Vol. B8 (1977) *ACTA PHYSICA POLONICA* No 2

LETTERS TO THE EDITOR

A NEW POSSIBILITY OF MEASURING LOW FLUXES OF GRAVITATIONAL RADIATION

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(Received December 12, 1976)

A method based on the utilization of an electromagnetic field is proposed for the detection of gravitation radiation in the metre range with fluxes of the order of 10^{-20} W/m^2.

The methods used so far for the detection of gravitational radiation, based on the measurement of acoustic vibrations excited in mechanical quadrupole aerials, have till now brought no conclusive results. The vibrational energy detectable in such a case consists of only a minute fraction of the wave scattered on the very small cross-section of the detector.

A similar mechanism of scattering of gravitational radiation may also occur in systems containing constant or varying electromagnetic fields. Particularly interesting suggestions have been made in this respect by Braginski et al. [1, 2, 3]. The weakness of gravitational interaction, however, results also in this case in the fact that the electromagnetic field energy obtained by interaction from the expected flux values of gravitational radiation will not be sufficient. On the other hand, attempts to obtain a larger detector cross-section lead to rapidly increasing technical difficulties [3].

These difficulties can be avoided by applying the idea that the gravitational radiation should be used for the modulation of energy rather then as an energy source. This idea, which is well known in electromagnetics, could e.g. consist in constructing a system in which the interaction of gravitational radiation with a monoenergetic beam of particles would lead to a small modulation of the particle momenta.

Free motion of the beam modulated in this way leads in general to spatial bunching

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of particles, as a result of which relatively small initial perturbations may lead to easily detectable deformations of the beam. The measurement of the latter may in principle provide information about the primary interaction i.e., in our case, the energy of gravitational radiation.

In electrodynamics the above mentioned amplification is usually realized by using an electron beam. As a result of the interaction of the beam with an alternating electric field the velocity of the beam is modulated and after traversing a certain distance we obtain a spatial clustering of electric charge. The measurement of charge density in space is usually easy and the currents obtained from the initial energy of the beam may correspond to energies much higher than that used for modulation of the beam (klystron).

If one considers the possible applications of the method to the case of very weak gravitational interaction, the question about the limiting values of energy amplification arises. It is well known that the energy taken by electric charges from the electromagnetic field depends on the mass of the charge and finite time of stay in the field. If electrodynamics allowed the existence of charged particles with zero rest mass, there would be no field energy losses connected with the modulation of the beam. On the other hand, the search for most effective measurement of beam deformations is also connected with the properties of the particles forming the beam. If the beam consisted of particles (or quasi-particles) which would be spatially coherent in the whole region of interest, the limiting values of small beam deformations could be regarded as spatial phase disturbances above the overall monochromatic background. A proper method of measurement would be the interference of particles obtained from two suitably chosen points in the beam.

In electrodynamics it is possible to obtain coherent charged particle beams in the superconducting phase. However, so far no mechanism is known which would permit the modulation of such beams in this phase. Therefore, in electrodynamics the use of this optimum method is not possible.

Such a solution, however, is possible for a gravitational field as it can interact with massless particle beam which is at the same time coherent.

A suitable beam may be, e.g., coherent electromagnetic radiation. In order to modulate a photon beam one can introduce it into a toroidal waveguide with its plane directed perpendicularly to the direction of gravitational wave. When the time of circulation of photons in the waveguide approaches the doubled value of the gravitational wave period, resonance exchange of momentum between the field and the photons will occur. Along the waveguide circumference four photon bunches with momenta alternatively larger and smaller than the primary undisturbed momentum will be formed, however, the entire momentum will remain constant. In the linear approximation of the gravitational field and electrodynamics this modulation process will occur without energy exchange.

Owing to the modulation of photons momentum in the initially monochromatic electromagnetic field, phase shifts Ψ_Δ between photon bunches which follow every 1/4 of the circumference will be observed. If the apparatus is located in the coherent field of gravitational radiation for a certain time t, then the process of modulation and phase shifts occur simultaneously and it can be shown that Ψ_Δ^2 becomes proportional to the flux of gravitational radiation S and the fourth power of interaction time t^4.

If the phase measurement is carried out by means of interference of field taken for two points on the waveguide which are 1/4 of the circumference apart, then such a procedure permits the extraction of

$$\bar{n}_\Delta = \Psi_\Delta^2 \bar{n}$$

photons for the total number $\bar{n}$. Thus detectable energy would be

$$E_\Delta = \bar{n}_\Delta \hbar\omega = \Psi_\Delta^2 \bar{n} \hbar\omega \sim \bar{n} S t^4.$$

The rapid increase in detectable energy (t^4 compared to the t dependence which is characterictic for detection methods using field energy scatter on detector cross-section) permits to avoid the difficulties encountered in the latter case. In general, the limits restricting the sensitivity of the method are due to two reasons: technical and quantum-physical. The first will occur in the case when the energy E_Δ becomes equal to the energy of the thermal noise kT_R of the microwave receiver used in the experiment, the second when Ψ_Δ becomes smaller than the uncertainty of the phase $\Delta\Psi = 1/2\sqrt{\bar{n}}$. In practice the technical restriction will be stronger. For observation frequencies $\nu = 30$ MHz the values that should be avoided for technical reasons are $\bar{n} = 10^{30}$, $T_R = 10^2$ K and $t = 10^2$ s, where t is the life-time of photons in the waveguide. This would permit the observation of gravitational energy fluxes of the order $S = 10^{-20}$ W/m^2. The width of the resonance curve of the apparatus is defined by the inverse life-time of photons in the waveguide.

The possibility of observing such small gravitational radiation fluxes opens new possibilities for carrying out experiments which are gravitational equivalents of the Hertz experiment. A suitable source of gravitational radiation satisfying the power criterion could be a relativistic "dumb bell" consisting of two wave packets circulating in the waveguide in a way similar to that of the detector [4]. On the basis of the above considerations one can also modify the already existing experiments by exciting an acoustical field in a mechanical resonator which can then interact with gravitational fields.

A more extended paper on these problems will probably be published in the nearest future.

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