MPC-204
Semiconductor Devices

Unit III- Optoelectronic Devices

Lecture 1

Radiative and Non-Radiative Transition

Photon and Phonon

In physics, a photon is **a bundle of electromagnetic energy**. The photon is sometimes referred to as a "quantum" of electromagnetic energy. A photon is the smallest discrete amount or quantum of electromagnetic radiation. It is the basic unit of all light.
Photons are always in motion and, in a vacuum, travel at a constant speed to all observers of 2.998×10^8 m/s. This is commonly referred to as the speed of light, denoted by the letter *c*.

Phonon, in condensed-matter physics, **a unit of vibrational energy that arises from oscillating atoms within a crystal**. A phonon is a definite discrete unit or quantum of vibrational mechanical energy, just as a photon is a quantum of electromagnetic or light energy.

A photon is a form of energy but the phonon is a mode of oscillation that occurs in lattice structures. A photon can be considered as a **wave** and a particle, which are physically observable entities. A phonon is a mode of vibration, which is neither a wave nor a particle.

Photon properties

- They have zero mass and rest energy. They only exist as moving particles.
- They are elementary particles despite lacking rest mass.
- They have no electric charge.
- They are stable.
- They are spin-1 particles which makes them bosons.
- They carry energy and momentum which are dependent on the frequency.
- They can have interactions with other particles such as electrons, such as the Compton effect.
- They can be destroyed or created by many natural processes, for instance when radiation is absorbed or emitted.
- When in empty space, they travel at the speed of light.

Phonon Properties

- A **phonon** is a quantized **mode** of vibration occurring in a rigid crystal lattice, such as the atomic lattice of a solid.
- The study of phonons is an important part of solid state physics, because phonons play an important role in many of the physical properties of solids, such as the thermal conductivity and the electrical conductivity.
- In particular, the properties of long-wavelength phonons gives rise to sound in solids hence the name **acoustic *phonon***. Acoustic phonons are **associated with long-wavelength vibrations**, where neighbored particles oscillate nearly in phase. They have relatively low frequencies, e.g. in the gigahertz region. Optical phonons are associated with vibrations where neighbored particles oscillate nearly in anti-phase.
- In insulating solids, phonons are also the primary mechanism by which heat conduction takes place.
- Phonons are bosons possessing zero spin.

Radiative Transition

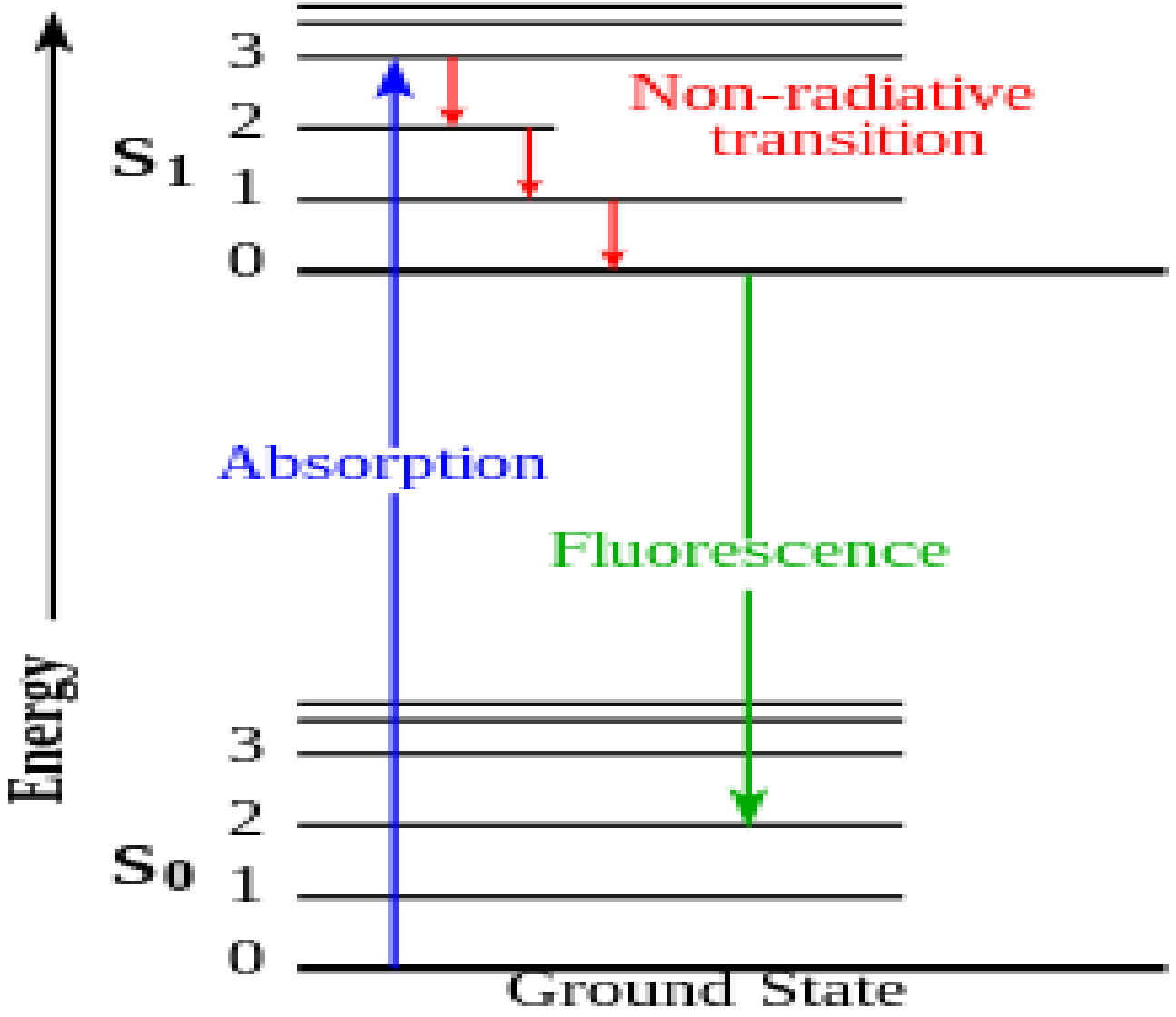
A radiative transition is **one in which the energy is released as a photon**. The nature of the emission depends on the nature of the initial and final states and the route to the excited state. The overlap between the lowest energy absorption and the high-energy emission is characteristic of this type of system.

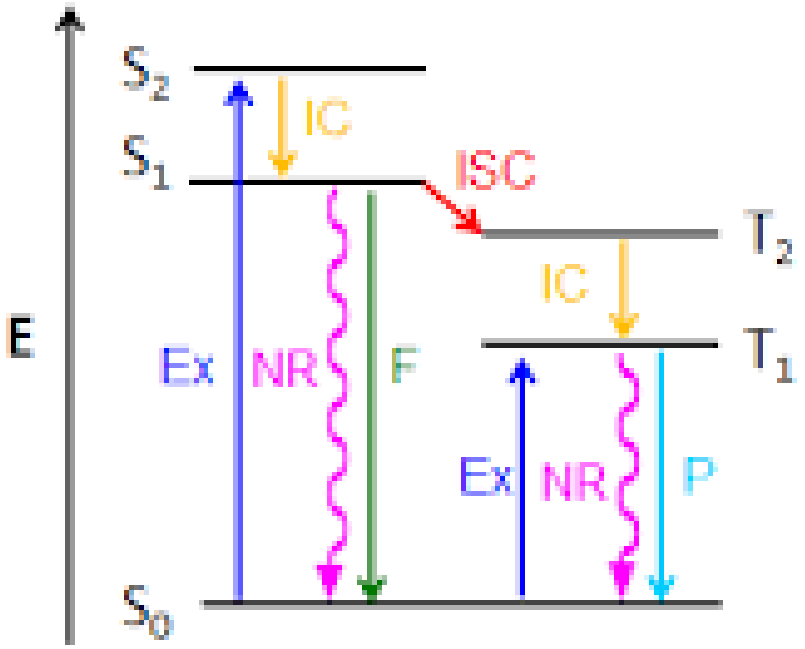
Non-Radiative Transition

The change an atom undergoes when an atomic system is changed from one energy level to another, without the absorption or emission of radiation.

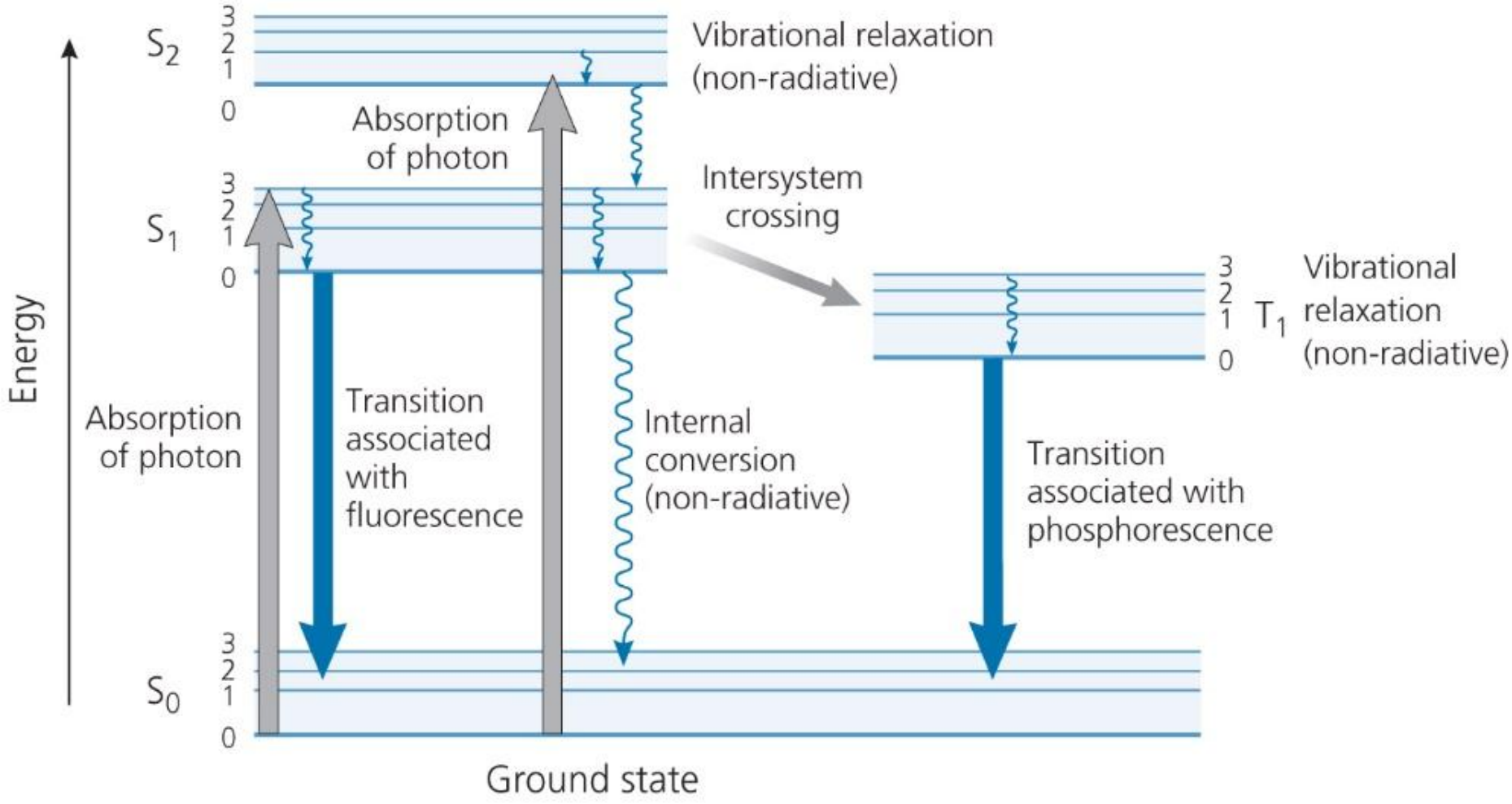
Or there are also mechanisms which allow for non-radiative transitions (or nonradiative or radiationless transitions), i.e., transitions **not involving light**. The excess energy is then dissipated in some other way – in most cases, in the form of phonons, which are associated with lattice vibrations of a solid.

The term nonradiative or radiationless transitions has been in common use for many decades to describe **radiation-induced processes in which no energy is exchanged with the radiation field**.


Energy
S1
3
2
1
0
Non-radiative
transition
Absorption
Fluorescence
S0
3
2
1
0
Ground State



Ex = excitation
F = fluorescence
P = phosphorescence
NR = on-radiative decay
IC = internal conversion
ISC =intersystem crossing


Energy
S_2
3
2
1
0
Vibrational relaxation
(non-radiative)
Absorption
of photon
S_1
3
2
1
0
Intersystem
crossing
3
2
1
0
T_1
Vibrational
relaxation
(non-radiative)
Absorption
of photon
Transition
associated
with
fluorescence
Internal
conversion
(non-radiative)
Transition
associated with
phosphorescence
S_0
3
2
1
0
Ground state

Definition of Recombination

A process whereby electrons and holes (carriers) are annihilated or destroyed

Reverse process is Generation: A process whereby electrons and holes are created.

Classification:

A. Radiative Recombination: Photon

B. Nonradiative Recombination: Phonon or Lattice vibration