Nonlinear Effect of Gas Flow on Helium Metastable Atoms in Weakly Ionized Gas Jet

Hyeondo Cho[1], Sungyong Shim[2], Duksun Han[2], and Sanghoo Park[1*]

[1]*Korea Advanced Institute of Science and Technology (KAIST),Daejeon, 34141, Republic of Korea*
[2]*Korea Institute of Fusion Energy (KFE), Gunsan, 54004, Republic of Korea*

Metastable atoms play a crucial role in low-temperature plasmas, particularly in weakly ionized gas jets (known as plasma jets). Nonetheless, experimental data regarding helium metastable atoms (He*) in plasma jets have been scarce thus far, thereby limiting our knowledge of plasma characteristics and its applied research. The aim of this study is to investigate the nonlinear effect of gas flow on the He* dynamics in a plasma jet. A pin-type plasma jet source operating with a 50 kHz bipolar square voltage waveform was utilized, and the spatiotemporal distribution of He*(2^3S_1) was obtained using tunable diode laser absorption spectroscopy. By varying the gas flow rate within a range of 1 to 5 standard liters per minute (slpm), we first observed a wave-like pattern of He* formation preceding the main ionization wave, which was not detected by a conventional intensified CMOS camera. To better understand this phenomenon, optical emission spectroscopy and flow simulation using Comsol were conducted. We conclude that the high penetration of ambient N_2 into the plasma channel somehow induces this phenomenon. Thus, this study provides valuable insights into the complexities of plasma jet in relation to Penning ionization of ambient N_2. Furthermore, our findings demonstrate that certain effects are sensitive to specific ranges of the flow rate, emphasizing the importance of understanding and controlling gas flow dynamics in plasma jet applications.

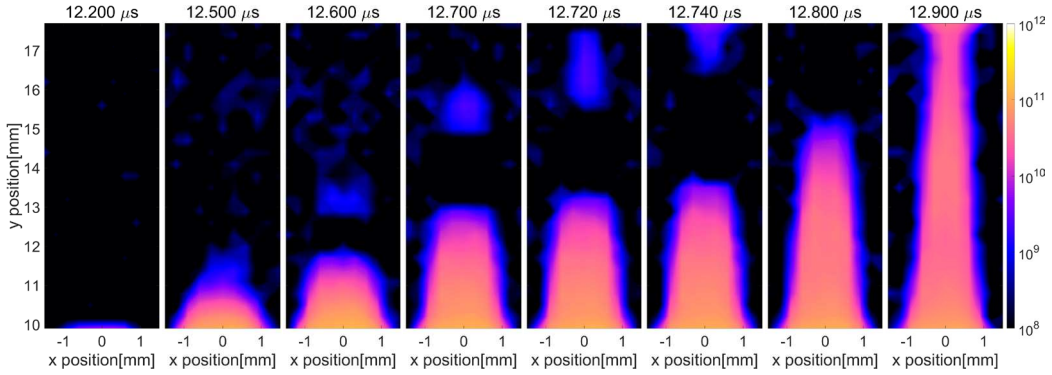

Figure 1. The wave-like pattern of He* observed in the plasma jet with a gas flow rate of 1 slpm.

*Presenting author: toptothe1@kaist.ac.kr