MAJOR

PYL 879: High Power Laser Matter Interaction

November 20, 2015, Time 2 hr, M. Marks 40

Attempt 6 problems.

1A) A laser of frequency $\omega_0 = 3\omega_p$ undergoes stimulated Raman scattering (in the backward direction) in a plasma of plasma frequency ω_p. Estimate the phase velocity of the plasma wave produced. (2)

1B) A laser of frequency ω, incident on a metal ($\varepsilon_r = 9, \omega_p = \sqrt{11}\omega$) at angle of incidence $\pi/6$ in the presence of a surface ripple of wave number $q\hat{z}$, resonantly excites a surface plasma wave. Estimate q. (2)

1C) An intense short pulse laser is normally incident on a metal. Inside the metal, $\vec{E} = \vec{A}_0(t)\exp(-x/\delta)\exp(-i\omega t)$. Obtain the time average heating rate H. How does the electron temperature scale with the fluence F of the pulse? (2)

1D) A laser of frequency ω and normalized amplitude $a_0 = e|E|/m\omega c$. is normally incident on an overdense plasma of $\omega_p = 2\omega$. Estimate the value of a_0 above which the laser would propagate in the plasma.
[Given, amplitude transmission coefficient $T_A = 2/(1+\varepsilon_{reff}^{1/2})$.] (2)

1E) Plot j versus E in GaAs with a word of explanation. Indicate the region of instability. (2)

2A) A two dimensional Gaussian laser beam with

$$\vec{E} = \hat{y}Ae^{-i(\omega t - kz)}, \quad |A|^2 = \frac{A_{00}^2}{f}\exp(-x^2/r_o^2 f^2)$$

propagates in a nonlinear medium having $\varepsilon_r = \varepsilon_{r0} + \varepsilon_2|E|^2$. The equation governing f is

$$\frac{d^2 f}{dz^2} = \frac{1}{R_d^2 f^3} - \frac{\varepsilon_2 A_{00}^2}{\varepsilon_{r0} r_0^2 f^2}$$

where $R_d = kr_0^2$. If $\varepsilon_2 A_{00}^2/\varepsilon_{r0}r_0^2 = 4/R_d^2$, obtain the minimum spot size the beam would acquire. Take, at $z = 0, f = 1, df/dz = 0$. (3)

2 B) A fully ionized carbon cluster of ion density n_0 and radius r_c undergoes ion Coulomb explosion. Estimate the energy an ion initially at $r = r_c/2$ would have after the explosion. (3)

3) A laser $\vec{E} = \hat{y} A e^{-i(\omega t - kz)}$ propagates through a plasma of $\varepsilon_{reff} = 1 - \omega_p^2 / \omega^2 + \alpha |E|^2$, $\alpha = e^2 \omega_p^2 / (4 m^2 c^2 \omega^4)$. Obtain k when $A = A_0$, a constant. For $A = A_0 + A_1(x,z)$, , $A_1 << A_0$, the wave equation governing A_1 is

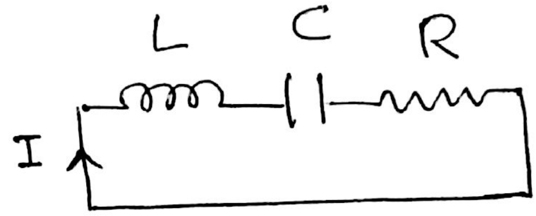
$$2ik \frac{\partial A_1}{\partial z} + \frac{\partial^2 A_1}{\partial x^2} + \frac{\omega^2}{c^2} \alpha A_0^2 (A_1 + A_1^*) = 0.$$

Obtain the growth rate Γ of filamentation instability (i.e., of amplitude perturbation A_1).

Plot Γ as a function of transverse ripple wave number q_x. (6)

4) A LCR circuit has a capacitor with $C = C_{00} + C_2 \cos(\omega_0 t)$, where $\omega_0 = 2\omega_r$, $\omega_r = 1/\sqrt{LC_{00}}$, $C_2 << C_{00}$, $R/\omega_r L << 1$.

Deduce the growth rate of parametric instability (of current) in the circuit. (6)



5) In the presence of a large amplitude plasma wave $\phi = A\cos\psi, \psi = \omega t - kz$, the $\gamma - \psi$ relation for an electron is $\gamma - \beta(\gamma^2 - 1)^{1/2} = A'\cos\psi + C_1$: $\beta = \omega/k = 0.99$, $A' = 0.3$. Plot the separatrix. If an electron initially has $\gamma = 2, \psi = \pi$, estimate the maximum energy this electron would attain. (6)

6A) A laser $\vec{E}_0 = \hat{y} A_0 e^{-i(\omega_0 t - k_0 z)}$ propagates through a plasma In the presence of a plasma wave $\phi = A e^{-i(\omega t - kz)}$. Obtain the nonlinear current density at $\omega_1 = \omega_0 - \omega$. (3)

6B) Obtain the difference frequency ponderomotive force and nonlinear electron density perturbation n_ω^{NL} due to lasers $\vec{E}_j = \hat{y} A_j e^{-i(\omega_j t - k_j z)}, \omega = \omega_1 - \omega_2$, $j = 1, 2$. (3)

OR

6) Explain the feedback mechanism of stimulated Raman scattering. The coupled mode equations for plasma wave potential $\phi = A e^{-i(\omega t - kz)}$ and the scattered wave field $\vec{E}_1 = \hat{y} A_1 e^{-i(\omega_1 t - k_1 z)}$ in the presence of the pump $\vec{E}_0 = \hat{y} A_0 e^{-i(\omega_0 t - k_0 z)}$ are

$$(\omega^2 - \omega_p^2)\phi = \omega_p^2 \phi_p$$

$$(\omega_1^2 - \omega_p^2 - k_1^2 c^2)\vec{E}_1 = -i\omega_1 \vec{J}_{\omega_1}^{NL} / \varepsilon_0,$$

where $\phi_p = -e\vec{E}_0 . \vec{E}_1^* / (2m\omega_0 \omega_1^*)$, $\vec{J}_{\omega_1}^{NL} = k^2 \varepsilon_0 \phi^* e \vec{E}_0 / (2mi\omega_0)$.

Deduce the growth rate. (6)