

# Nonlinear susceptibility

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# Nonlinear polarisation

## □ Constitutive equations

$$\mathbf{D} = \epsilon \mathbf{E} = \epsilon_0 \mathbf{E} + \mathbf{P},$$

$$\mathbf{P} = \epsilon_0 \chi \mathbf{E}$$

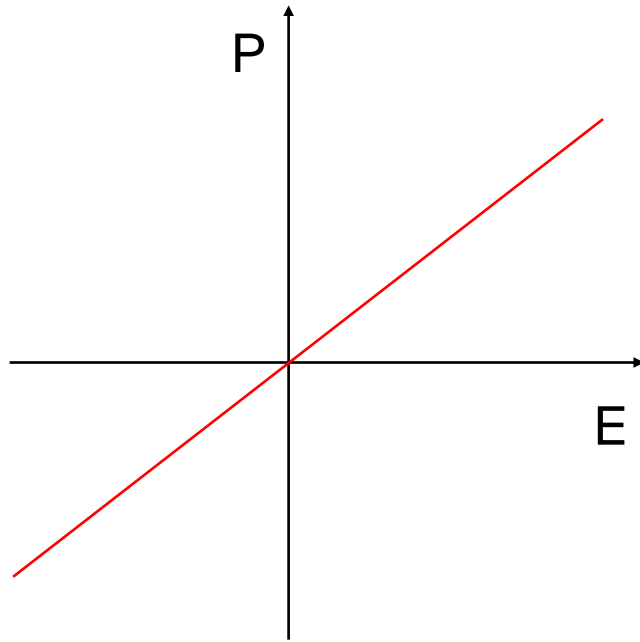
## □ Origin of nonlinear response

Related to anharmonic motion of bound electrons under the influence of an applied field.

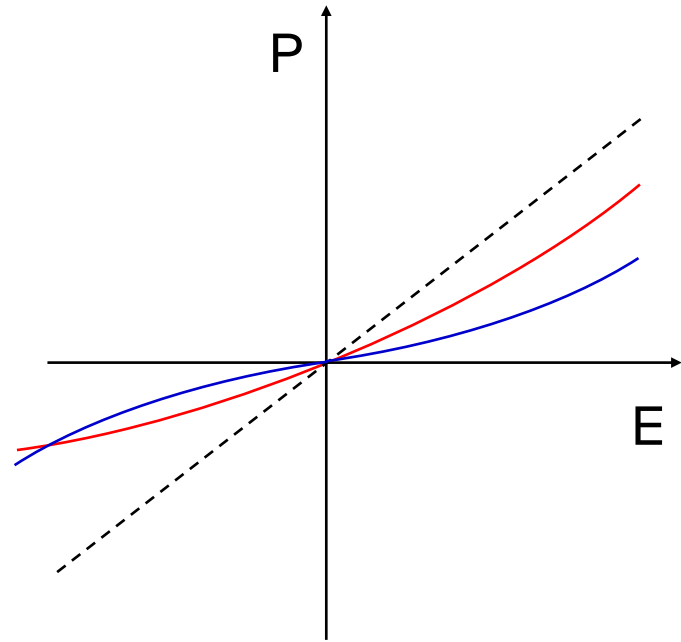
$$\mathbf{P} = \epsilon_0 \chi \mathbf{E} = \epsilon_0 \left( \chi^{(1)} \mathbf{E} + \chi^{(2)} \mathbf{E} \mathbf{E} + \chi^{(3)} \mathbf{E} \mathbf{E} \mathbf{E} + \dots \right)$$

Note:  $\chi^{(2)}$  is non-zero only for media that lack an inversion symmetry (centrosymmetry).

# Linear and nonlinear response

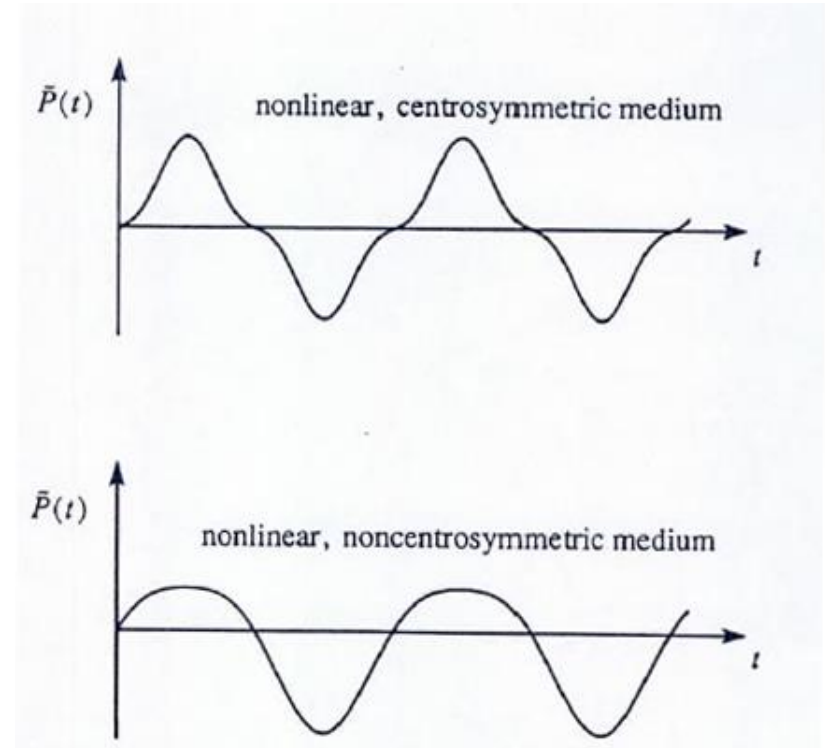
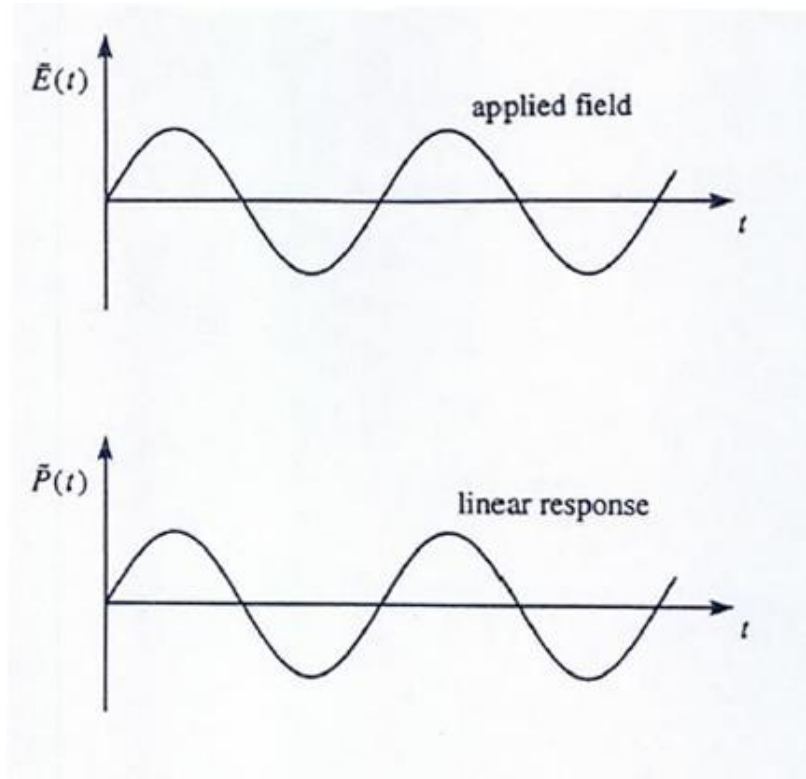


Linear medium



Nonlinear medium

# Waveforms with the atomic response

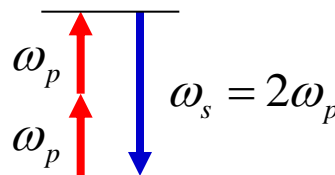


Source: Nonlinear Optics, R. W. Boyd, Chap. 1

# Nonlinear interactions

## Second-order nonlinear interaction

- Linear (or Pockels) electro-optic effect
- Second-harmonic generation
- Sum frequency generation



## Third-order nonlinear interaction

- Quadratic (or Kerr) electro-optic effect
- Third-harmonic generation
- Four-wave mixing
- Self-phase modulation
- Cross-phase modulation
- Self focusing

