Fano profiles in transmission spectra of THz radiation through periodic metallic structures

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***Abstract*—The transmission properties of ultrashort THz pulses through 1-dimensional periodic metallic structures are investigated experimentally and theoretically. The characteristic minima known as Wood's anomalies demonstrate so-called Fano profiles caused by the coupling between resonant surface plasmons and non-resonant diffraction orders.**

I. Introduction

Already in 1902 R. W. Wood[1] observed anomalies in reflected spectra of ruled metallic gratings using a white light source. These were later identified as being caused by surface plasmon-polaritons (SPPs)[2]. The terahertz spectral range offers new possibilities to investigate plasmon features of metallic structures. In this contribution we present results of THz pulses transmission through a layer of identical metallic cylinders positioned equidistantly in a plane and separated by distances essentially smaller compared to the central THz wavelength. For simplicity the structure is oriented normal to the THz beam to prevent additional modification of transmission spectra by other effects being out of the scope of this paper.

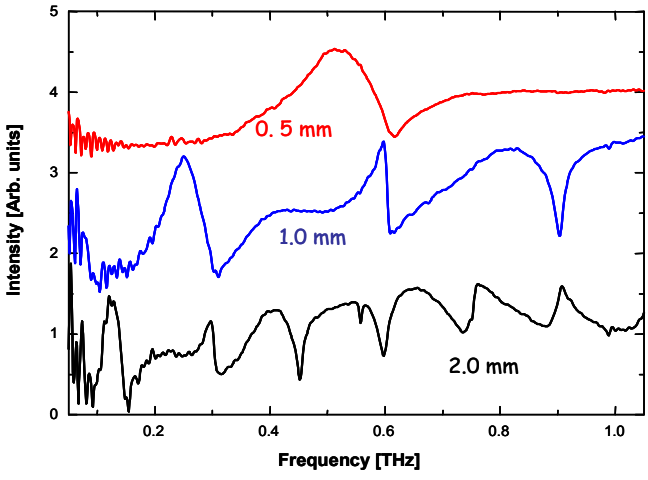

Fig1. Measured sample transmission spectra through periodic structures of metallic rods for three different rod diameters. Dispersion-like line shapes – the Fano profiles – were detected.

II. Results and Discussion

The experimental set-up consists of a standard THz time domain spectroscopic (THz-TDS) system pumped by a femtosecond mode locked Ti:sapphire laser producing ultrashort optical pulses with a repetition rate of 82 MHz. The THz-TDS system has an InAs sample as surface emitter and an LT-GaAs photo-conductive switch of 60 µm dipole length as detector. The latter was chosen since being efficient at low THz frequencies in spite of limiting the overall spectral range of the system to 2 THz. Single cycle broad-band THz pulses with the center frequency of around 600 GHz are generated by 100 fs short pulses from the pump laser. Excitation of SPPs is performed in the collimated part of the THz beam where its diameter reaches 50 mm and interacts with a wide area of the structure under investigation. A typical periodic structure is made of a series of parallel metallic rods with diameter **d** varying from sample to sample between 0.5 mm and 2.5 mm. The rods are mounted in a plastic holder and the distance between the cylinders fixed by grooves in the holder. The distance can vary from direct contact to 200 µm, and the effective size of the structure reaches 60 mm by 80 mm. The transmitted electric field is measured behind the structure and the spectrum obtained via a fast Fourier transform (FFT) with a resolution of 4 GHz in the range from 45 GHz to 1100 GHz (Fig 1).

A considerable transmission through the structure is observed extending over a wide frequency range with dominant absorption peaks at the frequencies of SPPs excited by the THz pulses[3]. The overall transmission is enhanced with respect to the ratio between the slit width and the diameter of the cylinders. The shape of absorption peaks can be understood in terms of the interference between the resonant part and a non-resonant part leading to typical Fano profiles[4] (Fig.2). The resonant part is due to SPPs propagating along the surface, which are diffracted normal to the grating, whereas the non-resonant part is caused by direct transmission through sub-wavelength slits between the cylinders. By changing the width of the slits the ratio between the contributions of resonant and non-resonant part can be modified causing a variation of the shape of the Fano profile. Numerical simulations using the classical electrodynamics theory are performed for

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the position and the shape of absorption peaks. Several

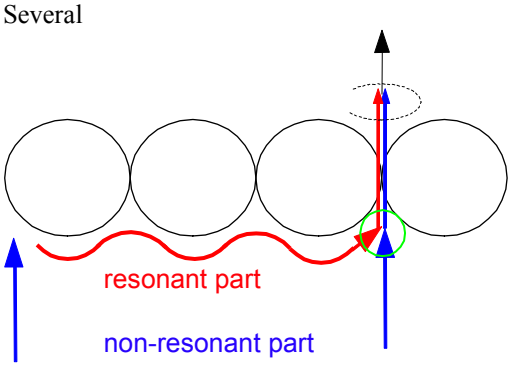

Fig 2. Schematic diagram illustrating the interference between direct transmission of THz radiation and scattered surface plasmon-polaritons leading to the observed Fano profiles.

gap widths realized in the experiment are considered.

The simulations show excellent agreement with the experimental observations and confirm the validity of the offered physical mechanism based on the interference between the resonant and non-resonant THz waves.

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