Towards sensitive and precise plasmonic fiber biosensors through phase analysis

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Abbreviated abstract: A gold-coated tilted fiber Bragg grating (TFBG) can detect the surrounding refractive index (SRI) change by surface plasmon resonance (SPR) shift following a similar principle as in commercial devices based on the Kretschmann prism. Although information from optical fiber sensors only rely on spectral characteristics. Using phase analysis, we are able to detect HER2 protein (an oncogene overexpressed in breast cancer cells) at 1 $\mu g/mL$.

- $\Lambda = 550\ nm$
- $n_{eff}^{co} \sim 1.4447$

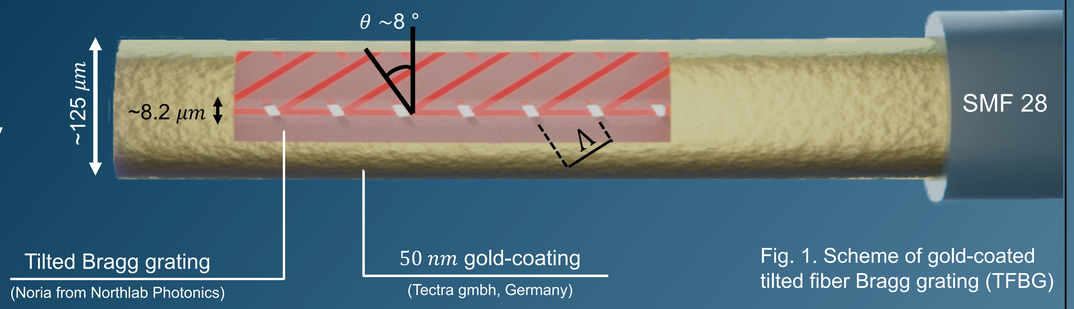

Fig. 1. Scheme of gold-coated tilted fiber Bragg grating (TFBG)

Previous work, challenge, and approach

To promote a single-mode fiber (SMF28) to a biosensor, light should first be coupled out of the core (see Fig.1). This is done by inscribing a tilted grating inside the core of the fiber. Then in order to enhance refractive index sensitivity, a gold layer is coated. Then, the fiber is functionalized with specific receptors.

The detection is performed in a microfluidic system and spectra are extracted using an Optical Vector Analyzer (OVA CTE from Luna Technologies Inc), as shown in Fig.2.

The resulting insertion loss spectrum is usually used for the analysis, it is known that a phase analysis would lead to better results.

However, it is well known that only the p-polarized mode can resonate with a surface plasmon and the phase acquired by this mode is then required.

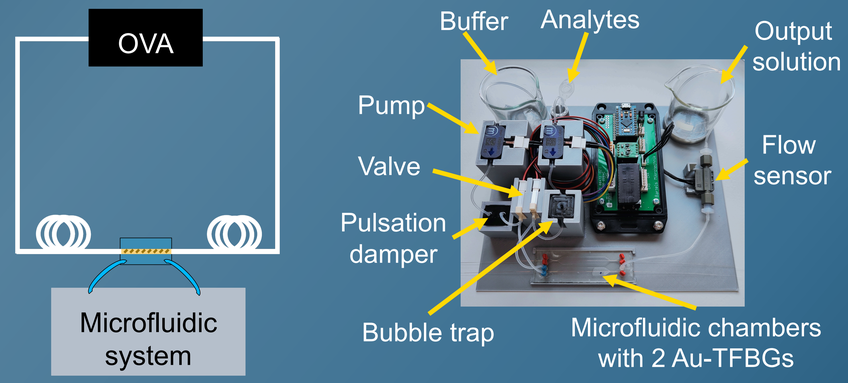

Fig. 2. On the left-hand side, a scheme of the experimental setup. The functionalized fiber placed in a microfluidic chamber made of Topas (from microfluidic ChipShop) is connected in transmission to an Optical Vector Analyzer (OVA CTE from Luna Technologies Inc). On the right-hand side, a picture of the microfluidic system (from Bartels mikrotechnik, Germany).

Techniques and Methods

Using the Jones matrix elements given by the OVA, one can emulate a virtual polarizer connected to the system and extract the p and s-polarized Jones Vector ($|p>$ and $|s>$).

Then, the phase acquired while sending p and s-polarization state are extracted using the Pancharatnam connection such as

$$\varphi_p(\lambda) = \arg(<p|J|p>),$$

and

$$\varphi_s(\lambda) = \arg(<s|J|s>),$$

where J is the Jones matrix.

Since only the p-mode can lead to SPR, in order to only extract this resonance effect, the phase difference $\delta\varphi(\lambda)$ between the p and s-polarized mode is computed resulting in the spectra shown in Fig.3

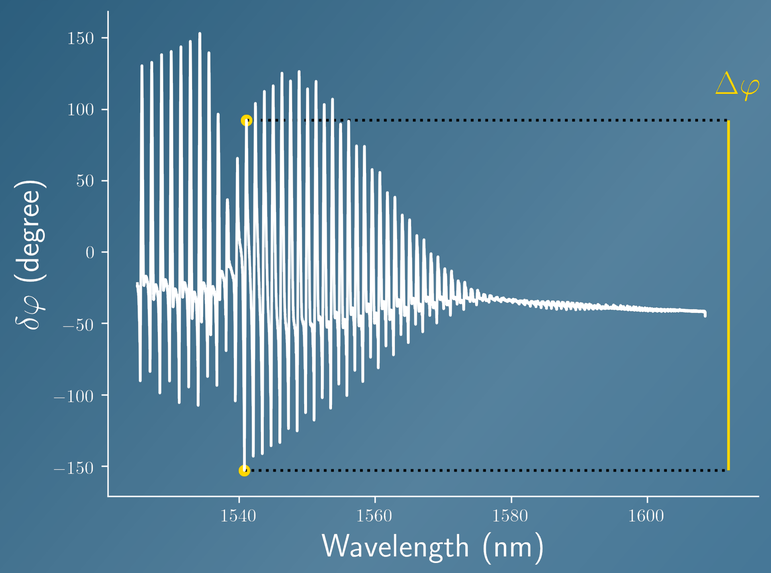

Fig. 3. Phase difference between p and s-polarized modes obtained using Jones formalism (see QR code). $\Delta\varphi$ is the amplitude between the maximum and the minimum of two neighboring peaks. This is what is followed for the detection.

For more information about the method :

Results and Conclusions

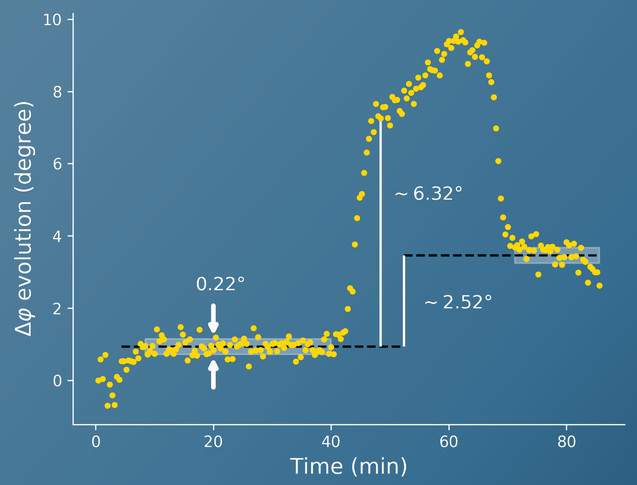

Fig. 4. Experimental detection of HER2 at $1\ \mu g/mL$. Using phase difference method. During the 40 first minutes, the sensor is immersed into a physiological solution (PBS) to ensure stabilization. Then, HER2 solution replaces PBS and a rinsing is finally performed.

Gold-coated TFBGs are a transposition of the Kretschmann prism configuration into a small and cost-effective physical platform. Once the fiber is functionalized with specific receptors, it acts as a precise and sensitive biosensor.

The phase difference spectra obtained through the Jones formalism can be used to detect HER2 protein at concentration as low as $1\ \mu g/mL$ with better precision than using the insertion loss spectra (see QR codes).

The simplicity of the method also allows automatization of the demodulation process. The latter could lead to real-time analysis of chemical binding dynamics for various types of analytes in future work.

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