COMMISSIONING OF THE CHINESE LARGEST SUPERCONDUCTING HIGH-FLUX LINEAR PLASMA DEVICE SWORD

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Funded by China's major national science and technology infrastructure programme CRAFT, a new high-flux linear plasma device named SWORD (Superconducting plasma Wall interactiOn lineaR Device) is being built at our institute. Recently, we have achieved its first milestone—continuous helium plasma discharges with a flux higher than 10^{24} $m^{-2}s^{-1}$ and a duration longer than 1000 s. This marks an important step by the Chinese fusion community towards addressing plasma material interaction issues in fusion devices.

Figure 1 shows the layout of SOWRD, which consists of a 3-tesla superconducting magnet (dia. 1.21 m × 2.1 m), a target exchange chamber, and a target manipulator. Enclosed by the superconducting magnet is a vacuum chamber pumped by 3 pump stations, which individually has a maximum pump speed of around 44, 000 m^3/h. Plasmas are generated by a cascaded arc source at the right end of the vacuum chamber. A customized Langmuir probe that can handle intense plasma load is used to measure the particle flux. Additionally, optical emission spectroscopy (OES) is used to cross-check the flux measurement.

Figure 1. The SWORD facility and its target exposed to high flux He plasma.

Figure 2(a) shows a typical current (I)-voltage (V) curve collected by the target Langmuir probe. A four-parameter model [1] is fitted to the data to determine the ion saturation current, I_{sat}, and the electron temperature, T_e. I_{sat} from the fit and the collection area of the probe is used to calculate the particle flux, which gives (1.09±0.05)×10^{24} $m^{-2}s^{-1}$. This analysis also reveals that the ion current saturates and negligible sheath expansion effect occurs at a target bias of -50 V. Therefore, we applied a fixed bias voltage of -50 V to the target probe to continuously measure particle flux. A representative discharge is recorded in Fig. 2(b) with an average particle flux of (1.1±0.05)×10^{24} $m^{-2}s^{-1}$ and a pulse duration greater than 1000 s.

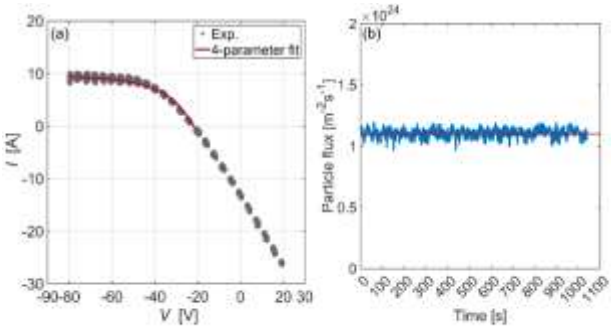

Figure 2. (a) I-V curve and the corresponding fit using the four-parameter model. (b) Continuous particle flux measurement at a fixed target bias voltage of -50 V.

The OES is used to cross-check the flux measured by the target Langmuir probe. To this end, a small amount of 50 sccm hydrogen gas was fed into the plasma source because its line broadening is pronounced but the gas exhaust system is not ready yet. The Boltzmann method [2] is then used to determine T_e, yielding 2.94 eV (Fig. 3a). Due to the scarcity of the hydrogen plasma, only the 434 nm and 486 nm lines were detected. On the other hand, the helium lines were saturated and therefore not usable. Nevertheless, because previous discharges under similar conditions showed that the Boltzmann method is applicable, T_e determined from two data points are not expected to drastically deviate from its true value. Additionally, from the broadening of the hydrogen line in Fig. 3(b), the electron density, n_e, is 3.56×10^{20} m^{-3} [3]. Using the Bohm criterion, the particle flux, Γ_i, is $(1.5\pm0.23)\times10^{24}$ m^{-2}s^{-1}. Both measurements yield consistent results.

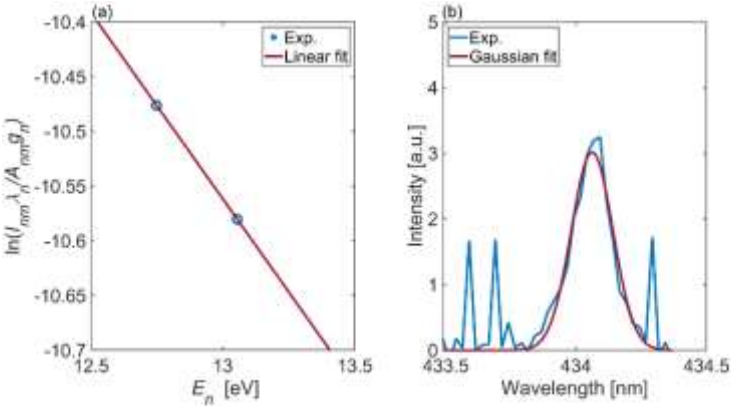

Figure 3 (a) Te determined by the Boltzmann method, and (b) n_e determined by the Stark broadening effect.

In summary, we have achieved >1000 s, >10^{24} m^{-2}s^{-1} continuous helium plasma discharges in the SWORD linear plasma device. At present, only a 0.6 T magnetic field was used during the discharge. With higher magnetic fields in the future, we expect to obtain higher flux discharges, including hydrogen plasmas.

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