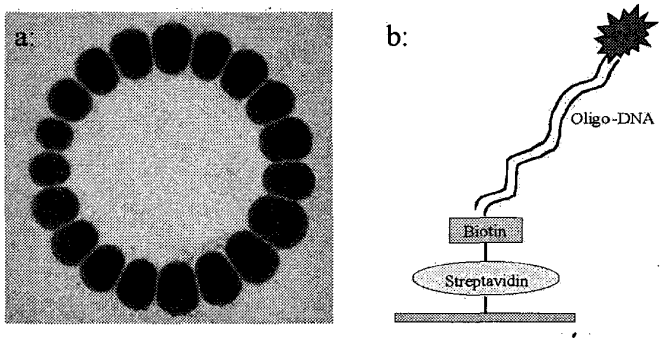

Fig. 1. a): Micrograph of the end facet of the air-clad PCF used in the experiments and b): the Cy5-labeled DNA-Oligo hybridized with the complementary single-strand DNA-Oligo string immobilized on the Steptavidin-Biotin film.

In the measurements, the fiber is exposed from the side with the line-shaped beam from a 25mW diode laser (λ=658nm) as illustrated in Figure 2. In order to maximize the fluorophore excitation efficiency, the short axis of the

beam is focused to match the fiber diameter. Fluorescence emitted in regions with a strong evanescent field from the guided modes, can tunnel into the core [6], and is guided to the fiber end, where a spectrum is measured.

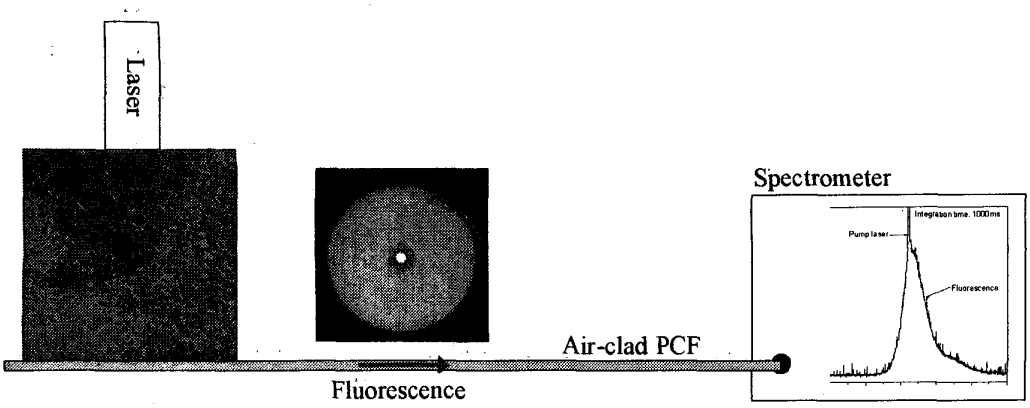

Fig. 2. The experimental setup for the detection of the hybridized DNA. A 25mW laser providing a line-shaped beam illuminates the air-clad fiber. As seen in the inserted micrograph image, the fluorescence emitted from the fluorophore tunnels into the fiber core and is guided to the fiber end. The graph shows the fluorescent signal captured by the spectrometer, when a sample containing the correct DNA is analyzed.

3. Results and discussion

A comparison between spectra measured on two samples containing a complementary and a completely non-complementary DNA string, respectively, shows a clear difference in the intensity of the fluorescent signal transmitted through the fiber as seen in Figure 3.

In similar devices operating by evanescent field excitation of the fluorophores [6], the overlap between the exciting field and the fluorophores is relatively weak. Exposing the fiber from the side ensures a strong interaction between the laser beam and the fluorophores. This makes our approach more sensitive than the evanescent field excitation devices. The sensitivity of the method is not affected significantly by the fiber coating. Leaving the fiber coating on the fiber makes the device very robust.

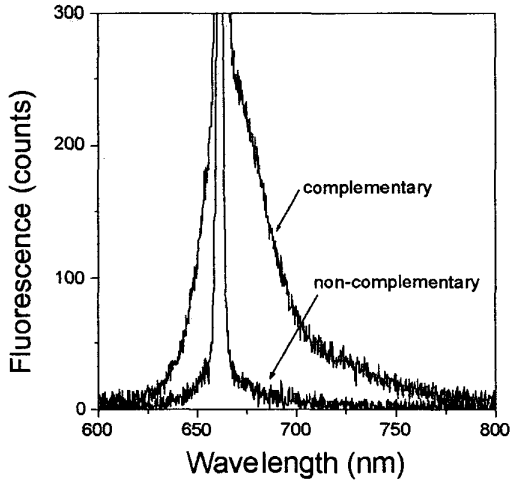

Fig. 3. Two measurements showing the signals from two samples containing the complementary and the non-complementary DNA strings, respectively. The laser beam with a wavelength of 658nm is also collected and guided through the fiber as seen especially in the signal from the non-complementary sample.

4. Conclusion

We have demonstrated selective detection of fluorophore-labeled DNA from an aqueous solution by hybridization inside the air holes of an air-clad PCF. Highly efficient excitation of the fluorophores is realized by exposing the fiber from the side with a line-shaped laser beam. The emitted fluorescence tunnels into the fiber core and is transmitted to a spectrometer at the fiber end. The fiber coating and cladding does not need to be removed, thus ensuring a very robust device.

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