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強制冷却型プラズマ電極を利用した負イオン源による負イオンビームの長パルス生成

Production of long pulse negative ion beam by using actively cooled plasma grid

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The negative-ion-based neutral beam injector for JT-60SA is required to provide 500keV, 10 MW D^0 beams for 100s in order to achieve steady-state fusion plasmas. Toward this requirement, 500 keV, 22 A negative ion sources have been developed in Japan Atomic Energy Agency. After the achievement of the 500 keV, 3 A negative ion beams for 0.8 seconds by improving a voltage holding capability in 2009, long pulse productions of the negative ions are being developed. One of key issues for the long pulse beam production is a stable long-pulse production of the negative ions over the large ion extraction area (45cm ×110cm) by optimizing cesium coverage for the high-power arc discharges.

In order to achieve a steady-state production of the negative ions, the surface temperature of the plasma grid (PG) covered with cesium should be sustained to be higher than 150 °C because the high negative ion production requires the high surface temperature of the PG to lower the work function. Hence, the temperature control of the PG is an essential technique for the long pulse production of the negative ions.

Active cooling/heating system is proposed and developed by JAEA to control the surface temperature of the PG. with high-temperature fluid. A fluorine fluid with a boiling point of 270 °C is adopted.

As shown in figure 1, while the temperature of the original PG without control increases linearly during the arc discharge, the developed cooling/heating system controls the PG temperature with a time constant below 10 s, which is faster than the variation time of negative ion production (30s) measured in JT-60U long pulse operations.

By using this temperature-control system, the negative ion production has been kept during the long pulse operation for 100 s. As shown in figure 2, the sustained beam current density was much higher than that without control in an range of >20s. As a result, achieved current density for 100 s reached to 120 A/m^2 which is 90 % of the required value for JT-60SA. Obtained results about the temperature-control capability and the decay time of the negative ion productions will be applied for the design of the JT-60SA negative ion source.

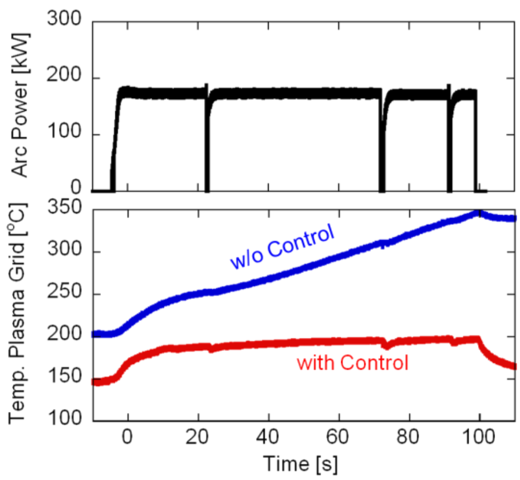

Figure 1. Waveforms of the temperature on the original (w/o control) and new (with control) PGs.

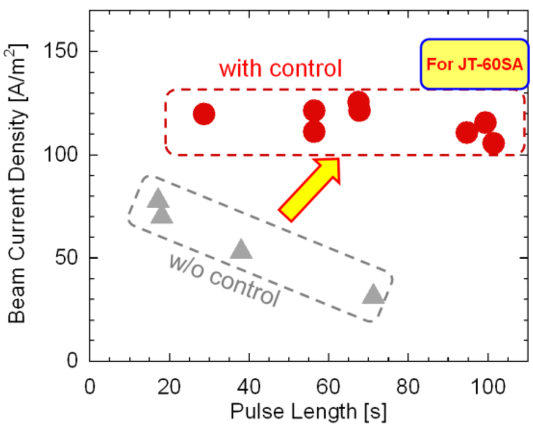

Figure 2. Progress of the long pulse production of the negative ions. The target value for JT-60SA is 130-170 A/m^2 for 100 s.