

# Present Status of the J-PARC Cesium RF-driven H<sup>-</sup> Ion Source



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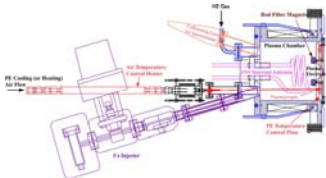
## ABSTRACT

Operation of a cesiated RF-driven negative hydrogen ion source was initiated in September 2014 in response to the requirements of beam current upgrade in J-PARC linac. Delivery of the required beam current from the ion source to the J-PARC accelerators has been successfully performed. In 2016-2017 campaign, **continuous operation of the ion source for 1,845 hours** (RUN#75 from April to July 2017) was achieved with beam current, RF macro pulse width and repetition of 45 mA, 0.8 ms and 25 Hz, respectively. We present the operation status of the ion source and a **high current H<sup>-</sup> beam with 70 mA extracted from the ion source** for further high-power upgrade in J-PARC accelerators.

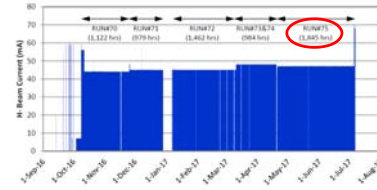
## J-PARC cesiated RF-driven H<sup>-</sup> ion source and operation status in 2016/2017 campaign

The J-PARC cesiated RF-driven H<sup>-</sup> ion source has been fully studied at an off-line test stand [1] and the operation of the ion source at the J-PARC front-end has been successfully providing the required beam current to the accelerators. In this poster, the operation status of the H<sup>-</sup> ion source for the J-PARC accelerators after the previous report [2] is presented.

From the RUN#68 in April 2016, the beam run cycle was extended from 1.5 months up to 2.5 months. In the RUN#75, **1,845 hours continuous operation** was achieved with a beam current of 47 mA. The ion source was operated in two modes; user operation mode and accelerator study mode. In the user operation mode, the H<sup>-</sup> beam current of approximately 45 mA was extracted from the ion source. While the H<sup>-</sup> beam current more than 50 mA was extracted in the accelerator study mode. On the final day (6<sup>th</sup> July 2017) of the 2016/2017 campaign (RUN#75), the **H<sup>-</sup> beam current of approximately 70 mA was extracted from the ion source** as the first step aimed for demonstration of the beam power of 1.5 MW-equivalent at the RCS in a few years [3]. The ion source parameters for the user operation and those at the 68 mA extraction, that was fixed value after the fine tuning for the linac beam study, are listed in the Table. During the 2016/2017 campaign, the ion source has been stable and successfully provided the H<sup>-</sup> beam with the required current to the J-PARC accelerators without any serious issues causing long-term interruptions.



Cross-sectional view of the J-PARC RF-driven H<sup>-</sup> ion source.



Operation history of the J-PARC cesiated RF-driven H<sup>-</sup> ion source in 2016/2017 campaign.

Ion source parameters at 47 mA for user operation mode and those at 68 mA for accelerator study mode.

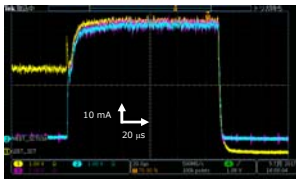
Parameters	H <sup>-</sup> beam current of 47 mA	H <sup>-</sup> beam current of 68 mA
RF pulse length (ms)/repetition (Hz)	0.8 / 25	
Extraction /Acceleration Voltage (kV)	9.8 / 43.0	
2 MHz RF power (kW)	22.4	25.2
H <sub>2</sub> gas flow rate (sccm)	24.0	23.0
Vertical/Horizontal steering magnet current (A)	-3.5 / -2.0	-5.0 / -4.0
LEBT solenoid magnet 1/2 current (A)	460 / 600	500 / 660

## High-intensity H<sup>-</sup> beam current operation for linac beam study

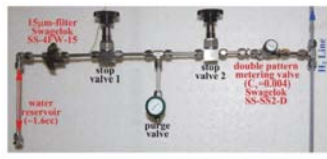
The ion source produced H<sup>-</sup> beam with the current of approximately 70 mA for a linac beam study. At the first shot of the beam study, the beam current of **70.4 mA was extracted from the ion source**, and that of 60.8 mA at the MEBT1 (downstream of the RFQ) was measured. **After the fine tuning** of the solenoid magnetic field and the steering magnetic field, the **H<sup>-</sup> beam with the current of 62 mA was measured at the MEBT1**.

Emittance increase is worried about in the higher beam current operation. Recently, Ueno *et al.* reported the effect of the H<sub>2</sub>O feeding for improvement of the beam emittance [4]. An H<sub>2</sub>O feeder was installed in the hydrogen gas line of the ion source for the J-PARC linac in the summer of 2017. We expect the improvement of the beam transmission to the RFQ by using this technique.

The lifetime of the internal antenna remains an issue for expanding the continuous operations. A test bench [5] will be employed for investigation of the lifetime of the antenna.



Waveforms of the H<sup>-</sup> beam current measured by Slow Current Transformers (SCT). The H<sup>-</sup> beam current of 70.4 mA at MEBT\_SCT (Yellow), 60.8 mA at MEBT\_SCT03A (Cyan), 60.4 mA at MEBT\_SCT03B (Magenta), respectively.



Photograph of an H<sub>2</sub>O feeder for improvement of the beam emittance (referred from [4]).

## Development of J-PARC internal antenna

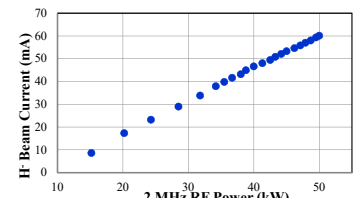
In J-PARC, development of an internal antenna was initiated in order to deeply understand the characteristics of the antenna and establish the manufacturing procedure. **A plasma was produced by a prototype antenna attached to the J-PARC RF-driven ion source and a preliminary result of H<sup>-</sup> beam test was obtained** [6]. Further investigation is necessary to adopt the antenna to the ion source for J-PARC linac operation.



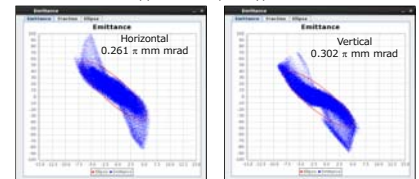
Photograph of the SNS-developed RF-antenna (upper) and a J-PARC prototype one (lower).



Waveforms of H<sup>-</sup> beam from the ion source using a J-PARC antenna, RF powers (forward and reflect) and extraction current.



H<sup>-</sup> beam current extracted from the ion source plotted as a function of 2 MHz RF power applied to the prototype antenna.



Normalized RMS emittances of H<sup>-</sup> beam of 55 mA extracted from the ion source with a J-PARC antenna.

## SUMMARY

The J-PARC cesiated RF-driven H<sup>-</sup> ion source is being operated since September 2014 without any serious issues. In the 2016/2017 campaign, the continuous operation of the ion source for the J-PARC linac approximately 1,840 hours was achieved. A high-intensity trial was executed in this campaign as the first step aiming for demonstration of the beam power of 1.5 MW-equivalent at the RCS in a few years. The beam current of 68 mA was extracted from the ion source and maximum beam current of 62 mA was measured at the RFQ exit. The emittance improvement technique by slight H<sub>2</sub>O feeding is expected to become better transmission to the RFQ. The macro pulse length of the H<sup>-</sup> beam will be increased from 0.5 ms to 0.6 ms for the next step of the 1.5 MW-equivalent demonstration.

## References

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