## §3. Absolute Negative Ion Density Measured with Cavity Ringdown Method in Negative-Hydrogen-Ion-Source Plasma

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Negative-ion-based neutral beam is required for the neutral beam system with the energy of more than 100 keV, as LHD, ITER and DEMO. One of the most important subject for improving the negative ion source, IS, is to produce high negative hydrogen ion density and efficiently to extract negative hydrogen ion. The absolute negative ion density $n(H^-)$ measurement during beam extraction is required for studying this subject. The density $n(H^-)$ is measured with some techneques; laser photodetouchment with Langmuir probe, direct absoption spectroscopy, optical emission spectroscopy, and Cavity RingDown (CRD)[1]. CRD is the unique available method for fitting the purpose in those technique.

Figure 1 shows a schemetic view of a CRD system on a negative-ion-source for development, which has a half arc volume and two fifth beam extraction area compared with the negative IS of LHD-NBI. The principle of CRD method is followings. A laser pulse is injected to an input side of a high reflective mirror of an optical cavity. The laser light gradually exits both side of the mirror with reciprocating in the cavity. A photo-detector is installed on the other side (laser output side). The exponential decay signal is observed with the photo-detector as is shown in Fig. 2, even if no measuring object is in the cavity. If measuring object exists and reacts with the laser is in the cavity, the decay time (ringdown time) decreases. The line average density $n$ on the laser pass can be evaluated by comparing the ring-down time with the measuring object to that without one, as is following equation,

$$n=\frac{1}{c}\cdot\left(\frac{1}{\tau}-\frac{1}{\tau_0}\right)\cdot\frac{d}{L}\cdot\frac{1}{\sigma} \quad ,$$

where $c$ is light speed, the variables $d$ and $L$ are lenghts of a optical cavity and a laser pass in measuring object, respectively, and $\sigma$ is the reaction cross section between phton and measuring object particle.

In the CRD system, a Nd-YAG laser with the wavelength of 1064 nm was applied. Cavity mirrors seperated by 1.2 m are mounted on flanges connected an isolation flange of the IS for diagnostics between arc chamber and plasma grid (PG) flange. The laser passes through about 10 mm far from the PG and upper extraction apertures. The output laser transmitted in an optical fiber is detected an InGaAs-Diode detector.

The density $n(H^-)$ is $3.3 \times 10^{16}$ $m^{-3}$ in the Fig. 1 case where arc power is 72 kW and introduced $H_2$ gas pressure is 0.34 Pa without Cs vapor and beam extraction. Assuming Bohm criterion and Child-Langmuir law, the density $n(H^-)$ nearby extraction surface evaluated from negative ion current measured with downstream calorymetric arry is the same order. A dependece of the negative ion current $I(H^-)$ on $n(H^-)$ measured with CRD is shown in Fig. 3. Here, an operation parameter changes only arc power, introduced $H_2$ gas pressure is 0.4 Pa. In this condition, the current $I(H^-)$ is proportional to $n(H^-)$.

The CRD system was installed on the IS for development, and the absolute density $n(H^-)$ was measured with the CRD system and is proportional to $I$(H-).

[1]NAKANO H. et al., *19th International Toki Conference* P2-67, Toki, Japan, December 8 - 11, 2009.

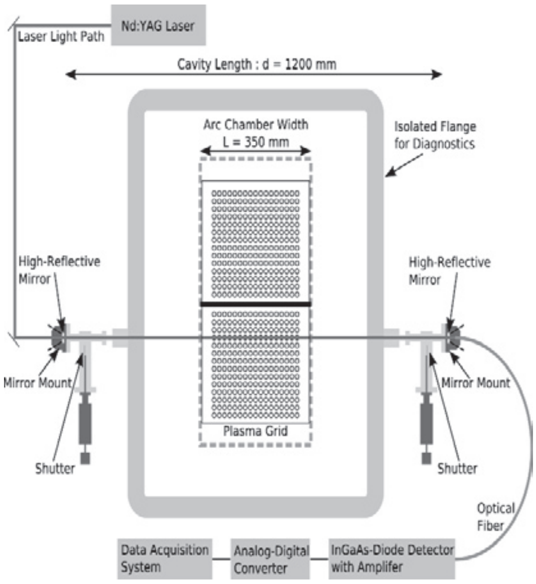


Fig. 1 Schematic view of CRD system on the ion source for development.

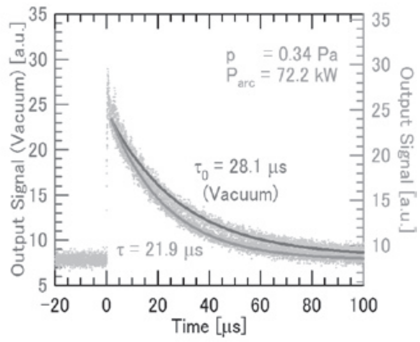


Fig. 2 Ringdown signals obserbed with CRD on the negative ion source. Constants $\tau_0$ and $\tau$ are ringdown times with and without plasmas, respectively.

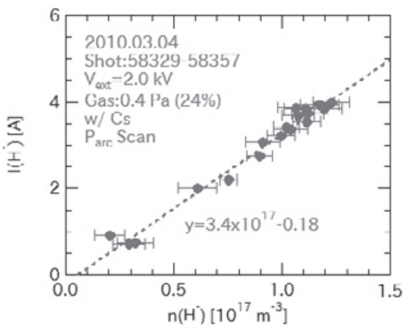


Fig. 3 The dependence of accelerated negative ion current on negative ion density nearby extraction surface.