RADIATION OF MOVING CHARGES IN WAVEGUIDES CONTAINING DISPERSIVE AND ACTIVE MEDIUMS

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A bstract:

Problems of radiation of charged particles moving in waveguide structures containing dispersive mediums were analyzed in many publications (see, for example, [1,2]). However, the role of the concrete dispersive characteristics of materials were considered relatively rarely [3-5]. In this paper the radiation of charged particles beam in waveguide structure is analyzed. The structure is a circular waveguide containing dielectric with resonant dispersion. The dielectric fills the waveguide fully or partially. In the last case the waveguide has cylindrical dielectric layer and circular vacuum channel. It is supposed that the dielectric has resonant dispersion with a single resonant frequency. The dielectric conductivity is taken into account. It is important that the medium may be both passive and active. In the latter case the medium dispersion is anomalous for the greater part of the frequency range.

The main attention is given to the case of ultrarelativistic motion of the charges. In the case of passive medium we shown that the resonant dispersion influences significantly on the frequencies and amplitudes of harmonics. As a rule, the influence of dielectric conductivity is essentially less than the influence of dispersion of real dielectric constant. The harmonics frequencies in the case of dispersive medium are less than one in the case without dispersion. The dispersion depresses all harmonics, and this effect increases with the harmonic number. For thin waveguide, the amplitude of the first harmonic is maximum. In the case of sufficiently thick waveguide the maximum falls on the harmonic with the number being not equal to 1. This number increases with the radius of waveguide. It is noted that the influence of the medium dispersion may be essential even for very thin dielectric layer. The computation of typical wakefields show that resonant dispersion leads to decreasing field maximums and variation of the field structure. These effects are reduced with increasing the length of the beam.

The case of active (inverse) medium differs radically from the case of passive medium. In this case we have two sources of energy: kinetic energy of the beam and energy of the medium. The electromagnetic radiation may be amplified at the expense of medium energy. However, for this purpose some correlations between geometrical parameters, medium characteristics and the beam velocity should be fulfilled. Depending on problem parameters the following regimes are realized: (1) all harmonics are damped or slightly amplified; (2) the only harmonic is greatly amplified; (3) several harmonics are greatly amplified. It is noted that the amplified harmonics frequencies lie not far from the resonant frequency. In the cases 2 and 3 the wakefield is determined at enough large distance by amplified modes only.

The obtained results show that the resonant dispersion influences essentially on electromagnetic fields in waveguides with dielectrics. The dispersion must be taken into account in the design of electromagnetic radiation generators based on Vavilov-Cherenkov phenomenon.

References

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