relaxation processes in air discharge at atmospheric pressure and in plasma during ECRH by a packet of microwave pulses

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To study wide range of physical processes undergoing in fields of high power microwave radiation it is useful to have a regime of microwave source operation with fast sequence of pulses – a “packet” of pulses. Such regime would be also useful for some technological applications of mm-wave gyrotrons. Pulses in the packet should be from 0.1 ms up to dozens of milliseconds length and pulse “off-time” should be regulated on the same time scale. Packets themselves can be generated with some repeating frequency. The processes study of which requires this pulse regime are dynamics of electron-cyclotron resonance heating (ECRH) with subsequent electron temperature relaxation processes in toroidal magnetic confinement devices and relaxation processes of dissociation and excitation of gas molecules and of gas temperature in microwave discharges at wide range of gas pressures.

Gyrotrons power source design allows one to switch-off supply voltage by modulating gyrotron pulse enable signal. An additional sub-unit with modulation program was introduced into the original pulse formation unit to implement this approach.

Packets which consist of three 2.5 ms length pulses were used for ECRH at the second harmonic of electron gyrofrequency in the L-2M stellarator. The interval between pulses within one packet was varied from 1.5 to 2.5 ms. Average electron density was 1.7–2.0 × 1019 m–3 during the experiment. Two different values of microwave power were used, of 0.2 MW and 0.4 MW. During the first pulse of the packet the density reaches its quasi stationary value 1 ms after the pulse start and then gradually decreases until the end of the packet. However, during pulse “off-time” within the packet the density remains constant. The electron temperature almost reaches its quasi stationary value during the second pulse of the packet and also during each subsequent pulse. The electron temperature decreases during pulse “off-time” by 70% when the “off-time” is 2.5 ms and by 50% when the “off-time” is 1.5 ms. Electron temperature increase rate at the pulse start is always higher than decrease rate at the “off-time” start. This possibly indicates increase of anomalous heat losses until the end of each pulse. Short-wavelength (*k* = 20 cm–1) turbulence in the ECRH region was measured with diagnostics that utilizes an effect of collective scattering of gyrotron radiation. Long-wavelength (*k* = 1 cm–1) turbulence was measured with another diagnostics that also utilizes the effect of collective scattering of gyrotron radiation. It was found that levels of both the short-wavelength turbulence and the long-wavelength turbulence don’t decrease during pulse “off-time”. It should be noted that the level of turbulent density fluctuations don’t decreases while the electron temperature is decreased.

A sub-threshold microwave discharge in air was excited with a specially designed initiator. The discharge propagated towards the microwave source with 100 m/s speed. At microwave power 0.  MW, pulse length within the packet 2.5 ms and pulse “off-time” 16 ms the length of the second discharge and of subsequent discharges remained the same, 25 cm from the initiator. At pulse “off-time” 8 ms the discharge elongated up to two times during the second pulse. This allows us to suggest that relaxation time of air excitation within the discharge volume don’t exceed 16 ms.

References

1. G.M. Batanov, V.I. Belousov, Yu.F. Bondar’ et al. Plasma Physics Reports, 2013, V.39, I.13, P.1088.