Mixer and Beamforming Advances in Millimeter-Wave Imaging

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***Abstract*—Millimeter-wave imaging diagnostics have been developed in the 50~150 GHz region which provide 2D localized measurements of electron temperature and electron density fluctuations inside magnetic fusion plasma devices. New mixer and antenna geometries are being developed to extend these techniques to THz frequencies. Also under investigation are beam shaping techniques which offer the possibility of matching the illumination and receive beams in real time to density profile changes as the plasma evolves.**

I. Introduction

THE University of California at Davis has pioneered the use of two plasma visualization techniques: electron cyclotron emission imaging (ECEI) [1] for electron temperature fluctuations, and microwave imaging reflectometry (MIR) [2] for electron density fluctuations. ECEI involves the imaging of plasma radiation emitted at harmonics of the electron cyclotron frequency, and is a passive radiometric technique. MIR, on the other hand, is an active radar technique that illuminates the plasma with a beam whose curvature is well matched to the plasma cutoff surface, and then images the radiation reflecting from these cutoff surfaces.

Both techniques employ a similar type of single-ended mixer; a beamlead Schottky diode attached at the center of a dual dipole antenna fabricated on a thin microwave laminate printed circuit board. Plasma radiation is focused onto arrays of small antennas/mixers through small elliptical mini-lenses (see Fig. 1). These mini-lens diameters vary from 18 to 51 mm, depending on the application (MIR or ECEI) and the plasma device on which the imaging diagnostic is installed.

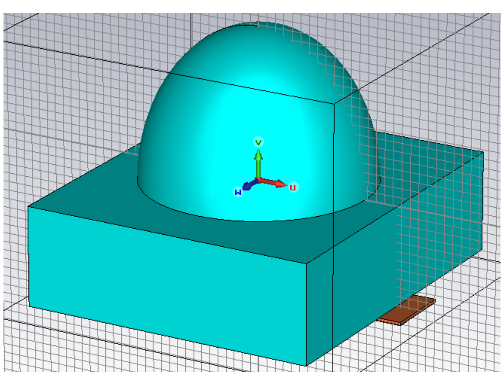

Fig. 1. Illustration of a mini-lens placed over a planar antenna, coupling both RF and LO power to a single-ended Schottky diode mixer.

II. Subharmonic Mixers

Two factors that limit present single-ended mixer array designs to ~145 GHz are the physical size of the beam lead Schottky diodes and the unavailability of high power LO sources above 140 GHz with which to drive the imaging arrays. Subharmonic mixers (SHMs) are pumped at half the frequency of the single-ended diode mixers, due to their anti-parallel diode pair structure, thus alleviating the LO source problem. Separated RF and LO slot folded dipole antennas, each residing at the center of its own mini-lens (see Fig. 2), eliminates the need for extremely small diodes. To avoid interference between the RF and LO antennas, the two antennas are perpendicularly polarized.

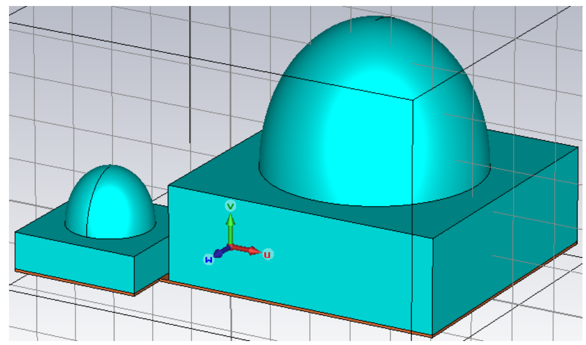

Fig. 2. Illustration of a mini-lens based SHM, with the larger lens coupling to an LO antenna and the small to an RF antenna. An anti-parallel diode pair and RF/LO input networks are placed in the small region between lenses.

III. Beam Shaping/Steering

The MIR technique requires not only an illumination beam whose wavefront curvature matches that of the plasma cutoff, but which also can benefit from accurate positioning and shaping of the focal plane that is imaged onto the detectors. Phased antenna array (PAA) methods are employed to both shape and steer beams at millimeter-wave frequencies. Here, control of the beam curvature emitted and/or received by the PAA, combined with an external set of optics, allows the size and curvature of the beam at the plasma cutoff to be electronically controlled. Microelectromechanical systems (MEMS) phase shifters are one of many approaches under investigation at UC Davis for wide bandwidth PAA operation. Such phase shifters may then be combined with CMOS or GaAs chip amplifiers to increase the power of the MIR illumination beam (if used on the transmitter) or to enhance the sensitivity of the detected beam (if used on the receiver).

IV. Acknowledgement

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References

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