8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Topological plasma metamaterials with tunable electromagnetic properties

Jingfeng Yao[1,2], Jianfei Li[1], Xin Ye[1], Yongge Wang[1], Chengxun Yuan [1,2]

[1] School of Physics, Harbin Institute of Technology, China, [2] Heilongjiang Provincial Key Laboratory of Plasma Physics and Application Technology, China
e-mail (speaker):yaohit@163.com

Topological plasma metamaterials have significant applications in modulating electromagnetic waves, such as plasma communication blackout due to the cutoff effect, as well as low mutual coupling and reconfigurable plasma antennas in wireless communication. However, the generation of high-density and strongly collisional plasma requires significant energy consumption. Therefore, new mechanisms are urgently required to attenuate the demand for electron density and collision frequency. Lowering the plasma frequency and increasing the incident wave frequency can only mitigate the effect of the plasma blackout problem on the signals, but it is not a fundamental solution. Plasma photonic crystals (PPC) combine plasma with air or high permittivity materials to create structures that inherit the properties of forbidden bands, localized modes, and surface states found in photonic crystals. These structures have the properties of tunability and switchability. Our aim is to find suitable plasma metamaterials with tunable electromagnetic properties and to explore a new mechanism to solve the plasma blackout problem. To achieve this, we introduce topological edge states into PPC.

Plasma photonic crystal has been widely studied for the tunable and reconfigurable properties, but its topological nature has hardly been investigated theoretically and experimentally. With the development of topological insulator in condensed matter, photonic topological insulators and photonic Weyl crystals have been realized one after another, and topological property in photonics has become a hot topic. The plasma photonic crystal can be served as a promising experimental platform to explore topological electromagnetic phenomena.

As the communication problem caused by plasma blackout during re-entry process of the aircraft into the atmosphere, the gaseous plasma around aircraft strongly reflects, absorbs and scatters electromagnetic waves, resulting in severe amplitude and phase jitter of the electromagnetic waves. Traditional methods of increasing the frequency of incident waves or reducing the frequency of plasma can only reduce the impact of plasma on electromagnetic waves, but cannot be used as a fundamental solution. We found that topological edge states with their properties of unidirectional propagation, backscatter suppression, and immunity to impurities can be well applied to this problem. Then, we use gas discharge plasma to generate uniform plasma and construct plasma photonic crystal combining with alumina rods. The potential well constraints of electromagnetic waves in plasma correspond to the electronic system described by the tight- binding model. The evanescent waves are expected to couple in the dielectric columns to realize the transmission in the plasma sheath. By tuning the coupling strength between dielectric columns, a transmission mode is obtained in the plasma cutoff region, and the transmission mode is also verified experimentally.

References
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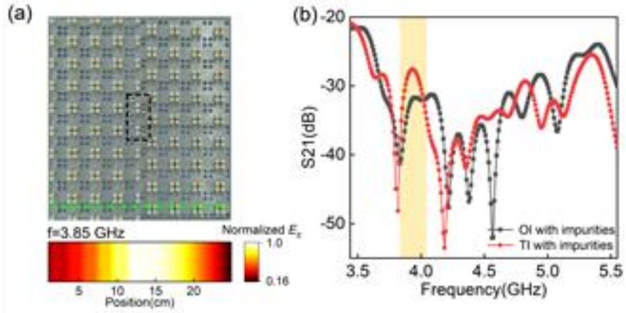

Figure 1. (a)A straight-line topological waveguide is constructed in plasma photonic crystal and (b)the topological edge states can be excited.