Optoelectronic Device Simulation

Abstract:

This project consists of three parts. First part, we simulate how rectangular-shaped and cross-shaped plasmonic structures help Terahertz EM wave transmit through slits whose width is less than the diffraction limit. We observe electric fields enhanced at the corners of those plasmonic gratings using Comsol Multiphysics. Second part, we simulate the performance of a log-spiral antenna operating with input in different frequency using Comsol Multiphysics. We also observe the difference between the spiral metal structure and spiral slot structure. Third part, we simulate how a phased antenna array works using Matlab.

Part I

Project discussion and results:

The simulation setup is in Fig. 1. The left and right boundary are set as periodic conditions. We can notice that electric fields are enhanced around the corner of Au, indicating great amount of electrons excited. Fig. 2 shows that the transmission rate of this structure has a strong dependency with the input optical frequency. This is because the plasma frequency is the function of the distance between each metallic gratings.

Fig. 3 shows the 3D simulation of cross-shaped plasmonic structure. The electric field enhancement can also be observed. Fig. 4 also shows that the transmission rate of this structure has a strong dependency with the input optical frequency.

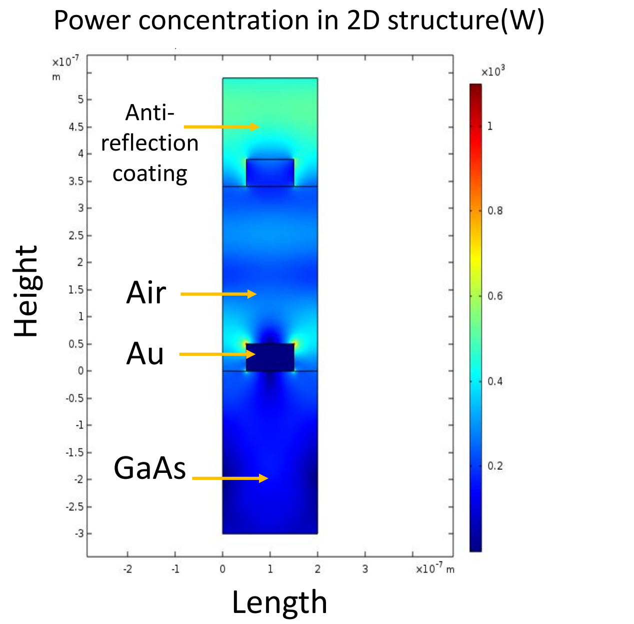

Fig. 1. The color bar represents power concetration. EM wave with 0.85μm wavelength propagates from top to down. Boundary conditions are applied to the left and right, forming periodic structures of Au gratings (repeat itself every 100 nm). The structure reacts with incident wave and triggers oscillating electrons allowing EM wave to overcome the diffraction limits.

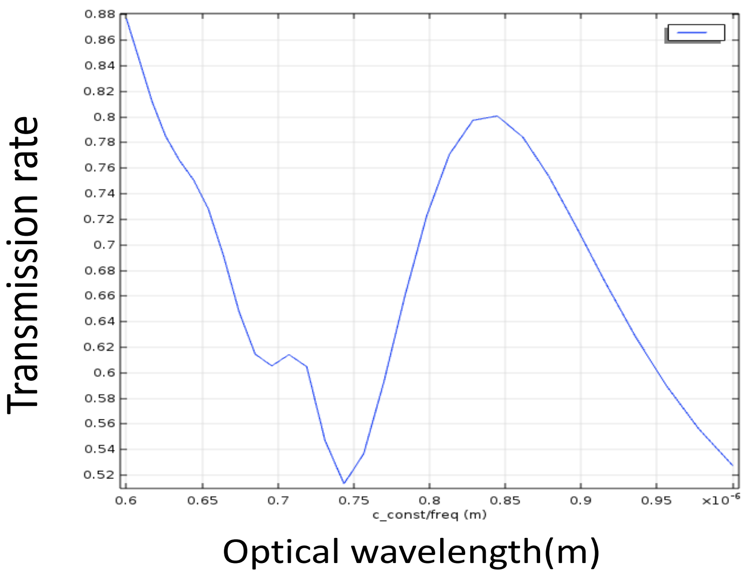

Fig. 2. The transmission rate peaks at a some wavelength because the EM wave can overcome the diffraction limits only when resonance of electrons occurs. A certain periodicity allows one resonance frequency. If we change the periodic distance, the peak of transmission differs.

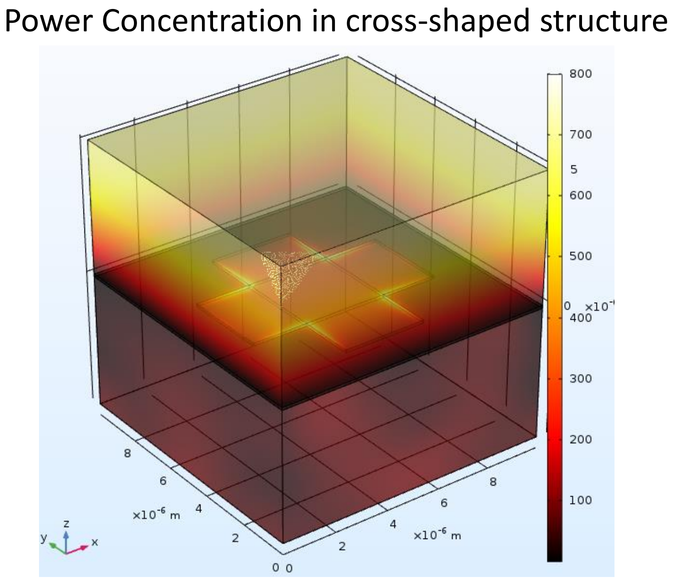

Fig. 3. Cross-shape structure. Periodic boundary conditions are applied to four plane boundaries parallel to x-z or y-z planes. This is also a periodic structure so the EM wave with wavelength 4μm can trigger plasma to overcome the diffraction limit. The electric fields at the corner of the cross shape are enhanced. This shape provides more freedom for designers to tune compared to the shape in Fig. 1.

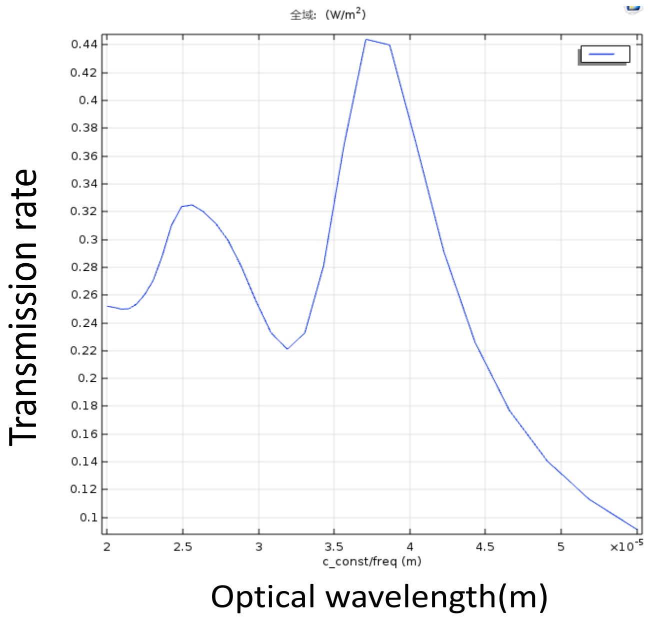

Fig. 4. The transmission rate peaks at a some wavelength because the EM wave can overcome the diffraction limits only when resonance of electrons occurs. A certain periodicity allows one resonance frequency. If we change the periodic distance, the peak of transmission differs.

Part 2

Project discussion and results:

The log-spiral antenna structure is shown in Fig. 5. The electric field is the stronger in the central of the spiral. The growing rate is 0.314. The spiral structure is metallic in fig. 6. The spiral structure is dielectric in fig. 6. From the far-field plots in Fig. 6-7, one can notice that this antenna is suitable for operation at low-frequency part of THz region. Moreover, directivity of the metallic spiral is better, Fig. 6, than the dielectric one in Fig. 7.

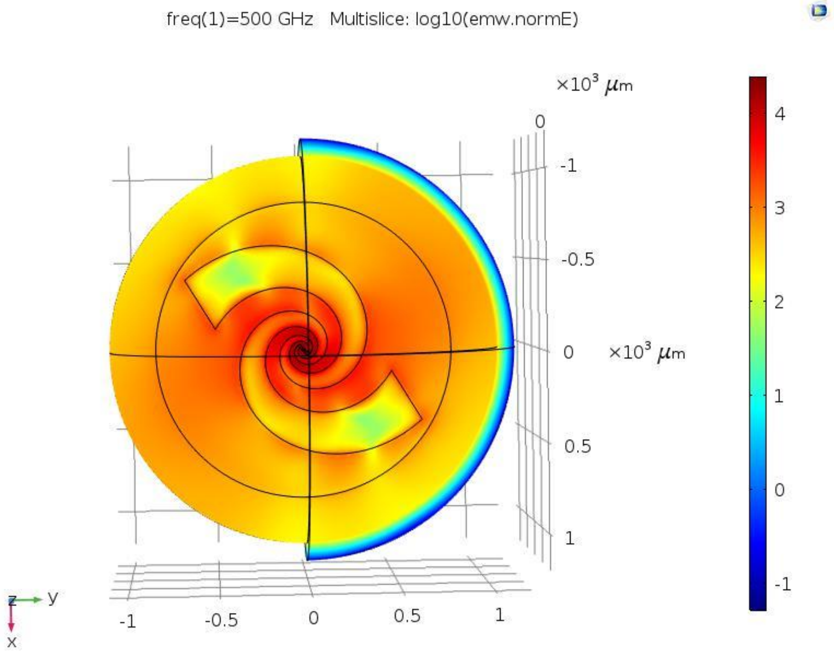

Fig. 5. Log-spiral antenna aims to operate at 1 THz. The spiral structure is metallic and the rest is insulator. The input signal is fed at the center of the disk.

Fig. 5

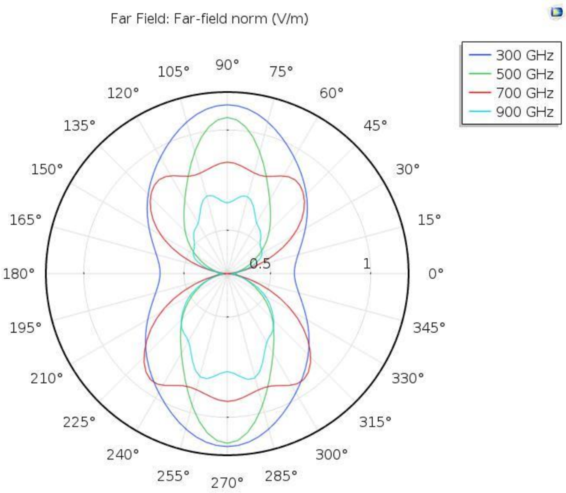

Fig. 6. 1D far field plot for structures in Fig. 5 fed with input with different frequency. The maximum power decreases as the frequency of input rises.

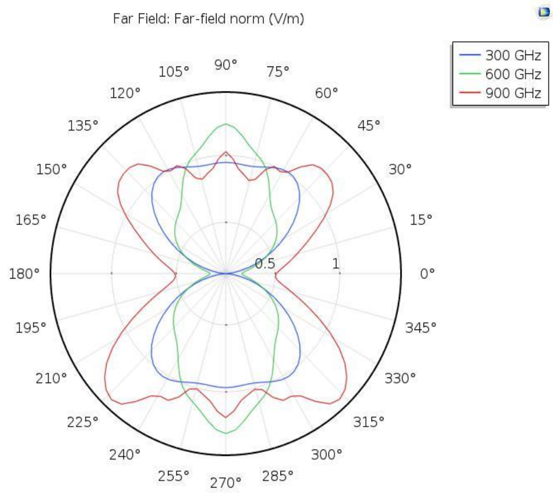

Fig. 7. 1D far field plot for structures in Fig. 5 with the sipral structure insulating and the rest of the structure conducting. It is fed with input with different frequency. The maximum power decreases as the frequency of input rises. Directivity peaks at 600 GHZ

Part 3

Project discussion and results:

We build up antenna array simulations using Matlab. There are N1×N2 antennas. In our codes, phase and amplitude of each antenna can be adjusted. Different types of antenna can be modeled into array once the characteristics of a single antenna is obtained.

In this project, we use dipole antenna as the basic antenna element. The power plot of the antenna is shown in Fig. 8. The two horizontal axes represent the angles that construct a sphere. The vertical axis is the amplitude of the power of EM wave in a specific angle. The half power band width (HPBW) is 78 degrees.

In Fig. 9, there are 3×3 dipole antennas. d is the distance between antennas. We can observe that HPBW is better with antenna arrays than that of a single antenna. Moreover, when d is too large, the amplitude of side lobes may be close to the main lobe. Fig. 10 shows that when the number of antennas increases, directivity enhances. Directivity is almost linear with the number of antennas in one dimension.

Fig. 11. shows that there is always a combination of phases for an antenna array to steer its beam to the full extent (0 and 180 degree) when there are at least 2×2 antennas. Fig 12 shows that when 1×1 antenna expands to 6×6 antennas, HPBW improves from 78 to 15.9 degree/axis. It is the tradeoff between performance of HPBW and the cost of areas.

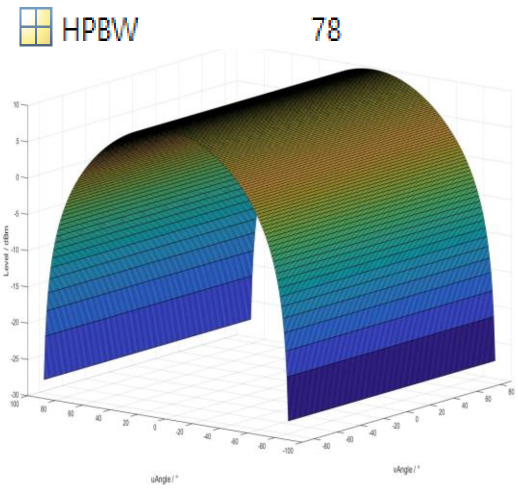

Fig. 8. The power plot of a dipole antenna. There two axes representing angles that form a sphere in the horizontal plane. The HPBW for this antenna is 78 degree.

3×3 of dipole antennas

1 THz, d=λ/2

1 THz, d=λ

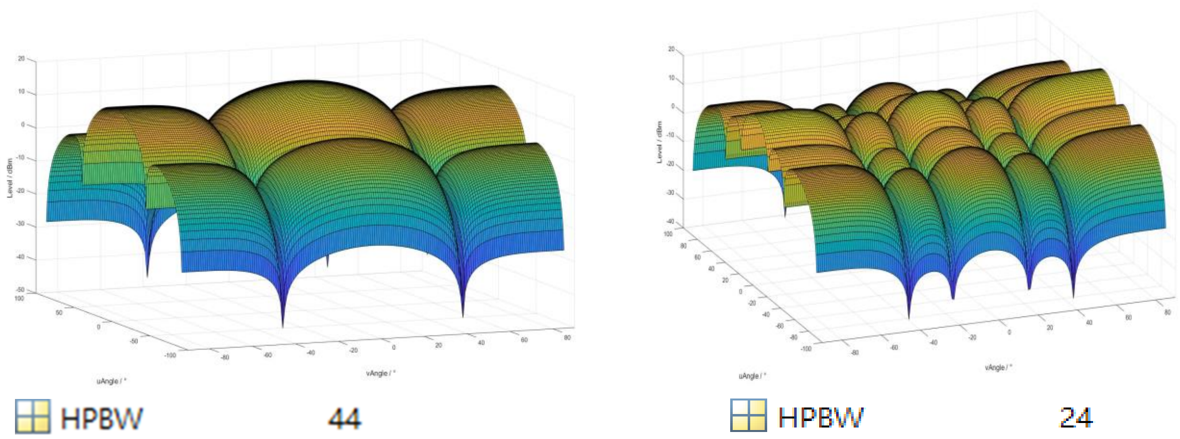

Fig. 9. Power of 3×3 antennas in different spacings. Smaller spacings between antennas result in lower amplitude of the peak of sidelobes. Larger spacings result in better directivity.

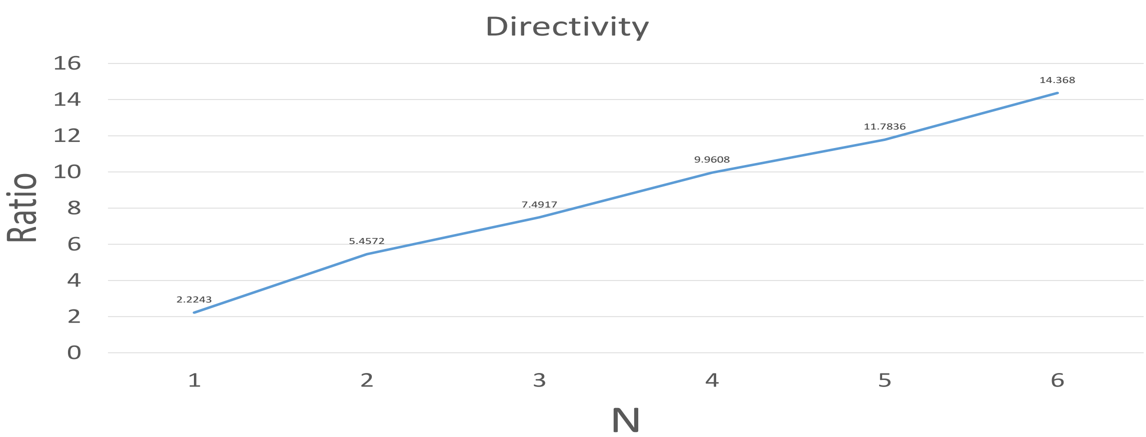

Fig. 10. Directivity increases as N increases in an N×N array.

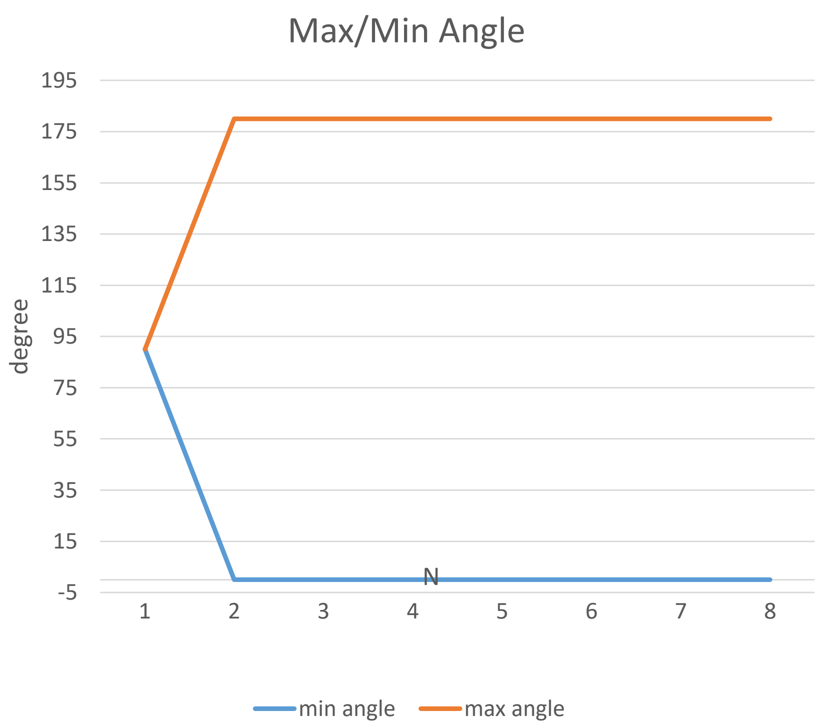

Fig. 11. Maximum and minimum angles of an N×N antenna array can be adjusted to full extent with chosen phases for each antenna when N is larger or equal to 2.

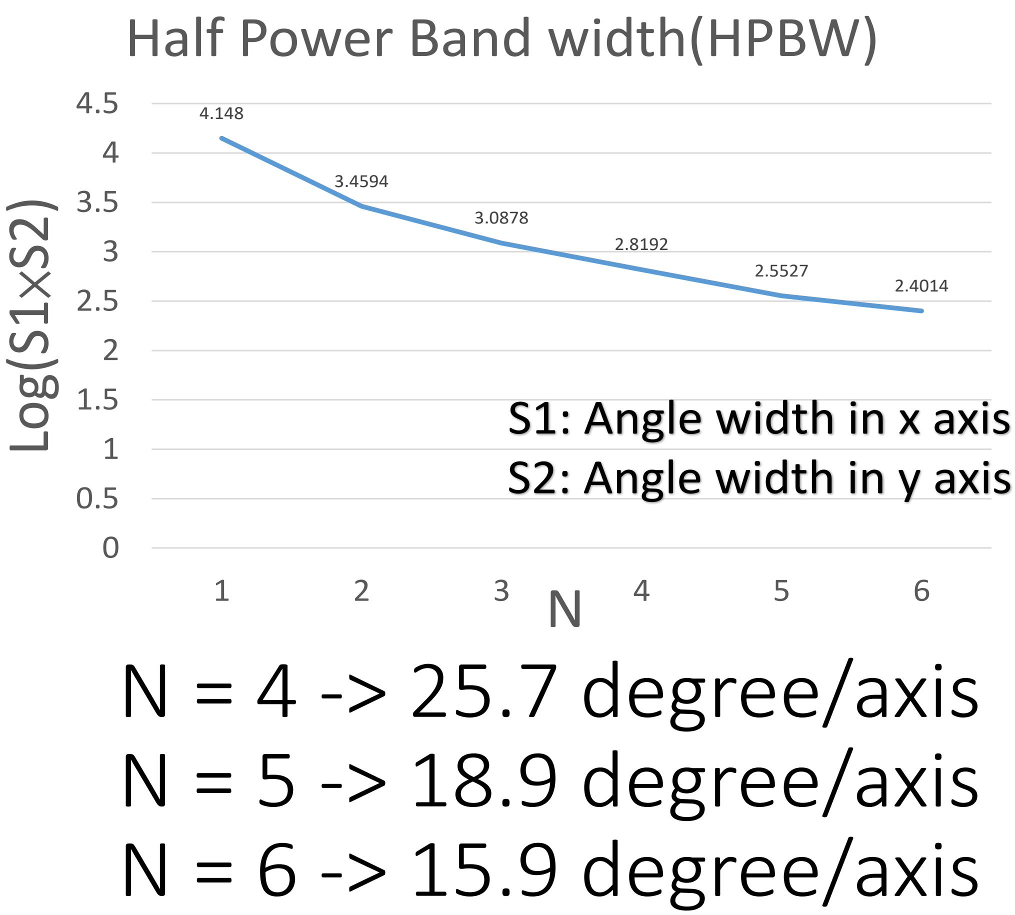

Fig. 12. HPBW improves from 78 degree/axis to 15.9 degree/axis when N is changed from 1 to 6 in an N×N antenna array.