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Microwave Imaging Radar Reflectometer System Utilizing Digital Beam Forming[1] FENGQI HU, MEIJIAO LI, CALVIN W. DOMIER, XIAOGUANG LIU, NEVILLE C. LUHMANN, JR., University of California, Davis — Microwave Imaging Reflectometry is a radar-like technique developed to measure the electron density fluctuations in fusion plasmas. Phased Antenna Arrays can serve as electronically controlled "lenses" that can generate the required wavefronts by phase shifting and amplitude scaling, which is being realized in the digital domain with higher flexibility and faster processing speed. In the transmitter, the resolution of the phase control is 1.4 degrees and the amplitude control is 0.5 dB/ step. A V-band double-sided, printed bow tie antenna which exhibits 49% bandwidth (46 - 76 GHz) is employed. The antenna is fed by a microstrip transmission line for easy impedance matching. The simple structure and the small antenna are suitable for low cost fabrication, easy circuit integration, and phased antenna array multi-frequency applications. In the receiver part, a sub-array of 32 channels with 200 mil spacing is used to collect the scattered reflected signal from one unit spot on the plasma cutoff surface. Pre-amplification is used to control the noise level of the system and wire bondable components are used to accommodate the small spacing between each channel. After down converting, base band signals are digitized and processed in an FPGA module.

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☐ Prefer Oral Session
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Microwave Imaging Radar Reflectometer Transceiver System Utilizing Digital Beam Forming

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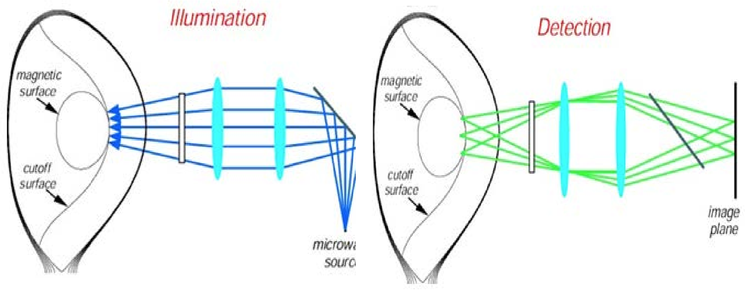
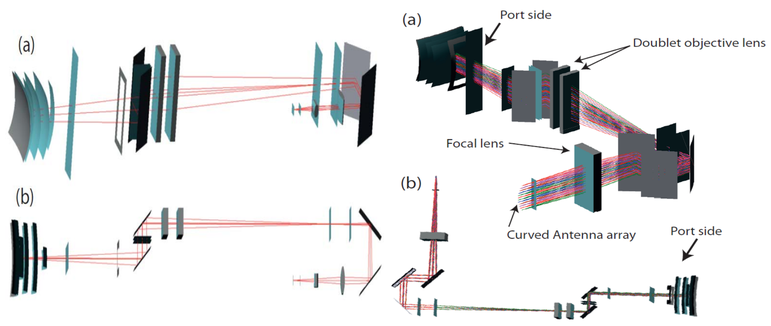
Conceptual Schematic of MIR system



Microwave Imaging Reflectometry (MIR) is a radar-like system developed to measure electron density fluctuations in fusion plasmas

Beam Shaping through Remote Control of Optics in current system

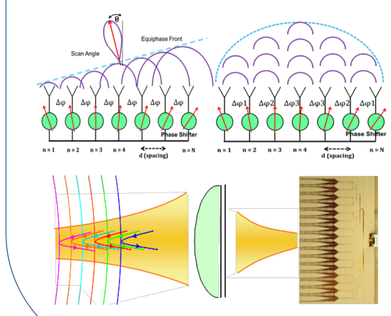


Side view (a) and top view (b) of the transmitter optical system

Side view (a) and top view (b) of the receiver optical system

Optical lenses in current system are used to collect scattered wave from cutoff layer and focus the reflected beam onto the receiving antenna array with the capability of shaping a curved wave-front over a certain spatial range into a flat one.

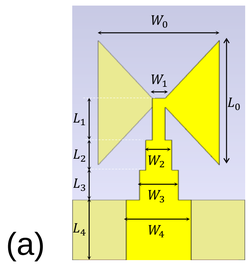
Disadvantages: Slow to adjust; Suffer from reflections from lenses; Lack flexibility



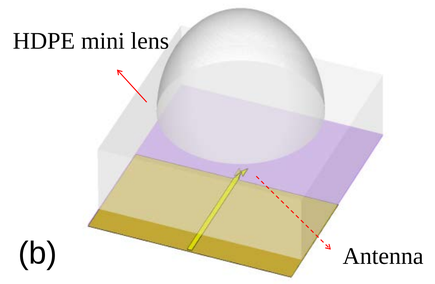
Advantage of the DBF:

- Flexibility & accuracy
- Data memory allowed
- Long term stability
- Ease of phase & amplitude adjustment
- Easy circuit integration

Antenna Design and Testing

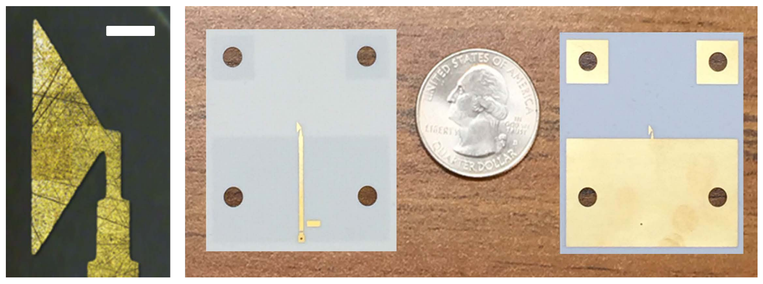


(a)

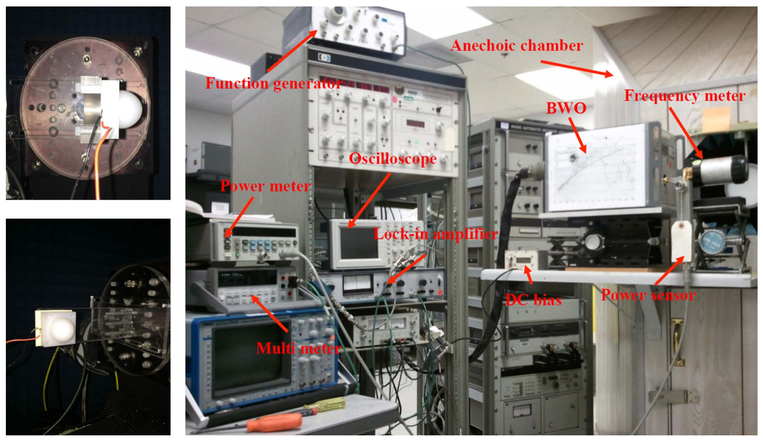


(b)

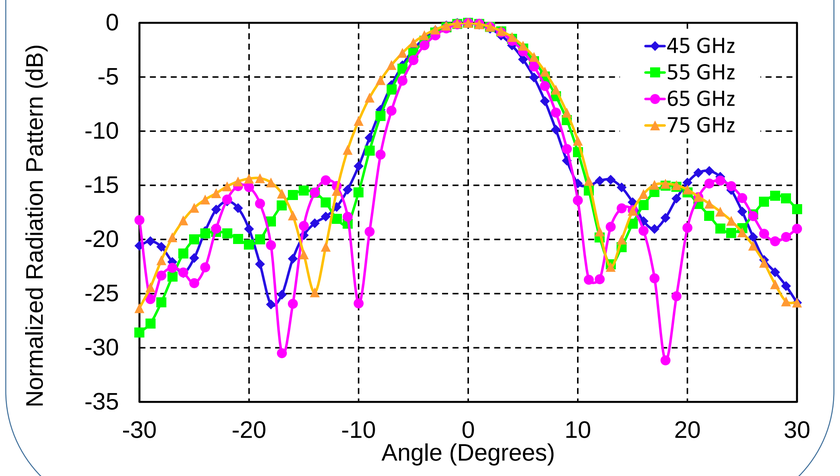
(a) Antenna geometry (b) Antenna structure with the mini-lens



Photograph of the antenna with Zoom in (scale bar 0.5 mm)

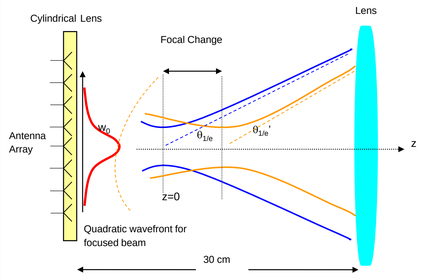


Antenna's test setup inside and outside anechoic chamber.

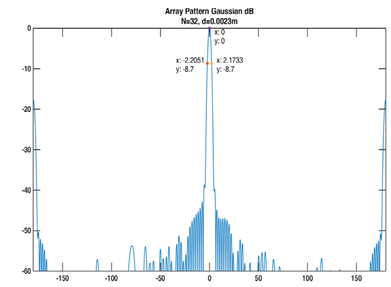


Measured E-plane far-field patterns.

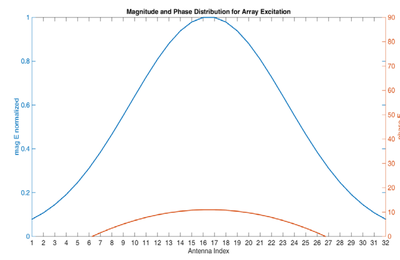
Phased array synthesis integrating optical simulation



Optical simulation was used to obtain the corresponding Gaussian beam waist along with the waist moving range required for refocus.
The required array size and corresponding magnitude and phase coefficients for each channel are then calculated for different focusing scenarios

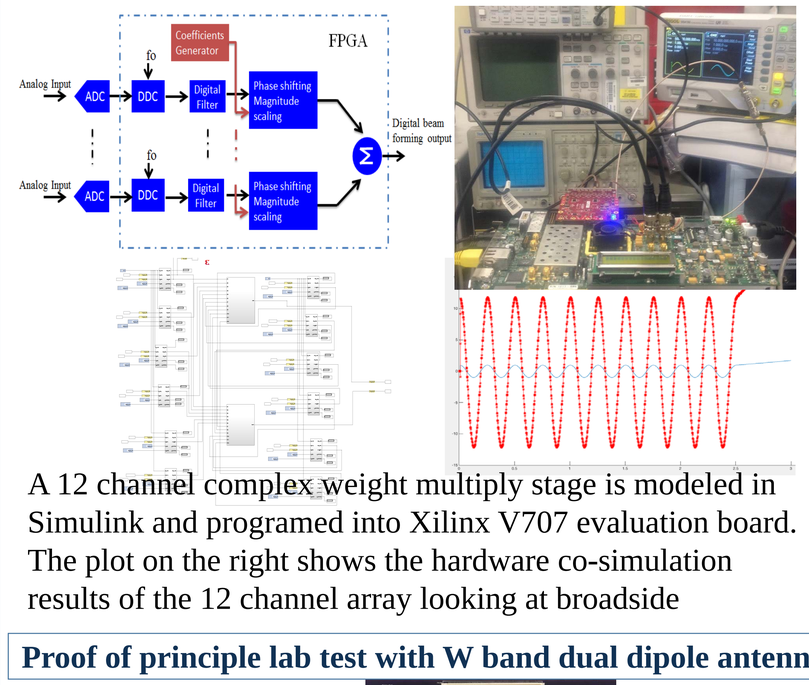


Far field pattern of an N=29 array with Gaussian taper to achieve a Gaussian beam with 22 mm beam waist



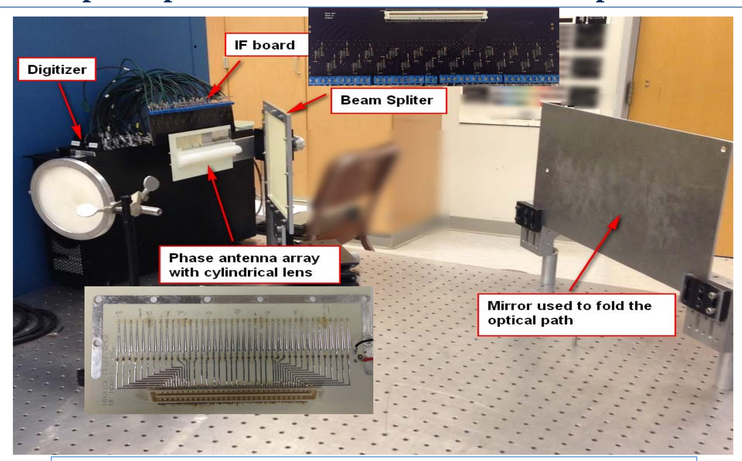
Magnitude and phase coefficients for a 10 cm axial focal shift

Initial complex weight multiply stage with Xillinx 7 hardware co-simulation

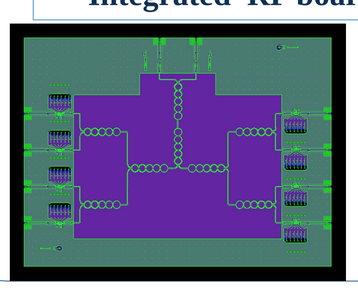


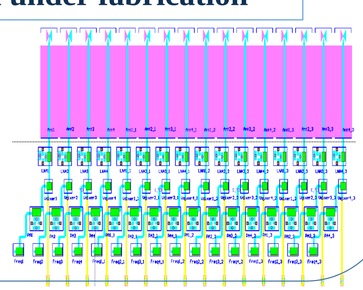
A 12 channel complex weight multiply stage is modeled in Simulink and programed into Xilinx V707 evaluation board. The plot on the right shows the hardware co-simulation results of the 12 channel array looking at broadside

Proof of principle lab test with W band dual dipole antenna



Integrated RF board under fabrication





Multi_Frequency DBF Transmitter/Receiver System