Attenuation of Electromagnetic waves in Plasma in Ku band

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Summary

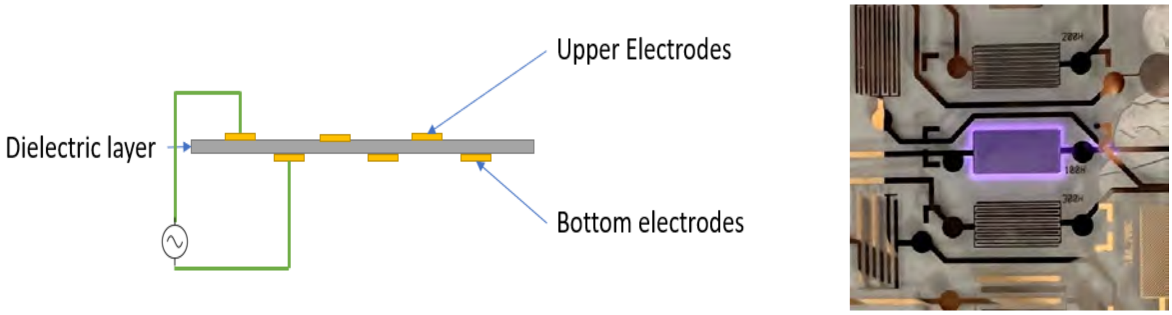
The attenuation of electromagnetic waves in a Plasma medium is a complex topic that has attracted the interest of researchers in both fundamental physics and technology. It may be utilized for a variety of applications such as radar cross section reduction, beam steering, etc. In this study, we described a Surface Dielectric Barrier Discharge micro-plasma slab that was positioned in front of a WR62 waveguide to study the interaction properties of electromagnetic waves with plasma. The plasma slab was found to cause a 3-10% attenuation in the S21 parameter, with the amount of attenuation depending on the frequency of the incident wave.

1. Introduction

Plasma is a gaseous component that contains free electrons and ions that can act like an electric conductor. The behavior of a weakly ionized plasma to an incident EMW is determined by the wave's angular frequency ω, the plasma frequency ω_p, and the electron-molecular collision frequency ν_m. There are three possibilities for the EMW interacts with plasma: 1) reflection, occurring at the surface when $\omega < \omega_{pe}$, 2) transmission, passing through the plasma if $\omega > \omega_{pe}$, and 3) surface mode, propagating along the plasma-dielectric boundary [1]. In this work, we focused on a collisional low-temperature plasma with high plasma frequency to be able to manipulate the incident EMW and explore its attenuation characteristics in plasma. Hence, a micro-plasma-based Surface Dielectric Barrier Discharge (SDBD) is used to create a plasma curtain in front of the wave guide, and the S-parameters of the transient and receiver ports are measured. This research might lead to new insights and breakthroughs in the field of micro-plasma-based THz and microwave devices.

2. Experimental Setup

To create plasma, an SDBD structure is used as shown in figure 1-A which categorize as a cold plasma. The reason to choose cold atmospheric pressure plasma over other types of plasma is that it is simpler to generate than high vacuum plasma, it does not require a gas inlet if we work in ambient air, it has higher electron and consequently plasma density, which causes higher plasma frequency, allowing us to use it at higher frequencies.



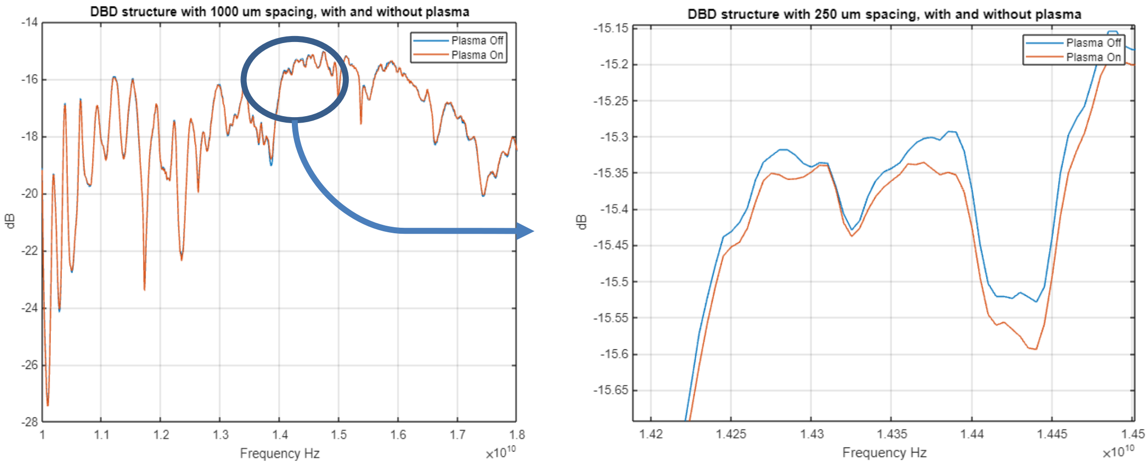
A B

Figure 1: A: Surface Dielectric Barrier discharge (SDBD) configuration, B: A glow discharge of the biased electrodes to the power supply (Plasma ON) on the electrodes with the distance of 100 µm

The SDBD consisted of two series of parallel electrodes separated by a dielectric layer of thickness 250 µm. The discharge area of the SDBD was 15 mm x 8 mm, covering the WR62 waveguide opening.

3. Results:

To measure the S-parameters, the waveguide was connected to the VNA through two coaxial cables. The plasma curtain was placed in front of the waveguide, and the S-parameters were measured with the plasma curtain on and off.



A B

Figure 2: A-S21 measurement for structure with the dielectric thickness of 250 µm and electrode distance of 100 µm, and B- The same measurement with higher accuracy demonstrated in 14.3 GHz frequency

Figure 2 shows the S_{21} measurement with plasma ON/OFF mode for the structure with the dielectric thickness of 250 µm and the electrode spacing of 100 µm with the frequency sweep set from 10 to 18 GHz. The attenuation was around 3% in all frequencies, except for certain single frequencies where the attenuation was about 10%.

References

[1] A. E. Robson, R. L. Morgan, and R. A. Meger, "Demonstration of a plasma mirror for microwaves," *IEEE Transactions on Plasma Science*, vol. 20, no. 6, pp. 1036–1040, Dec. 1992, doi: 10.1109/27.199569.