Metamaterial Lenses for Electron Cyclotron Resonance Heating in Nuclear Fusion Devices

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Electron Cyclotron Resonance Heating (ECRH) is a technique for plasma breakdown and heating in nuclear fusion experiments. Hundreds of KW of microwave power are generated by gyrotron oscillators that operate with a strong magnetic field inside. Power is then transferred by using two different approaches: overmoded waveguides, used when the available space is limited or electromagnetic compatibility (EMC) and interferences are relevant factors. Otherwise, quasioptical (QO) waveguides where power is guided using metallic mirrors are preferred, since power coupling is much simpler and they are less sensitive to arcing. On the other hand, QO solutions need extra room to accommodate big metallic mirrors to avoid spillover effects, and are susceptible to the excitation of higher order modes and aberrations in the beam due to focusing with off-axis metallic mirrors. Lenses are interesting candidates to overcome all these problems. However, conventional lenses are made of dielectric materials which are easily degraded under high power exposition.

The solution explored in this research work was to design, fabricate and measure only-metal engineered lenses, inspired on metamaterial concepts reinterpreted to fit with the stringent constraints imposed by high power handling. Radically novel lens designs were envisioned, using only smooth apertures to avoid arcing. Highly demanding analytical and simulation tools have been necessary, due to the large size of the structures and the small size of the apertures. Also, complex measurement procedures were developed: first a low-power anechoic chamber characterization and later a high-power in situ measurement of the developed prototypes. Some initial measurements are shown in Fig. 1 with a reflection based measure setup as indicated in Fig. 2 that also displays a picture of the lens.

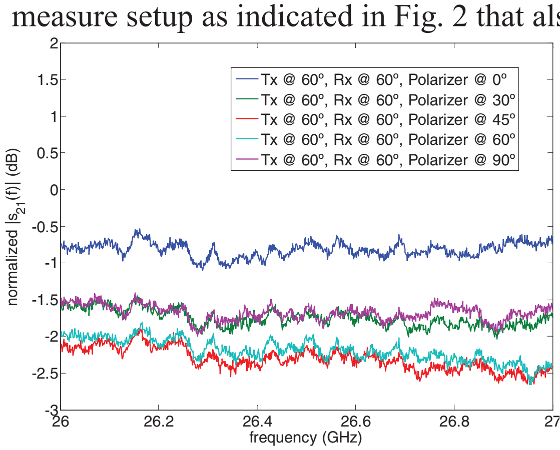

Fig. 1. Example of data traces $s_{21}(f)$.

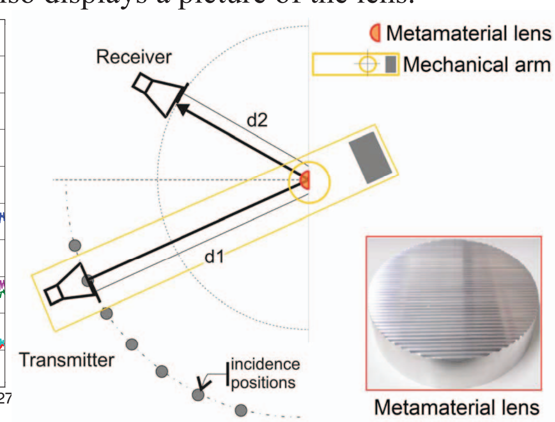

Fig. 2. Measurement setup and lens.