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Surface current phase governing Fano type resonance in metasurface

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We consider the simplest inverse periodic metasurface (MS) composed of two parallel slits of different lengths, oriented perpendicular to the applied microwave electric field and cut in a copper foil. It will be shown that the Fano effect appears as a consequence of the phase shift of the current flowing in the inner ends of the strips, parallel to the E-field.

The measured and calculated dependencies of the transmittance on frequency are shown in Fig. 1. In the inset, the elementary cell of the investigated structure is depicted. At a lower frequency, a sharp change from near-complete transparency to almost total suppression within a 150 MHz frequency range is seen, which is characteristic of the Fano effect [1]. It is worth mentioning that in this frequency range, currents in the shorter and longer slits flow in opposite directions, whereas at a higher frequency, where the second, much wider maximum is noticed and is ascribed to plasmonic resonance, they flow in phase.

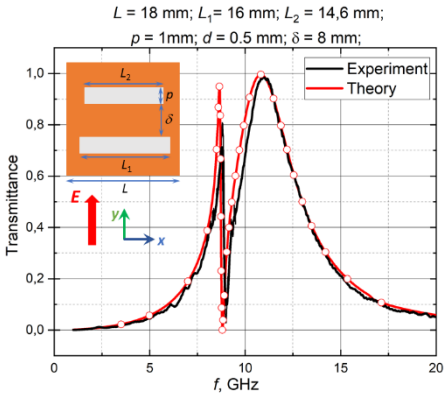

Fig. 1. Dependence of transmittance on frequency. In the inset - unit cell of MS.

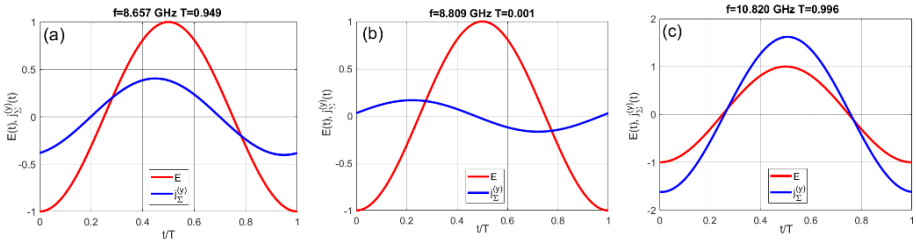

FIG. 2. Calculated electric field and summed average current j_y dependences on time at the Fano interference maximum f = 8.657 GHz, (a); at minimum f = 8.809 GHz (b), and at the maximum of plasmonic resonance f = 10.82 GHz (c).

Calculated waveforms of summed current $j_{\Sigma y}$ and the electric field within one period at characteristic frequencies of Fano interference and plasmonic resonance are shown in Fig. 2. It is seen that at transmittance maxima (a) & (c), the phases of the electric field and current approximately coincide, whereas at the minimum, the shift of the phase by $\pi/2$ appears. This suggests that the current phase in the slits is a primary factor determining the observed sharp transition from total transparency to opacity that is characteristic of Fano resonance. It is worth mentioning that the same peculiarities we observe in an inverse metasurface designed according to Babinet's principle and consisting of conductive strips oriented parallel to the external electric field. The only difference is that in the MS made from strips, the minimum of transmittance appears at lower frequency followed by its maximum.

REFERENCES

[1]. M. F. Limonov, Advances in Optics and Photonics, vol. 13, no. 3, pp. 703–771, 2021.