PHASMA Facility Components

**Magnetic Field System:** Ten water-cooled electromagnets in the helicon source portion of the facility produce a steady-state magnetic field of 0-1500 Gauss. Twelve 1.25 m diameter water-cooled, electromagnets with a 0.53 m diameter bore produce a steady-state, 0-350 G magnetic field in the modular expansion chamber region.

**Vacuum System:** The centerpiece of the new PHASMA vacuum chamber is a fixed position “diagnostics” module that provides exceptional access for laser and probe diagnostics for ivdf and evdf measurements. The figure to the right shows the diagnostics module including measurement planes for LIF, Thomson scattering, and microwave scattering. Since large rectangular vacuum windows are not commercially available, each optical system is mounted on a stepping motor controlled 3D linear stage for generating measurement maps across the entire 3D volume. Additional linear stages are mounted on the end of PHASMA for axial laser injection for axial LIF and TS measurements. A secondary diagnostic chamber is on the other side of the helicon source in PHASMA and enables two different experimental campaigns to operate near-simultaneously on PHASMA.

**Probe Diagnostics:** The 3D structure of the density and electric field in PHASMA is measured with emissive and Langmuir probes mounted on a 3D scanning probe assembly. Moveable magnetic probes containing multiple (6–20) sense coils are available in the central vacuum chamber. Each magnetic probe measures the complete vector magnetic field.
**Microwave Scattering Diagnostic:** PHASMA includes a 300 GHz coherent Thomson scattering (CTS) diagnostic for non-perturbative measurements of the frequency and wavelength of electrostatic fluctuations at scales of a few to < 1 mm (from ~1 to 100 rad/cm). The homodyne CTS scattering system, a quasi-optical interferometer, consists of three beam paths: an “interaction” beam path, a “scattered” beam path, and a “reference” beam path. The CTS system’s scattered power detection threshold of 750 pW limits detectable density fluctuation amplitudes to 5.5 x 10^{11} cm^{-3} (a 5% density fluctuation for a peak density of 10^{13} cm^{-3}). CTS measurements are made in a plane swept over a 3D volume by scanning the injection position and collection angles over many discharges. The narrow range of accessible collection angles restricts CTS measurements to the central region of the discharge and to measurements perpendicular to the guide field.

**Electron Diagnostics:** Spatially localized, 3D evdfs over a 3D volume are measured by Thomson scattering (TS). As is typical of TS, the primary challenge in accomplishing TS in PHASMA is the suppression of light at the laser wavelength while still collecting enough photons across the rest of the scattered light lineshape. Fortunately, recent advances in the fabrication of Volume Bragg Gratings (used to suppress light at the laser wavelength) now make TS possible in low density plasmas with temperatures as low as 2 eV (see Figure at right) [Vincent et al., 2016]. Scattered light is collected with optical fibers aligned to view the entire injected beam path (with spatial resolution of 0.2 cm or better) through the diagnostic chamber (radially or axially). Both the injected beam and collection fiber array are scanned to measure the evdf throughout the relevant volume. The collected light passes through the Bragg grating and then into an existing single grating spectrometer. An image-intensified fast CCD camera is placed at the exit of the spectrometer to produce evdf measurements from each of the collection fibers. While the TS measurement will be challenging, it is important to note that TS measurements of the evdf in plasmas of similar densities, electron temperatures, and timescales have been demonstrated in other experiments with similar plasma parameters [Schaeffer et al., 2010; Vincent et al., 2016]. Note that since density measurements by TS are not required, there will be no need to absolutely calibrate the entire diagnostic system.

**Ion/neutral Diagnostics:** To enable simultaneous vdf measurements of an entire plane of PHASMA, the laser beam is spread into a sheet beam before injection and a filtered, triggered, CCD camera is used to acquire the fluorescent image from the entire excitation plane (with < 0.2 cm resolution). The location of the sheet beam is then electromechanically scanned across the sample volume to create 3D maps of metastable density, flow, and temperature. For parallel vdf measurements, the LIF lasers are injected along the axis of PHASMA.

Available LIF and Two Photon LIF (TALIF) equipment includes:
**LIF and TALIF Systems:**
3 Stanford and lock-in amplifiers  
1 EG&G lock-in amplifier  
Spectra-Physics Millennium Pro 10 W NdYAG laser  
Sirah Matisse Ring Dye laser  
Bristol 612 Vis Wavemeter  
Burleigh 1000 and 1500 wavemeters  
2 SRS mechanical choppers  
2 Newport beam profilers  
Spectra-Physics PRO-270 pulsed NdYAG laser (100 MW)  
High speed Hamamatsu photomultiplier detector assembly  
Sirah Cobra Stretch dye laser with 205 nm tripler module  
SRS boxcar averager  
Angstrom pulsed laser wavemeter  
Toptica DL-Pro tapered amplifier visible tunable diode laser  
Sacher IR diode laser

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Toptica CQ tunable diode laser.

Pulsed dye laser with third harmonic stage to produce tunable UV laser light.

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 CW Matisse ring dye laser