MICRO-523: Optical Detectors

Week One: Light - Exercises

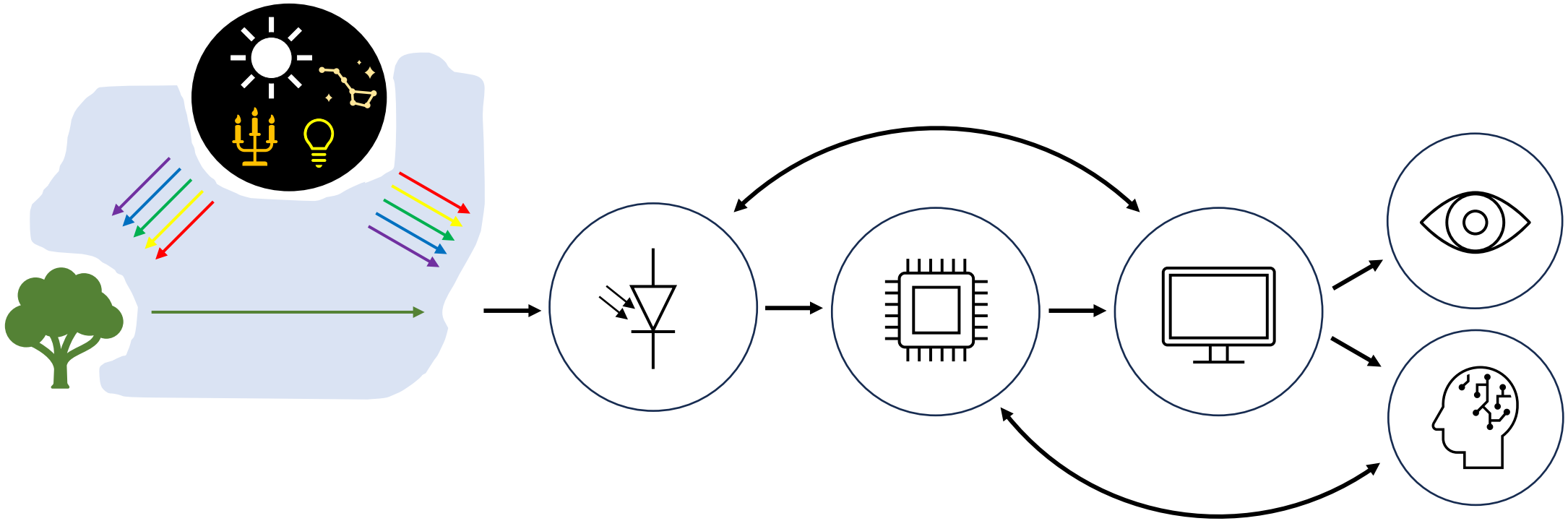
Claudio Bruschini

Institute of Electrical and Micro Engineering (IEM), School of Engineering (STI)

Ecole polytechnique fédérale de Lausanne (EPFL), Neuchâtel, Switzerland

TAs: Samuele Bisi, Kodai Kaneyasu

Exercise 1.1: Components of an optical system



Light source → Optical medium → Detector → Signal processing → Output (display) → Interpretation (analysis)

Exercise 1.1: Components of an optical system

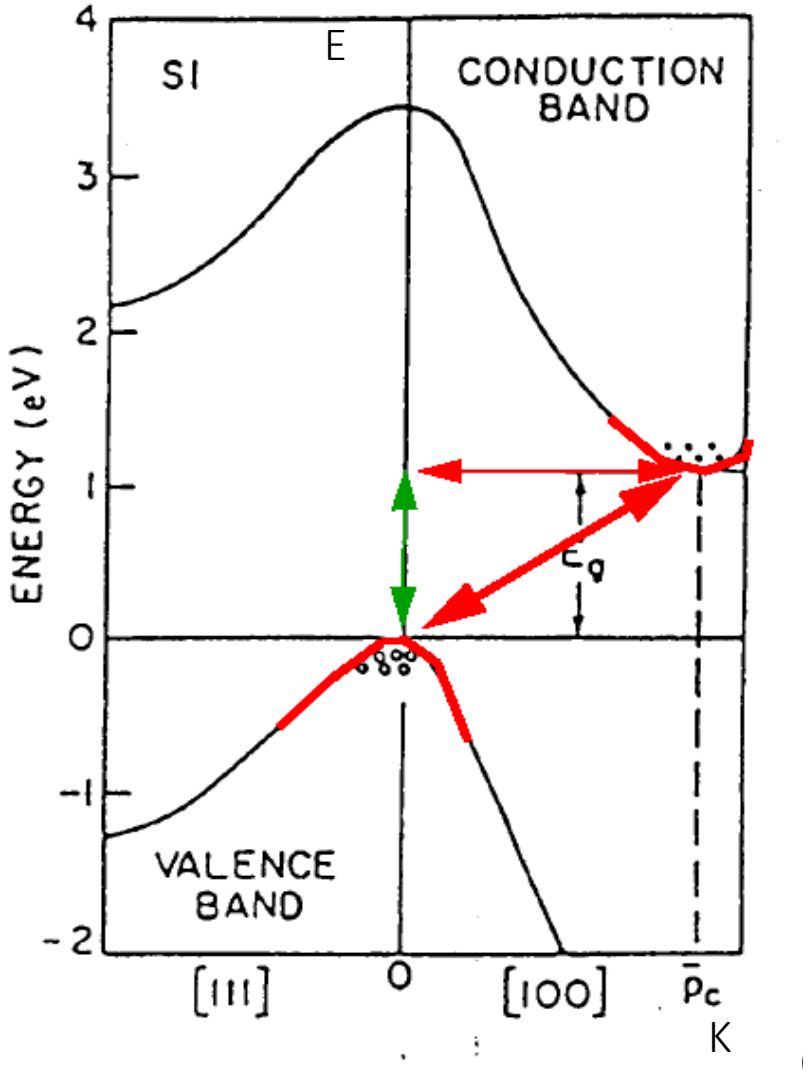
Select 1-2 key blocks in the previous slide:

- What are their main parameters?
- Can you think of examples?

Ideas:

- **Light source**: laser vs thermal light, CW vs pulsed operation, wavelength, …
- **Optical medium**: air, tissue, …, close by, far, …
- **Detectors**: single-point vs 2D camera, all-solid-state vs photomultiplier tube, size, number of pixels, …
- **Signal processing**: one single image vs a movie, averaging (mean value) vs peak finding, …
- **Output (display)**: human eye vs screen, colour palette, bit depth, …
- **Interpretation**: simple intensity, time of arrival = distance, multispectral -> fruit ripening, …

Exercise 1.2: Band structure: photons and acoustic phonons



Questions

Consider a semiconductor with an indirect bandgap, for example silicon:

1) What is the maximum value of the horizontal axis (wave vector K) for a crystal with spacing a_p=3 Å? (the spacing a_p corresponds to the spacing of the primary cell, i.e. to half of the crystal lattice).

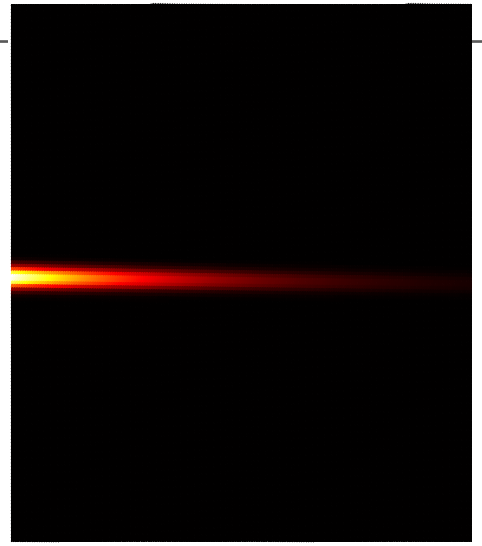
2) What are the wave vector K and the energy E (in eV) of a photon of wavelength λ=1 μm?

3) An acoustic phonon is a crystal vibration that propagates at the speed of sound (about v_a = 1500 m/s). What is the energy of such a phonon, knowing that its wave vector is at its maximum value (see question 1)?

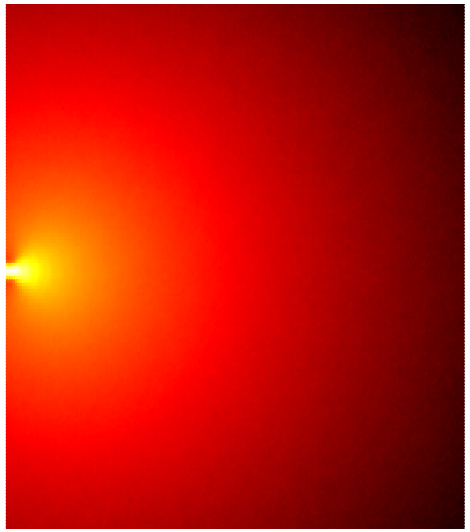
Exercise 1.2: Summary Table (to be completed)

	Photon	Phonons
Wavelength		
Speed		
K		
E/q in [eV]		

Exercise 1.3: Beer-Lambert in tissue



Absorption



Scattering

Questions

In tissue, scattering can represent an important component in addition to absorption

- Can you think of the related implications?
- Which kind of measurement set-up could be used?
- Which kind of illuminator could be used?
- Which kind of detector?

Homework 1.1: Boltzmann vs. FD vs. BE

1) Sketch the Boltzmann, Fermi-Dirac and Bose-Einstein distributions at T=300K.

2) For a single state, how do a) photons, b) electrons, and c) gas atoms distribute?

3) For a two-level system describe all the possible configurations for the three kinds of particles, assuming to have either two photons, or two electrons, or two gas atoms.

    3.1) How many different configurations are possible for each case?

    3.2) If 10 photons arrive at the same time, can they all enter into the same state?

    3.3) If 10 electrons try to enter the same state, what happens?

    3.4) If 10 gas atoms try to enter the system, how do they distribute?