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Modeling of Millimeter-Wave Discharge at Under-Critical Intensity Considering Excitation on Ionization Front

Yusuke Nakamura[1], Kimiya Komurasaki[2], and Hiroyuki Koizumi[1]
[1] Department of Advanced Energy, The University of Tokyo, [2] Department of Aeronautics and Astronautics, The University of Tokyo
e-mail (speaker): y.nakamura@al.t.u-tokyo.ac.jp

Recent years, megawatt class millimeter-wave oscillators such as Gyrotron have been developed for an electron heating in a nuclear reactor[1)]. This development enables us to observe various discharge phenomena. One of them is an ionization front propagation. When the seed plasmoid is irradiated by millimeter-wave beam in atmosphere, an ionization front propagates toward the beam source. A propulsion system using this phenomenon have been proposed[1)].

In some earlier researches[2,3)], discharge experiments were conducted using millimeter-wave whose peak intensity is higher than the discharge criteria, which is 15 GW/m^2 at atmosphere. The ionization-front propagations observed in these experiments were well understood and numerically reproduced[4,5)]. However, this propagation was also observed even in the millimeter-wave whose intensity is lower than 1/100 of the discharge criteria[6)], and this phenomenon cannot be explained with a theory proposed for the discharge in the critical intensity.

Some earlier researches on a microwave discharge[7,8)] suggested that increasing of electric field at a head of a streamer maintain the propagation of the ionization front even in the under-critical intensity. But in the millimeter-wave discharge, such increment cannot occur because a depth of the ionization front is not so much smaller than the wavelength of the incident beam. An effect of a heavy-particle motion on under-critical millimeter-wave discharge was discussed in an earlier research[9)]. But, it still could not explain this propagation.

In a recent spectroscopic analysis of a radiation from the propagating ionization-front[10)], it was found that the vibrational temperature reaches to 6000 K when the incident millimeter-wave intensity is lower than 1/100 of the criteria. Generally, an excitation temperature is higher than the vibrational temperature. This excitation temperature is high enough to affect ionization. It suggest that the high excitation temperature plays an important role on the under-critical discharge. In this research, new model of ionization-front propagation was proposed considering the effect of the excited particles and a role of these particles were discussed.

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