High temperature plasma emission in the MHz frequency range

S.V. Lebedev, G.I. Abdullina, L.G. Askinazi, A.A. Belokurov, N.A. Zhubr, V.A. Kornev, S.V. Krikunov, A.D. Melnik, D.V. Razumenko, A.I. Smirnov, A.S. Tukachinsky, F.V. Chernyshev, A.E. Shevelev

Ioffe Institute, 194021, St. Petersburg, Russian Federation

Emission in the frequency range of 1-100 MHz is caused by the presence of magnetized ions in the tokamak plasmas. At the magnetic induction of 1-5 T and a plasma density of 1019-1020 m-3, Alfven waves (AW) and Ion Cyclotron Emission (ICE) appear in this range. The observation of AW and ICE makes it possible to analyze the composition of plasma and the behavior of energetic ions. In most cases, radiation in the megahertz frequency range is not thermal, but is caused by the development of instabilities in the presence of energetic particles. The analysis of this radiation allows studying the physics of excitation of plasma instabilities. The practical significance of the study of the generation of megahertz-range emission is that the strong magnetic disturbances, being a potential channel for losses of alpha particles, are dangerous for achieving a self-sustaining fusion reaction in a thermonuclear reactor and, therefore, methods that prevent their development should be elaborated.

Along with a brief overview of the characteristic instabilities that lead to the appearance of MHz-range emission, the report presents the results of the AW and ICE study on the TUMAN-3M tokamak. In particular, the results of experiments on the identification of the type of Alfven waves that occur in plasma with different composition of working gas (protium, deuterium, helium) are presented. These experiments showed that the frequency of oscillations recorded by magnetic probes varies proportionally to the Alfven velocity, $ ∝{B\_{T}}/{\left(A\_{i}n\_{i}\right)^{0,5}}$. Based on the obtained data, it was concluded that the observed AW is a global Alfven mode (GAE), the excitation region of which is located in the central part of the tokamak cross-section.

ICE was detected in TUMAN-3M both in ohmic and NBI heated plasmas. The ohmic ICE is characterized by a significant number of observed harmonics – about 10 in deuterium plasma and by the a frequency dependence on the location of the probe – the recorded frequency of the first harmonic is close to the frequency of the Ion Cyclotron Resonance in the probe vicinity – the frequencies on the probes located on the sides of the low and strong magnetic field differ by more than a factor of 2. This feature indicates the local nature of the ohmic ICE generation. In contrast to the ohmic ICE, Ion Cyclotron Emission observed during NBI heating in the TUMAN-3M (NBI ICE) has the same first-harmonic frequency on all probes, regardless of their location, and occurs in the central region of the plasma. The amplitude of the recorded harmonics decreases with the harmonic number, as a result of which the first 4 harmonics remain available for observation at best. The paper presents models of generation of ohmic and NBI Ion Cyclotron Emission.

Of particular interest is the diagnostic potential of MHz-range plasma radiation. The report presents the results of experiments on measuring the isotopic composition of plasma from the spectra of Alfven waves and ion cyclotron radiation observed in the absence of energetic ions. Measuring the ratio of the amplitudes of the main harmonics of the ICE in plasmas consisting of a mixture of hydrogen isotopes can serve as a method for determining the isotope ratio in modern and future fusion devices.