

1. (1.1) Explain the parametric fluorescence and parametric amplification processes mediated by $\chi^{(2)}$ in a nonlinear medium.
 (1.2) Using two monochromatic plane waves incident on a positive uniaxial crystal, obtain the perfect phase match condition for the difference frequency generation process due to second order nonlinearity of the crystal.
 (1.3) Continuing on the above, write the corresponding nonlinear for all the interacting waves. Obtain and plot the result for weak signal (higher frequency output) generation from the crystal thickness L with coherence length L_c .
 (1.4) Describe spontaneous and stimulated Raman scattering processes through proper mathematical expressions for the corresponding polarizations and energy level representations.
2. Gaussian laser pulses of Δt duration in a Gaussian beam of Δw width are made to transmit through a completely transparent homogeneous isotropic nonlinear medium of thickness L . Experiments are conducted with varying pulse and beam characteristics and the material parameters of the nonlinear medium. Explain the conditions under which the laser pulses can pass through the medium without any change in their characteristics.
3. (3.1) By writing the Hamiltonian for a quantum linear harmonic oscillator, define a number operator suitable for obtaining the photon number states. Describe the complete process for obtaining the photon number states and corresponding eigen values for quantum light.
 (3.2) Establish the correspondence between a classical linear harmonic oscillator and electromagnetic waves through the equivalence of the energy in the two cases. What is the mass of the harmonic oscillator equivalence here?
4. (4.1) In terms of photon statistics, describe a perfectly coherent, a quantum and a chaotic source of light. Give one example of each of the three sources. How does the second order correlation function behave in all the three cases? Explain.
 (4.2) A weak light source delivers at power 1 pW and photon energy of 2 eV while random occurrence of single photon events is being counted with the help of a PMT detector and an electronic counter. The detector has quantum efficiency of 10% and counter timer is set for 0.1 sec. What is the photon count rate? Determine the mean value of the photon count and the standard deviation in the count number. What does the photon statistics tell about the source?