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Consideration of Negative Hydrogen Ion Temperature Measurement with Cavity Ringdown Method

光共振器を利用した水素負イオン温度計測法の検討

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Negative hydrogen ion is utilized high-energy neutral beam injector. The mechanism from negative hydrogen ion production to extraction as beam is not understood well enough. The temperature of negative hydrogen ion is one of the important values to understand it. However, it is difficult to measure the temperature with optical emission spectroscopy and normal laser absorption spectroscopy due to no emission from negative hydrogen ion itself in plasma and broad absorption spectrum. Here, new concept of negative hydrogen ion temperature is considered by developing cavity ringdown method. This concept utilizes two measure lines. One is normal cavity ringdown method. Another is high laser input one. The design calculation was performed, and its feasibility was found.

1. Introduction

Negative hydrogen ion (H$^-$) is utilized for plasma source of high-energy neutral-beam injector and is considered to exist in detached plasma in diverter region of fusion device. The behavior and physical role of H$^-$ are not fully understood. In the plasma source with cesium seeded, mostly extracted H$^-$ as beam is produced on boundary electrode between plasma and beam, than is Plasma Grid electrode (PG), with opposite velocity component to beam direction. It is not sufficiently understood the dynamics to change the velocity components to the beam direction and the contributions of electric field and other particles (electron, positive ions and neutral atom and molecular) to the H$^-$ dynamics. The studies to clarify the mechanism from H$^-$ production to beam extraction are performed by means of experiment, simulation, and theory. In the experimental study, one of the useful measurement values is H$^-$ density with and without beam extractions. The H$^-$ density can be measured with Cavity RingDown (CRD) method which is a sort of laser absorption spectroscopies with high sensitivity [1]. It is known that divergence of the H$^-$ beam is smaller such as ~5 mrad than that of positive hydrogen ion beam from filament arc discharge sources. This suggests H$^-$ temperature near the boundary between beam and plasma, that is meniscus, is low such as ~1 eV or less. Negative hydrogen ion temperature may reflect processes of H$^-$ production, emission from PG, relaxation by other particles etc. In this paper, the concept of H$^-$ temperature measurement by developing CRD method and its feasibility are shown.

2. Concept of H$^-$ Temperature Measurement

Figure 1 shows a schematic view of CRD method for H$^-$ density measurement by using pulse Nd:YAG laser. Two high-reflective plano-concave mirrors are coaxially aligned both side of plasma. Laser plus injects one side of the mirror and travels back and forth between the mirrors with gradually

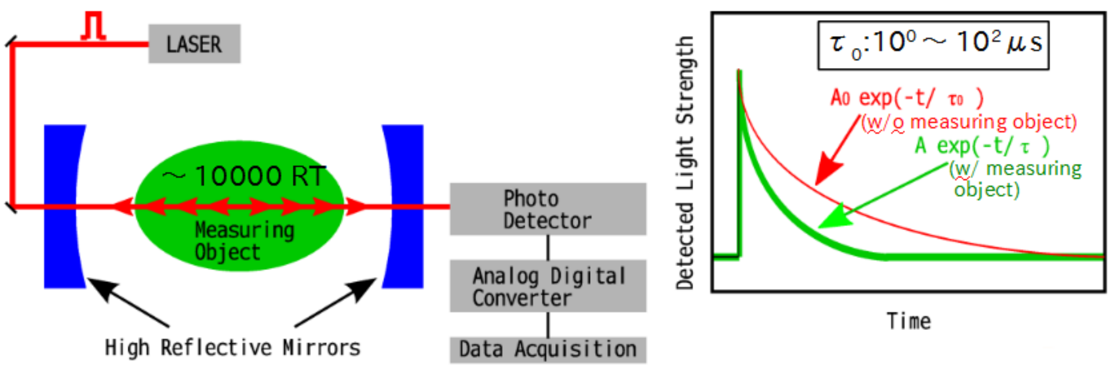

Fig.1. schematic view of CRD method

losing from mirrors. Intensity of laser light through another side of mirror decays exponentially even without plasma. The decay time of the laser light which is called ringdown time becomes short with plasma due to the laser light absorbing H^- by photdetachment process. Line average H^- density is derived by comparing both ringdwon times without and with plasma.

The laser absorption spectroscopy including CRD method is taken account of absorption saturation in normal cases. It means laser intensity has to be week as far as ignoring absorption saturation. Although there is not absorption saturation in photodetachment process of H^-, similar attention needs. When CRD method is applied for the H^- density measurement, the H^- density inside of laser rod has to recover by thermal diffusivity, flow and so on before next round trip laser plus comes. If not, the H^- density is underestimated. Inversely, there is a possibility to evaluate the H^- temperature and flow without direction may be estimated by using two set of CRD measure lines near each other. One line is a normal H^- density measurement setup which consists of high reflectance mirrors and week laser intensity. Another line consists of lower reflectance mirrors and high laser intensity. The difference of both estimated density reflects the temperature and flow.

3. Estimation of Temperature Measurement Possibility

Here, only temperature influence is considered without background H^- flow. First, Temperature influence of the present CRD setup on the H^- source in National Institute for Fusion Science (NIFS) [2] is confirmed. Fundamental wave (1064 nm) of Nd:YAG laser with 5 (to 6) ns and about 20 mJ of pulse energy is utilized. The cavity length L is 1.6 m and plasma length d along cavity axis is 0.18 m. The nominal average reflectance, transparency and curvature of high reflective mirrors are 0.99996, 0.00004 and 1 m, respectively. The ringdown time without plasma τ_0 is 133.42 μs. When H^- density and temperature are $3.0\text{x}10^{17}$ m^{-3} and 0.1 eV, the ringdown time τ is 23.31 μs which equals with 0.1 % accuracy in the case without consideration of temperature influence. The present CRD system has poor sensitivity for the temperature.

Temperature sensitive CRD system is considered. The same laser is utilized but the plus energy changes to 500 mJ. The cavity length is the same. The mirror reflectance sets 0.999 therefore the transparency is 0.001. Four meter of mirror curvature is selected. This affects to expand laser diameter inside of the cavity. The ringdown time τ_0 is 5.33 μs. The same density is assumed. When the temperatures are 0.1 eV and 1.0 eV, the ringdown times τ become 5.08 μs and 4.63 μs from which the densities are estimated to be $8.1\text{x}10^{16}$ m^{-3} and $2.4\text{x}10^{17}$ m^{-3}, respectively. The ringdown time τ without temperature influence is 4.49 μs. There is 3 % difference of τ between 1.0 eV of the temperature and no temperature influence cases. This may be almost accuracy limitation of higher temperature. Because the accuracy of the present CRD system is less than 1 % and actual density difference between measure lines may arises to a few % even if the measure lines are very near each other. Figure 2 shows an example of H^- temperature measurement system with CRD method which is utilized two measure lines that position very near each other.

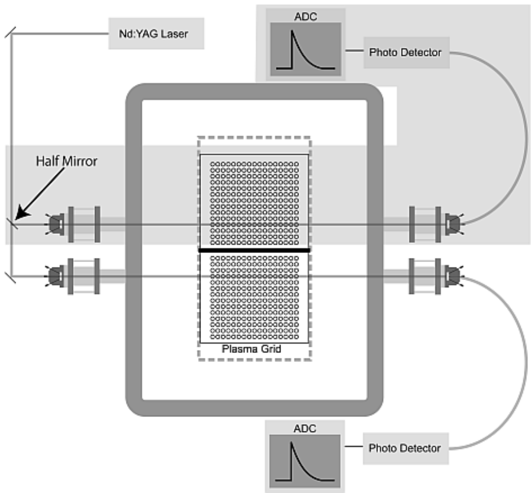

Fig.2. example of H^- temperature measurement system with CRD method

Acknowledgments

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References

[1] G. Berden and R. Engeln eds., Cavity Ring-Down Spectroscopy: Techniques and Applications, John Wiley and Sons Ltd., 2009.

[2] H. Nakano, *et al.*, AIP Conference Proceedings **1515** (2013) pp. 237-245.