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Design and Development of 140 GHz D-Band Phase Locked Heterodyne Interferometer System for Real Time Density Measurement

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In a tokamak, an interferometer system measures plasma density using an electromagnetic wave which experiences a phase shift with respect to a reference signal while passing through the plasma column. In millimetre wave spectrum, usually homodyne and heterodyne systems are used to determine phase information. One of the limitations of the homodyne scheme was its inability to differentiate the increase or decrease in phase and corresponding plasma density. Hence a heterodyne scheme was required which can detect the increase or decrease of phase with precision and is capable of real time density measurement with feedback control. This paper deals with the design, development and characterization of a 140 GHz D-Band phase locked heterodyne interferometer system with real time density measurement. Here the transmitter and receiver are phase-locked by a reference crystal oscillator of 100 MHz to provide a stable signal and minimize errors in measurement due to phase mismatch. This phase locking provides a highly stabilised intermediate frequency (IF) of 2 GHz. The IF signal is further down converted by IQ mixer to 100 KHz I & Q signals in form of sine and cosine waves. These signals are used calculate the absolute phase by zero crossing method. These signals are digitized by 12-bits ADC. The controller uses the digitized signals to generate real time density signal which can be used for density feedback control. The system has a temporal resolution of 5 μs and phase error measurement of 0.07 radians. The performance of the microwave and RF electronics has been shown in the paper. The overall performance of the heterodyne phase locked interferometer system with AGC signal has been shown. Laboratory tests results and plasma results after installation of the system on Aditya tokomak has been presented. Real time density signals and actual density signal has been measured for various plasma shots. One typical plasma discharge with gas puff is shown.

(a) Heterodyne Interferometer System (b) Plasma discharge with gas puff

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