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41

ON THE DAMPING OF ELECTROMAGNETIC WAVES IN A PLASMA SITUATED IN A MAGNETIC FIELD

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THE damping of high frequency electromagnetic waves in a completely ionized plasma is usually determined by the frequency of collisions between electrons and ions[1] $\nu_{eff} = 2\sqrt{2\pi}\, e^4 n_0 L / m_e^{1/2} T^{3/2}$, where e is the charge, m_e the mass, n_0 the electron density, T the plasma temperature, and L the Coulomb logarithm. For high temperatures and low plasma densities, ν_{eff} is small. Under these conditions it may turn out that the damping of electromagnetic waves γ due to the existence of thermal motion of electrons is significant (this damping is similar to the well known[2] damping of longitudinal plasma oscillations. γ increases sharply when the frequency of the wave ω becomes close to the Larmor frequency ω_H of the electron or to a multiple of it ($\omega_H = eH_0/m_e c$, $\mathbf{H}_0$ is the intensity of the external magnetic field).

Using the expressions obtained by Silenko and Stepanov[3] for the components of the dielectric permittivity tensor, we obtain for the damping coefficient $\gamma = \gamma_m$ for $\omega \approx m\omega_H$, m = 1, 2, 3, ... the following expression:

$$\frac{\gamma_m}{\omega} = \sigma_m [\sin^2\theta n^4 - (1-v)(1+\cos^2\theta) n^2 + 2\left(1 - \frac{v}{1-u} + \frac{v\sqrt{u}}{1-u}\right)(1 - v - \sin^2\theta\, n^2)] \times [(2 - 3u - 3v + 4uv\cos^2\theta) n^4 + (4u + 8v - 2 - 6v^2 - 3uv - 3uv\cos^2\theta)\, n^2 - u - v(3 - 6v + 3v^2 - 2u)]^{-1}, \tag{1}$$

$$\sigma_m = \frac{\sqrt{\pi}\, m^{2m-2} \sin^{2m-2}\theta\,(u-1)\,\Omega^2}{2^{m+3/2} m!\,|\cos\theta|\,\omega_H^2} (\beta n)^{2m-3} e^{-z_m^2},$$

$$z_m = \frac{1 - m\omega_H/\omega}{\sqrt{2}\,\beta n \cos\theta},$$

where $n = kc/\omega$, $\mathbf{k}$ is the propagation vector, θ is the angle between $\mathbf{k}$ and $\mathbf{H}_0$,

$$u = (\omega_H/\omega)^2, \quad v = (\Omega/\omega)^2, \quad \Omega = (4\pi e^2 n_0/m_e)^{1/2},$$
$$\beta = v_T/c, \quad v_T = (T/m_e)^{1/2}.$$

In deriving expression (1) it was assumed that

$$kv_T \ll \omega_H, \quad \gamma_m \ll kv_T |\cos\theta|, \quad |z_{1,2}| \gg 1.$$

The frequency ω is found from the equation

$$(1 - u - v + uv\cos^2\theta) n^4 - [2(1-v)^2 + u(v-2) + uv\cos^2\theta] n^2 + (1-v)[(1-v)^2 - u] = 0. \tag{2}$$

If it follows from (2) that $\omega \approx \omega_H, 2\omega_H$, with $|z_{1,2}| \sim 1$, then formula (1) is not valid for $\gamma_{1,2}$. In this case $\gamma_{1,2}/\omega \sim \beta n$ for values of θ which are not close to zero. However, the exact value of $\gamma_{1,2}$ for $|z_{1,2}| \sim 1$ may only be obtained numerically. For the case $\theta = 0$, the resonance $\omega = \omega_H$ which occurs for the extraordinary wave has been investigated by Silin.[4]

The damping (1) is determined by the interaction with the electromagnetic wave of those electrons, whose thermal velocity in the direction of $\mathbf{H}_0$ is close to $(\omega - m\omega_H)/k\cos\theta$. For $n \gg 1$ formula (1) gives for γ_m the result obtained by Sitenko and Stepanov.[3]

For large T and small n_0, γ_m may be considerably larger than ν_{eff}. For example, let $n_0 \sim 10^8\,\text{cm}^{-3}$, $H_0 \sim 20$ gausses, $n \sim 1$, then $\gamma_{1,2}/\nu_{eff} \sim 10^6$ for $T \sim 10^{6\,\circ}$K. Far from resonance, γ is exponentially small and is usually much less than ν_{eff}.

In conclusion, I wish to express my sincere

gratitude to A. I. Akhiezer and Ia. B. Fainberg for discussing the results of this work.

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42

NUCLEAR ISOMERISM AND ATOMIC SPECTRA

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In two earlier works[1] we predicted a shift of the atomic spectrum of In^{115} III as the result of nuclear isomerism.

This result can be generalized to include all odd nuclei, subject to the following assumptions: (1) In accordance with the shell model, the nuclear transitions are single-particle transitions. (2) In nuclei with optical protons, the shift is connected with the Coulomb interaction. In nuclei with optical neutrons the shift is due to the electron-neutron interaction. (3) In the first approximation, the effect is expressed in terms of perturbation theory in the Rosental-Breit form.[2] The "unperturbed" wave functions of the electron are calculated for uniform charge distribution over the nuclear volume.

It can be shown that the absolute value of the shift is determined only by the difference in the nucleon distributions in the nucleus. Since the nuclear excitation is connected only with the change in the state of the optical nucleon, the effect is expressed, in the final analysis, by the difference between the mean-squared radii of the optical nucleons. This is an important property of the phenomenon and determines its significance; it can yield new information on the outer shell of the nucleus and on the mechanism of nuclear excitation.

The sign of the shift depends, on one hand, on the entire nuclear configuration and, on the other, on the quantum numbers of the two corresponding nuclear states. For a given configuration, the sign, in the case of the potential of a harmonic oscillator, is determined by the sign of the difference $N - N'$, where N and N' are the principal quantum numbers of the ground and excited states respectively. An analogous result is obtained for the quantum orbital number l in the case of a well with infinite walls. Incidentally, in the latter case the shift is proportional to the difference in the orbital momenta of the corresponding nuclear states and, thus, the measurement of the shift consists in principle of measuring these momenta.

The theoretical value of the shift ΔE was calculated for two transitions, $1g_{9/2} - 2p_{1/2}$ and $2d_{3/2} - 1h_{11/2}$ (these transitions are characteristic of a large number of isomers with an optical proton). The shape of the well was found to have little effect on the result of the calculation, carried out with the aid of four potentials independent of the velocity (harmonic oscillator, rectangular well with infinite walls, and diffuse well of two types, given in references 3* and 4).

For these transitions, in nuclei with odd Z and even N, the shift ΔE was found to be greater than 10^{-2} cm^{-1} for s electrons. This can apparently be observed experimentally. The Nilsson nonspherical potential leads in our case to practically the same results as the harmonic oscillator. This is due to the degeneracy of the eigenfunctions of the harmonic oscillator, which were assumed in reference 5 as the basis vectors.

In nuclei with even Z and odd N, the isomer excitation causes a change in the neutron distribution, which in turn leads to a change in the energy of interaction between the electron and the neutron. Although here the theoretical order of magnitude of the shift is at the experimental limits of observation (in Hg^{197} II, for example, $\Delta E \approx 10^{-4}$ cm^{-1} for the transition $3p_{1/2} - 1i_{13/2}$), it would be particularly important to be able to observe this effect. Actually, we deal here in principle with a pure electron-neutron interaction (if we neglect the possible exchange effect), even in those particular conditions when the neutron is bound.† In those conditions, the effective mass of the nucleon in the nucleus is less than the mass of the free nucleon and the magnetic moment of the nucleon can also be expected to have another (greater) value