Realisation of High Power Microwave Artificial Material Devices

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High power RF generation is a crucial component to many applications, ranging from security to medicine. By designing and creating novel materials, Artificial Materials (AMs), we can produce specific desired electromagnetic responses with relative ease, reducing cost and size of devices.

AMs are periodic composite materials whose 'macroscopic' electromagnetic behaviour depends on their sub-wavelength 'microscopic' constituent elements, or unit cells, rather than their material composition, appearing homogeneous over certain wavelengths to an incident wave. This enables the description of these materials as effective materials, therefore can be described by the abstract bulk properties of permittivity and permeability.

By manipulating the geometry of the unit cells the user can tailor the bulk electromagnetic behaviour of the device. This enables the user to, for example, engineer the dispersion curve for the material. This is useful for applications where energy transfer between a charged particle beam and RF wave is required. They could also create an arbitrary phase shift of the incident RF, removing the wavelength dependence of these devices, drastically reducing the size of conventional microwave technologies. However, existing AM designs cannot withstand high power RF, as shown by the experimental results in Fig. 1, which exposed a typical metamaterial (one type of AM) to 1W of RF at 10GHz for 15 seconds.

In this presentation we explore the applications of AMs to vacuum electronics. By loading optimised AMs (see Fig. 2) into a Travelling Wave Tube, we demonstrate that the dispersion curve of the system can be optimised to ensure low-loss energy transfer between an electron beam and X-Band RF. We move on to discuss the numerical results from HFSS and COMSOL for the optimised material, before concluding with the current results from Particle In Cell simulations conducted in MAGIC.

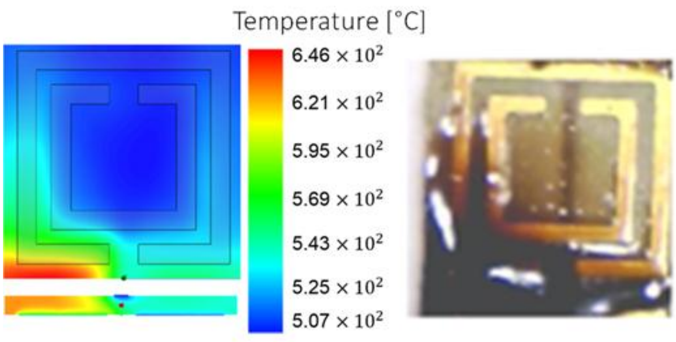

Figure 1: (Left) Heat map for one of the unit cells simulated in COMSOL. (Right) Experimental outcome after 15 seconds from exposing structure to 1W of RF at 10GHz, validating the simulation [1].

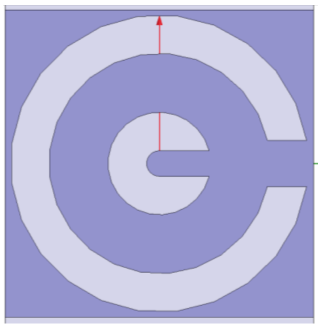

Figure 2: Optimised design for the unit cell

References

[1] R. Seviour, *et al*, “Effects of High Power on Microwave Metamaterials”, *8th International Conference on Advanced Electromagnetic Materials in Microwaves and Optics (METAMATERIALS)*, IEEE, pp 142-144, (2014)