Second harmonic generation of electromagnetic radiation by electron-positron vacuum

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Investigation of the gamma-ray burst GB 870303, observed by the Ginga satellite, confirms the existence of spectral features at 20 kev and 40 kev. These are interpreted as the fundamental and the second cyclotron harmonics [1, 2]. This leads to the problem of determining the source of radiation at the second harmonic. In the present work, we show that a nonlinear dependence of electric and magnetic permeabilities on the strength of an electromagnetic wave, which propagates in magnetized electron-positron vacuum, can result in the generation of the second harmonic in gamma-ray emission. It is well known, that electron-positron vacuum in the presence of a constant magnetic field behaves as an anisotropic medium with double refracting characteristics. Then the equations of electromagnetic wave propagation in a magnetic field become nonlinear at $B \geq B_c = m^2c^3/e\hbar = 4.4{\cdot}10^{13}$ G. As a result, vacuum polarization leads to an extra nonlinear term in a Lagrange function for an electromagnetic field [3]. The dependence of polarization and magnetization of electron-positron vacuum on the strength of electromagnetic wave is examined up to the square terms. The nonlinear equation for electromagnetic waves propagating in the medium "vacuum plus rarefied plasma" is obtained. The problem of the second harmonic generation by electron-positron vacuum is analogous to the same problem in nonlinear optics of single-axis crystals [4]. A simplified system of equations for fundamental and second harmonics is derived using the method of a slowly changing profile. In the case of "pure" magnetized vacuum, phase synchronism occurs between an ordinary electromagnetic wave and a nonlinear medium polarization. It leads to an absolute conversion of the first harmonic energy to the second harmonic. In the presence of a very rarefied plasma, where magnetized vacuum dominates, wave disorder appears between the first harmonic and square polarization, which leads to spatial periodic beatings of amplitudes.

References

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