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Improvements of stable negative ion production for long pulse beam operation toward the negative ion source for JT-60SA

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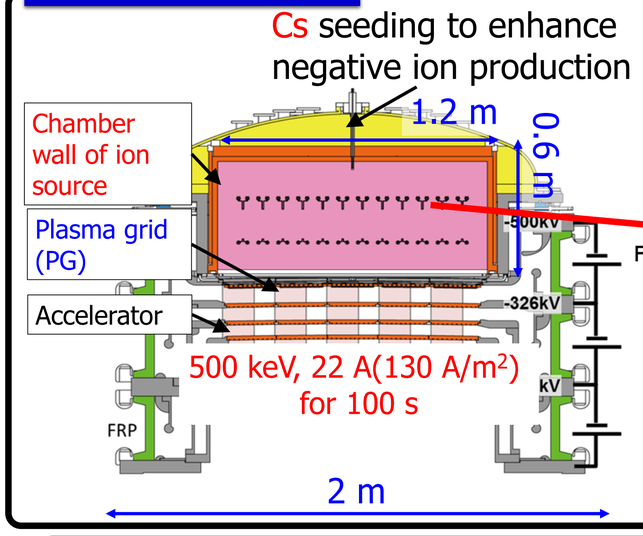
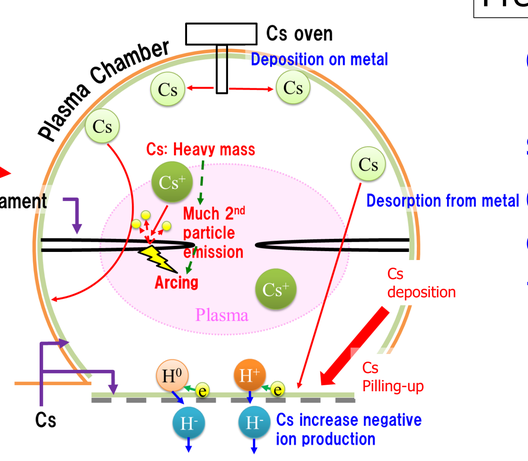
Overview and Summary

JT-60SA operation will be started in 2020, and neutral beam injection (NBI) will be started from 2023. For this target, stable H^- negative ion production and acceleration, 500keV, 156 A/m^2, 118 s, which fulfill to the requirement of the Cesium(Cs) seeded negative ion source of JT-60SA, has been demonstrated in 2019 by using 1/8 ion source. As next step to full size, the following modification and new development have been performed.

- Filament damage due to arcing has been drastically reduced and the lifetime of a filament is extended 3 times longer by developing fast cut-off system of the power supply. The operational principal established in the test simulation 1 of 8 group was extended to all 8 groups.
- Increment of negative ion current density has been investigated. The heat transfer of air cooling plasma grid (PG) was investigated using prototype PG and plasma of 30 kW/m^2. New PG for negative ion production was designed based on the information.

Introduction





Present status for ion source for JT-60SA

① Arcing increases if impurities such O and Cs increases
- A fast arc P/S cut-off system achieve reducing filament damage due to arcing in 1/8 scale ion source. Application of the system to the ion source for JT-60SA is in progress.

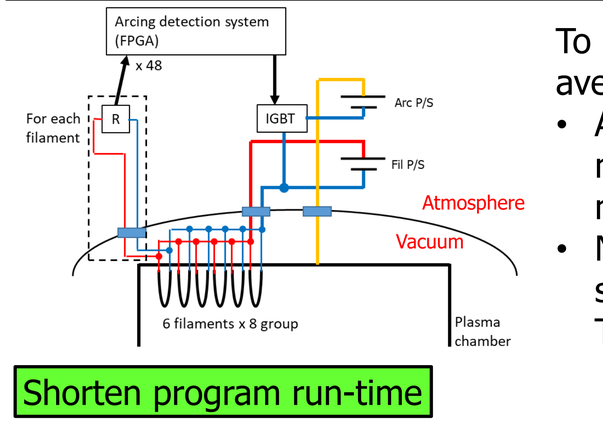
② More beam current density is required due to the limitation of uniform beam extraction area.
- A method to control PG temperature at range of 200~300 ºC is developing.

③ Modification for D^- operation
- Modifying arrangement of magnets to improve beam current uniformity and suppress electron current is in progress. – will be presented by Y. Shimabukuro in P2 session, 8th-Sep.

Reduction of filament damage due to arcing

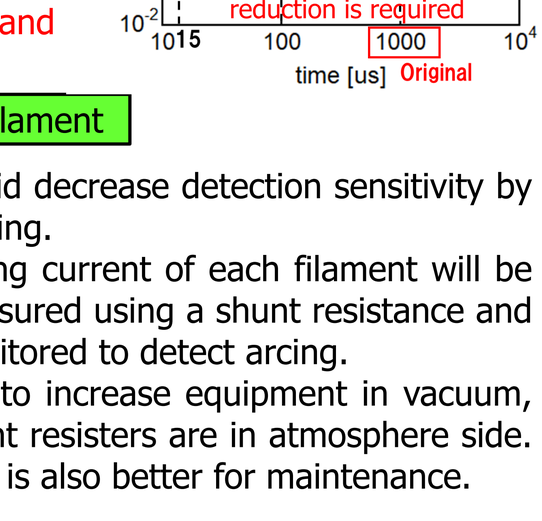
Improvement to reduce cut off time

Cut-off time 1 ms -> 100 μs



Arcing damage was suppressed and lifetime of a filament was extended 3 times longer.

This result contributed to achievement of 500 keV, 158 A/m^2 and 118 s beam in the test using 1/8 scale prototype ion source.

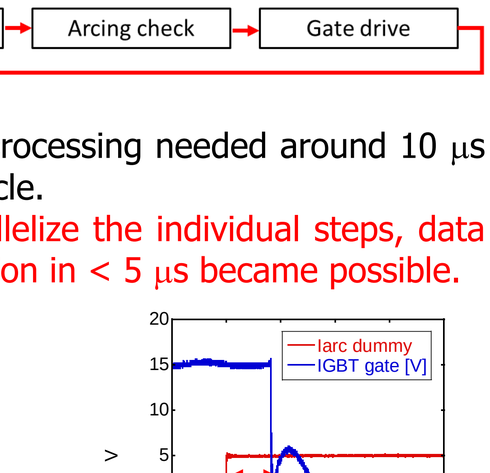


M. Ichikawa, et. al., Rev. Sci. Instru. 91, 023506 (2020)

Application to the ion source for JT-60SA

The arc power supply system of the1/8 scale small ion source simulates 1 of 8 groups in the ion source for JT-60SA.
The fast cut-off system can applied the ion source for JT-60SA directly.

Because applied arc current is almost 10 times larger than small ion source, it is considered arcing current (arcing damage) is larger and faster cut-off time is required.



Monitor arcing current of each individual filament

To avoid decrease detection sensitivity by averaging.
- Arcing current of each filament will be measured using a shunt resistance and monitored to detect arcing.
- Not to increase equipment in vacuum, shunt resisters are in atmosphere side. This is also better for maintenance.

Shorten program run-time

Old flow (series processing)

New flow

Series processing needed around 10 μs for 1 cycle.
By parallelize the individual steps, data acquisition in < 5 μs became possible.

Result of time saving modification

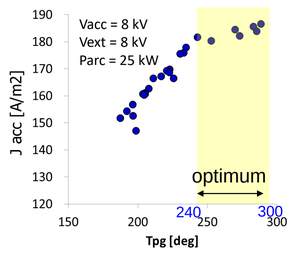
Detection → Program run time → P/S turn off

Monitoring each filament — Parallelize — GTO -> IGBT

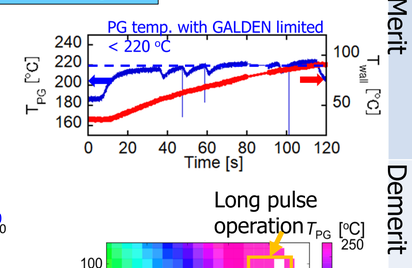
To be measured

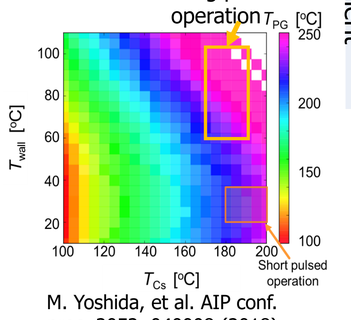
Suppression of beam current degradation

Requirment for PG temp.



Optimum temp. (~250 ºC) is higher than the conventional controlled temp. (~220 ºC).



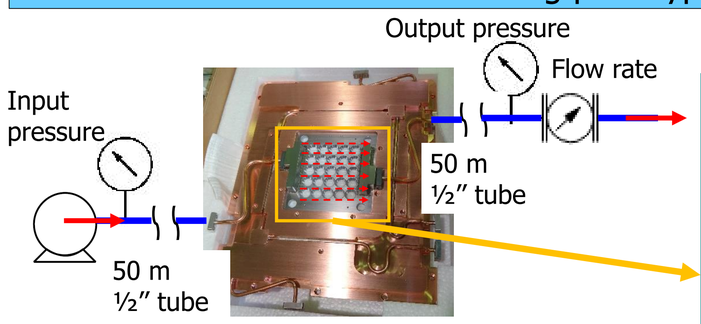


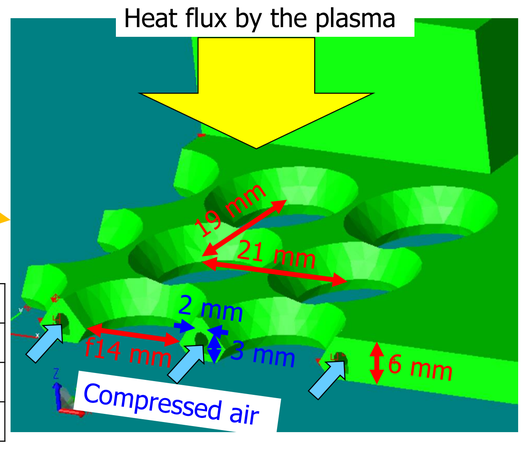
M. Yoshida, et al. AIP conf. proc. 2052, 040008 (2018)

	Hot water	GALDEN	Air
Merit	•Large heat transfer	•200 ºC at normal temp. and pressure •Insulator	•No limitation about temp. •Easy to handle
Demerit	•Difficult to raise temp. above 200 ºC •Leak current	•Risk of decomposition above 200ºC	•Low heat transfer

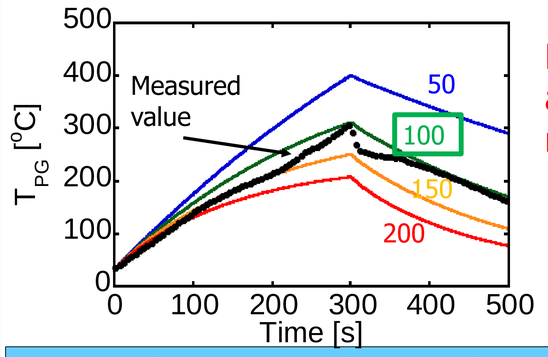
Air was considered as new coolant.
Its heat transfer coefficient required for designing new PG was investigated using prototype.

Measurement of heat transfer using prototype air-cooling PG



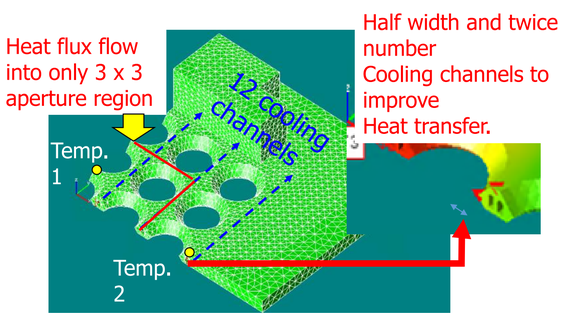


Input pressure	0.65 MPa
Output pressure	0.50 MPa
Flow rate	58 NL/min
Heat flux	30 kW/m^2 (1/2 of nominal value)

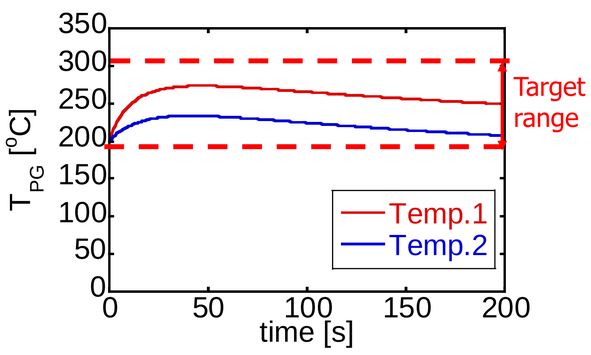


Heat transfer coefficient was estimated as 100 W/m^{2}K by compering between measured value and calculation.

Design of new air-cooling PG for negative ion production



Input pressure	0.65 MPa
Output pressure	0.50 MPa
Flow rate	58 NL/min
Heat flux	70 kW/m^2 (Nominal value)



The PG which can keep target temperature range in over 100 s pulse with nominal arc power was designed.

Maintaining negative ion production by controlling PG temperature in higher range will be confirmed.