Impurities Reduction Conditionings to Recover Best Beam Quality of J-PARC Cesiated RF-Driven H^- Ion Source with New Parts Exposed to Plasma

Akira UENO, Kiyonori OHKOSHI, Kiyoshi IKEGAMI, and Hidetomo OGURI

J-PARC Center, Tokai-mura, Naka-gun, Ibaraki-ken 319-1195, Japan (akira.ueno@j-parc.jp)

Introduction

The J-PARC cesiated RF-driven H^- ion source (IS) is successfully suppling about 58 mA beam with a duty factor of 1.25 % (0.5 ms 25 Hz) for the ordinary J-PARC LINAC 50-mA operations and about 72 mA beam for the 60-mA acceleration studies for a few days at each end of the operation of about 3 months by using the internal-RF-antenna developed at the Spallation Neutron Source (SNS). For the J-PARC operations, only three plasma chambers (PCHs) of #7, #8 and #9PCHs among ten PCHs have been used since the transverse emittances of the beams produced with them are more superior than those with others for unknown reasons. However, the #7PCH beam emittances were enlarged by 16 % with a brand-new plasma electrode (PE) temperature control plate (PETCP) to solve the air leak at the VCR vacuum fitting. The impurities from the new parts exposed to the plasma seemed to cause the degradation. The results of the impurities reduction conditionings (IRCs) performed on #4PCH with a brand-new PETCP are presented. Since the most likely parts, from which the impurities were released by the plasma bombardments and/or heating for a very long duration, were the 99.7 % alumina tubes covering the PETCP stainless-steel (SS) tubes for the PE temperature control air flow inside, sapphire (purity 99.9 %) tubes were installed instead of the alumina tubes for #4PCH.

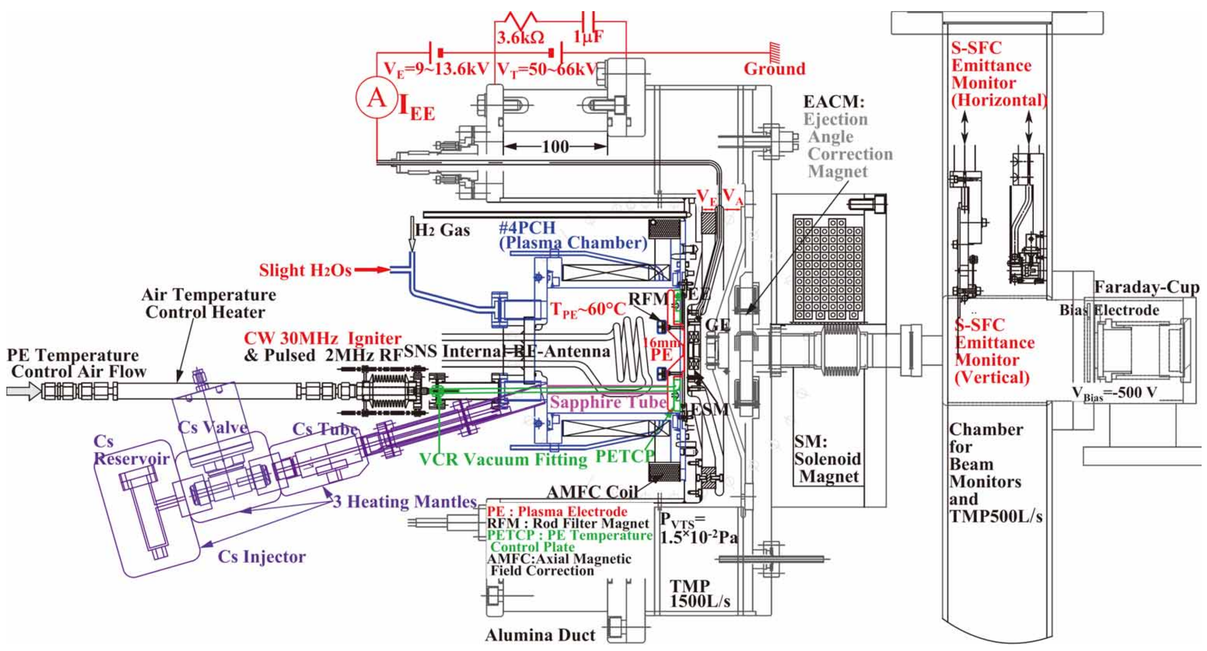

Fig.1 Cross-sectional view of experimental setup of J-PARC IS test-stand.

Impurities Reduction Conditionings (IRCs)

Day1 : At first, 95% beam transverse normalized rms emittances ($_{95\%nrmsx/y}$) of H^- ion beam intensity (I_H-) of 72mA was measured as 0.239/0.260 mm•mrad, after shortest start-up. Next, 15-min plasma operations with 2-MHz RF power (P_{2MHz}) of 33.4, 37.6, 41.8, 45.9 and 50kW with 2.5%(0.5ms 25Hz) duty factor, plasma electrode temperature (T_{PE}) of 454°C, Cs-valve open and Cs-reservoir temperature (T_R) of 100°C (after each operation P_{V1} lower than 1 10^{-5} Pa was waited).

Day2, 4 and 5 : P_{2MHz} and axial magnetic field (AMF) correction (AMFC) scanning plasma operations with P_{2MHz} between 14.7 and 50kW, AMFC between -1311 and 1311 AT, extraction voltage (V_E) and H^- ion beam energy (W_H-) of 4 kV and 52.5 keV and a duty factor of 5%(1ms 25Hz) as shown in Figs.2(a), (b) and (c) are performed. AMF inside of #4PCH produced with solenoid magnet (SM) fringe field {I_{SM}=300A(42000AT)} and AMFC between -1311 and 1311 AT were calculated with Poisson code [6] as shown in Fig.3.

Day3 : $_{95\%nrmsx/y}$(72mA)=0.225/0.253 mm•mra and IRCs.

Day6 : After remaining P_{2MHz} and AMFC scanning operations, I_H-=72mA was impossible for W_H-=52.5keV due to impurities on PE.

Day6 : P_{2MHz} (22.1~29.2 kW) and AMFC (-1109~-303) scanning plasma operations as shown in Fig. 2(d). The operation parameters for the IRCs are listed in the 1st row of Table 1.

Day7 and 8 : Full maintenance (inner surfaces clean-up et. al.).

Day9~12 : $_{95\%nrmsx/y}$ of 72- and 110-mA beams were reproducibly measured as 0.204/0.236 and 0.220/0.263 mm•mrad, respectively.

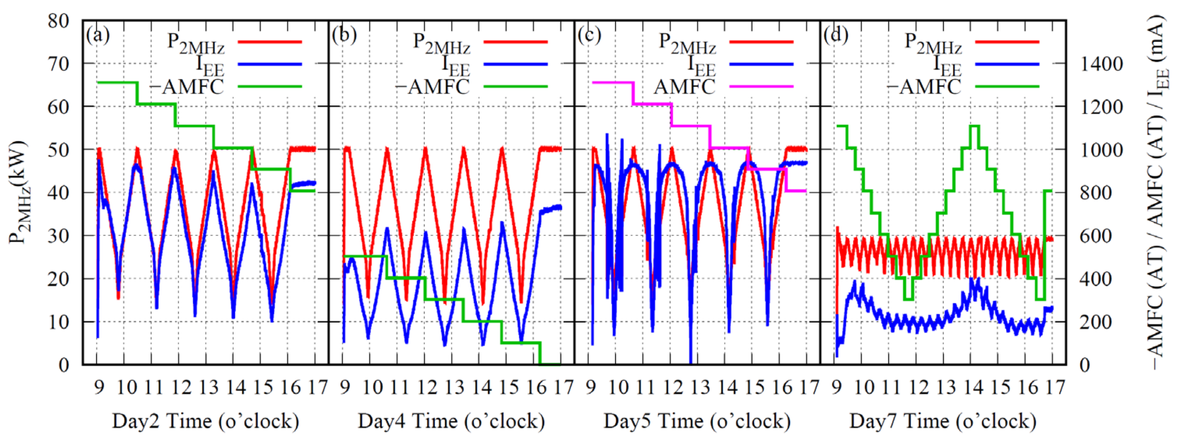

Fig.2. Trends of P_{2MHz}, I_{EE} and AMFC in IRCs on Day2(a), 4(b), 5(c) and 7(d).

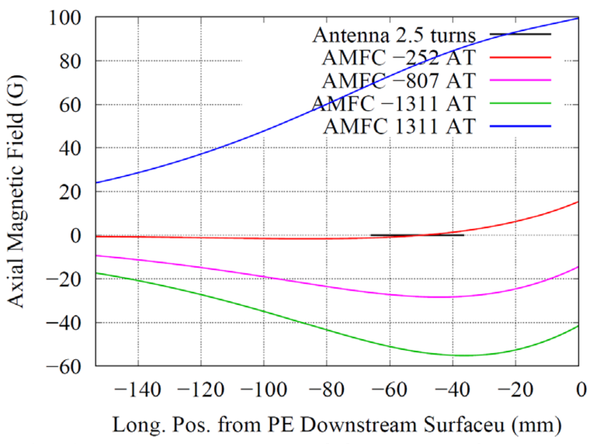

Fig.3 Antena position and AMF calculated with Poisson code.

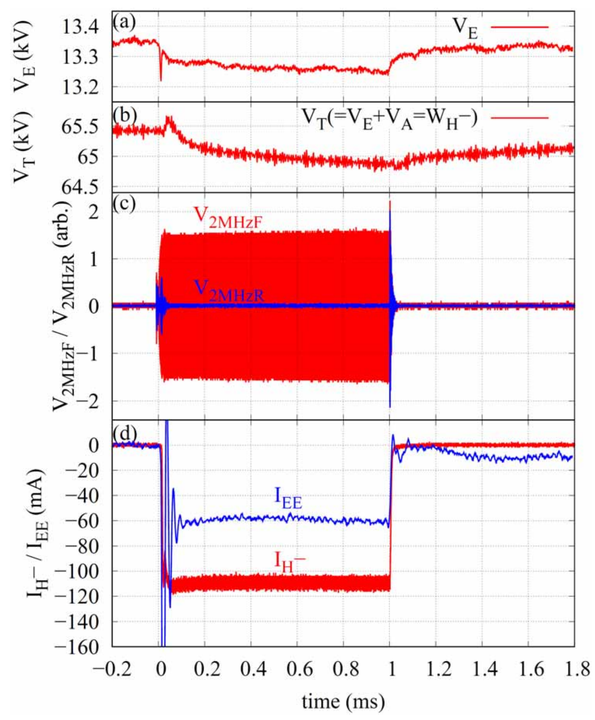

Fig.6. Waveforms of 110mA beam.

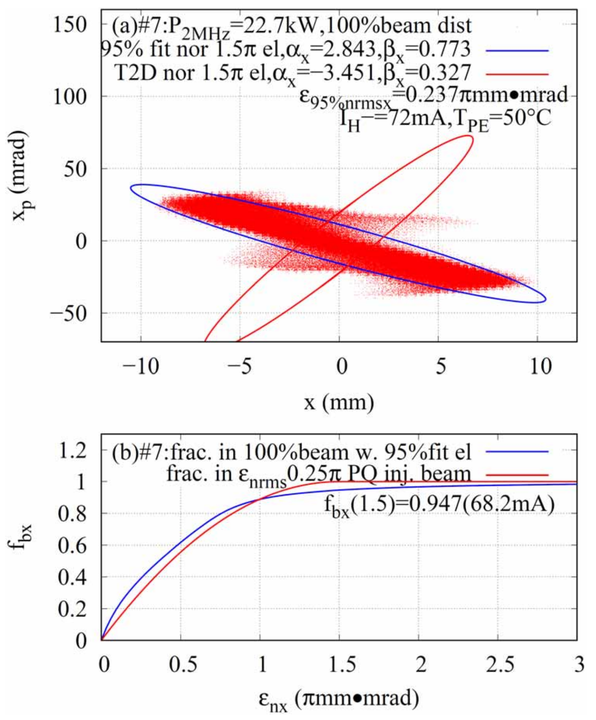

Fig.4. 100% beam distribution in horizontal phase-plane and fitted ellipses (a) and beam fractions in $_{nx}$ (b) of 72-mA beam without IRCs.

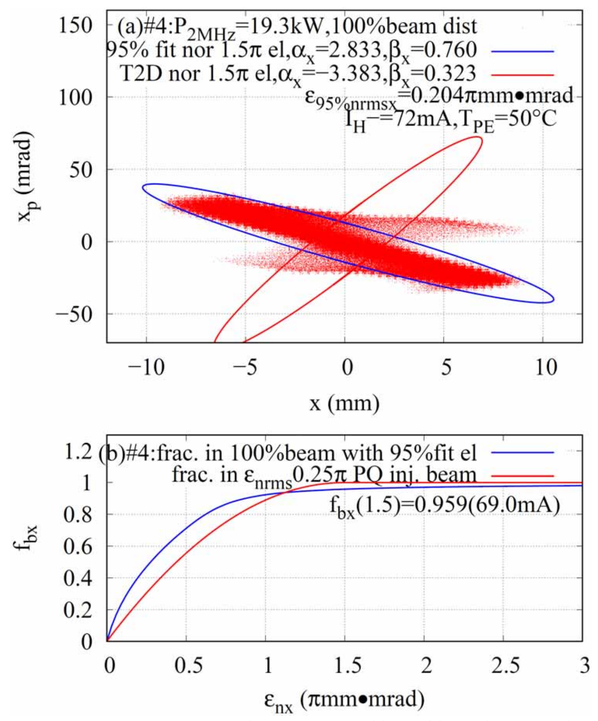

Fig.5. 100% beam distribution in horizontal phase-plane and fitted ellipses (a) and beam fractions in $_{nx}$ (b) of 72-mA beam after IRCs.

Table 1. Parameters for IRCs and 72- and 110-mA operations.

	IRCs	I_H-=72 mA	I_H-=110 mA
H_2 gas flow rate	17 SCCM	17 SCCM	17 SCCM
CW 30-MHz-RF power	42 W	42 W	42 W
2-MHz-RF duty factor	5%	5%	4.5%
~Beam duty factor			*For permitted 5mA average.
Beam energy (W_H- = V_T)	52.5 keV	52.5 keV	65 keV
Extraction Voltage (V_E)	4 kV	10.4 kV	13.25 kV
2-MHz-RF power (P_{2MHz})	16~50 kW	19.3 kW	28.6 kW
Ex. Electrode Current (I_{EE})	-	27 mA	59 mA
RF power efficiency	-	3.73 mA/ kW	3.85 mA/kW
I_H- density at PE (ϕ_{PE}=9mm)	-	1245 A/m²	1729 A/m²
Plasma electrode temp.(T_{PE})	454 °C	~50 °C	~60 °C
Solenoid magnet current	300A:42000AT	350A:49000AT	390A:54600 AT
AMFC coil current	-167.84~167.84A (-1315~1315AT)	0 A (0 AT)	0 A (0 AT)

Conclusions

The third PCH indispensable for the J-PARC operations as the backup providing against accidents was restored by performing the IRCs for 48 hours, in which the impurities produced by the plasma were reduced as small as possible by scanning both of 2-MHz-RF power and axial magnetic field, on #4PCH with a brand-new PETCP. Not only $_{95\%nrmsx/y}$ of 72-mA beam satisfied the J-PARC requirements, but also RF efficiencies and I_{EE} of both of 72- and 110-mA beams were much improved. After the IRCs, the full maintenance of #4pCH, in which the inner surfaces were cleaned up and the antenna was replaced to brand-new one, was mandatory to recover the H^- ion production efficiency decreased due to the impurities on PE surface. The sapphire tubes instead of the alumina tubes should contributed to reduce the time of the IRCs.

Acknowledgment

The authors express their sincere thanks to Dr. Martin P. Stockli of the SNS and the SNS ion-source group members for their support to purchase antennas and their information on the SNS H^- ion-source.