§8. Development of Doppler-free Spectroscopy for Plasma Diagnostics

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A requirement for diagnostics in LHD experiments is the development of high-resolution spectroscopy at the Balmer-α line of atomic hydrogen. If the high-resolution spectrum of the Balmer-α line with Zeeman splitting is measured, one can estimate the place of electron impact excitation of atomic hydrogen with the help of the knowledge of the distribution of the magnetic field strength. The place of electron impact excitation roughly represents the place of electron impact ionization. The knowledge on the place of electron impact ionization is helpful for investigating the particle balance in LHD. However, the Zeeman-split spectrum of the Balmer-α line is masked by the Doppler broadening. The goal of this work is to develop a technique of Doppler-free spectroscopy (saturation spectroscopy) at the Balmer-α line of atomic hydrogen, with the intention of applying it to LHD experiments.

In this year, we developed a system of saturation spectroscopy, and examined the characteristics of saturated absorption spectrum at the Balmer-α line in a linear magnetized plasma source with an axial magnetic field of 350 G. The experimental apparatus is schematically shown in Fig. 1. The system of saturation spectroscopy employed an oscillator-amplifier system of diode lasers, which yielded tunable, single-mode, cw radiation with a power of 200 mW. A part of the laser beam obtained from the master oscillator was picked up using a beam splitter and was used as the probe beam. The other part of the master oscillator beam was injected into the amplifier to obtain the intense pump beam. The probe and pump beams were launched into a hydrogen plasma produced in a linear magnetized plasma source from the counter axial directions. The probe and pump beams were overlapped carefully.

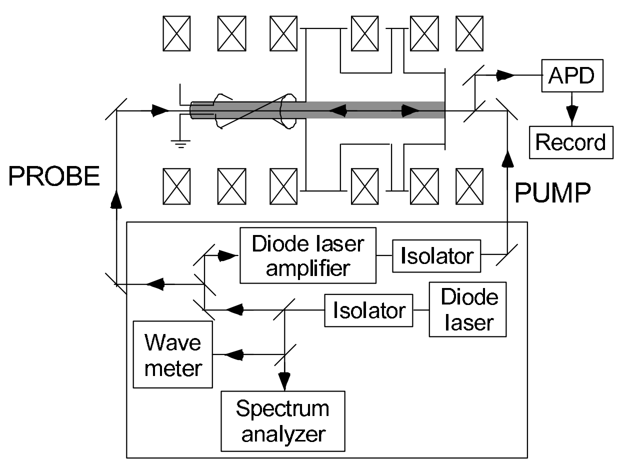

Fig. 1: Experimental apparatus.

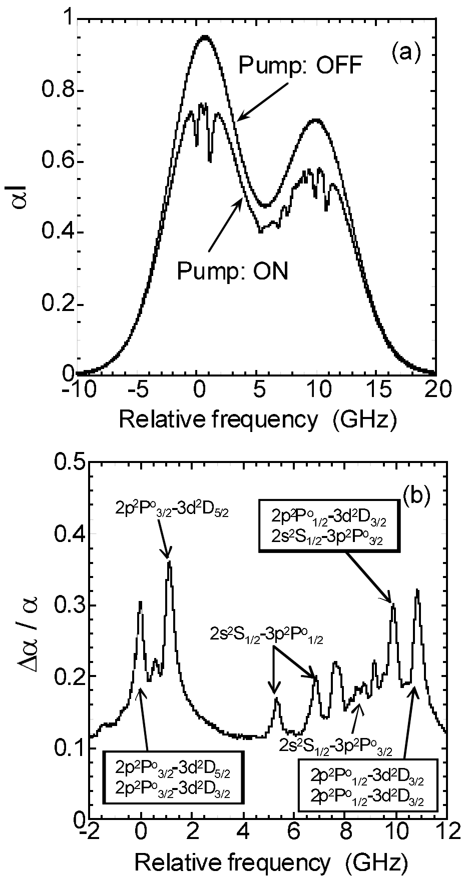

Fig. 2: (a) Absorption spectra of probe beam with and without the pump beam, (b) the difference in the two spectra shown in (a).

Figure 2 shows absorption spectra of the probe beam. As shown in Fig. 2(a), we found difference in the absorption spectra observed with and without the pump beam. The absorption spectrum obtained with the pump beam had many dip components. Figure 2(b) was obtained by subtracting the spectrum with the pump beam from that without the pump beam. The lines shown in Fig. 2(b) were assigned to fine-structure components of the Balmer-α line with Zeeman splitting and their crossover signals, as indicated in the figure. The subtracted absorption spectrum had a broadband component in addition to the lines. The broadband component suggests the change in the velocity of atomic hydrogen due to collisional processes. We examined the amplitudes of the line and broadband components as functions of the pump laser power, the discharge power, and the discharge pressure. In addition, we examined the widths of the lines as a function of the pump laser power.