

## Highlights

Light-matter interaction and non-equilibrium dynamics in advanced materials and devices - 2019

### Geometrical Dependence on the Onset of Surface Plasmon Polaritons in THz Grid Metasurfaces

G. P. Papari<sup>1,2,3</sup>, C. Koral<sup>3</sup>, A. Andreone<sup>1,2,3</sup>

<sup>1</sup> Department of Physics, University of Naples "Federico II", Naples, Italy

<sup>2</sup> CNR-SPIN, Naples, Italy

<sup>3</sup> INFN Naples Unit, Naples, Italy

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Surface plasmon polaritons are e.m. radiation modes propagating at the interface between a metal and a dielectric layer. The threshold energy of SPPs is connected to the plasma frequency of the conducting layer that in standard metallic films is of the order of  $10^{15}$  Hz, preventing the exploitation of these excitations at lower frequencies. Patterning the conducting layer in a periodic array "dilutes" the metal and allows to lower its plasma frequency by orders of magnitude.

We show that in THz conducting metasurfaces in shape of grids the corresponding plasma frequency ( $\omega_r$ ) and hence the excitation of SPPs can be controlled over a factor 10 simply manipulating the amount of metal per unit cell area (filling factor  $F$ ). A simple lumped element analytical model is developed to trace out experimental data acquired through Terahertz Time Domain Spectroscopy measurements and results from full wave simulations. In Fig. 1 a sketch of the experiment presenting the THz signal passing through two different metagrids is reported. In Fig. 2 the dependence of the plasma frequency versus  $F$  is displayed for both typologies of analyzed metasurfaces. In the region  $\omega < \omega_r(F)$  the optical device is fully homogenous (metamaterial regime) with respect to the impinging wave, and its dielectric function smoothly depends on frequency. On the contrary, for  $\omega > \omega_r(F)$  the transmission spectrum starts showing "geometric" resonances (photonic crystal regime) indicating the onset of commensurability between the unit cell periodicity  $p$  and the beam wavelength.

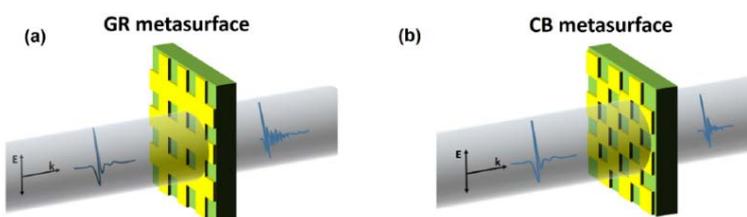


Fig. 1: In the two panels a simple schematic of the experiment showing the THz beam normally impinging (a) a pure grid (GR) and (b) a chessboard (CB) metasurface with same periodicity  $p = 600 \mu\text{m}$ . Metallic layer is copper  $30 \mu\text{m}$  thick on  $150 \mu\text{m}$  dielectric FR4 substrate.

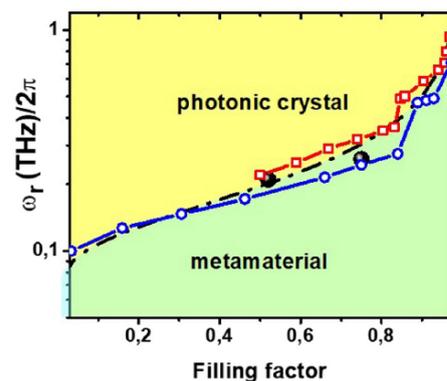


Fig. 2: Plot of the THz metagrid plasma frequency  $\omega_r$  as a function of the filling factor. Full black dots represent experimental values measured on the samples shown in Fig. 1, red squares and blue circles are obtained via full wave simulations. The black dash-dotted line describes the result obtained using the lumped element model.