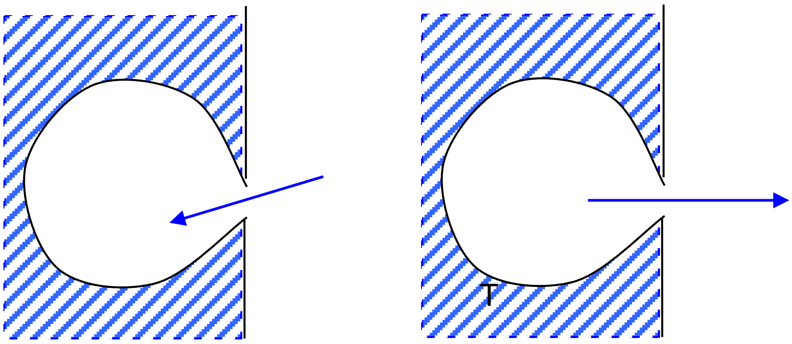
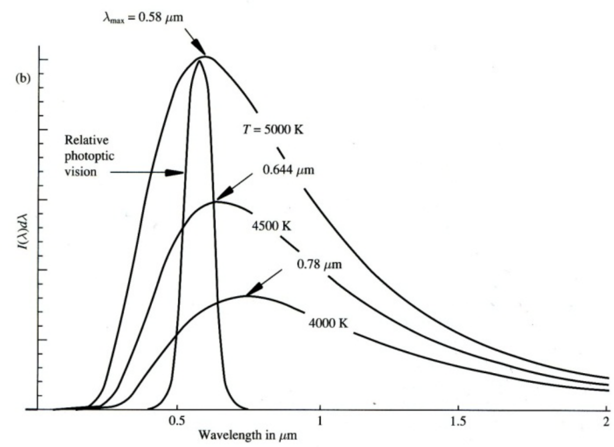
Lecture 3: Black body radiation, Einstein's model

Black body definition

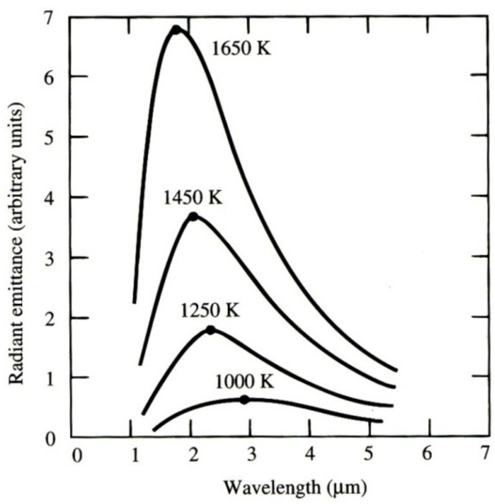


1) A cavity with small input hole
2) Radiation which enters the hole has a very little chance of escaping
3) In thermal equilibrium, it emits electromagnetic radiation called black-body radiation.
4) The radiation escaping from the cavity does not depend on dimensions, shape of cavity and material of walls.

Spectral distribution of the black body radiation:



C.C. Davies, **Lasers and Electro-Optics**, Cambridge University Press, Cambridge, 1996



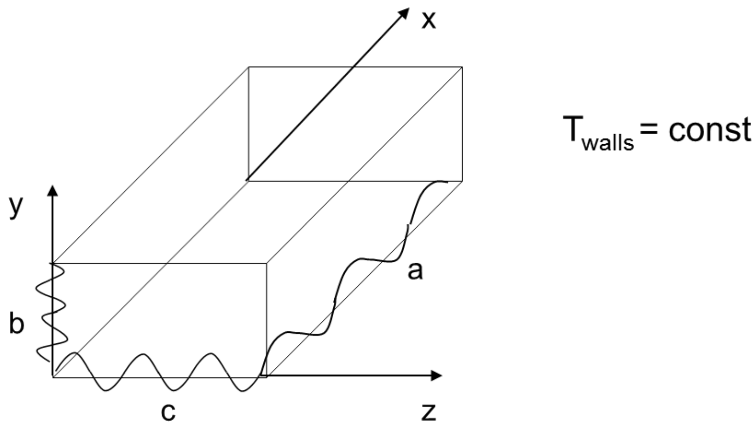
J.T. Verdeyen, **Laser Electronics**, Prentice Hall, Englewood Cliffs, 1995

Wien's law:
$\lambda_{max} * T = const = 0.2898$ [cm*K]

If the temperature increases, the peak wavelength decreases – frequency increases (blueshift).

Planck’s model

In Planck’s model, the black body cavity has a shape of a rectangular cavity with perfectly conducting walls kept at temperature T.



Each mode (resonance) can have certain quantized energies:

$$E_h = nh\nu$$

where h – is famous so-called “Planck’s constant” h = 6.62×10^{-34} [Js].

Einstein’s model

An atom might have two energy levels, E1 and E2:

A radiative transition between two atomic levels E_2 and E_1 is connected with emission or radiation of photon which energy ΔE is described by:

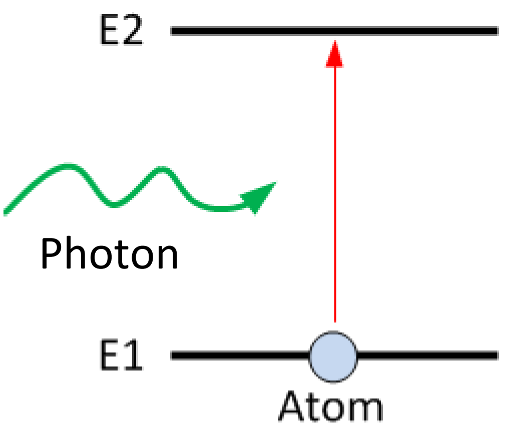
$$\Delta E = E_2 - E_1 = h\nu$$

Einstein’s three elementary quantum transitions:

1. Absorption
2. Spontaneous emission
3. Stimulated emission

1) Absorption

An atom in the lower energy state (E1) can absorb a photon, and therefore transfer into the upper energy level (E2).



Probability of this transition:

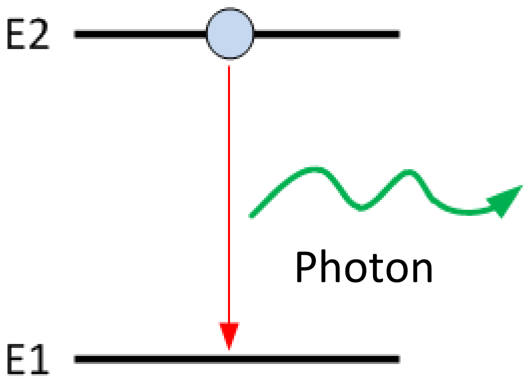
$$dP_{12} = U(\nu,t) \cdot B_{12} \cdot dt$$

$u_\nu(\nu,T) \quad \left[\frac{J}{m^3 Hz}\right]$ - energy density of the input field

B_{12} – Einsteins absorption coefficient.

2) Spontaneous emission

Atom in the upper energy level (E2) might spontaneously decay to level E1 and loose its energy by emitting a photon in random direction, with random phase and polarization.



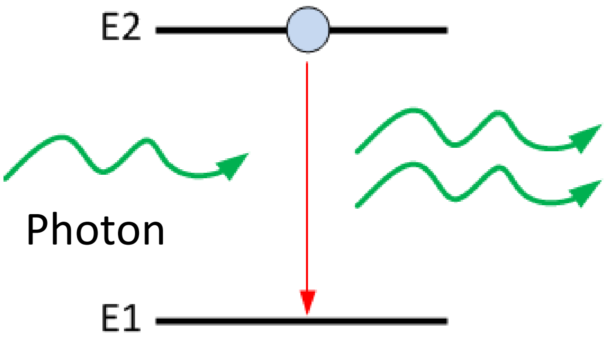
Probability of this transition:

$$\mathbf{dP_{21\_spont} = A_{21}\, dt}$$

A_{12} – Einsteins spontaneous emission coefficient.

3) Stimulated emission

The atom is in excited state (E1). Due to external radiation **U(v,t)** the external photon **hv** stimulates coherent photon from the atom (the same direction, polarization, phase, frequency).



Probability of this transition :

$$dP_{21\_stim} = U(v,t)\, B_{21}\, dt$$

B_{21} – Einsteins stimulated emission coefficient.

Important:

- Radiation of the black body (spectral distribution, Wien's law)
- Einstein's model – three elementary transitions