$$G'(p\mid A) = -\int_0^\infty d\nu \int_0^\infty d\mu e^{-\varepsilon(\nu+\mu)} \exp\{-i(m'-up)\nu - i(m'+up)\mu\}(m'\mid\nu+\mu\mid)^{e^2/\pi}$$
$$\times \exp\left\{-\sqrt{4\pi}\frac{eu^\mu}{(2\pi)^2}\int \frac{\exp\{-i(uk)(\nu-\mu)\}-1}{(uk)} A_\mu(k)\,dk\right\}, \quad (5)$$

where $m' = m + e^2M/2$ is the observed mass. In particular, for $A = 0$, we have:[4]

$$G'(p/0) = \frac{1}{m'^2 - p^2}\left|\frac{m'^2}{m'^2-p^2}\right|^{e^2/\pi}. \quad (6)$$

Applying the Green function,[5] we calculate the probability of the following process. A particle is scattered in the external field and radiates an arbitrary number of long-wave photons with energies less than ε' and n additional photons with energies from E_1 to E_2. It is assumed that the energy and momentum of the radiated photons are small compared with the energy and the change of momentum of the particles in scattering, *i.e.*, $\varepsilon' \ll m'$ and $E_1 > \varepsilon'$. The probability of this process is given by the following expression:

$$dw = dw_0\left(\frac{\varepsilon'}{m'}\right)^{2e^2/\pi}\frac{1}{n!}\left\{\frac{2e^2}{\pi}\ln\frac{E_2}{E_1}\right\}^n, \quad (7)$$

where dw_0 is the scattering probability in the zeroth perturbation theory approximation.

If the condition $(2e^2/\pi)\ln(m'/\varepsilon') \ll 1$ is satisfied, Eq. (7) assumes the form

$$dw = dw_0\frac{1}{n!}\left\{\frac{2e^2}{\pi}\ln\frac{E_2}{E_1}\right\}^n.$$

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305

Coherent Scattering and Radiation of Electromagnetic Waves by a Plasma in an Inhomogeneous Magnetic Field

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IN VIEW OF THE INTEREST in the potentialities of the intense radiative acceleration interaction in a plasma[1] and the difficulty involved in the formation of stable plasma bunches which provide effective coherent radiation scattering, we propose another possible method for enhancing radiation scattering in a plasma, *viz.* the application to the plasma of local magnetic fields.

It is well known that the presence of a magnetic field in a plasma causes a change in its electromagnetic properties, in particular, in the dielectric constant ε; this change depends not only on the magnitude of the field but also on its direction. Furthermore, the use of an inhomogeneous magnetic field can bring about an inhomogeneous plasma density distribution because of the dependence of the ionization efficiency of a given ionizing agency, for example a high-frequency wave, on magnetic field. Hence, regions of the plasma in which the magnetic field differs noticeably in magnitude or direction are analagous to "optical inhomogeneities."

If the dimensions of the localized region of a given magnetic field are considerably smaller than the wavelength of the incident radiation, the radiation associated with the particles of the plasma is coherent; if there is no strong shielding of the field in the external region (small difference in dielectric constants in the internal and external regions) the radiation is proportional to the square of the number of particles.

For purposes of illustration, we consider coherent scattering of a quasi-plane wave of frequency ω propagating in a wave guide filled with plasma to which there is applied a longitudinal magnetic field to bring about colinear motion of the particles. If the plasma density falls off sharply between the axis of the wave guide and the walls, an effective scattering region may be formed by the application of a supplementary local field having, for example, a localized longitudinal component. The quantities which characterize the average values of the plasma parameters inside and outside the region of effective scattering will be denoted in the following by the subscripts i and a. For simplicity we will assume that $\varepsilon_a \approx \varepsilon_i \approx 1$ and $|1 - \varepsilon_i| \gg |1 - \varepsilon_a|$. Then the effective cross-section for radiation scattering (of wavelength λ) in the region of inhomogeneous magnetic field, which we will assume to be quasi-spherical and of dimensions $l \ll \lambda$, is

$$\sigma \approx \frac{2\pi^5}{3}\frac{l^6}{\lambda^4}\left(\frac{\varepsilon_i - 1}{\varepsilon_i + 2}\right)^2 \approx \frac{2\pi^5}{3^3}\frac{l^6}{\lambda^4}\left\{\frac{\omega_0^2(n_i)}{\Delta\omega^2(H_{zi})}\right\}^2,$$

where the plasma frequency $\omega_0 = (4\pi e^2 n/m)^{1/2}$, n is the electron density in the plasma, e and m are the charge and mass of the electron, and $\Delta\omega^2(H_i) \approx \omega^2 - \omega_H^2(H_i)$, where the Larmor frequency is given by $\omega_{Hi} = eH_{zi}/mc$. For $\Delta\omega^2 \sim \omega^2$, $\sigma_i \approx 8\pi r_0^2 N^2/3$ (r_0 is the classical electron radius and N is the total number of electrons in the scattering region) and the intensity of the field equivalent to the radiation force acting on the electron in the region is $\mathbf{E}_{\mathrm{eff}} \approx \sigma_i \mathbf{S}/Nec$. For example, with a radiation flux $S \approx 300\,\mathrm{kw/cm}^2$ and $N \sim 3 \times 10^{12}$; these crude calculations yield $E_{\mathrm{eff}} \sim 100$ v/cm.

The multiplication of the radiation force acting on each particle which participates in scattering can be used, in practice, for the formation of intense coherent fluxes of plasma particles. In fact a judicious choice of the periodicity of the spatial distribution of the localized-field regions can provide coherent radiation by the different plasma regions and by increasing the number of inhomogeneous field regions it may be possible for the radiation mechanism to provide continuous (in transition) acceleration of the particles as they travel from one acceleration zone to another. Furthermore, the application of a localized magnetic field in the plasma can be used to inhibit undesired radiation propagation in the wave guide and to enhance conversion in a resonator. In this case, with a given power input, it is possible to achieve much higher radiation pressures and interactions at resonance than is possible in scattering by traveling waves.

As an interesting example of the inverse problem we consider the coherent radiation of a bunch in an electron plasma which travels through a spatially-periodic, axially-symmetric magnetic field ("longitudinal undulator") comprising, for example, a system of magnetized rings of alternating longitudinal polarity or a succession of magnetic lenses or coils in which the direction of current flow is alternated. (Undulators in which transverse fields are employed are discussed in Refs. 2 and 3.)

The radiation of a bunch which travels along the axis of such a system arises by virtue of the change in the induced moment of the bunch. The appearance of a magnetic moment in the bunch and the effect of the focusing forces due to the external field and the induced motion of the electrons themselves can be interpreted and evaluated most simply in a coordinate system which moves with the center of the bunch. In this system the fixed sinusoidal distribution of axially-symmetric magnetic field in the laboratory system can be considered an axially-symmetric wave whose effect on a bunch (if the coherence conditions apply and if the change of dimensions of the bunch is neglected) is that of a quasi-homogeneous sinusoidally varying magnetic field on a quasi-cylindrical or quasi-spherical section of the medium (the expression for the field is given, for example, in Ref. 4). An estimate of the average ponderomotive force indicates that over a wide range of the plasma parameters, which are of practical interest, the plasma tends to focus the bunches; there is a longitudinal focusing effect which arises as a result of the attraction between the induced currents flowing in the same direction. This effect may make possible the use of compact hollow rings or intense solid bunches for relatively long periods of time.

It would be of interest to investigate the dissipation of the alternating component of the energy of a plane quasi-neutral plasma when it is penetrated by periodic or otherwise inhomogeneous axially-symmetric fields.

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Translated by H. Lashinsky
306