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[REGULAR POSTER TWIN] 100 seconds negative ion accelerations for JT-60SA negative-ion-based neutral beam injector

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The pulse length of the negative ion beam has been successfully extended over 100 s stably. The beam parameter was 500 keV, 154 A/m^2 for 118 s, which exceeds the requirement of negative ion beams (500 keV, 130 A/m^2, 100 s) for the negative-ion-based neutral beam injector (N-NBI) of JT-60SA. This is the first achievement over 100 s stable beam with intensity of > 75 MW/m^2 required practically in the N-NBI. The beam accelerations were very stable without degradations of the voltage holding due to Cesium. This achievement was realized by integration of i) stable high-voltage insulation, ii) precise beam control technique and iii) stable negative ion production, which is especially described in this paper. These techniques to demonstrate stable operations of high intensity beams can be applicable to the NBIs for ITER and DEMO.

1. Introduction
   In a Cesium (Cs)-seeded negative ion source for JT-60SA negative-ion-based neutral beam injector (N-NBI), the requirement is to produce high intensity beams over 65 MW/m^2 for 100 s of the deuterium/hydrogen negative ions (D^-/H^-) with 500 keV, 22 A (130 A/m^2) from a three-stage electrostatic accelerator [R1]. Though negative ion productions have been examined in various institutes, QST has proceeded high energy beam accelerations with sufficient beam optics and with allowable grid power loadings. MeV-class beams were achieved up to 60 s by improving i) stable high-voltage insulation and ii) precise beam control technique [R2,R3]. In parallel, iii) stable negative ion production was tested by using a large negative ion source for JT-60SA [R1]. The H- ions with 15 A (90 A/m^2) for 100 s was achieved by improving special non-uniformity of negative ions and developing the temperature-controlled plasma grid (PG) to enhance the negative ion production under Cs-seedings. However, a remarkable degradation of the beam current was observed after 60 s. The operational window was also limited due to an abnormal discharge around a filament, so-called arcing. This paper reports the integration test to achieve stable 100 s operation with 500 keV, 130 A/m^2 beams for JT-60SA N-NBI by suppression of the degradation of negative ion current and a protection system of filament from arcing for iii) in addition to i) and ii) [R4].
2. Negative ion beam acceleration from a three-stage accelerator
   The schematic view of this test is shown in Fig.1. The chamber of the negative ion source is a 1/8 scale of the JT-60SA's one. The Cs is introduced in this chamber to lower the work function on the PG where atoms and positive ions as major particles in a plasma are converted to the negative ions by getting electrons. The PG temperature is kept over 200°C to enhance this negative ion production. The accelerator is a three-stage accelerator with the gaps of 88 mm as same as JT-60SA's ones to simulate the beam optics in JT-60SA.
3. Suppression of damage to the filament due to arcing under high power operation
   As past experiences, the arcing at the filament was enhanced due to increases of the input power and increases of impurities in the plasma such as the Cs and the oxygen. In addition, if the arcing happens once, the arcing occurs more frequently, and finally broke the filament after several arcings. Thus, the arcing has limited the performance of the negative ion source with sufficient arc power. To suppress the damage of the filament under the Cs operation, high speed cut-off system of the arc power supply was introduced as shown in Fig.1. This can reduce the input energy to the filament at arcing and protects the filament. Judgement of overcurrent by the arcing and sending a cut-off signal to GTO switch is managed by Field Programmable Gate Array (FPGA) at the high voltage side. Finally, the cut-off duration could be shorten from 1-2 ms to 100 us. This improvement extended a lifetime of filament more than three times longer and contributed to this test.
4. Demonstration of 100 s beam accelerations
   As shown in Fig.2, the negative ion current was gradually decreased for 100 s in the previous test. Simultaneously, the optical light of Cs in the plasma became rather increased with the rise of the chamber temperature. To understand the influence of the increase of Cs in the plasma to the negative ion production, the Cs transportation was numerically examined. This analysis showed that the Cs evaporation from the chamber is drastically increased at the chamber temperature of > 60°C. This evaporated Cs deposits on the PG even if the PG temperature is maintained over 200°C. This result suggests that the required condition to keep high negative ion production is to maintain the temperature balance

between the chamber temperature of < 60°C and the PG temperature of > 200°C. The cooling channel and water flow were modified to keep this temperature balance during long pulse. As the result, the chamber temperature was kept less than 50°C during 100 s, the Cs evaporation was suppressed, and then, the negative ion current became stable. Finally, 75 MW/m^2 beams (500 keV, 154 A/m^2) for 118 s was successfully demonstrated. During operation, the grid power loading by the beams was suppressed less than 5 % of the total beam power, which satisfied the requirement. One breakdown was observed at 80 s. This was occurred in the initial extraction system of the negative ions with around 6 kV and recovered immediately. This type of incidental breakdowns and stable recovers were within the scope of the operational condition for the NBI. This suggests that the beam optics is accordingly good as designed. The total amount of the Cs seeding was 5 g in the 1/8 scale chamber, which corresponds to the amount of the Cs used in annual operation of JT-60SA's chamber. Though the voltage degradation due to the Cs leakage into the accelerator was concerned, 500 kV was sufficiently kept during this test. As shown in Fig.3, the long pulse beam accelerations over 100 s with a practical power density for the N-NBI have been successfully demonstrated, which is the breakthrough toward the long pulse beam acceleration for the N-NBIs.

References

[R1] A. Kojima et. al., Nucl. Fusion 55 (2015) 063006.
[R2] J. Hiratsuka et. al., Proc. 26th IAEA FEC (2016) FIP/1-3Ra.
[R3] A. Kojima et. al., Nucl. Fusion 59 (2019) 086042.
[R4] J. Hiratsuka et al., Rev. Sci. Instrum. 91(2020) 023506.

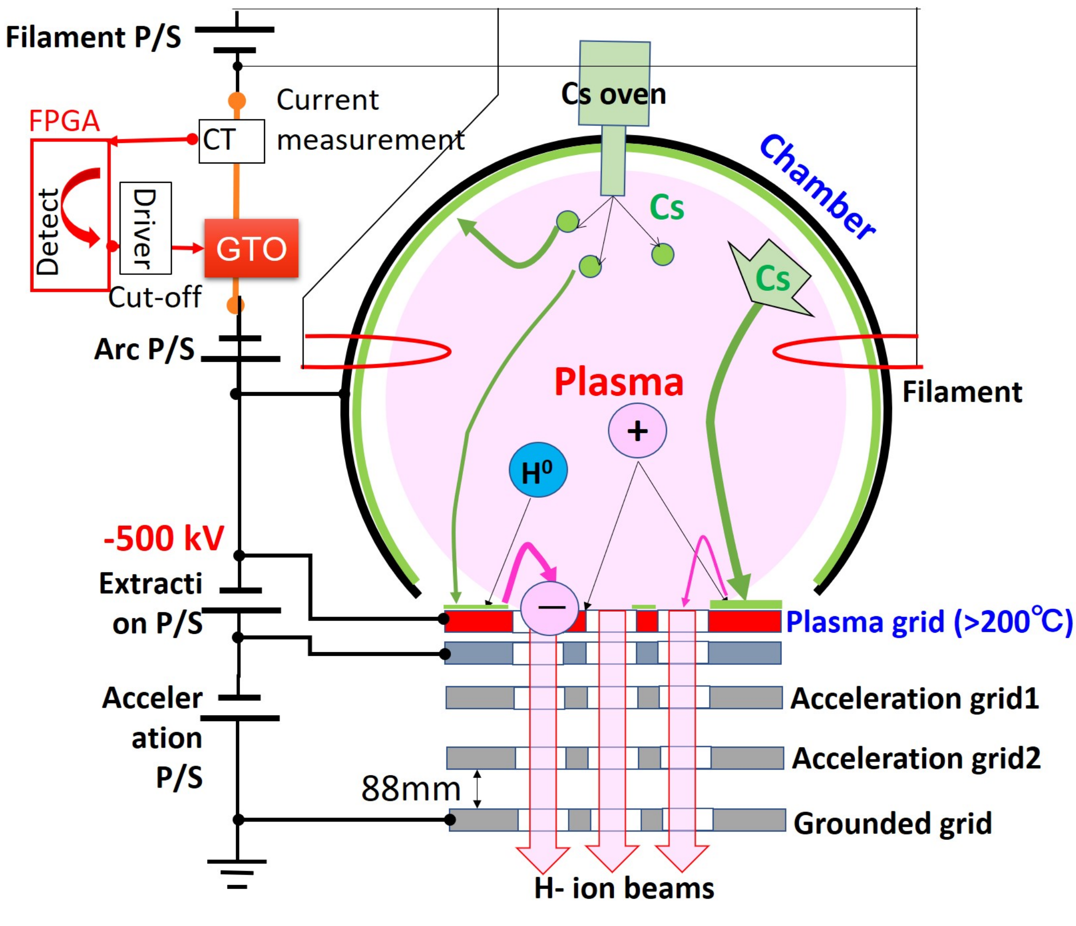

Figure 1: Schematic view of this test.

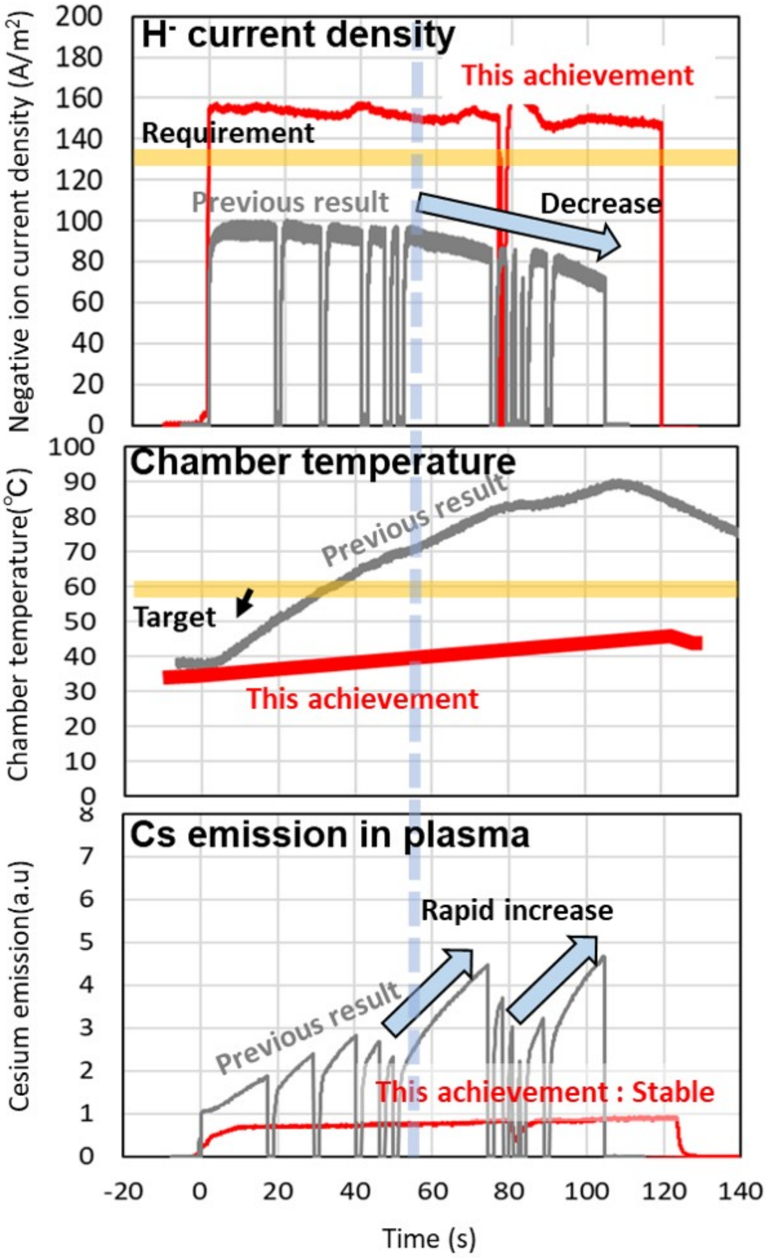

Figure 2: 100 s beam accelerations in the previous test and this test.

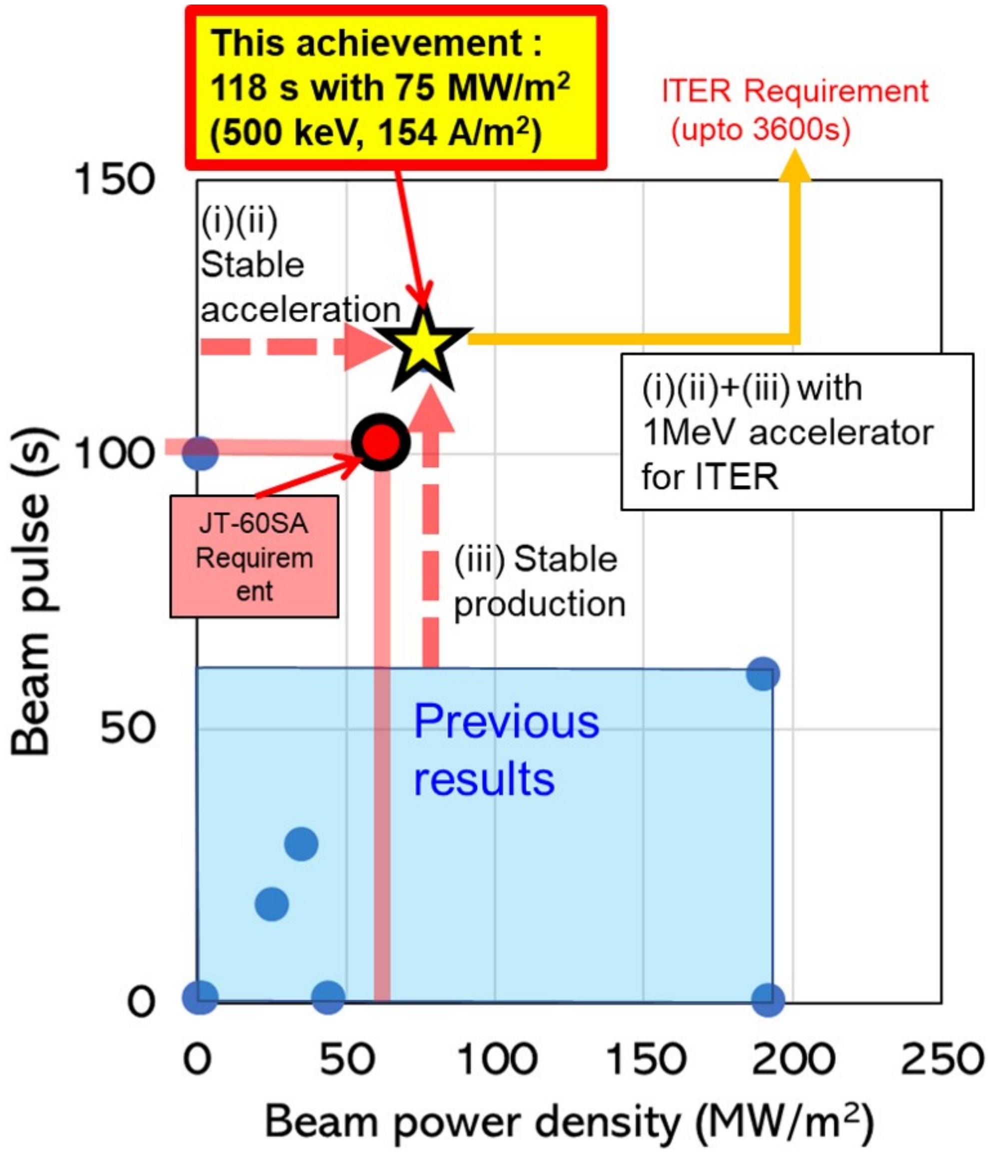

Figure 3: Progress of long pulse test with high intensity beams.

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