Optical wave microphone measurements for plasma application

Fumiaki Mitsugi[1]
[1] Faculty of Advanced Science and Technology, Kumamoto University
e-mail (speaker): mitsugi@cs.kumamoto-u.ac.jp

An optical wave microphone works based on Fraunhofer diffraction of laser beam and be able to detect small refractive index changes in phase objects. As the optical wave microphone does not disturb the electric field and acoustic field during measurement, it is suitable for observing refractive index changes such as pressure (Blast) waves emitted at plasma generation. Utilization of this technique to plasmas gives us information regarding physical changes in atmospheric ambient gas around plasmas, which is helpful for understanding plasma induced phenomena. The optical wave microphone was applied to atmospheric pressure plasmas including plasma jet, surface dielectric barrier discharge, and gliding arc discharge so far. Basically, the experimental setup of the optical wave microphone is very simple and composed from a laser, a Fourier lens, and a detector. The detector should be placed at Rayleigh region of the lens as the laser is Fourier transformed after the lens. As such, the laser beam, which is phase modulated by a refractive index changes such as pressure waves, can be Fourier transformed spatially and the refractive index changes can be detected at an optimum detector position. The development of the optical wave microphone was started from the above-mentioned fundamental setup, then followed by a fiber type optical wave microphone. Because optical fibers enclosed optical path and enabled to put the detector far away from plasma sources, the signal to noise ratio of the fiber type optical wave microphone was improved drastically. Currently, the fiber type optical wave microphone is used for detecting the refractive index changes caused by plasma sources.

The measurement of pressure waves and its distribution could be done successfully in He gas flow of capacitive plasma jet. The origin of the generation of the pressure waves must be local heating of the gas around breakdown plasma which appears between electrodes. A single blast wave was emitted from each breakdown plasma, however, the obtained pressure waves observed above 1 kHz of sinusoidal applied voltage showed continuous waves because of the overlap of each blast wave. According to the analysis between the pressure waves measurement and the distribution of reactive oxygen species observed with KI-starch reagents, it is considered that the pressure waves give some damage on targets and influence on the distribution of reactive oxygen species on the surface of targets. The pressure waves must be additional physical factor to be considered in the analysis of plasma related phenomena including plasma-liquid interface, as they have possibility to have direct and/or indirect influence on targets.

The synchronized measurement of high-speed camera image and pressure waves emitted from each micro-discharge of surface dielectric barrier discharge was done with the fiber type optical wave microphone. The visualization of pressure waves emitted by surface dielectric barrier discharge was also done by combining with computer tomography. The averaged two-dimensional distribution of pressure waves in the top view on the device was firstly visualized and their sound pressure was quantified. Because the optical wave microphone is designed using all physical parameters concern with measurement, the possibility in the theoretical quantification of measured pressure waves was discussed. The details of such measurements will be discussed at the conference.

References

[1] F. Mitsugi, T. Nakamiya, Y. Sonoda, H. Kawasaki, IEEE. Transactions on Plasma Science, 43(8), 2642-2648, 2015.
[2] F. Mitsugi, T. Nakamiya, Y. Sonoda, T. Kawasaki, IEEE. Transactions on Plasma Science, 44(11), 2759-2765, 2016.
[3] F. Mitsugi, S. Kusumegi, T. Kawasaki, IEEE. Transactions on Plasma Science, 47(2), 1057-1062, 2019.
[4] F. Mitsugi, S. Kusumegi, T. Nakamiya, Y. Sonoda, T. Kawasaki, IEEE. Transactions on Plasma Science, 47(2), 1063-1070, 2019.
[5] T. Kawasaki, F. Mitsugi, K. Koga, M. Shiratani, Journal of Applied Physics, 125, 213303, 2019.
[6] F. Mitsugi, M. Wago, R. Sakamoto, K. Nishida, T. Kawasaki, IEEE. Transactions on Plasma Science, in print, 2021.
[7] F. Mitsugi, R. Kikuchi, S. Honda, V. Paiva, J. Sakamoto, T. Nakamiya, Y. Sonoda, IEEE. Transactions on Plasma Science, submitted.