# Plasmonic metasurfaces: From perfect absorption to phase modulation

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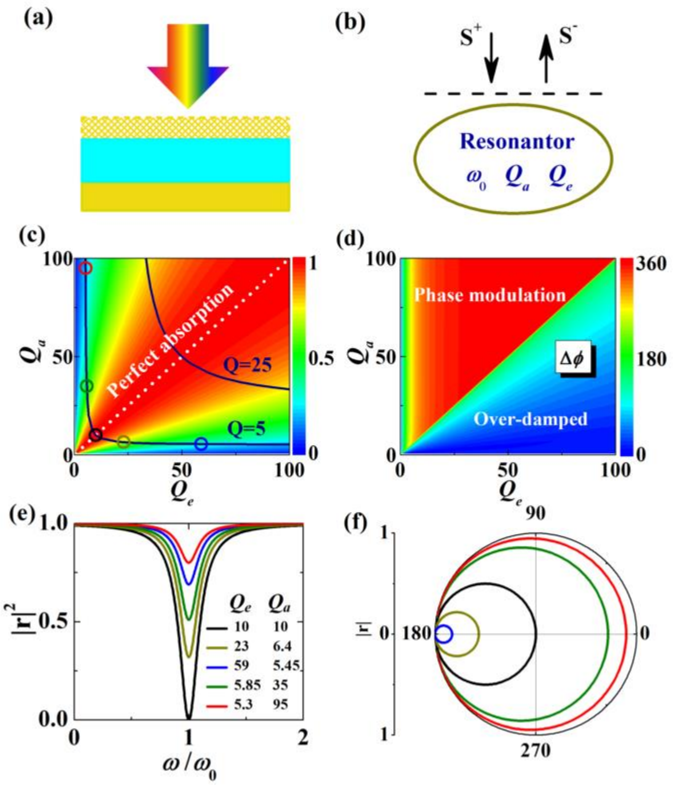
***Abstract*—Metasurfaces in metal/insulator/metal configuration have recently been widely used in photonics research, with applications ranging from perfect absorption to phase modulation [1, 2], but why and when such structures can realize what kinds of functionalities are not fully understood. Here, based on coupled-model analysis, we establish a complete phase diagram for such systems, in which their optical properties are fully controlled by two simple parameters (the intrinsic and radiation losses), which are in turn, intimately related to the geometrical/material parameters of the underlying structure. These results can guide one to design appropriate metasurfaces with tailored functionalities (e.g., perfect absorption, phase modulator, electric/magnetic reflector, etc.), which are demonstrated by our experiments and simulations in the Terahertz regime.**

## I. INTRODUCTION

Metamaterials, artificial EM composites composed by subwavelength-engineered units, can possess arbitrary values of electric permittivity and magnetic permeability and thus exhibit amazing EM wave manipulation abilities. As a quintessential example in the big family of metamaterials, Metal-insulator -metal (MIM) resonant configuration consisting of a layer of periodic metallic arrays and a continuous metallic film separated by a dielectric spacer has captured a great deal of attention in recent years, since host of charming wave-manipulation effects were discovered based on the structure. Such as, the tri-layer configuration has been utilized to dramatically enhance absorption (thermal emission) and freely manipulate polarization for a variety of frequency from microwave to visible regime. Furthermore, due to the thickness of the whole system is usually in deep-subwavelength scale, much smaller than the operating wavelength, the structured MIM configuration can be functioned as ultrathin compact planar optical elements, the so-called metasurface, and has also been demonstrated to work as efficient phase modulator in reflection. Although these previous works reported many intriguing new discoveries, the presented results were mostly based on full-wave numerical simulations performed by employing commercial software package, underlying physics was generally studied by analysis of such brute-force numerical computation outcome, the functionalities of such kind of metasurface have not been systematically explored, it is still lack of investigation to show us what factors dominantly determine the optical properties of the structure in some condition which behaviors as fascinating full-range phase modulator, and other as high efficiency optical absorber, what the relationship is between these remarkable effects and the geometric parameters of the structure. Especially, one would ask if there is any crucial rule for guiding the design of hypothetical devices.

## II. RESULTS

In this work, we developed a theoretical model for the MIM resonator configuration based on temporal coupled-mode theory. The model incorporates a full description of the scattering properties (including both amplitude and phase) of the structure, and can predict a general criterion that tailors the system as perfect absorber or full-range phase modulator via tuning coupled-mode parameter – the absorptive quality factor $Q_a$ and the radiative quality factor $Q_e$. Finite-difference-time-domain (FDTD) simulations and terahertz experiments are also performed to demonstrate our ideas.



## REFERENCES

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