M.Sc. PHYSICS
FOURTH SEMESTER
LASER & NON- LINEAR OPTICS- II
MSP – 403D
(Use Separate Answer Scripts for Objective & Descriptive)

Duration: 3 hrs.

Full Marks: 70

[PART-A: Objective]

Time: 20 min.

Marks: 20

Choose the correct answer from the following: *1X20=20*

1. Which of the following is the best tool for high resolution spectroscopy?
    a. Photo-acoustic Raman Spectroscopy (PARS)
    b. Coherent Anti-Stokes Raman Scattering (CARS)
    c. Stimulated Raman Spectroscopy (SRS)
    d. Saturated Absorption Spectroscopy (SAS)

2. In a Free electron laser (FEL), the free electron moving at relativistic velocity is scattered by a spatially varying magnetic field where the upper laser state consists of a fast electron together with -------------.
    a. virtual photon
    b. few slow electrons
    c. plasma
    d. few ions

3. In a Free electron laser, their frequency is tunable by ---------- electron energy.
    a. slowing down
    b. accelerating by
    c. spreading of
    d. variation of

4. Population of the upper energy level of a transition is accomplished in PARS by a -------.
    a. direct absorption
    b. Stimulated Raman process
    c. acoustic pressure oscillations
    d. none of these

5. Which of the following process is most suitable for overcoming the Doppler broadening effect?
    a. SRS
    b. PARS
    c. CARS
    d. SAS

6. Laser induced collision process was first considered by
    a. Gudzenko and Yakovlenko
    b. Schwarz and Hora
    c. Olicer and Cutler
    d. Harris

7. During single atom detection, a few ------ dye laser is usually sufficient to saturate transition to create high probability that the atom is in excited state.
    a. watts
    b. milli-watts
    c. kilo-watts
    d. mega-watts

8. Using -------- forces exerted by laserlight, one can trap neutral atoms and cool them to very low temperature.
    a. gravitational
    b. electric
    c. mechanical
    d. magnetic

9. During modulation of an electron wave by a light wave, an electron beam of --------
   energy is used.
   a. 50 eV
   b. 50 meV
   c. 50 keV
   d. 50 MeV

10. Which of the following is most efficient one?
    a. A two level laser
    b. A four level laser
    c. A three level laser
    d. None of these

11. For a pure state with density operator 'ρ', which of the following condition is true?
    a. $\text{Tr}(\rho)=1$
    b. $\text{Tr}(\rho^2)=1$
    c. both (a) and (b) are true
    d. none of the above

12. The completeness equation related to a two state system having states $|a\rangle$ and $|b\rangle$ is
    a. $|a\rangle\langle a| + |b\rangle\langle b| = 0$
    b. $|a\rangle\langle b| + |b\rangle\langle a| = 1$
    c. $|a\rangle\langle a| + |b\rangle\langle b| = 1$
    d. $\langle a|a\rangle + \langle b|b\rangle = 1$

13. The Rabi-oscillation associated with a two-level system and an external field E is given
    by
    a. $\Omega_R = \dfrac{\hbar}{i}|\mu_{ab}|E$
    b. $\Omega_R = \dfrac{|\mu_{ab}|E}{\hbar}$
    c. $\Omega_R = \dfrac{\hbar|\mu_{ab}|}{E}$
    d. $\Omega_R = \dfrac{\hbar E}{|\mu_{ab}|}$

14. The dipole matrix approximation for a light-matter interaction suggest the following
    relation to be true
    a. $K.r = 0$
    b. $K.r = 1$
    c. $K.r \ll 1$
    d. $K.r \gg 1$

15. The Von-Neuman or Liouville equation for density operators "ρ" is given by
    a. $\dot{\rho} = \dfrac{1}{i\hbar}[H,\rho]$
    b. $\dot{\rho} = \dfrac{1}{i\hbar}[H,\Gamma]$
    c. $\dot{\rho} = \dfrac{1}{i\hbar}[\rho,\Gamma]$
    d. $\dot{\rho} = \dfrac{1}{i\hbar}[\Gamma,H]$

16. Which among the following represents Kerr nonlinearity
    a. $n = n_0 + n_2 I$
    b. $n = n_0 I + n_2 I^2$
    c. $n = \sqrt{n_0 + n_2 I}$
    d. $n = (n_0 + n_2 I)^2$

17. Which among the following is not determined by Z-scan technique
    a. Nonlinear absorption
    b. Raman Effect
    c. Nonlinear refractive index
    d. Two photon absorption

18. The pump-probe method is successful in study _____ phenomena.
    a. ultraslow
    b. ultrafast
    c. Stopped light
    d. none of these

[2]

19. In close aperture Z-Scan method, the phase shift for the case of $\Delta\Phi > 0$,
    a. peak trails the valley
    b. valley trails the peak
    c. no peak and valley appears
    d. none of the above

20. For Normal dispersion, the group velocity dispersion follows
    a. $\beta_2 > 0$
    b. $\beta_2 < 0$
    c. $\beta_2 = 0$
    d. $\beta_2 = \infty$.

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[3]

PART-B : Descriptive

Time : 2 hrs. 40 min.   Marks : 50

[Answer question no.1 & any four (4) from the rest]

1. a. What is Saturation absorption spectroscopy? How is the method used to study red line of Hydrogen H_α?   5+5=10

    b. What you mean by nonlinear optical susceptibility of a medium? Discuss the three-fold motivation towards obtaining nonlinear susceptibilities

2. a. How can modulation of an electron wave be done by a light wave?   5+5=10

    b. Explain briefly the mechanism of achieving Electromagnetically Induced Transparency in a nonlinear quantized system.

3. a. Discuss elaborately about Coherent Anti-Stokes Raman Scattering (CARS).   4+6=10

    b. How can Pair-excitation be achieved by Laser induced collision process?

4. a. How can single atom detection be done with Lasers? How can laser cooling be achieved to trap neutral atoms?   7+3=10

    b. Write a short note on Isotope separation

5. a. Write about five applications of lasers.   5+5=10

    b. Discuss about the Free electron laser.

6. If a single mode field $\vec{E}$ interacts with a two-level atom, having states $|a\rangle$ (upper) and $|b\rangle$ (lower), with energy eigenvalues $\hbar\omega_a$ and $\hbar\omega_b$ associated with the states, respectively, then using completeness equation and dipole matrix element write the expressions for the following   4+6=10
    a. Unperturbed Hamiltonian (H_0)
    b. Interaction Hamiltonian (H_i)

7. Describe the operation of Z-scan technique. Discuss briefly the observations through Open and Close appertures.   4+6=10

8. What are the step-index and gradded-index fibers? Define V-parameter and relative index difference of a fiber.   1+1+2+3+3=10
    Discuss briefly the following nonlinear phenomena
    a. Self-phase modulation
    b. Cross-phase modulation.

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