Electromagnetic and gravitational waves conversion in a nonlinear dielectric medium by intense light source irradiation

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Abstract. Various types of gravity wave sources were considered in this paper. It is proposed to use the effect of mutual conversion of electromagnetic and gravitational waves in a nonlinear optical dielectric medium irradiated by an intensive light source as a perspective method of generating gravitational-wave radiation.

1. Introduction

Gravitational waves are the subject of numerous theoretical studies carried out since the beginning of the twentieth century and attract attention as a new way of information and energy transmitting over long distances at the speed of light. According to the modern theory, their spatial distribution is connected with a change in space-time metrics (a component of the metric tensor) and is caused by oscillations of the physical objects' quadrupole moment of masses [1].

Another source of gravitational waves, according to the theory of cosmological inflation, are quantum fluctuations of the scalar field at the early stage of evolution of the Universe [2,3,4]. Indirect assessment of how relict gravitational waves impact on anisotropy and polarization of relict radiation is the basis for experimental testing of theoretical models of the early Universe [5]. It should be noted that the relict gravitational waves were not directly registered and, at present, various methods of their possible detection are proposed [6-10].

Also, the radiation of gravitational waves can be identified in astrophysical objects at various dynamic processes and is characterized in this case by the frequency, depending on the size of the emitting medium. In 2016, the first experiments on detecting gravitational waves from a distant space object were performed [11]. The frequency of detected waves was in the range of 10-100Hz using the method proposed earlier in [12] (also [13]).

It should be noted that the developed earlier theory [14,15] predicts the possibility of gravitational radiation of astrophysical objects with a very high frequency (10^{15}-10^{16} Hz) as a result of the process of conversion of electromagnetic radiation of stars into gravitational radiation in the presence of a strong magnetic field. The amplitude of the gravitational wave depends linearly on the square of the static magnetic field and on the length of the wave interaction path, provided that the so-called conditions of synchronism are met (the law of conservation of momentum at photon-graviton conversion).

2. Parametric processes of electromagnetic and gravitational waves interaction

In works [13,16] the theory of generation of gravitational waves in the star medium as a result of so-called parametric processes of interaction of electromagnetic waves with gravitational ones has been developed. At the same time, if in an interstellar medium there is an intensive electromagnetic radiation at the frequency of ω_0, then as a result of the process of parametric interaction a gravitational wave with the frequency of $2\omega_0$ is formed. As a result of parametric interaction of a gravity wave with the frequency of $2\omega_0$ with the initial electromagnetic wave with the frequency of ω_0, an electromagnetic wave with the frequency of $3\omega_0$ should also be formed in an interstellar medium. Thus, based on the registration of electromagnetic radiation with the frequency of $3\omega_0$, one can judge about the generation of a gravitational wave with the frequency of $2\omega_0$. Naturally, such parametric processes can occur only at high intensity of initial electromagnetic waves inside the star.

In order to implement a sufficiently high intensity of the convertible gravity wave, large sizes of the medium are required in which there is an effective parametric interaction between the electromagnetic and gravitational waves [13,16].

3. Conversion of electromagnetic waves into gravitational

The method of generation and detection of high-frequency gravitational radiation based on conversion of electromagnetic waves into gravitational ones in an external stationary magnetic field was proposed for the first time in [17].

The equations defining the mixed state of the gravitational and electromagnetic field in the external magnetic field are follows [17]

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} \right) a = \frac{2kH_0}{c^2}\sqrt{G}b ,$$

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} \right) b = \frac{2kH_0}{c^2}\sqrt{G}a ,$$

Where a and b characterize electromagnetic and gravitational fields, H_0 - static magnetic field strength, k- wave vector, G - gravitational constant. The coefficient of conversion α of an electromagnetic wave into a gravitational one is determined as follows

$$\alpha = \frac{GH_0^2 L^2}{c^4} .$$

Since the conversion coefficient $\alpha \ll 1$ for small distances L, this process with a large α value can be implemented as a result of a nonlinear optical process reinforced in a condensed dielectric medium as a result of a large optical nonlinearity of the condensed dielectric and a sharp deceleration of the group velocity of light in the interaction of intense laser radiation with matter.

In laboratory conditions it is proposed to use high-frequency pulsed laser radiation instead of a constant magnetic field and to carry out an experimental study of the possibility of realization of the method of mutual conversion of electromagnetic and gravitational waves in nonlinear-optical dielectric medium proposed by us. At the same time, it is planned to convert electromagnetic radiation into gravitational one on the basis of the use as a source of excitatory radiation of intensive pulsed-periodic laser that generates laser pulses characterized by high power density (up to 10^{11}W/cm^2), short duration (~10-11s) and sufficiently high repetition frequency (10-100Hz). Photon-graviton conversion is expected in a condensed dielectric medium of relatively small dimensions (10-100 cm), i.e. in laboratory conditions.

4. Conclusion

The method of generation of high-frequency gravitational waves based on mutual conversion of electromagnetic and gravitational waves in nonlinear-optical dielectric medium irradiated by intensive light source was discussed. Perspectivity of the given research trend is caused by possibility of

generation of gravitational waves of big enough intensity for the subsequent detection in laboratory conditions.

Acknowledgements

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