Birla Institute of Technology & Science - Pilani, K. K. Birla Goa Campus

PHY F433 : Topics in Nonlinear Optics, Second Semester 2022-23

Comprehensive Examination. Date: May 16, 2023. Time: 14.00 to 17.00 hrs

Max. marks: 70 (To be normalized to 35 as Compre weightage is 35%)

Section 1 : Solve the following four problems [7 or 8 marks each, Total 30 marks]

Important : The answers should be in the units specified.

[$\varepsilon_o = 8.854\times10^{-12}$ F/m, $m = 9.1\times10^{-31}$ kg, $e = 1.6\times10^{-19}$ C, $c=3\times10^{8}$ m/s]

1.1) Show that in a plasma having an exponential electron density profile given by $n = n_c e^{(-x/L)}$, the expression for current density for n^{th} harmonic is: $j(n\omega)= i(1/\{n-1\}!)[n_c e\omega/L^{n-1}][eE_p/m\omega^2]^n \exp^{-in\omega t}$. **[7 marks]**

1.2) A Ti:sapphire laser beam of wavelength 0.81 μm is incident on a solid aluminium target. The focussed intensity on the target is 10^{14} W/cm^2. Calculate the following. **[8 marks]**

a) The density up to which the laser beam will penetrate for normal incidence. (in cm^{-3}) (2 marks)

b) The density up to which the laser beam will penetrate for 30^o incidence. (in cm^{-3}) (2 marks)

If the intensity of the laser beam is increased to 10^{20} W/cm^2, calculate the following:

c) The laser strength parameter (a_o) of the beam [$a_o = 0.857 \times 10^{-9}\, \lambda(\mu m)\, \sqrt{I(W/cm^2)}$] (2 marks)

d) The density up to which this laser beam will penetrate for normal incidence. (in cm^{-3}) (2 marks)

1.3) In the inertial confinement fusion, given that 1) The energy required to heat the DT fuel to 10 keV is 1.16 x10^{10}J/g, 2)The energy released from fusion of DT fuel is 3.4x10^{11}J/g, 3) The density of uncompressed DT fuel is ρ = 0.2 g/cm^3, and 4) The Lawson criterion for ICF is ρR = 6 g/cm^2, find the following **[7 marks]**

a) Mass of the fuel required to start fusion with 10^4 compression. (in μg) (3 marks)

b) Radius of the uncompressed fuel pellet. (in μm) (2 marks)

c) Energy required to heat this pellet to 10 keV (in MJ) (1 marks)

d) Fusion energy released after this heated DT fuel ignites (in MJ) (1 marks)

1.4) For laser beat wave acceleration (LBWA) scheme of electron acceleration, two CO_2 laser beams are used, one operating at 10.6 μm and other one at 9.6 μm. **[8 marks]**

a) Find the angular frequencies of the two laser beams (in rad/s). (2 marks)

b) Find beat frequency (in rad/s) . (1 mark)

c) If the beat wave frequency is to be equal to the plasma frequency (ω_p), find the value of the required density of the plasma (in cm^{-3}) . (3 marks)

d) Using the expression E_{max} = 0.511 [ω_p/c (m/s)] MV/m, find the magnitude of the electric field generated in the process (in GV/cm) . (2 marks)

Section 2 : Answer any *five* (out of 6) questions. [4 marks each, Total 20 marks]

Line 1: State whether the each of the following statements is true or false.

Line 2 onwards: If true, justify why it is true;

Line 2: If false, write down the corrected statement by modifying the underlined word/s only.

Line 3 onwards: Justify why the corrected statement is true.

In either case, justification should be at least 3-4 sentences.

2.1) Metal vapour is a very good medium for second harmonic generation.

2.2) An ion acoustic wave with dispersion relation $\omega = k \{K_B T_e/[(1+k^2\lambda_D^2)M]\}^{1/2}$, in the approximation that $k >> 1/\lambda_D$, becomes a constant frequency wave.

2.3) Portrait holography can be done with a continuous wave (CW) laser.

2.4) Positive nonlinearity in a wave leads to the formation of a shock wave.

2.5) Rayleigh-Taylor instability occurs once in inertial confinement fusion.

2.6) Conditions of the Lawson-Woodward theorem have to be followed to accelerate electrons with light.

Section 3 : Answer any *five* (out of six) questions [4 marks each, Total: 20 marks]

Give brief (3-4 sentences) correct explanation for the following.

3.1) Explain why in a centro-symmetric molecule, a vibrational mode will be either Raman active (i.e. Raman transition) or infra-red active (i.e. vibrational transition) but not simultaneously active for both.

3.2) Explain why there exists an "optimum" angle of incidence for p-polarized light to get maximum resonance absorption.

3.3) Explain why for circularly polarized laser light, all the above threshold ionization (ATI) electrons produced have the "same" energy $2U_p$.

3.4) Give any five differences between a "photograph" and a "hologram". *(You have studied 10 in class)*

3.5) Explain the "indirect drive" scheme of inertial confinement fusion.

3.6) Explain the concept of "self-modulation" of a laser pulse used in laser wake-field acceleration.

Examination Type: Off-line, Open Books/Handwritten notes (unlimited pages)

{No Laptops, No Cell phones, No printouts of lecture ppts}