Nonlinear Optical Phenomena

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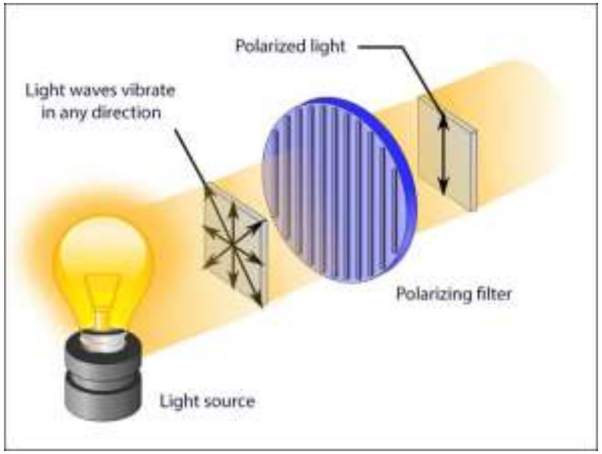
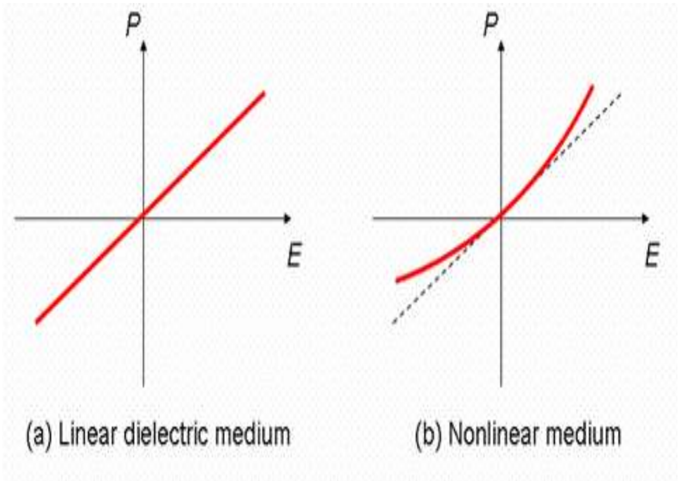
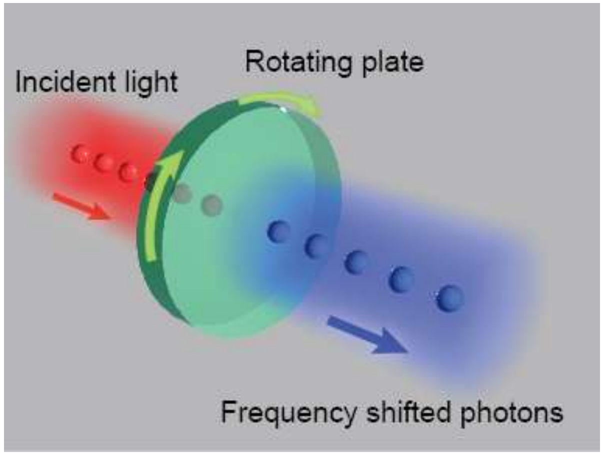
Polarization – Linear and Nonlinear

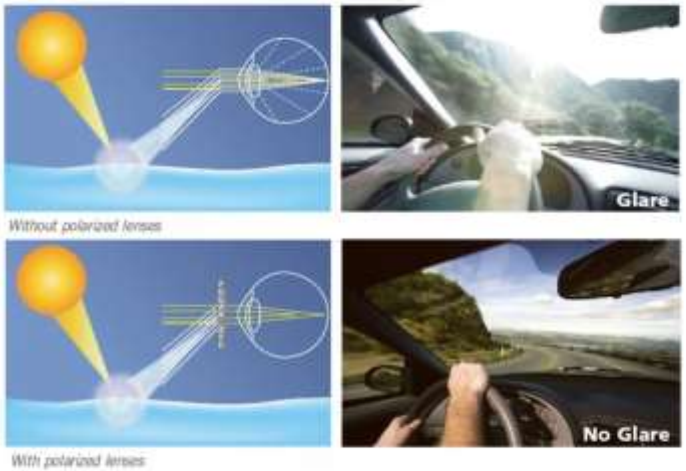


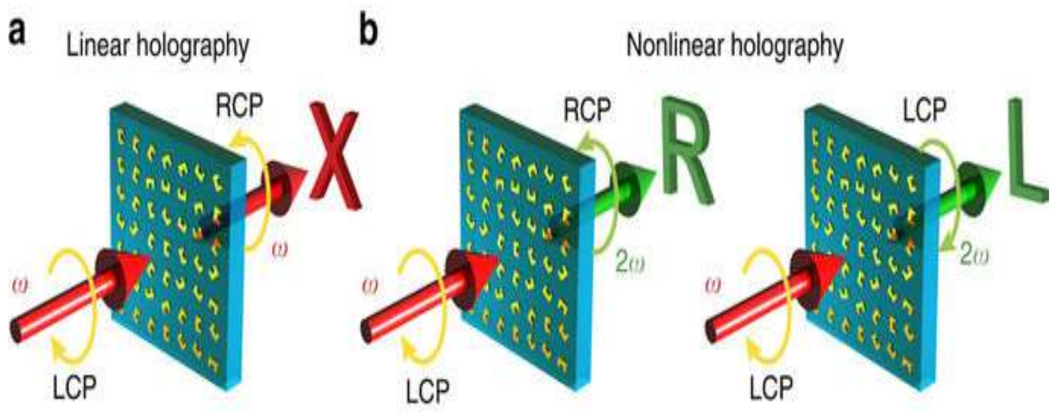




Linear Polarization

Nonlinear Polarization





Material Response to the Light

- $P = \varepsilon_0 \chi^{(1)}E + \varepsilon_0 \chi^{(2)}EE + \varepsilon_0 \chi^{(3)}EEE + \ldots$
- P: induced polarization of medium

  ε_0: dielectric constant of vacuum

  E: electric field

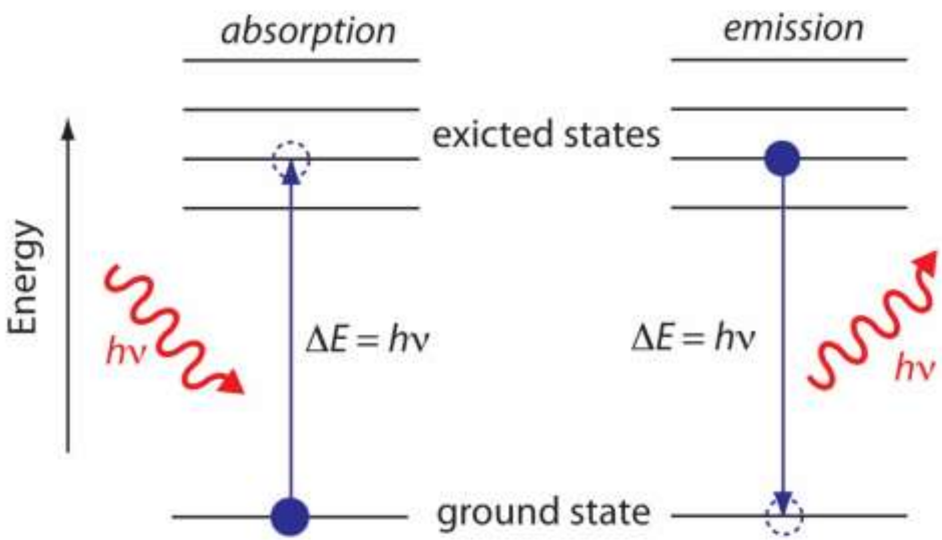
  $\chi^{(i)}$: constant

$$P_i = P_i^0 + \chi_{ij}^{(1)} E_j + \chi_{ijk}^{(2)} \mathrm{E}_j \mathrm{E}_k + \chi_{ijkl}^{(3)} E_j E_k E_l + \cdots$$

Nonlinear Polarization

- Permanent Polarization P_i^0
- First order polarization $P_i^1 = \chi_{ij}^{(1)} E_j$
- Second order Polarization $P_i^2 = \chi_{ijk}^{(2)} E_j E_k$
- Third Order Polarization $P_i^3 = \chi_{ijkl}^{(3)} E_j E_k E_l$

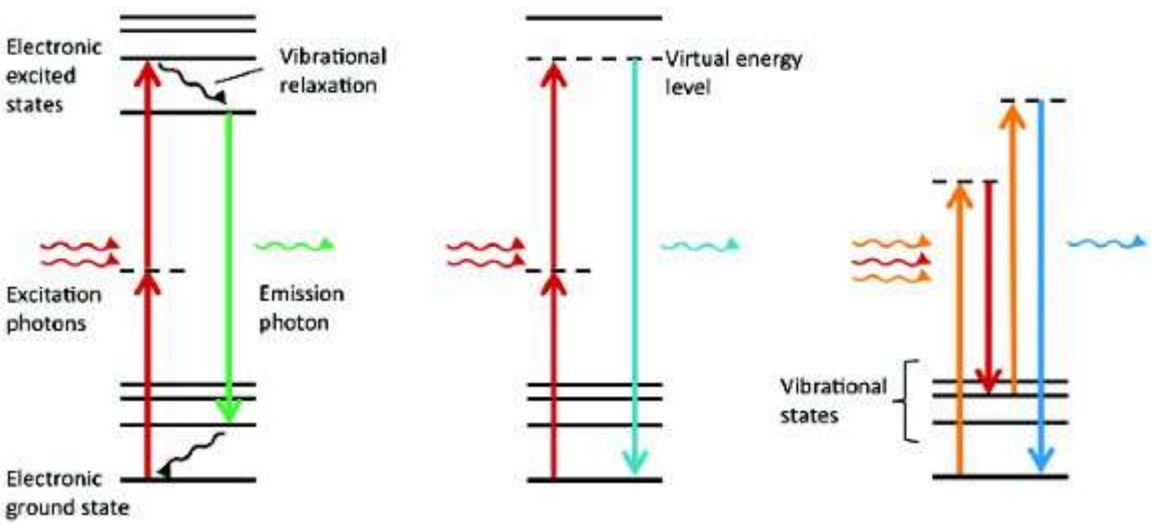
Absorption – Linear and Nonlinear



Linear Absorption

Nonlinear Absorption

$$\alpha(I) = \alpha_0 + \beta I$$



Nonlinear Absorption - NLA

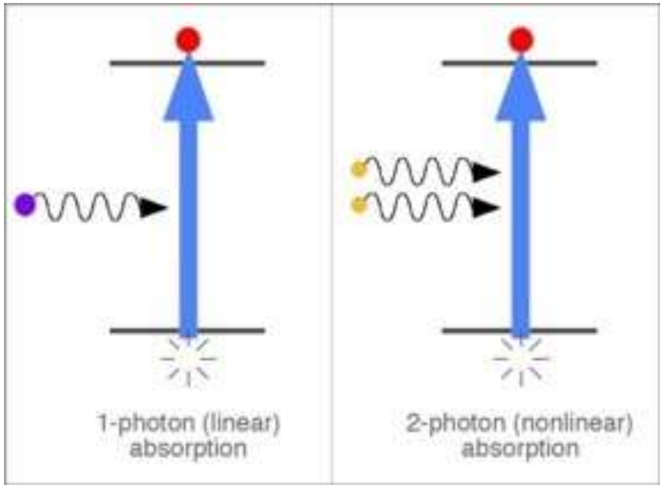
- Nonlinear absorption - change in transmittance of a material as a function of intensity or fluence.
- At sufficiently high intensities - probability - material absorbing more than one photon before relaxing to the ground state can be greatly enhanced.
- These phenomena are manifested optically in a reduced (saturable) or increased (reverse saturable) absorption.
- Applications - nonlinear spectroscopy and optical limiting.

EXCITED STATE ABSORPTION

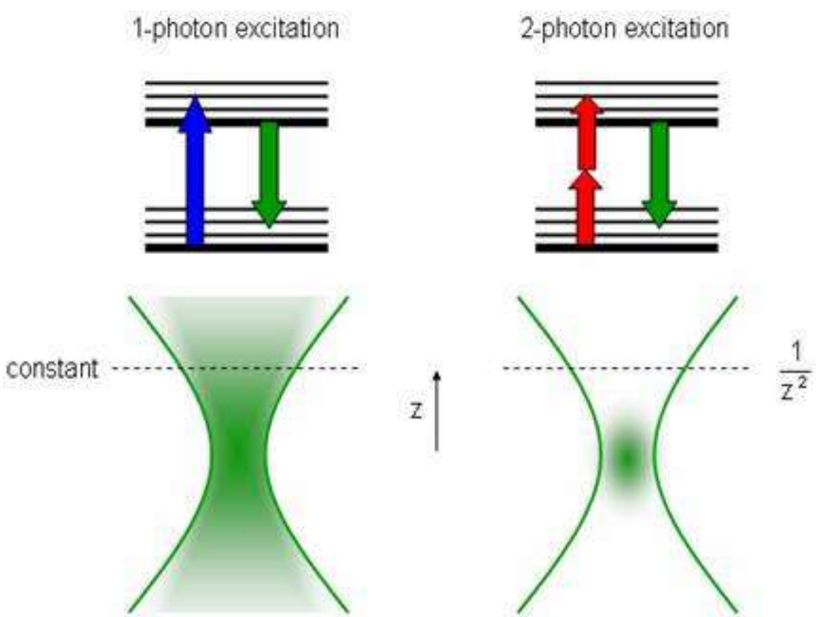
Absorption cross-section of the excited state < ground state – highly transmissive increased when excited - **saturable absorption** (SA).

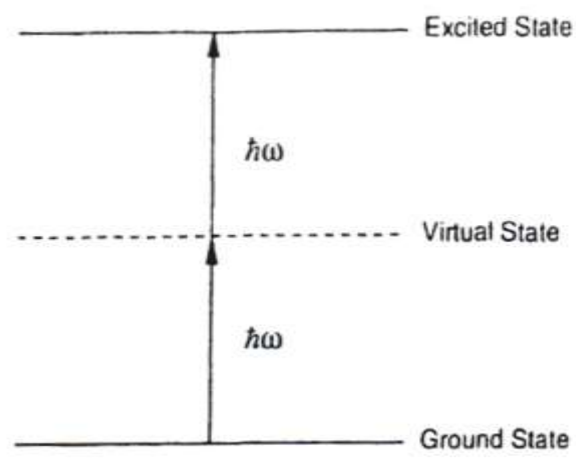
Absorption cross-section of the excited state > ground state - less transmissive when excited - **reverse saturable absorption** (RSA).

NLA - TWO PHOTON ABSORPTION



$$\frac{dI}{dz} = -\alpha I - \beta I^2$$

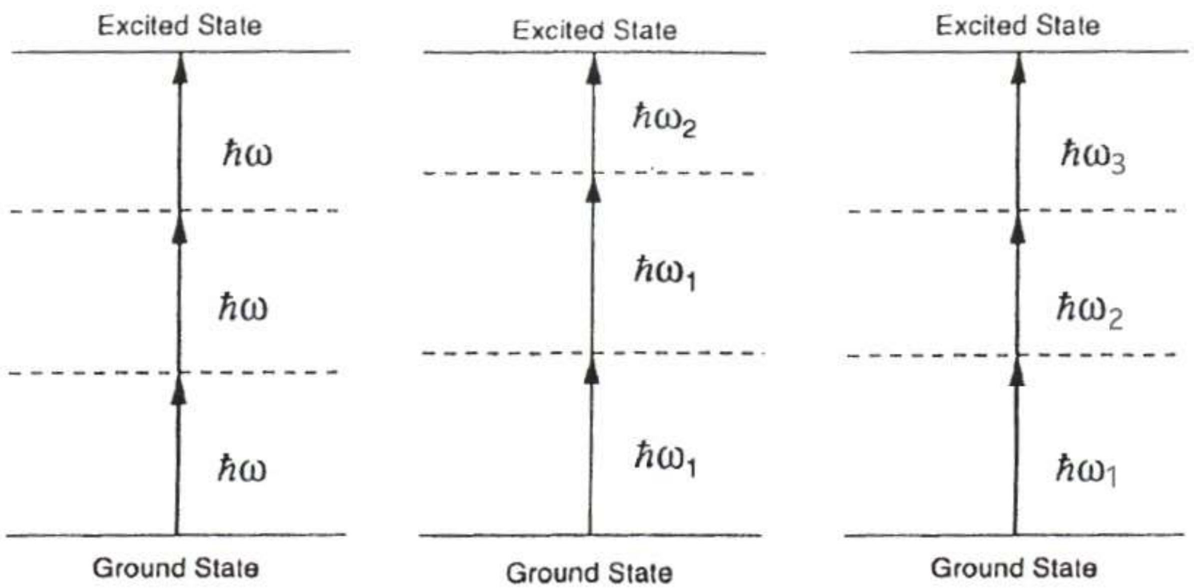




(a)

NLA - THREE PHOTON ABSORPTION

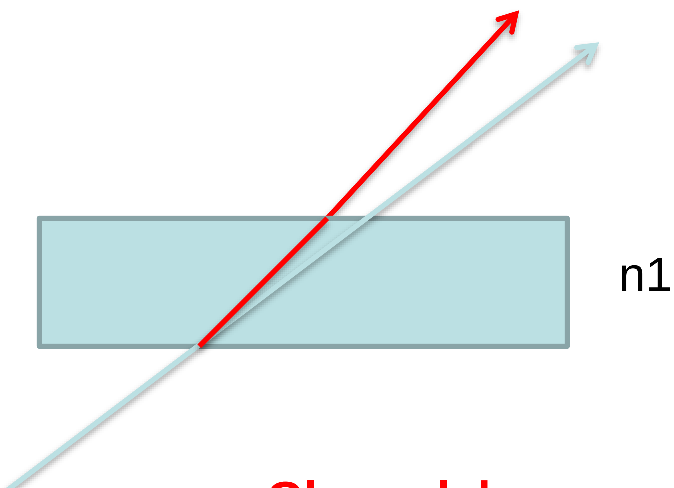
NLA-3PA (a) Self (b) Two Beam (c) Three beam



$$\frac{dI}{dz} = -\alpha I - \gamma I^3$$

Refraction – Linear and Nonlinear

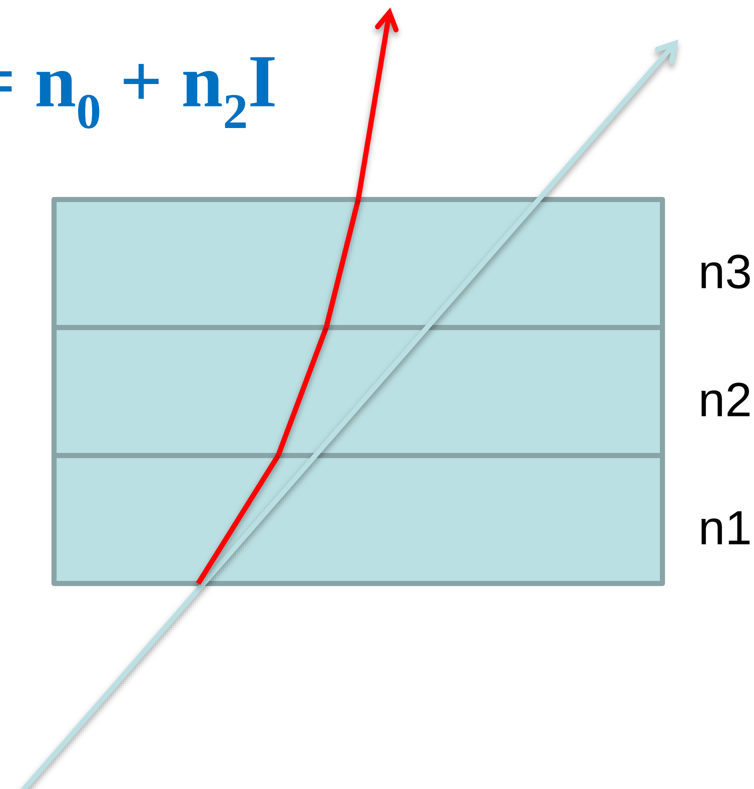
LINEAR REFRACTION



Glass slabs

NONLINEAR REFRACTION

$$n(I) = n_0 + n_2 I$$



Composition of glass slabs with different refractive index – acts like lens

NONLINEAR REFRACTION - NLR

- Origin of thermal nonlinear optical effect - fraction of the incident laser power is absorbed - passing through an optical material.
- The temperature of the illuminated portion of the material consequently increases - change in the refractive index of the material.
- Thermal Lens effects - power / intensity in a continuous wave (cw) laser - pulse energy (fluence) in a pulsed laser.
- In the case of a cw laser beam, thermal effects are usually more dominant.