Semiconductor metasurface refractive index sensing via optical radiation pattern

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An innovative sensing mechanism based on the variations in the sensor radiation diagram in correspondence of changes in the refractive index of the surrounding material is illustrated.

Keywords: optical sensing, radiation pattern, optimization.

1. Introduction

Optical micro-sensors have a paramount importance in technological applications due to their speed, flexibility, and low cost [1,2]. In this context, we propose a new sensing scheme based on the reflectivity and transmittivity variations of a dielectric metasurface upon small modifications of the surrounding medium refractive index [3,4]. We study the metasurface's geometry and composition in order to maximize the sensor's performance.

2. Geometry and optimization scheme

In Figure 1 a) we display the unit cell composing the metasurface. It consists of two identical cylindrical nanodisks separated from each other by a distance T, with four lateral supports or spokes, necessary to sustain the nanodisks at a variable height.
By varying the gap dimension T, the refractive index of the metasurface and of the environment, we find the optimal configuration for sensing applications.

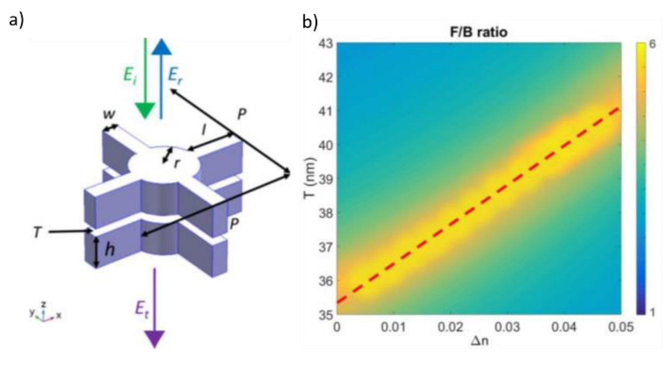

Fig. 1 a) Sketch of the investigated geometry. b) F/B ratio (color scale) as a function of the distance between the two nanodisks T (vertical axis) and of the refractive index variations Δn (horizontal axis). The nanodisks are made of AlGaAs and shined with a continuous light plane wave at wavelength 1550 nm.

3. Results

In Figure 1 b) we investigate the case of a metasurface made of AlGaAs, shined with a continuous light. We report the ratio between the transmitted electric field and the reflected electric field - called Front to Back (F/B) ratio (colour scale), as a function of T (vertical axis) and of the variations of the refractive index $\Delta n = n - n_0$ (horizontal axis), where $n_0 = 1$. For T in the range of 35-45 nm, the graph shows a strong dependence of F/B ratio on the environment refractive index.
This result paves the way to the sensing mechanism: by measuring the F/B ratio of a metasurface with a fix gap dimension T it is possible to quantify the refractive index of the surrounding medium. The latter information could give information on the composition of the surrounding medium, such as the presence and the quantification of a certain gas in the metasurface's environment.

4. Conclusions

We numerically investigate a sensor based on a metasurface composed by AlGaAs nanodisks. A structure with a vertical separation of 35-45 nm between the nanodisks allows a precise quantification of the environment refractive index upon measurements of the transmitted and reflected electric field, allowing to identify the composition of the surrounding medium.

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