Supporting Information

Ferroelectric-controlled graphene plasmonic surfaces for all-optical neuromorphic vision

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Section S1. Model definition

As shown in Figure S1, Section S2, a patterned graphene split ring is placed onto a 200-nm-thick $BiFeO_3$ (BFO) ferroelectric layer with $SrTiO_3$ (STO) substrate. As the thickness of the patterned graphene layer is far-thin within the simulated model, it is simulated as a surface current, while the remaining simulation field is air-filled.

To simulate the infinite 2D array, Floquet-periodic boundary conditions are enforced on four sides of the unit cell. Meanwhile, Perfectly Matched Layers (PMLs) are used to effectively dampen the excited mode from the source port and any higher order modes generated by the periodic structure, on the top and bottom of the unit cell. This attenuation is essential as the PMLs reduce wave propagation in the direction perpendicular to the PML boundary. Since the model is solved for the incident angles, the wavelength in the PMLs is set to $2\pi/|k_0\cos\theta|$, which takes into account the angular dependence of the normal component of the wave vector inside the PMLs.

Port boundary conditions are placed on the internal boundaries of the PMLs next to the air and substrate domains, which automatically determine the S-parameter characteristics in terms of reflection and transmission. In particular, interior port boundaries with PML backing necessitate the slit condition to be fulfilled, which permits different values of the dependent variable on either side of the boundary. The port orientation is specified to accurately determine the inward direction for S-parameter calculation. Given that higher-order diffraction modes are not a significant concern in this example, a domain-backed type slit port and PML combination is preferred over numerous diffraction order ports to account for each diffraction order and polarization.

The use of periodic boundary conditions necessitates paired boundaries with identical surface meshes. This requirement is satisfied in two steps: 1) By generating a mesh for one of the boundaries and then duplicating it for the other boundary with the Copy Face operation. This specific mesh configuration is automatically established when utilizing the physics-controlled mesh, as per the step-by-step instructions. 2) For users interested in examining further details about the mesh, generating the physics-controlled mesh initially and subsequently changing the mesh sequence type to the user-controlled mesh in the mesh settings will allow inspection of the mesh sequence generated. The periodic conditions are segmented by ports, which require slit conditions to couple different dependent variables on both sides of the slit condition. To guarantee that the periodic conditions couple the correct dependent variables, multiple periodic conditions are defined, both in front of and behind the port.

Section S2. Supplementary figures

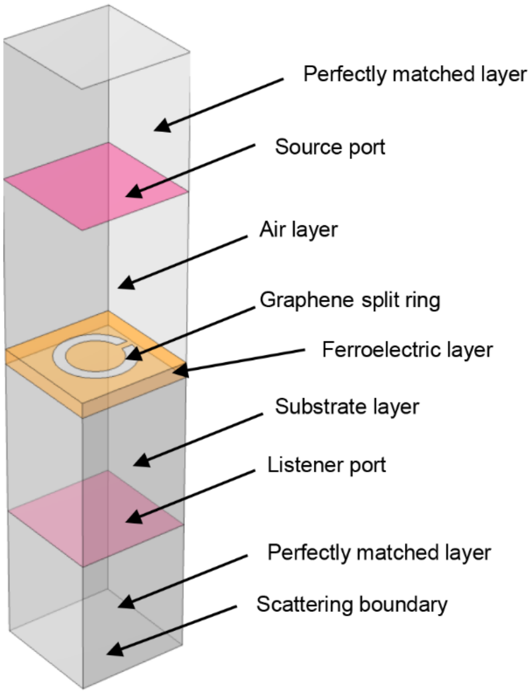

Figure S1. A single unit cell of the complementary split ring resonator with periodic boundary conditions to simulate the FSS array. To absorb excited and higher-order modes, perfectly matched layers are utilized at the top and bottom of the unit cell.

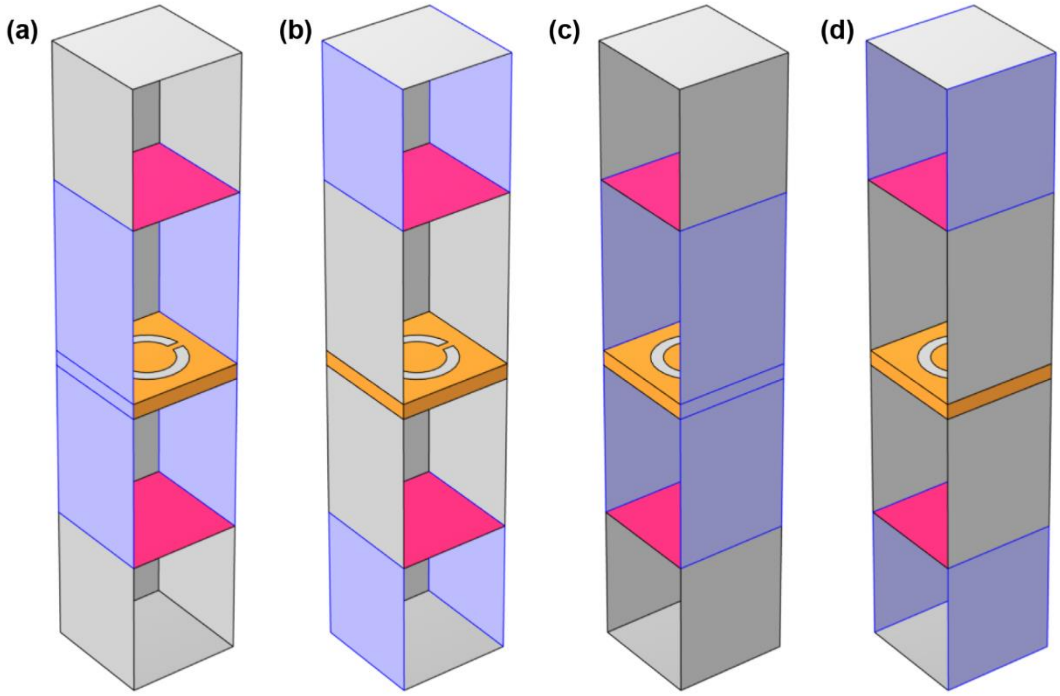

Figure S2. Periodic condition settings. Floquet periodicity with *k*-vector from periodic port in (a-d).

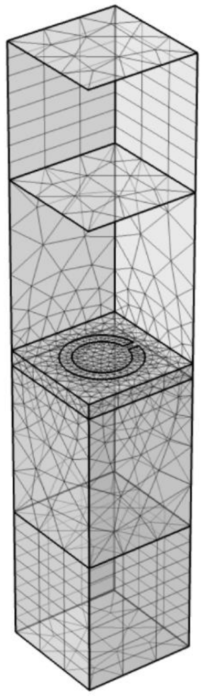

Figure S3. Mesh setting with extremely fine mesh and the the graphene split ring are meshed with modified fine structures.

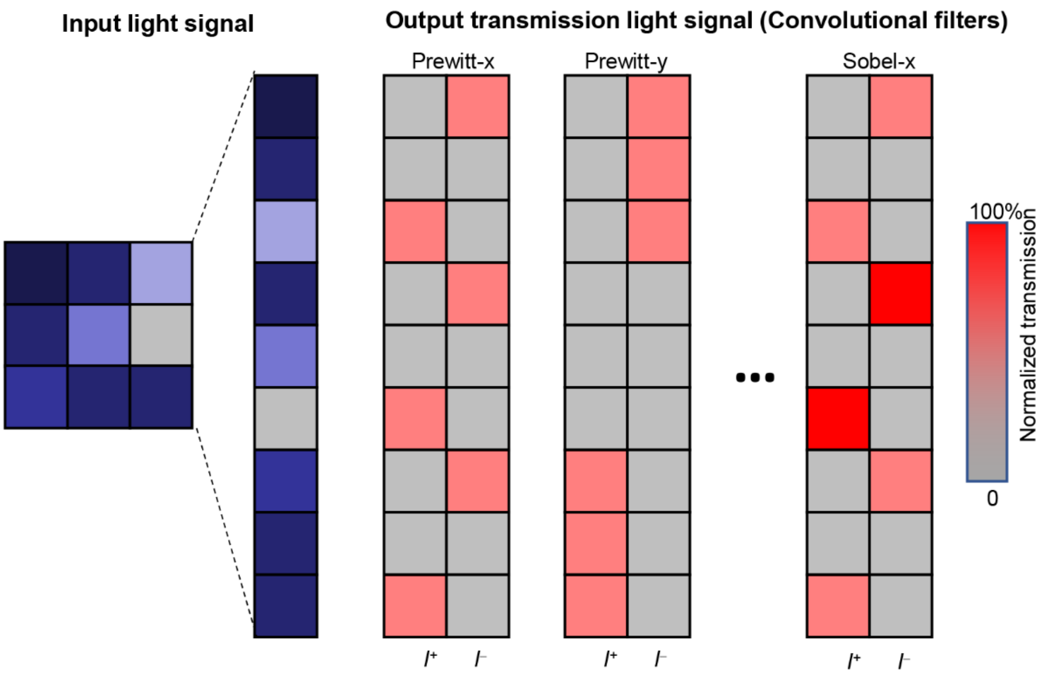

Figure S4. Each pixel in the filtered image was generated by the dot product of the 9 input light signals by using ferroelectric-modulated graphene split ring resonator vectors and the 9 convolutional weight vectors.