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INVESTIGATION OF ZEEMAN EFFECT BY TUNABLE DIODE-LASER SPECTROSCOPY

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Laser spectroscopy using diode lasers is one of powerful tool that can be used to investigate the species present in a plasma environment. The narrowness of external cavity diode laser systems offers a high spectral resolution. The line profiles affected by different processes such as Doppler broadening or Zeeman splitting can be thus measured using this diagnostic method. The contribution shows haw to use the Tunable Diode-Laser Induced Fluorescence technique (TD-LIF) in investigation of Zeeman effect in magnetized plasma. In this technique, a diagnostic laser beam whose linewidth is less than the absorption line is directed through the plasma. If the Zeeman shift is larger compared to the absorption linewidth, then from spectral line splitting, we can measure the magnetic field having arbitrary distribution of direction and amplitude. Laser Induced Fluorescence is an optical diagnostic technique that can measure the magnetic field in a spatially localized volume without using Abel transform [1]. In this paper, we measure the magnetic field strength from Zeeman splitting of Ar line emitted at 811.531 nm, corresponding to the transition of argon metastable atoms ($3s^2 3p^5 4s(^3P_2) \rightarrow 3s^2 3p^5 4p(^3D_3)$).

The measuring setup consists of three parts – a laser system, a source of Ar metastable atoms and a fluorescence detection system. The laser was tuned linearly around 811.531 nm, which corresponds to the absorption wavelength for argon metastable atoms. The bandwidth of the laser is less than 10 MHz and the fine scanning range is about 10 GHz. The source of metastable argon atoms was a planar circular magnetron discharge, and the measurements were taken in vicinity of an additional permanent magnet. The interrogation volume for LIF is defined by the intersection of the laser beam and the collection optics axis, ensuring that LIF measurements can be made with high spatial resolution (usually a millimeter). The magnetic field in the laser acting area is produced by an additional permanent magnet which has a rectangle shape and interrogative volume for LIF is situated on magnet axis. Because of a small acting area, the distribution of the magnetic field in laser acting area is considered uniform and parallel. The magnetic field strength is controlled by adjusting the distance between magnet and acting area. The magnetron discharge is located far away from acting area and the influence of cathode magnetic field at this distance is negligible.

As a starting experimental set-up, the laser beam is linear polarized with vector $\vec{E}$ orientated along the magnet axis and parallel to the magnetic field lines, while the direction of the fluorescence detection is perpendicular to the laser beam and magnetic field lines. In this configuration, the fluorescence detection system records only the π – component, which can't offers information about magnetic field strength because this component is not shifted.

For supplementary measurements, a half wave plate (λ/2) was used. The plate allows rotation of the laser polarization vector $\vec{E}$ perpendicular to the magnetic field $\vec{B}$ (perpendicular to the magnet axis) and separate observation of the σ – components becomes possible. Using this experimental set-up, the fluorescence signal of σ – components linear polarized measured at different position from the magnet surface, corresponding to the different magnetic field strength are illustrated **i**n figure 1. The position of LIF detection system was fixed, while the magnetic field strength in the laser acting area was modified varying the distance between additional magnet and laser acting area.

When laser polarization vector $\vec{E}$ is perpendicular to a large magnetic field $\vec{B}$, Ar metastable atoms absorbs laser radiation and then emits linear polarized radiation (σ – components) along the optical axis of LIF detection system with polarization vector $\vec{E}$ orientated along the laser path direction and circular polarized light along the magnetic field line. For large magnetic field, high atoms density of Ar metastable and large absorption cross-sections, the emitted radiation by the absorbing metastable atoms can be absorbed and re-emitted in the same direction preserving the polarization state, just like a coherent radiation. This process may occur several times before the radiation will pass the high magnetic field area, with an apparent lifetime being equal to the sum of the individual lifetimes for each coherent absorption process. Due to the coherent absorption, along the magnetic field direction, increasing distance from magnet surface, the light intensity corresponding to σ – components circular polarized is amplified [2]. At low values of the magnetic field, the light emitted by the Ar metastable atoms becomes partly polarized (Hanle effect) and therefore the LIF signal decreases.

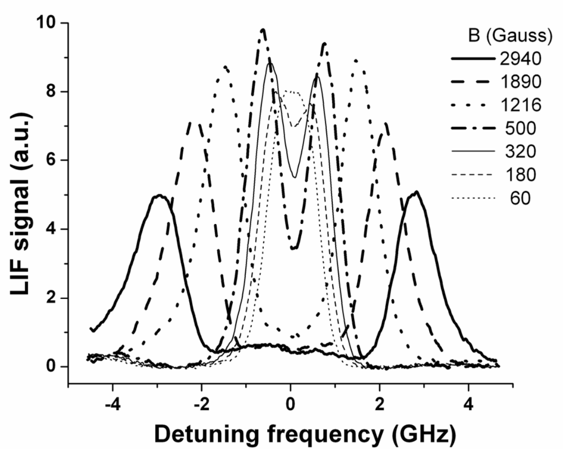

Fig. 1: The LIF signal of σ – components corresponding to the different magnetic field strength ($\vec{E} \perp \vec{B}$).

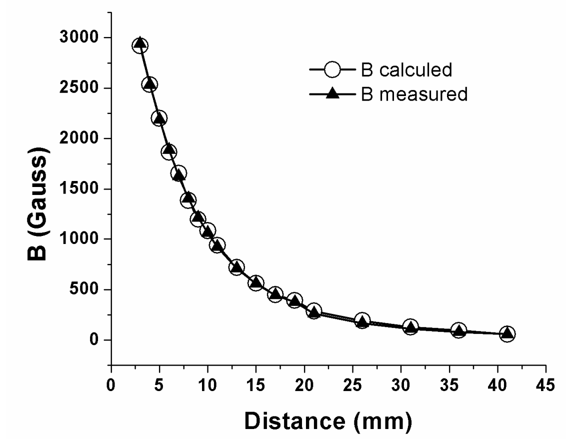

Fig. 2: The distributions of the measured magnetic field and the calculated magnetic field from Zeeman splitting.

The σ – components linear polarized emitted by the absorbing atoms situated in magnetic field are splitted with a frequency shift corresponding to the magnetic field strength and have a Gaussian profile due to Doppler broadening. The evolution of the LIF signal reveals the influence of the magnetic field on the spectral lines splitting. From spectral line splitting, we can calculate the magnetic field strength (figure 2). Figure 2 shows the distributions of the calculated magnetic field from Zeeman splitting and the measured magnetic field by means of a Hall probe.

LIF technique is a powerful non-perturbing optical diagnostic tool which may be quite useful to measure the magnetic field distribution. There is a good agreement between calculated magnetic field from Zeeman splitting and the measured magnetic field using a Hall probe.

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