APPLICATION NOTE [LP20]

Plasma Characterisation of the superconducting proton linear accelerator plasma generator using a 2 MHz compensated Impedans' Langmuir probe

INTRODUCTION

In order to produce high intensity beams of neutrinos and radioactive ion beams, an upgrade of the Linac4 accelerator towards a superconducting proton Linac (SPL) is under consideration. The large increase in duty factor from Linac4 to SPL operation (Linac4: 2 Hz, 0.5 ms pulse length; SPL: 50 Hz, 0.4 to 1.2 ms pulse length) requires a high-repetition rate H^- ion source. In a first step towards this, a plasma generator (PG) was constructed that can operate at up to 6 kW of average RF power.

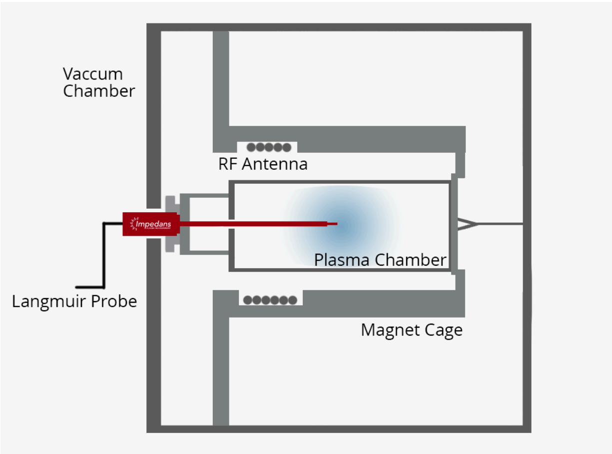

Figure 1. Schematic of the SPL plasma generator.

EXPERIMENT

Figure 1 shows the experimental setup. The compact nature of the SPL plasma generator means that the Langmuir probe is introduced through the collar electrodes at the outlet side of the source.

Measurements were performed with a repetition rate of 22 Hz and a 1.2ms pulse length. All measurements were performed using an Impedans' automated Langmuir Probe System mounted on a 450 mm linear drive, with the parameters calculated using Laframboise Langmuir theory. Unless stated otherwise, the nominal position of the probe was 10 mm from the plasma electrode, with a power of 10 kW.

RESULT

Figure 3 shows the dependence of n_e, n_i and the plasma power (P_{power}) on the RF frequency, which was tuned in order to minimise the reflected voltage and thus optimise the coupling of the RF power into the plasma. An RF power of 10 kW and a gas pulse length of 300 μs was applied, with the probe 4 mm from the plasma electrode, meaning it is further from the core plasma resulting in an order of magnitude reduction of the plasma density. The pressure has a strong influence on the plasma properties and is adjusted by changing the pulse duration. Figure 4 shows the dependence of V_p, T_e and the average electron energy with increasing gas pressures. All three parameters show a systematic reduction as the pulse length, and therefore pressure, is increased. Over this measurement range, the RF power transmitted to the plasma was approximately constant at 5.65 kW while the electron density, n_e, dropped by 30%.

The dependence of the plasma density on the RF power is shown in figure 4, with forward powers

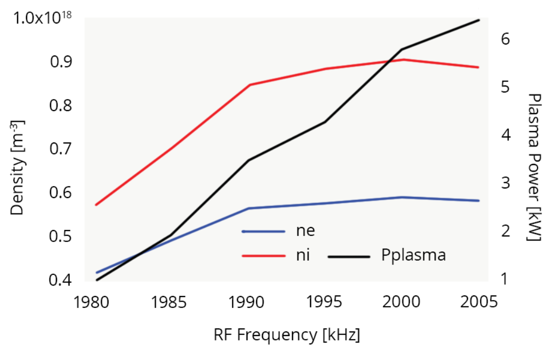

Figure 2. The dependence of n_e, n_i and the plasma power on the RF frequency when applying a forward power of 10 kW.

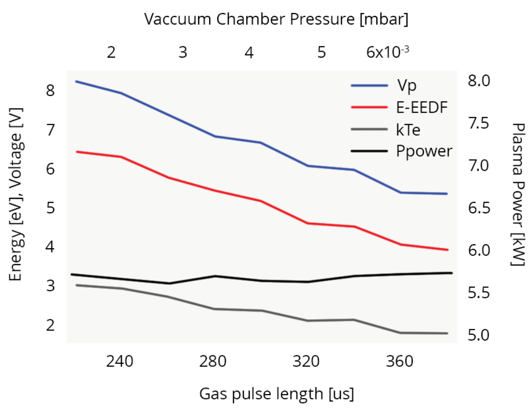

Figure 3. Temporal evolution of the electron density and effective temperature for various pressures.

ranging from 10 to 40 kW (6-27 kW plasma power). The plasma densities scale approximately linearly with the RF power, while the electron temperature and average electron energy do not show such clear trends. However the EEDF's derived from the IV characteristics show a marginal increase in the most probable electron energy with the RF power, although at higher powers a Single Maxwellian does not accurately describe the distribution meaning a direct definition of an electron temperature is physically incorrect.

CONCLUSION

An Impedans Langmuir probe was used to measure the plasma density (n_e, n_i), plasma potential (V_p), electron temperature (T_e) and the Electron energy distribution function (EEDF) for a range of RF powers, Frequency settings and gas injection pulse lengths. It was found that the plasma density scaled with RF power and the coupling efficiency. The EEDF is non-Maxwellian in the collar region and is influenced by the gas pressure and the plasma generators forward

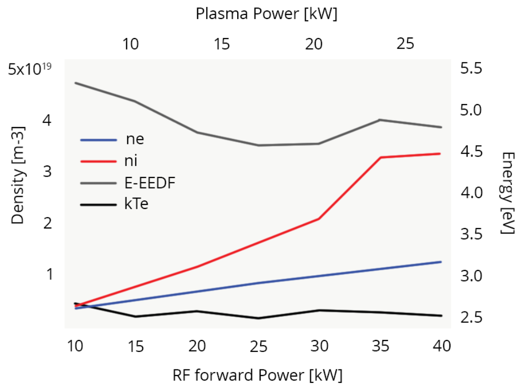

Figure 4. Temporal evolution of the electron density and effective temperature for various powers.

RF power. Typical values in the collar region at 20 kW are: 6.9 V for the palsma potential, 2.57 eV for the electron temperature and range from 3.1×10^{18} to 1.1×10^{19} m^{-3} for the electron density. The discrepency between the Ion and electron density could be explained by the presence of negative H^- ions in the plasma.

REFERENCES

*Schmitzer, C. et al, "Plasma characterisation of the superconducting proton linear accelerator plasma generator using a 2 MHz compensated Langmuir probe".

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