Space Propulsion Powered by Millimeter-Wave Discharge

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This paper presents a beamed energy propulsion thruster, “Microwave Rocket” which obtains propulsive energy by a millimeter-wave beam transferred from the ground as illustrated in Fig. 1. A megawatt-output oscillator, Gyrotron, which is exclusively developed as a heating device for a nuclear fusion application, is a promising beam source device for rocket propulsion.

The millimeter-wave beam is received through a tapered beam-concentrator and guided into a cylindrical thruster body. Then, millimeter-wave discharge is induced in the thruster: An ionization front propagates at a supersonic speed by absorbing the beam energy and drives a millimeter-wave supported detonation (MSD) wave: Atmospheric air inside of the thruster is shock-compressed, resulting in impulsive thrust.

Figure 2 100 g model rocket launch in a multi-pulse operation.

We have demonstrated thrust generation in single pulse and repetitive pulse operation modes and launched a 126 g thruster model up to 2 m altitude as shown in Fig. 2 using a 1-MW class gyrotron developed by Japan Atomic Energy Agency.

Physics of millimeter-wave discharge has not been fully understood and propagation speed of the detonation wave is unpredictable. Figure 3 shows the measured and computed millimeter-wave discharge.

Father studies in both experiment and calculations are necessary for the optimization of the thruster design and operation.

Figure 3 Millimeter-wave discharge in atmospheric air. The power beam frequency is 170 GHz and its intensity is over 10MW/cm². (a) observed and (b) computed.

References
2) K. Kajiwara, et al., Full high-power modulation on a 170 GHz 1 MW ITER gyrotron with a triode magnetron injection gun, Nuclear Fusion, 53(2013) 043013_1 - 043013_5.