Cherenkov Radiation from Optical Pulses

The recent Letters by Auston *et al.*[1,2] have demonstrated experimentally the generation of Cherenkov radiation by femtosecond pulses in electro-optic media. This Comment calls attention to an earlier theoretical prediction of this effect,[3,4] and to an essential fact that such an effect is not restricted to electro-optic media by nonlinear force created by the gradient of the light intensity:

$$\mathbf{F}=\frac{e^2}{m(\omega_0^2-\omega^2)}\nabla\langle E_{10}^2\rangle_{\mathrm{av}},$$

where e and m are the charge and mass of the electron, ω_0 is the resonance frequency, $E_{10}(\mathbf{r},t)$ and ω are the amplitude and frequency of the electromagnetic wave, and $\langle\;\rangle_{\mathrm{av}}$ denotes time averaging.

Comparative characteristics of the average polarization of volume unity due to anisotropic nonlinearity (electro-optic media) and due to gradient force (in any media) can be estimated as

$$\frac{P_c}{P_\nabla}\simeq\frac{\langle x\rangle_c}{\langle x\rangle_\nabla}\simeq\frac{\alpha e E_c l}{m\,\omega_0^2(\omega_0^2-\omega^2)}\simeq\alpha\left(\frac{E_c}{E_a}\right)\frac{la}{\omega_0^2-\omega^2}\simeq\frac{E_c}{E_a}\frac{l}{a},$$

where E_a is the atomic field, $eE_a\simeq m\,\omega_0^2 a$, a denotes atomic dimensions, α is the parameter of nonlinearity (from comparability of αx_m^3 and $\omega_0^2 x_m$; according to the equation of nonlinear oscillator for critical displacement $x_m\simeq a$ we obtain $\alpha a^2\simeq\omega_0^2$), E_c is the external field or that in a crystal cell (which causes anisotropic nonlinearity in electro-optic media), l is the typical size of the bunch of light. For example, when $E_c<0.1E_a$ and $l/a\simeq10^4$, we obtain $P_c/P_\nabla<10^3$. Such a high amplitude $E_c\simeq0.1E_a$ takes place only in electro-optic media; in usual media $E_c\ll E_a$, and the gradient force effect is predominant. The fact that, in widely spread media, radiation can be produced on a long path makes this effect still more intense since Cherenkov radiation depends on the length of path. Plasma, air, water, and other media were found to be of most interest. For example, the plasma has a low threshold of nonlinearity and its dispersion may be changed by magnetic fields. The frequency range of radiation may be fairly large, i.e., from radio and light waves up to x-rays.

Note that, in addition to the radiation of single bunches, we obtain the interference radiation from a bunch sequence which can be produced by beating the mixture of the near frequencies.[3,4]

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