Physics, Radiophysics, Materials Science

On the effect of transformation of the wavelength, duration, and power of laser pulses scattered by accelerated moving particles

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The transformation effect of the duration of electromagnetic influences from an accelerated moving source was predicted by W. Ritz in 1908 on the basis of the ballistic theory of light [1; 2]. According to it, the source additionally reports its speed **v** to the emitted light, moving relative to the source with the standard speed *c* (speed of light), and relative to the receiver - with the speed **c** + **v**. Then, with the accelerated motion of the source towards the observer, the wave fronts, acquiring ever greater velocities at the moments of emission, catch up with each other, reducing the wavelength and pulse duration. If the acceleration of the source is directed away from the observer, the crests of light waves diverge, increasing the wavelength and pulse duration. From the kinematics and the law of conservation of energy follows the law of variation of the duration Δt, wavelength λ and power P of light pulses [2]:

$$\Delta t' = \Delta t\left(1+\frac{La_r}{c^2}\right),\ \ \lambda' = \lambda\left(1+\frac{La_r}{c^2}\right), P' = P\frac{\Delta t}{\Delta t'} = P\left(1+\frac{La_r}{c^2}\right)^{-1}, \quad (1)$$

where a_r is the radial acceleration of the source, L is the light path. Effect (1) will be called the Ritz effect.

In terrestrial conditions, the effect is small, because the denominator (1) contains the square of the speed of light. But it is noticeable at cosmic distances L. Thus, in galaxies in the visible regions of the nuclei of which the accelerations are directed from us to the centers of galaxies ($a_r > 0$), the wavelengths λ' would grow in proportion to the distances L of the galaxies. This effect (1) is similar to the redshift law $\lambda' = \lambda(1 + LH/c)$ discovered by E. Hubble, who denied its cosmological nature. The proportionality coefficient H = 75 (km/s)/Mpc (Hubble constant) is close to the coefficient a_r/c calculated from the accelerations $a_r = V^2/R$ in galaxies. Taking our Galaxy as a sample, the characteristics of which are typical for spiral galaxies, and the core has a radius of $R = 0.002$ Mpc and a circumferential velocity $V = 210$ km/s, we obtain the calculated value of the Hubble constant $H_c = a_r/c \approx 74$ (km/s)/Mpc, close to the measured H. At laboratory distances L and accelerations a_r, effect (1) is so small that it would be recorded only by the Mössbauer effect. Indeed, in Boehmmel's experiment with the acceleration a_r of a γ-ray source, a shift of their wavelength at the absorber $(\lambda' - \lambda)/\lambda = La_r/c^2$ was observed, proportional to the distance L [1]. That is, laboratory experiments do not contradict the Ritz effect.

For the transformation of Δt, λ and P at times in (1), $La_r/c^2 \sim 1$ and $a_r = c^2/L \sim 10^{17}$ m/s^2 should be provided, at distances $L \sim 1$ m. This acceleration can be easily communicated to electrons or ions re-emitting light. In an electric field E, the acceleration $a = Ee/m$ of an electron (where $e/m = 1.76 \cdot 10^{11}$ C/kg is its specific charge) will reach 10^{17} m/s^2 at $E \sim 10^6$ V/m - a value that is easily realized. The installation for checking the Ritz effect and light transformation should be a vacuum chamber, where the beam of electrons or ions acquires an acceleration of $\sim 10^{17}$ m/s^2 in an electric field. Laser pulsed radiation with a wavelength λ and a pulse duration $\Delta t \sim 1$ ps is focused on the beam and undergoes Thomson scattering on electrons (or ions), which become secondary radiation sources. Their light freely flies in vacuum at a distance $L \sim 1$ m to the light filter (delaying the emission of wavelength λ), enters the spectrometer or detector, which, in the case of the validity of the Ritz effect, will register a signal with a modified duration $\Delta t'$ and wavelength λ' (1). At $a_r \approx -c^2/L$, a small variation in ar caused by a change in E or L leads to a strong change in λ', which opens up a simple way to tune the wavelength from optical to UV, X-ray and gamma ranges. With the opposite sign of the field and acceleration, λ' grows, which will make it possible to transform optical radiation into IR and terahertz radiation.

The acceleration of electrons, atoms, or nanoparticles can also be caused by light pressure $p = 2I/c$. It gives a particle of radius $r \sim 10^{-9}$ m, density $\rho \sim 10^3$ kg/m^3 and mass $m = 4\pi r^3 \rho/3$, acceleration $a = p\pi r^2/m \sim I/\rho cr \sim 10^{17}$ m/s^2 even at intensity $I \sim 10^{16}$ W/cm^2 attainable in femtosecond pulses [3]. Then the laser light simultaneously accelerates the particles and, after being re-emitted by them, transforms according to the Ritz effect. Since the light pressure oscillates at the doubled frequency of the light field, the Ritz effect (1) will not only increase the frequency, but also distort the profile of the emitted wave, forming odd harmonics of the carrier frequency. This is actually observed in generators of attosecond pulses, where in the focused beam of a femtosecond laser, atoms and nanoparticles under the action of light pressure acquire giant accelerations, up to 10^{23} m/s^2 [3]. It turns out that attosecond X-ray pulses recorded in them can be converted from femtosecond optical pulses and according to the Ritz effect (1). The main mechanism of pulse generation can be clarified by studying the dependence of the spectrum on the distance L and on the acceleration a_r (on the magnitude of the light pressure).

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