Progress towards measurement of the slow wave in the WVU Helicon Plasma Source

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Abstract - Motivation

We report the updated status of the 300 GHz collective scattering system on the Hot Helicon Experiment (HELIX) at WVU. Vacuum chamber extensions for the injection beam and scattered beam collection apparatus have been installed on HELIX and optical component alignment was accomplished using a simple laser pointer. System calibration before injection was done using an acoustic cell scattering technique. The acoustic cell, using a 1 MHz transducer, was manufactured for the injection beam with angles of ~39° and ~60°, corresponding to scattered beam vectors of ~45° and ~35°, respectively.

Acoustic Cell Calibration System and Proof-of-Concept Experiment

In an effort to construct a method to calibrate the near-wave-scattering technique, we chose to try an acoustic cell scheme. The acoustic cell uses a piezoelectric transducer to produce sound waves in a matrix containing the density perturbations in a plasma for scattering. The preliminary materials chosen for the acoustic cell were HDPE, Teflon, and Teflon respectively, based on their optical transmission properties for 300 GHz in addition to their sound wave properties. After consideration of cost, available transducer frequencies and the theoretical scattering angles to be produced, HDPE and Teflon were chosen for use as the acoustic cells. With a 1 MHz transducer, theoretical scattering angles of approximately 39° and 60°, corresponding to scattered beam vectors of ~45° and ~35°, were calculated for HDPE and Teflon respectively.

Initial proof-of-concept tests were done using the HDPE acoustic cell. The transducer was designed to focus the 300 GHz beam into the focal zone of the HDPE cell for minimum scattering signal. The sound wave intensity is defined by two regions: the near field and the far field. In the near field, the sound waves initially go through a series of maxima and minima before reaching the far maximum a distance N away from the transducer. After a distance N, which is the natural focus of the transducer, the wave is in the far field regime and eventually decays in amplitude from this point to location N. The region N to the 6 dB point (~1.27N) is called the focal zone, and is the location to have a large enough source to produce scattering. The initial HDPE acoustic cell is 2.8" W x 2.8" H x 6.5" L, and the focal zone is located approximately 2.5" to 3.75" into the cell. The 1 MHz transducer is ~1" in diameter, and creates a sound beam diameter of approximately 0.25" at N, and expands to 0.34" at the -6 dB point.

Ultrasonic Transducer Characteristics

We are eager to collaborate with other experiments interested in short wavelength fluctuation measurements using our "portable" diagnostic.

Diagnose Status:
- Injection and reference optical components are in place and are aligned.
- Chamber and driver modification hardware construction is complete.
- Proof-of-concept measurements using the flat collection mirror and diffraction gratings are expected by June.
- We are eager to collaborate with other experiments interested in short wavelength fluctuation measurements using our “portable” diagnostic.

Tasks in Progress

1. Vacuum window is HDPE and the surface is cut at 2.5° to minimise direct reflections and standing wave interference.
2. Retro-reflector mounts are on a linear stage to lengthen/shorten the reference beam path depending on collection mirror location.
3. Detector/Mixer will be encased in a ¼" thick copper box along with a low noise voltage amplifier and associated circuitry for powering the amp.
4. Location of the beamsplitter. Currently the green laser pointer used for initial alignment is still in place until lenses are permanently positioned.
5. Beam mixer location. Mixer will be designed around the measured reference beam strength and approximate scattered beam strength based on the diffraction grating.
6. Vacuum mirror adjustment module. Angular mirror adjustment is accomplished by a micrometer attached to the end of the feedthrough shaft.

Rebeamsplitter Characterization

Initially we intended to use Mylar for a beamsplitter but due to large "losses" (~20%) in the beam intensity, even at normal incidence, we needed to find a material suitable for producing a transmission coefficient of approximately 90% (± 5%) with low loss. 2 and 0.625" thick Teflon seems to be our requirement for maximal loss (~7%) and appropriate transmission/reflection.

Failure of the Proof-of-Concept experiments for the HDPE acoustic cell

The failure of the acoustic cell to produce a measurable scattered signal can be attributed to the fact that either the magnitude of the sound pressure perturbation was insufficient, or the transducer’s wave pulse wasn’t long enough to create a perturbation long enough to create a detectable signal. The transducer and associated driver use pre-defined settings for negative voltage spike excitation, and pulse width based on the specific transducer being used. The adjustments available are the voltage range (~100 V to ~400 V in 100 V increments). This system is primarily designed for use in non-destructive testing where the transducer is used to “plug” materials for the detection of defects. The pre-defined settings of the transducers are for minimizing the beam increase associated with the voltage needed to excite the transducer to prevent damage of the transducer. The driver also limits the maximum frequency at which the transducer may be “pumped” to 5 kHz, limiting any chance of trying to create a standing wave.

For example, the pre-defined setting associated with the 1 MHz transducer is a pulse length of 0.5 μs, with an adjustment range of 0.3-0.6 μs. For the longest pulse length available for the 1 MHz transducer, the “wave train” will only be about 1.75 μs, which is comparable to the wavelength at 300 GHz (~5.25 μm). Thus, the 300 GHz beam will never reach the length of a perturbation wave to scatter. Attempts to use the transducer frequency settings (300 kHz) which gives the longest pulse length (0.6 μs) gave a “wave train” length of 1.5 μs approximately. This still did not result in a detectable scattered signal; this failure could be attributed to an insufficient number of the pulse waves being large enough to create a large amount of scattered transducer intensity, since the company recommends that when using a square pulse waveform, the best results are obtained when using a pulse width appropriately related to the transducer natural frequency. 

Answer to acoustic cell failure: diffraction grating

The diffraction grating consists of a 0.55 mm thick copper plate, two 0.19 mm (0.184 inch) spaced, separated by a small distance calculated to create the chosen scattering angle. Shown here is a grating with a separation of 1.5 mm, which theoretically gives scattering angles of approximately 1°, 3.5°, and 5° for m=1, 2, and 3 respectively. The diffraction pattern for m=1 and 2 are easily seen below.