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Development of *Ka*-band Reflectometer and Integrated Circuits Using GaN Process for Plasma Diagnostics

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A microwave reflectometer for fusion plasma is made of a transmitter and a receiver where the electromagnetic wave, either modulated or not, out of the transmitter is reflected by the plasma cutoff layer and then detected by the receiver. The measured time-varying phase shift and intensity therefore facilitate the determination of critical hot-electron plasma properties like the electron density fluctuation and electron density profile in the Tokamaks [1-3].

While the plasma frequency for the Formosa Integrated Research Spherical Tokamak, a.k.a. FIRST, in Taiwan is expected to be in the Ka-band, it then prompts the development of a prototypical reflectometry system in 26.5-29 GHz, as shown in Fig. 1. The continuous wave out of a phase-locked oscillator will be sent to a power splitter, amplified, and transmitted into the free space via the pyramidal feedhorn. Part of the power out of the splitter, however, is also amplified but sent to the mixer to down-convert the received signal. With I/Q mixer in use, both the in-phase and quadrature down-converted IF signals are sampled digitally via the NI-DAQ USB6210. The data acquisition process and subsequent analysis are carried out using LabView programming. At this moment, a metal plate that is moving back and forth periodically is used to model the plasma cutoff layer, and the I/Q signal from the vibrated metal plate is successfully measured and calibrated.

Since the reflectometer has to be located close to the Tokamak, where constant bombardments of high-energy particles are inevitable, a diagnostic system's durability under harsh radiation conditions has to be addressed. Rather than relying on the commonly-used CMOS or GaAs, it is preferred that the active transceiver circuits are made of wide-bandgap semiconductor processes such as GaN (Gallium nitride) [4]. Two circuits have been designed using WIN 0.12-μm GaN process. The first one is the 25-35 GHz amplifier, which is made of 3-stage transistors. By applying a low-frequency signal to the second-stage transistor through its gate or drain bias, this amplifier also functions as an amplitude modulator that can be used for AMCW (amplitude modulation continuous wave) reflectometry. The other circuit is the 25-35 GHz down-converting mixer that is made of two stages of amplification transistors, one mixing transistor and a 1-GHz low-pass filter at its output; this mixer also duals as an AM demodulator. The DC drain bias voltage for both GaN circuits is 28 V.

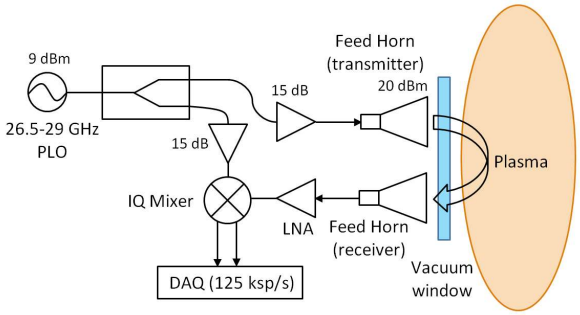

Fig. 1: The *Ka*-band reflectometer.

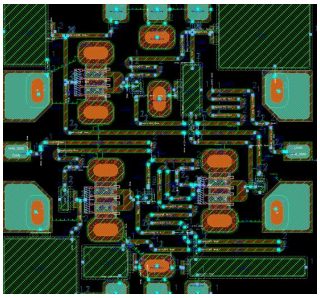

Fig. 2: 25-35 GHz amplifier design in 0.12-μm GaN.

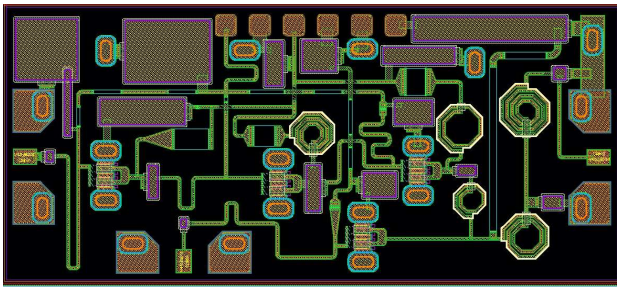

Fig. 3: 25-35 GHz down-converting mixer design in 0.12-μm GaN.

References

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