Canadian Association of Physicists

Association canadienne des physiciens et physiciennes

Contribution ID: **60** Type: **Oral Competition (Graduate Student) / Compétition orale (Étudiant(e) du 2e ou 3e cycle)**

Ultra-high-resolution optical absorption spectroscopy using a supercontinuum laser combined with a widely tunable filter and a hyperfine spectrometer

Tuesday 9 June 2020 13:20 (20 minutes)

For the first time, ultra-high-resolution optical absorption spectroscopy using a supercontinuum laser combined with a widely tunable filter and a hyperfine spectrometer is reported. The measurements were taken in a reduced pressure, nominally pure argon DC plasma. Such measurements allowed the determination of the number density of absorbing species (Ar $1s_2$ and $1s_4$ levels (Paschen notation) in this case) while overcoming many of the drawbacks associated with absorption spectroscopy. On the one side, the supercontinuum laser (SuperK EXTREME/FIANIUM, NKT Photonics) paired with a widely tunable filter (Laser Line Tunable Filter, Photon etc.) made it possible to probe any wavelength in the visible/near IR spectrum without altering the plasma properties. This would not have been possible with a spectral lamp emitting at only discrete wavelength or with a strong white light emitting a broad spectrum. On the other side, the ultra-high-resolution (Hyperfine spectrometer, LightMachinery Inc.,), with its 2 pm resolution over a simultaneous range of 25 nm, allowed the detection of the absorbed laser signal through the plasma, an accomplishment that could not be achieved with a typical high-resolution spectrometer (78 pm, Princeton Instruments, IsoPlane-320 spectrometer with a 2400 g/mm holographic grating and a PI-MAX4 iCCD camera). The results obtained were from analysing the absorption profile of the Ar $2p_3$-$1s_2$ and Ar $2p_8$-$1s_4$ emission lines at 840 nm and 842 nm respectively. At a pressure of 1 Torr, a discharge current of 20 mA and an absorption length of 18 cm, number densities of 1.3×10^{16} m^{-3} and 2.5×10^{16} m^{-3} were respectively found for the Ar $1s_2$ and Ar $1s_4$ levels. These values are typical of DC discharges under similar conditions. The $1s_2$ level is found to be less populated than the $1s_4$ level, a result ascribed to its energy being higher in the energy diagram, thus less easily populated. Moreover, the absorption of both lines was found to decrease when decreasing the optical absorption path, without actually resulting in smaller number densities, as expected. Finally, the number densities were found to increase with an increase of the discharge current, a result also coherent with the literature.

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Session Classification: DPP-1 : Plasma Physics Symposium

Track Classification: Symposia Day (DPP) - Plasma Physics