Experimental manipulation of the surface-plasmon polaritons in spatiotemporal photonic crystals

Xin Ye[1], Yongge Wang[1], Jingfeng Yao[1,2,3], Ying Wang[1,2,3], Chengxun Yuan[1,2,3], and Zhongxiang Zhou[1,2,3]
[1] School of Physics, Harbin Institute of Technology, [2] Heilongjiang Provincial Key Laboratory of Plasma Physics and Application Technology, [3] Heilongjiang Provincial Innovation Research Center for Plasma Physics and Application Technology
e-mail (speaker): yex@stu.hit.edu.cn

Spatiotemporal photonic crystals (STCs) are artificial materials with the dielectric parameter that is modulated periodically in both space and time, paving a new way in electromagnetic wave manipulation and field enhancement. [1-5]

The investigation of time-varying media involves dispersion effects, which are widespread in materials capable of dynamic modulation. Surface-plasmon polaritons (SPPs) are an important phenomenon available in strongly dispersive systems, appearing at material interfaces. Their intrinsic characteristics of subwavelength resolution and local-field enhancement are desirable in constructing STCs in finite size structures. The construction of these materials and the experimental tuning of their electromagnetic properties remain challenging due to the stringent requirements for uniform modulation of STCs on spatiotemporal scales. At present, researchers have only experimentally investigated one-dimensional (1D) STCs (i.e., photonic time crystals).[1]

In this work, we experimentally observe the surface state dispersion relation of 2D space-time metasurface, and measure the transmission of SPPs at the interface of STCs by modulating the DC bias voltage applied to the metasurface patches. Furthermore, we develop a CST simulation model of dispersive STCs to discuss the effect of the capacitance connecting each patch on the SPPs and compare it with the experimental results.

Figure 1 illustrates the experimental setup and results of the dispersion relation and transmission of SPPs modes at the interface of STCs. Figure 1(a) shows the fabricated STCs structure with 16×4 time-modulated meta-atoms. Figure 1(b) presents the CST simulation results of the dispersion relation of SPPs modes at the static STCs interface. It can be seen that there is a slight frequency shift of the energy band as the capacitance increases. Figure 1(c) shows the simulation result of the bandgap shifting (red dashed line) compared to the experimental measurements (blue triangles). It can be seen that the bandgap is shifted by almost 0.2 GHz as the applied voltage increases (simulated capacitance value decreases). Figure 1(d) shows the effect of time modulation on the transmission of the scanning electric field at the interface. The yellow star at the right end of the interface indicates the emission source. When the modulation on the STCs patch in Figure 1(a) is turned off at 1.5 V DC bias, the surface electromagnetic wave attenuates and eventually terminates its propagation, while it travels to the far left when the modulation on.

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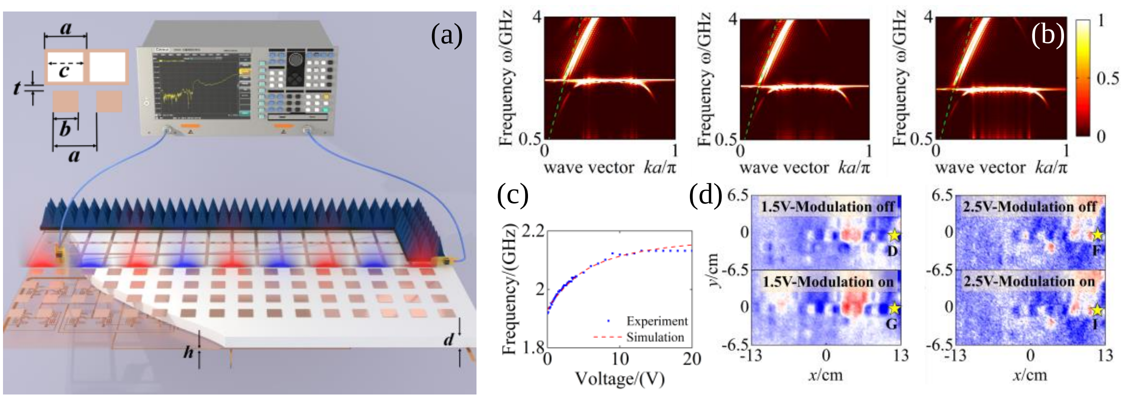

Figure 1. Effect of time modulation on SPPs at STCs interfaces. (a) Experimental setup for observation of SPPs in the anisotropic STCs. a = 22 mm, b = 9 mm, c = 19.4 mm, t = 5 mm, h = 0.4 mm and d = 9 mm. (b) The dispersion relation of SPPs modes by CST simulation for different capacitance values: 0.9 pF (left), 1.2 pF (middle) and 1.6 pF (right). (c) Comparison of experimental (blue triangles) and simulated (red dashed line) bandgap shift results. (d) Transmission of electromagnetic waves at the interface of patch and grid when modulation is turned on and off at two different voltages: 1.5 V in the left and 2.5 V in the right.