MULTIPLE STIMULATED SCATTERING OF ELECTRONS BY A POWERFUL LASER FIELD

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We consider the scattering of electrons in the high-power field of a laser standing wave, resulting from the Kapitza-Dirac effect. At sufficiently large width of the laser-emission spectrum, $\Delta\omega/\omega \approx 10^{-5}$, the electrons are diffracted by the standing wave as if it were a grating. The intensity of the higher-order scattering maxima is calculated in the electron random-walk model, and it is found that the maxima are large enough to be experimentally observable.

ACCORDING to the Kapitza-Dirac theory[1], an electron moving in the field of a standing light wave can acquire a momentum $\Delta p_x = 2h/\lambda_{ph}$, where p_x is the electron-momentum component perpendicular to the field and λ_{ph} is the wavelength of the light. The scattering probability, for the case of quasimonochromatic field, is given by[1-3]

$$w(t) = \frac{8\pi^2}{m^2\omega^4}\left(\frac{e^2}{\hbar c}\right)^2 \frac{I^2}{\Delta\omega} t \equiv at \quad (1)$$

(ω—light frequency, $\Delta\omega$—laser emission bandwidth, I—laser energy flux, t—time of travel through the beam).

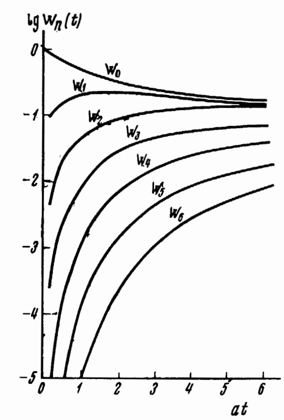
Since the scattering angle is very small (λ_e/λ_{ph}, where λ_e is the electron wave-length), the scattering of only slow electrons can be observed experimentally ($v_e < 10^0$ cm/sec). In this case, however, the probability (1) turns out to be larger than unity at laser energy fluxes on the order of several MW/cm^2.

This paradox is eliminated when account is taken of multiple scattering[4]. It is natural to expect that the electron can return, as a result of repeated scattering, to its initial position or again acquire from the field a momentum of the same sign. At a laser bandwidth $\Delta\omega/\omega = 10^{-5}$, the electron can acquire a momentum $\Delta p_x = 2nh/\lambda_{ph}$ (where $|n| \leq 10$ is an integer) without violatting the energy and momentum conservation laws.

The multiple scattering can be regarded as a random-walk process with step $\Delta p_0 = 2h/\lambda_{ph}$. Let us assume that (1) is valid for a short time interval, w(dt) = a dt. At a sufficiently large laser bandwidth, the events can be regarded as independent. Simultaneous interaction of more than two photons can be excluded. For the probability of an event in which an electron acquires ultimately a momentum $n\Delta p_0$ we get

$$\frac{dW_n(t)}{dt} = -aW_n(t) + \frac{a}{2}[W_{n+1}(t) + W_{n-1}(t)]. \quad (2)$$

For $W_0(0) = 1$ and $W_0(0) \neq 0$ the solution takes the form



$$W_n(t) = e^{-at} i^{-n} J_n(iat), \quad (3)$$

where J_n is a Bessel function.

The probabilities of n-fold scattering are shown in the figure. For moderate fields, the probability of multiple scattering reaches a measurable value.

The dispersion of the electron beam proceeds quite slowly. We obtain for the dispersion, from (3)

$$\sum_{n=-\infty}^{\infty} n^2 W_n(t) = at.$$

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38