Effects from detuning the resonant coupling between fiber gratings and localized surface plasmons

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ABSTRACT

In this work, we demonstrate the effect of detuning the resonant coupling between a long period grating and the plasmonic band of gold nanoparticles on the device sensitivity. In an intensity coded configuration, the sensitivity was measured at 568.12 nm and 598.62 nm, for surroundings refractive indexes ranging from 1.3629 to 1.4184. A comparison between the responses of the two dips centered at these wavelengths resulted in a sensitivity enhancement of about 17 times for the dip localized close to the center of the localized surface plasmon resonance.

Keywords: Long period grating, localized surface plasmon resonance, gold nanoparticles

1. INTRODUCTION

Refractometric optical fiber-based sensors associated with localized surface plasmon resonance (LSPR) have been widely reported along the last years[1-3]. Among these sensors is the long period grating (LPG), a spatially periodic modulation of the fiber core refractive index. Owing to coherent scattering by the structure[4,5], light from the fundamental core propagating mode couples to co-propagating cladding modes and then to radiation modes. The power attenuation and cladding-modes losses cause the appearance of resonance bands in the LPG transmission spectrum, in wavelengths that correspond to the phase matching condition given by:

$$\lambda_m = (n_{eff} - n_{cl}^{m})\Lambda \qquad (1)$$

where λ_m is the resonance wavelength of the m-th cladding mode, n_{eff} is the core mode refractive index, n_{cl}^{m} is the m-th cladding mode refractive index and Λ is the grating period. Normally, the periodicity of the LPG's refractive index modulation ranges from 50 μm to 1 mm, resulting in a device with total length of about 3 cm.

LPG is sensitive to the surrounding's refractive indices, especially those around 1.44 – 1.45, i.e., close to the fiber cladding refractive index[6]. However, some applications require refractometric sensors for water-based environments, which refractive index is around 1.33. The association of LPG with LSPR can provide increased sensitivity and dynamic range to these sensors, apart from chemical and biological selectivity[7,8].

In this work, the sensitivity of an LPG with 2-7 nm gold nanoparticles operating at two wavelengths in the visible spectral range was determined, for surroundings refractive indexes ranging from 1.3629 to 1.4184. Changes in the refractive index result in intensity modifications in the LPG visible transmission spectra, allowing the device operation as an intensity-coded refractometric transducer. The AuNPs plasmon band is centered at (544 ± 1) nm with FWHM of (78 ± 2) nm, as reported in our previous work[9]. Refractive index sensitivity was determined for 2 LPG dips at 568.12 nm and 598.62 nm. An efficient coupling between the LPG and the LSPR is observed at 568.12 nm, resulting in the ~17 times higher sensitivity obtained at this wavelength when compared to the sensitivity at 598.62 nm.

2. METHODOLOGY

The LPG was obtained by the point-to-point technique, using an excimer ArF laser (Coherent, Xantos XS, 193 nm, 300 Hz frequency), in a single-mode fiber (Thorlabs, FS-SN-3224, 630 nm wavelength), at the Photorefractive Devices Unit

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