Ghost-Imaging Laser-Absorption Spectroscopy of Pulsed Helicon-Wave Plasmas for Two-Dimensional Mapping of Metastable Helium Atoms

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Ghost imaging (GI) reconstructs an image from the correlation between the spatial structure of the incident light and the total intensity of the transmitted or scattered light detected by a single pixel detector, such as a photodiode or photomultiplier tube after the incident light has interacted with the measured object [1, 2]. This approach enables imaging at wavelengths for which image sensors are unavailable. We are developing computational ghost-imaging laser-absorption spectroscopy (CGI-LAS) by integrating GI with plasma laser-absorption spectroscopy. Random structured light, generated by a digital micromirror device (DMD), is sent through the plasma; the transmitted beam is focused onto a photodiode, and its total intensity is recorded. Because a two-dimensional absorbance profile is obtained from the correlation between each illumination pattern and the corresponding transmitted intensity, conventional CGI typically requires tens of thousands of patterns, limiting its time resolution to seconds owing to the DMD switching rate. Repetitive phenomena, however, offer a way around this constraint.

Here we apply CGI-LAS to pulsed helicon-wave plasmas in order to capture the temporal evolution of the metastable-helium (He*) distribution with high time resolution. During each discharge, we project a single structured light. The transmitted laser intensity from breakdown through afterglow is digitized at 500 kHz with a single standard ADC. After several thousand discharges, each with a different structured light pattern, the photodiode signals at a fixed time point within every discharge were assembled and processed with a correlation calculation. This procedure reconstructs a two-dimensional absorbance image with an effective temporal resolution equal to the ADC sampling interval (2 μs). Figure 1 presents a preliminary map of the He* absorption ratio measured 100 μs after the RF power was shut off. This image reveals a density depletion near the endplate, which can be attributed to quenching, alongside an increase upstream. We will discuss the measurement procedure in detail and show time-resolved maps of the He* population in the helicon-wave plasma.

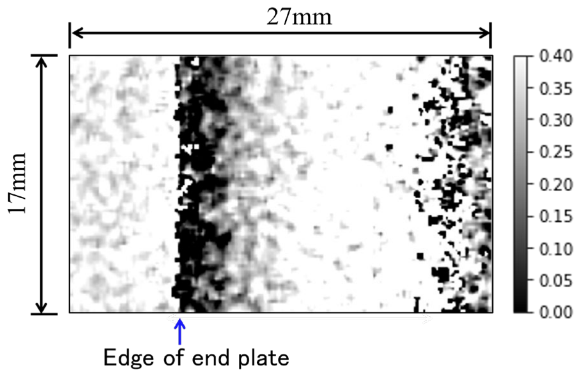

Figure 1. Two-dimensional distribution of absorption ratio of metastable helium atoms in front of the endplate, recorded 100 μs after RF power shut-off.

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