ELECTROMAGNETIC CURRENT AND CHARGE DUE TO INTERACTION BETWEEN A GRAVITATIONAL AND A FREE ELECTROMAGNETIC FIELD

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A gravitational field interacts with an electromagnetic one. For short waves, this interaction is manifest by a deflection of the photon trajectories (rays), but creation or annihilation of a photon pair is also possible in principle.

In Maxwell's equations, the gravitational field enters, as is well known, in the form of the dielectric constant and the magnetic permeability, which depend on the coordinates and on the time (cf., e.g., [1]).

Using the macroscopic terminology, it can be stated that the absence of "free" charges, div D = 0, in the case of variable ε, does not exclude the possible presence of a charge density due to polarization

$$\operatorname{div} E = \operatorname{div} D/\epsilon = D \operatorname{grad} \epsilon^{-1} = 4\pi\rho.$$

This concept can be explained in diagram language: we emphasize that diagrams can be used in the classical theory considered here. The gravitational field (η, dashed in Figs. 1 and 2) interacts with the energy-momentum tensor T of the electromagnetic field (F, wavy line). Since T depends quadratically on F, when two F lines join in a vertex they give rise to an η line - see Fig. 1.

Turning the diagram around (Fig. 2), we see that joining of the η line with one F line produces another F line. But the source of the F line can be called a charge; in electrodynamics of charged particles, the F line stems from the joining of two electron lines ℓ (see Fig. 3), and the source of F is ψ^2, i.e., the electron density.

Returning to the gravitational field, we formulate the following result: a gravitational field interacting with an electromagnetic one produces a definite charge and current density distributed in space and linearly dependent on the electromagnetic field. This charge density is produced in the absence of any particles, and is the result of the interaction of two truly-neutral fields, and thereby differs from all the charge variants considered heretofore.

All the phenomena such as ray bending, change of the intensity of electromagnetic waves, and others occurring in a gravitational field can be described as interactions of the electromagnetic waves and of the fields emitted by the new charge with the primary electromagnetic field. In particular, a diagram of the type of Fig. 2 describes the deflection of light rays by a heavy body.

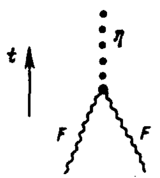

Fig. 1

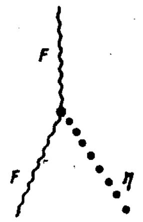

Fig. 2

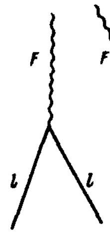

Fig. 3

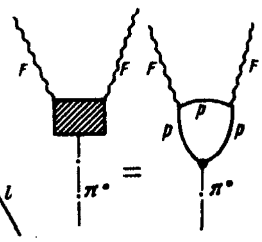

Fig. 4

The interaction of an electromagnetic field with a neutral scalar field ϕ or with a tensor field χ of second rank produces in the Lagrangian terms[1)] of the type ϕF^2 or χF^2. The roles of ϕ and χ can be assumed, for example, by the π^0 meson and the A_2 meson. The decay of π^0 into 2γ has been thoroughly studied experimentally.

When the Lagrangian is varied with respect to δF, the terms ϕF and χF appear in the right-hand sides of Maxwell's equations, and these can also be called charge. However, if the profound principle of minimal electromagnetic interaction is valid, then the connection of ϕF^2 and χF^2 is only a method for phenomenologically describing diagrams with charged-particle loops (for example, the protons in Oppenheimer's first work on π^0 decay, see Fig. 4).

In this sense, the charges ϕF and χF actually describe the densities of certain charged particles, for example protons and antiprotons, which appear virtually in vacuum in the presence of real external π^0 field and an electromagnetic field. In this sense, the electromagnetic interaction of the neutron depends on its strong interaction with charge hadrons.

The scattering of light by light, i.e., four-photon interaction (the terms $(E^2 - H^2)^2$ and $(EH)^2$ in the Lagrangian) depend on the polarization of the electron-positron vacuum; in this case the principle of the minimal electromagnetic interaction is fully confirmed by experiment. Thus, the "charges" that follow from quantum electrodynamics and are expressed in terms of F, say proportional to F^3, are the F-dependent densities of e^- and e^+. The same pertains also to the polarization corrections which are proportional to $\Box\Box F$ and contribute to the Lamb shift.

The universally known principles have been treated here with such detail, the more clearly to compare the features of the new type of charge.

The new charge is connected with the gravitational interaction, which is universal.

In a theory in which there would be no charged particles, the decay $\pi^0 \to 2\gamma$ and the interaction[2)] $\gamma' + \gamma'' = \gamma''' + \gamma^{IV}$ would vanish, but the energy of the free electromagnetic field and its gravitational action would remain. Consequently, the "new" charge would also remain. This charge is the only one that cannot be reduced to a density of charged particles.

The difference can become manifest in an analysis of the measurement of the total charge in a given volume. If the effect depends on the charged particles, the measurement should yield, with different probabilities, 0, $\pm e$, $\pm 2e$, where e is the elementary charge. But in the case of the charge due to the interaction between a gravitational and a free electromagnetic field, e does not play any role, and there are no whole-number charges.

Our aim is a new interpretation of the existing formulas and equations, but not to change the formulas. So far, the experience of theoretical physics has invariably confirmed the rule that any new interpretation of the principles makes it possible to discern properties, conclusions, and relations which were not revealed previously.

[1)] The tensor indices and the derivatives with respect to the coordinates are omitted in the symbolic notation.

[2)] Incidentally, the effect proportional to e^8 would vanish, but the gravitational effect $\propto G^4$ would remain.

[1] L.D. Landau and E.M. Lifshitz, Teoriya polya (Classical Theory of Fields), Fizmatgiz, 1967 [Addison-Wesley, 1971].

NARROW RESONANCES OF LASER-INDUCED γ-RAY EMISSION AND ABSORPTION BY NUCLEI

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The narrow emission of absorption resonances of recoilless quanta in nuclear transitions in crystals are well known. In this article we propose a method for obtaining narrow nuclear resonances in a gas. The method is based on modulating the frequency of the nuclear transition in molecules that are vibrationally excited by a coherent light wave and have the same velocity projection on the wave-propagation direction. The method makes it possible to obtain resonances both in nuclear absorption and emission, with a width smaller by a factor $10^2 - 10^4$ than the Doppler width, and to tune their frequency in a band $\Delta\omega/\omega_\gamma \simeq 10^{-5}$, which greatly exceeds the tuning band of the Mossbauer resonances.

We consider the molecules in a low-pressure gas with inhomogeneous broadening of the vibrational-rotational absorption line ω_0 belonging to a certain i-th vibration. Using a coherent light wave with frequency ω and wave vector $\vec{k}_0 = \vec{n}(\omega/c)$, we can excite molecules with strictly defined projections of the velocity $\vec{v}$ [2]:

$$k_0 v = \omega - \omega_0 = \Omega . \tag{1}$$

The density of the excited molecules is given by

$$N_2(v) = \frac{q}{2} N_0(v) \frac{x}{1+x}; \quad x = \frac{G\Gamma_0^2}{(\Omega - k_0 v)^2 + \Gamma_0^2}, \tag{2}$$

where $N_0(\vec{v})$ is the Maxwellian distribution of the molecule population on the lower vibrational level in the absence of a field; Γ_0 is the homogeneous width of the optical transition, determined by the molecule collisions and (at very low pressure) by the finite time of flight of the molecules through the light beam; G is the saturation parameter of the transition and is determined by the light-wave intensity; $q = g_J z_{rot}^{-1} \exp[-(E_J/kT)]$ is the number of molecules on the lower rotational level E_J and is determined by the degeneracy of the level g_J and by the partition function of the rotational states z_{rot}.

The atoms in the vibrationally-excited molecules execute forced oscillations of frequency ω_0 and amplitude

$$r_{is}(t) = r_{is}^{(0)} \cos(\omega_0 t + \phi), \tag{3}$$

where $\vec{r}_{is}^{(0)}$ is the displacement amplitude of the s-th atom upon excitation of the i-th normal vibration of the molecule; this amplitude depends on the force constants and the form of the molecule vibration and on its orientation relative to the light-wave polarization vector. The amplitudes of the atom displacements vary in a rather wide range, from 10^{-9} to 10^{-11} cm. The most important fact is that the average displacement $r_{is}^{(0)}$ is of the same order as the given wavelength $\lambda\!\!\!^{-}_\gamma$ of γ quanta of energy from 10 keV to 1 MeV. Lattice vibrations of this amplitude should cause an appreciable frequency modulation of the γ radiation.