Recent Progress in the Development of Phase Contrast Imaging Techniques to Measure GHz RF Waves in Fusion Grade Plasmas*  

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The Phase Contrast Imaging (PCI) method has been successfully deployed on tokamaks as well as stellarators to measure low frequency turbulent waves and MHD phenomena with frequencies up to 1 MHz and perpendicular wavelengths from a few mm to up to 10 cm [1, 2]. In addition, applying PCI supplemented by heterodyne modulation techniques with Acousto-Optical Modulators (AOM), ICRF waves with frequencies up to 80 MHz have been measured successfully in C-Mod [3]. PCI creates an image of plasma density fluctuations using CO₂ laser light that passes through the plasma which captures the line-integral of the fluctuations and using a phase plate, direct measurement of wavelengths and wave amplitudes becomes feasible. Recently interest has arisen in extending the PCI method up to the GHz range, for example to measure helicon (whistler or fast magnetosonic) waves at 476 MHz in DIII-D [4]. This presentation describes two approaches to extend the PCI method up to 1 GHz. In the first approach we describe the development of an Electro-Optical modulator (EOM) at frequencies close to that of the helicon frequency so that a heterodyne technique can be used to detect the beat wave with a MHz response cryogenically cooled detector array. A transverse Pockels cell made of water-cooled CdTe birefringent crystal, driven by a matched oscillator that provides a 2 kV peak-to-peak voltage is used for the modulator. A prototype variable frequency oscillator at 10s of MHz has been designed and tested successfully in the lab, to be followed by an 0.5 GHz oscillator circuit to be ready for the helicon wave experiments. The second independent approach uses a 1.55 micrometer 100 mW fiber-optics laser to create a beam suitable for scientific-grade interferometric imaging for PCI where detectors with 1 GHz bandwidth are commercially available. New phase plates with 1/8 of laser wavelength have been manufactured successfully both with a masked coating method, as well as semiconductor micro-fabrication technique. Initial laboratory tests using ultrasonic waves (20-200 kHz) indicate excellent signal-to-noise response and results from both methods will be presented.


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