

Terahertz pulse transmission of surface plasmon polaritons through semiconductor gratings

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Surface plasmon polaritons SPPs are electromagnetic waves coupled to the oscillation of free electrons on the surface of a metal. The large electromagnetic field at the metal surface and the possibility to guide waves beyond the diffraction limit has lead to an extraordinary interest in the field of surface plasmon optics or plasmonics [1]. This research has focused mainly in the optical and near-infrared frequency regimens. The huge permittivity of metals at low frequencies (THz and microwaves) leads to weakly bounded SPPs to the surface, limiting the usefulness of low frequency plasmonics. We have recently demonstrated that this limitation can be easily overcome by using doped semiconductors instead of metals [2]. Semiconductors have a permittivity at low frequencies similar to that of metals in the visible, thereby making possible to excite and propagate low frequency SPPs on semiconductors.

In Ref. [2] we investigated the transmission of SPPs through gratings structured in doped Si with different doping concentrations and reported the formation of a stop-gap for SPPs due to the Bragg reflection in the periodic structure. We extend here this study and show that the gap can be tuned by changing the lattice constant of the grating. In Fig. 1(a) we plot transmitted pulses through gratings consisting of 30 grooves structured in n-doped Si ($N \sim 10^{18} \text{ cm}^{-3}$). For clarity, a vertical offset have been introduced to the measurements. The blue line corresponds to the transmission through a grating with lattice constant $a_0 = 440 \text{ }\mu\text{m}$, while the red line is the transmission through a grating with $a_0 = 270 \text{ }\mu\text{m}$. The green line is a reference measurement of SPPs on a flat Si surface. The gratings modify the SPPs reference pulse introducing significant dispersion. To further analyze these time-domain data we calculate the Fourier transform of the transmission through the gratings and normalize it by the reference. This leads to the transmittance represented in Fig. 1(b). The blue line corresponds to the transmittance through the $a_0 = 440 \text{ }\mu\text{m}$ grating and the red one to the transmittance through the $a_0 = 270 \text{ }\mu\text{m}$ grating. The stop-gap can be clearly identified by the strong decrease of the transmittance at 0.29 THz and 0.41 THz respectively. The difference in the lattice constants gives rise to Bragg reflection at different frequencies and the consequent shift of the stop-gap.

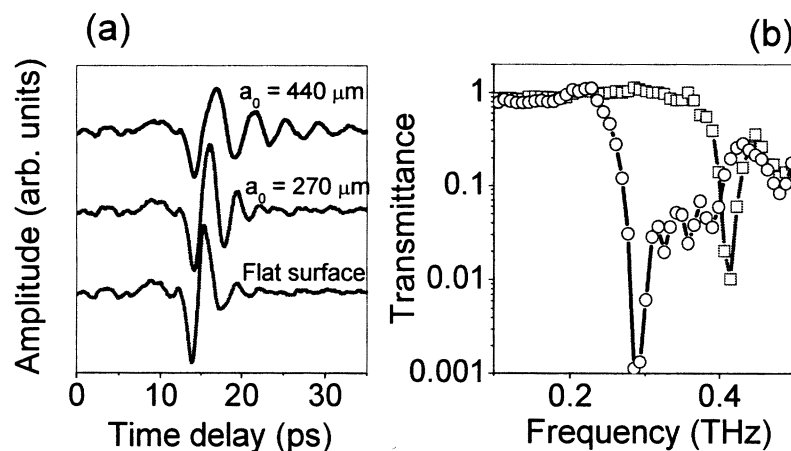


Fig. 1: (a) Terahertz pulses of surface plasmon polaritons on n-doped silicon. The green curve corresponds to a flat surface, while the red and blue curves are the SPPs transmission through gratings with different lattice constants a_0 . (b) SPPs transmittance through the gratings. The blue line corresponds to the grating with lattice constant $a_0 = 440 \text{ }\mu\text{m}$, while the red line is the transmittance through the grating with $a_0 = 270 \text{ }\mu\text{m}$.

- [1] W.L. Barnes, A. Dereux, and T.W. Ebbesen, "Surface plasmon subwavelength optics", *Nature* **424**, 824-830 (2003).
 [2] J. Gómez Rivas, M. Kuttge, P. Haring Bolivar, H. Kurz and J.A. Sánchez-Gil, "Propagation of surface plasmon polaritons on semiconductor gratings", *Phys. Rev. Lett.* **93**, 256804 (2004).