Plasmonic Fiber Grating Biosensors Demodulated Through Spectral Envelopes Intersection

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***Abstract*—Gold-coated tilted fiber Bragg gratings (TFBGs) have been highly studied over the last years, mainly for biosensing purposes. They present a comb-like spectrum of narrow-band cladding mode resonances that is often demodulated by tracking the change of a selected peak. In this paper, we report a twentyfold more sensitive demodulation method based on the intersection of the upper and lower envelopes of gold-coated TFBG spectra. This method has been successfully applied in biosensing experiments towards the detection of HER2 (Human Epidermal Growth Factor Receptor-2) proteins, a relevant biomarker for breast cancer. Practical improvements have also been implemented. First, a uniform FBG has been superimposed on the TFBG to reduce the read-out wavelength span to 10 nm instead of 70 nm while keeping the temperature-compensated measurements. Second, a micro-fluidic system has been implemented to smoothly deliver the samples to the sensor. These 3 originalities make this sensing platform even more attractive for use in practical applications.**

***Index Terms*—Biosensors, optical fibers, plasmonics, tilted fiber bragg gratings.**

I. Introduction

OPTICAL detection represents an important field of operated methods in biosensing, providing efficient and accurate solutions in medical diagnosis, agri-food quality control and environmental monitoring [1]–[3]. In this panel of techniques, surface plasmon resonance (SPR)-based Kretschmann prism sensors are highly sensitive tools for which most of commercially available sensors are automated, involving biochips and microfluidics. The use of the SPR excitation, a collective oscillation of electrons occurring at a metal-dielectric interface plays an important role in the highly sensitive behavior of such sensing methods [4]. The common metal used in practice to benefit from this phenomenon is gold, as it is stable and biocompatible. It has a specific refractive index (RI) exhibiting a negative real part, enabling the generation of plasmonic waves [5].

A challenging approach is to transpose and implement SPR biosensing on optical fiber to take advantage of their own assets [6], [7]. Indeed, in addition to their intrinsic properties (resistance to chemical corrosion, high temperature, weak light attenuation and easy light injection, EM field immunity, etc.) [8], optical fibers are flexible, small-sized, and reliable [9]–[12]. To achieve optical fiber-based biosensing, several geometries have already been proposed, including unclad, D-shaped, U-shaped, etched, tapered and grating-assisted optical fibers [12], [13], [22]–[24], [14]–[21]. Among the latter, tilted fiber Bragg gratings (TFBGs) are well suited to develop highly sensitive and accurate platforms to sense outer medium changes [4], [18], [25]–[27]. A TFBG is a periodic modulation of the RI of the fiber core, exhibiting grating planes that are tilted with respect to the fiber axis [28], [29]. This structure can therefore outcouple a fraction of light into the cladding, yielding interaction with the immediate surroundings at the cladding-medium interface [30]. Such gratings can be obtained by irradiating the fiber with a laser through a phase mask. The transmitted amplitude spectrum of TFBG-based sensors presents a comb-like set of cladding mode resonances [25]. Once covered with a gold layer of appropriate thickness (∼30–70 nm), the SPR excitation is spectrally manifested by a local attenuation that strongly depends on the RI of the surrounding medium (SM) and thus on the adhesion of biomolecules on the surface (the maximum penetration depth of the evanescent field lies between λ/3 to λ/2 where λ is the operating wavelength) [13]. It is worth noticing that the TFBG spectrum also features the Bragg wavelength that corresponds to the self-backward coupling of the core mode (Fig. 1(a)). It is not sensitive to the SM and is used as self-reference compensation towards temperature and strain fluctuations [31]. The plasmonic excitation only occurs if light is radially polarized (P-polarization) on the metal-dielectric interface and presents a tangential component equal to that of the plasmon wave [32], [33].

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