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2.C Enhanced Reflectivity Due to Pondermotive Rippling

Recent theoretical studies have elucidated a physical process which may play a significant role in determining the amount of light reflected from a target plasma corona. Unlike well-known scattering instabilities such as Stimulated Brillouin Scattering (SBS) and Stimulated Raman Scattering (SRS), this effect is due to an equilibrium feature of the coronal plasma flow.

The effect may be described using the simple model of the target plasma shown in Fig. 18. For simplicity, the light is taken to be normally incident (the extension to oblique incidence is straightforward). The corona is modeled by a uniform plasma of density n moving through the critical surface at a constant velocity v. To model the absorption processes, which are most effective near critical density, we assign the critical surface a partial reflectivity $R_0 < 1$. The incident light has wavenumber k; in combination with the light reflected from the critical surface it forms a standing wave of wavenumber $2k$. The electric field of this standing wave then gives rise through the pondermotive force to a stationary density ripple in the corona, also of wavenumber $2k$, which can Bragg-reflect the incident light and thus enhance the reflectance of the corona. A linearized analysis gives the following equation for the total reflectance R_{tot} due to the critical surface and the density ripples:

$$R^2_{tot} = R^2_o \, e^{\beta(1 - R^2_{tot})}.$$

The parameter β contains the laser and plasma parameters

$$\beta = \frac{1}{4} \, \frac{n/n_c}{1 - n/n_c} \; \frac{v/c_s}{[(v/c_s)^2 - 1]^2 + \left(\frac{\nu v}{2kc^2_s}\right)} \; \frac{V^2_{osc}}{V^2_{th}} \; \frac{\nu L}{c_s}$$

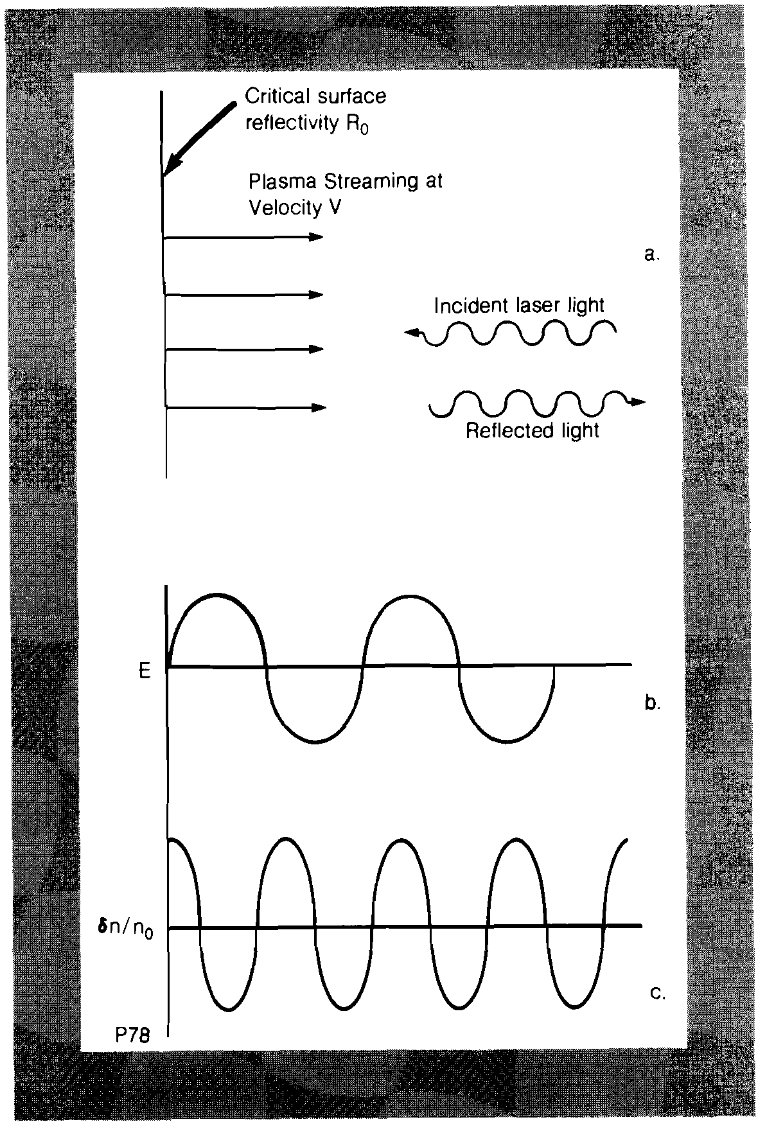

Fig. 18
Simplified model of corona. The incident laser light is taken to be normally incident to the uniform underdense plasma (a). The plasma is streaming at velocity v with respect tocritical surface. Also shown are (b) the standing wave part of the electric field, wavelength K; and (c) the density fluctuations due to pondermotive force, wavelength 2k. These density fluctuations can Bragg-reflect the incident light.

Here n_c is the critical density, c_s is the ion sound speed, V_{osc} is the electron quiver velocity in the incident light, V_{th} is the electron thermal velocity, L is the length of the plasma, and ν is a phenomenological damping factor, representing primarily ion

Table 2
Typical values of β in a laser plasma corona.

	INCIDENT LASER POWER (W/cm ^{2})		
	10^{14}	10^{15}	10^{16}
T_e/T_i = 10	β=0.938	9.38	93.8
15	0.251	2.51	25.1
20	0.101	1.01	10.1

Values of β for L = 100 μ, v/c_s = 1.5, n/n_c = 1.5, λ = 1.05 μ

P81

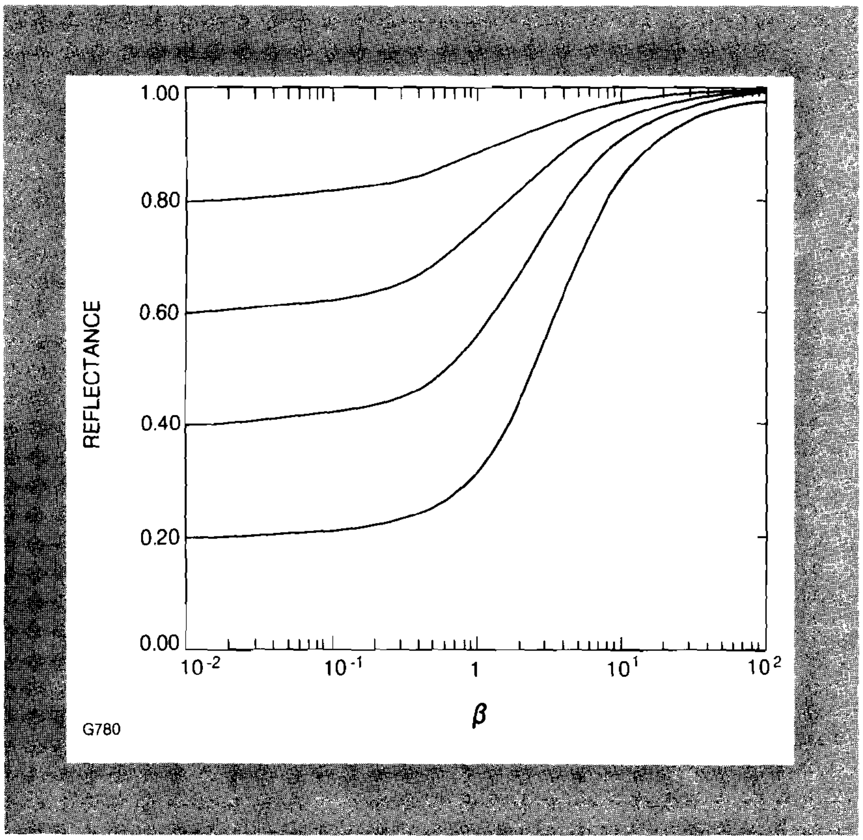

Fig. 19
Total reflectance as a function of β and R_o ($R_{tot} \to R_o$ as $\beta \to 0$). Density fluctuation may significantly enhance reflection from the corona for much of the parameter region of interest to laser fusion, $\beta > 1$.

Landau damping. Note that if $v = 0$ or $\nu = 0, \beta = 0$ and $R^2_{tot} = R^2_o$. Thus both damping and a non-zero flow velocity must be present to obtain enhanced reflection from the coronal density ripples.

Results for R_{tot} as a function of β are shown in Fig. 19 for several values of R_o, the critical surface reflectivity. Note that for $\beta << 1$, $R_{tot} \sim R_o$, while for $\beta >> 1$, $R_{tot} \simeq R_o, \simeq 1$. The transition between these two limits occurs near $\beta = 1$, so that for $\beta < 1$ we expect significant enhanced reflection. In Table 2 are listed some typical values for β in a laser plasma corona, calculated for

$$L = 100\ \mu m,\ v/c_s = 1.5,\ n/n_c = 0.5,\ \lambda = 1.05\ \mu m,$$

and several values of T_e/T_i (ratio of electron to ion temperature) and incident laser power. The strong dependence on T_e/T_i is due to the Landau damping factor ν in β. Table 2 shows that for much of the parameter region of interest to laser fusion $\beta > 1$, so that the density ripples may significantly enhance reflection from the corona.

Enhanced reflection is difficult to observe experimentally, since unlike SBS and SRS it does not alter the spectrum of the reflected light but rather augments the specularly reflected component. However, the density ripples themselves appear in simulations[1] and have been observed in microwave experiments[2]. When the coronal flow velocity is near the ion sound speed, the density ripples become ion acoustic waves and contribute to SBS[3].

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