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100 seconds negative ion accelerations for JT-60SA negative-ion based NBI

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ABSTRACT

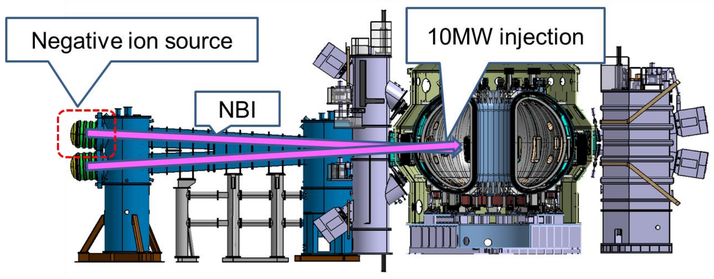
Toward the neutral beam injector (NBI) for JT-60SA, 500 keV, 154 A/m^2 for 118 s H- beams have been successfully demonstrated since last FEC.

This exceeded the requirement of 500 keV, 130 A/m2 for 100 s. To realize this, the followings have been examined and applied to this test.

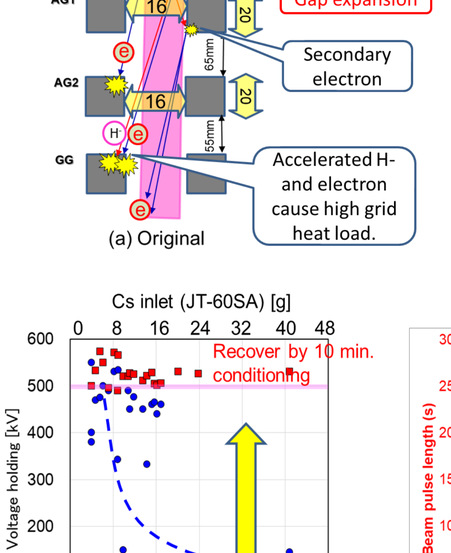
1) Optimum temperature for the stable negative ion production : Chamber wall < 50 ℃, the plasma grid > 200 ℃
2) Precise modification of the accelerator for HV holding and reduction of grid heat load: Expansion gap. Modification of diameter and thickness of grids.

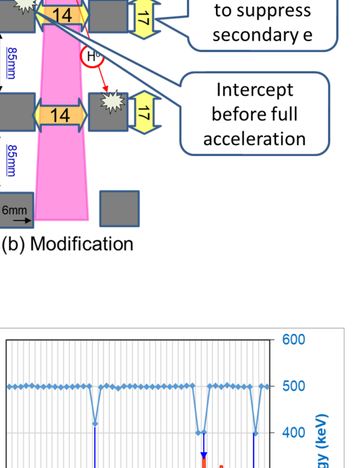
Background

JT-60SA NBI is upgrading from 10 s (JT-60U) to 100 s.
Realization of stable beam acceleration is important for the ITER NBI.



	Requirement	JT-60U	2016 (only extraction)		This achievement
Beam energy (keV)	500	340	10	10	500
D- / H- Current (A)	22	17	32	15	0.3
Current density (A/m^2)	130	102	190	90	154
Pulse (s)	100	30	1	100	118

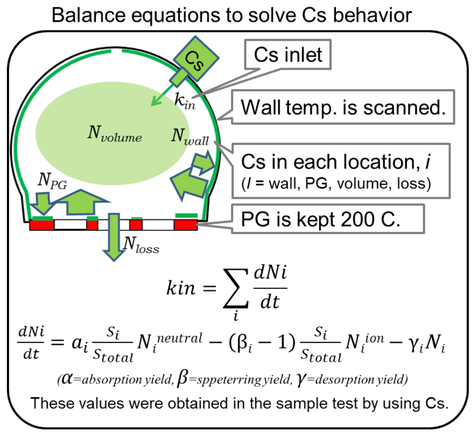




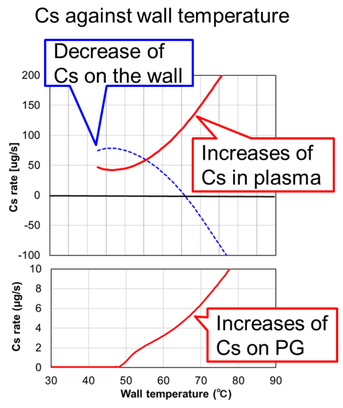
1/8 ion source and the three-stage accelerator was utilized for this test due to facility limitation.

(A) Cause of gradual current decrease

Balance equations to solve Cs behavior

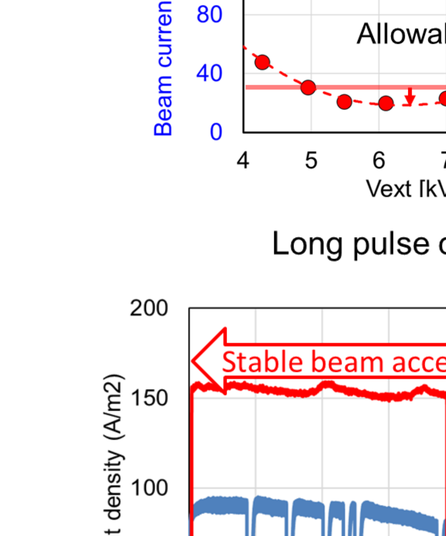


Cs against wall temperature

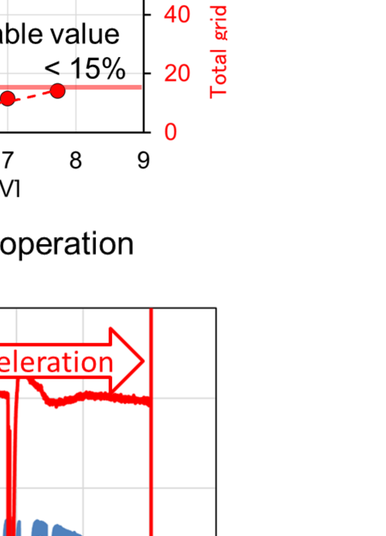


Increases of Cs on PG will change the work function on PG.
This will be a cause of the degradation of the negative ion current.
Temperature during operation should be maintained be to Wall < 50℃, PG > 200℃.

①Movement of water channel



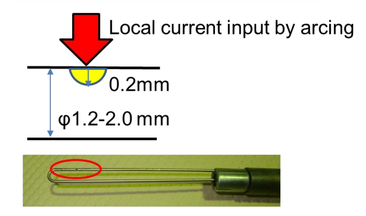
Experimental results



②Water flow rate : 10 L/min to 30 L/min.

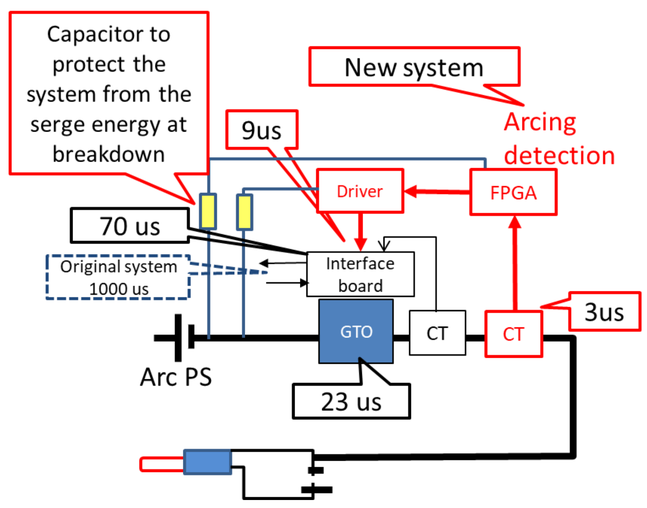
Protection of filament from arcing

Rough estimation of input energy to remove tungsten grain by arcing.



Energy to remove hemisphere of 0.2 mm
- Energy to melt = 0.06 J
- Energy from melt to boil = 0.09 J
- Energy to vaporization = 1.42 J

Totally 1.57 J

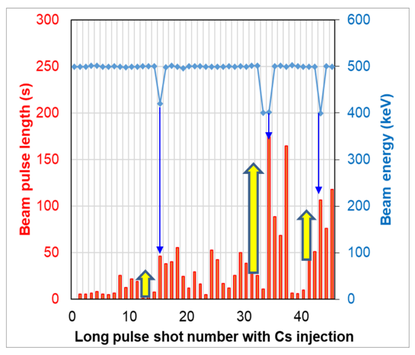


Fast cut-off system at arcing : 0.1 ms Filament lifetime 3 times longer.
Capacitor to protect the system from 500 kV breakdown worked effectively.

(B) Toward demonstration of stable beam

Insufficient voltage holding has been improved to expand the acceleration gap.
To reduce the grid heat load less than allowable value 15 % of the total beam power, following techniques developed for the stable beam were applied to this test.

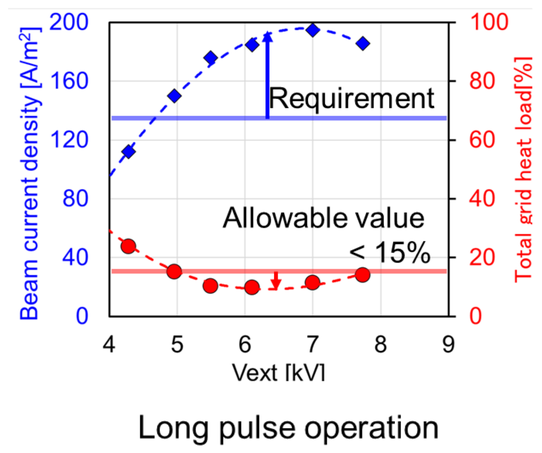
(a) Voltage in beginning of a day and conditioning



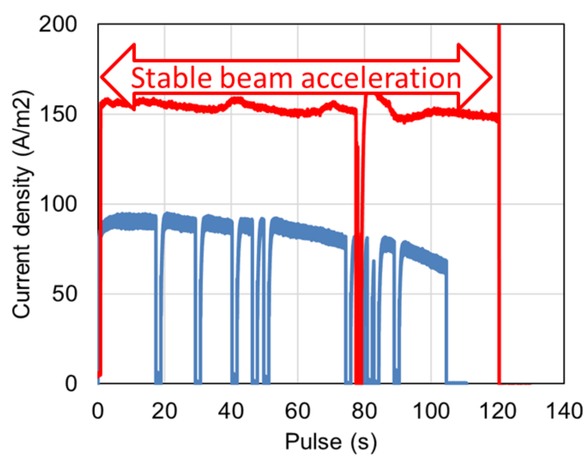
(b) Low energy conditioning to extend the pulse length

Stable beam acceleration at 500 keV

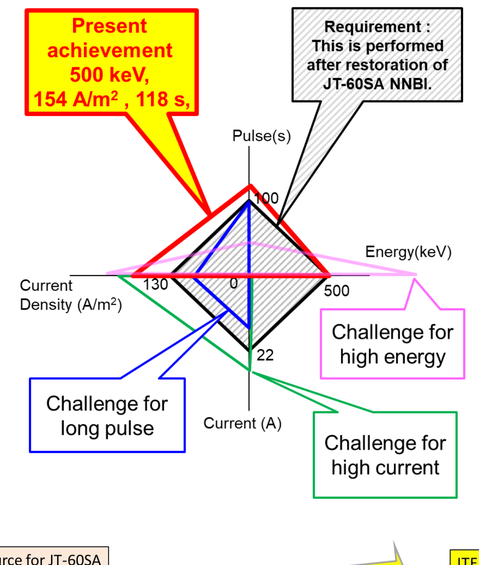
Grid heat load and current density

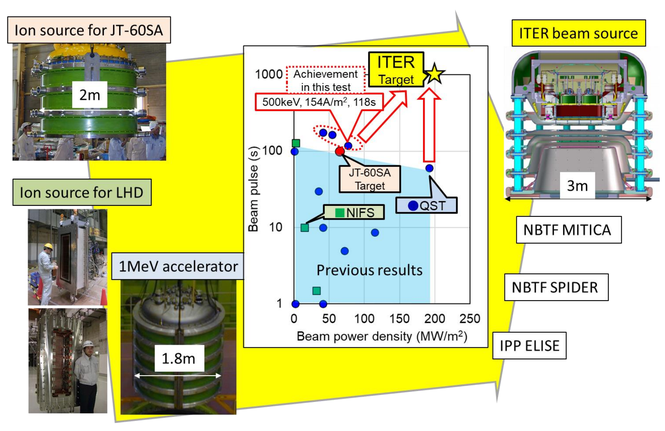


Long pulse operation



Achievement





CONCLUSION

500 keV, 154 A/m^2 for 118 s H- beam has been achieved, which exceeds the requirement of JT-60SA. To produce the negative ions stably, the important point is to maintain the wall temperature of < 50 C to suppress excess Cs evaporation from the wall and excess Cs deposition on the PG. The accelerator was modified to reduce the grid heat loads for long pulse operation based on the previous experiences. By achieving the stable beam acceleration, the conditioning methods of the high energy accelerator with Cs were able to examined. The physics mechanism will be discussed in further discussion. These results contribute to re-start JT-60SA NBI and more long pulse test in QST to conclude design for the ITER accelerator.