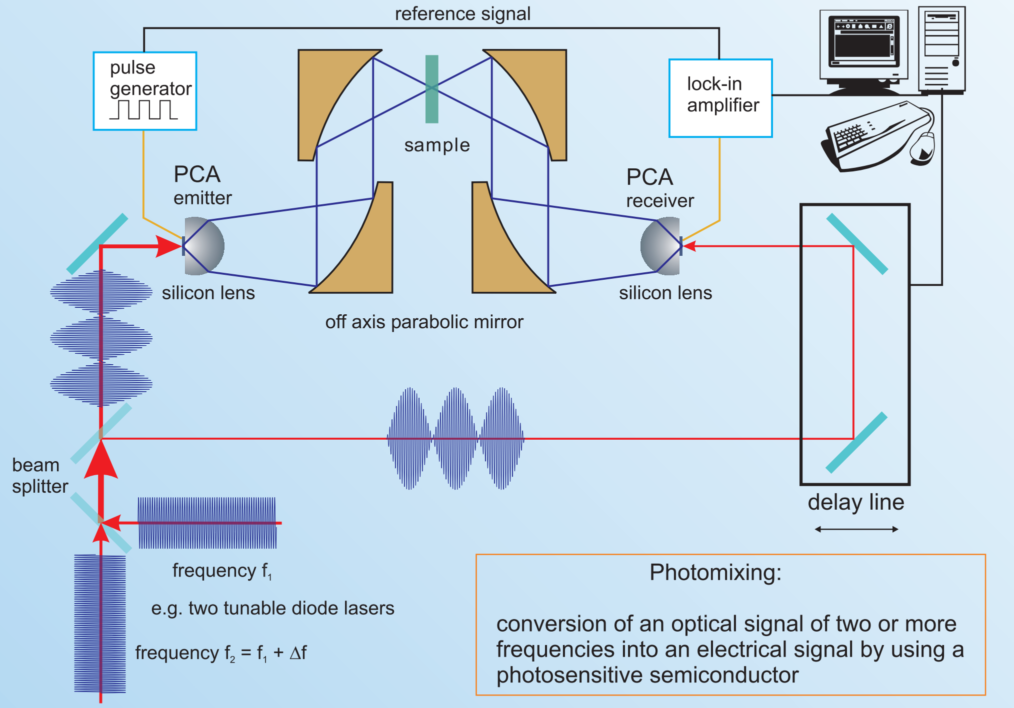
BATOP optoelectronics

photoconductive antenna as photomixer

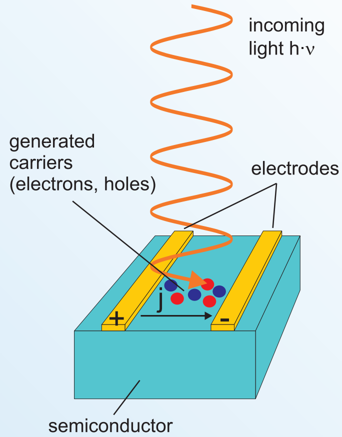
THz photomixing setup



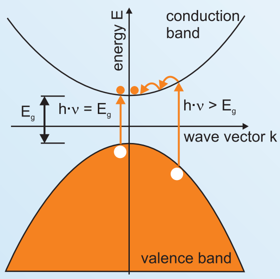
Photomixing:

conversion of an optical signal of two or more frequencies into an electrical signal by using a photosensitive semiconductor

Semiconductors as optical switch

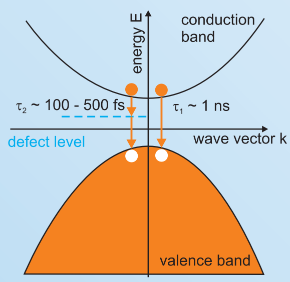


Carrier generation



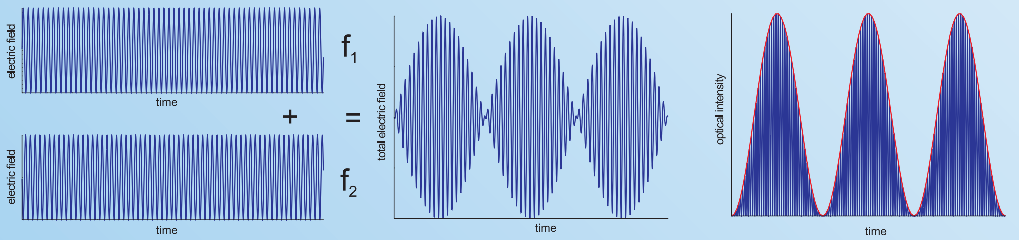
- absorption of photons if $E_g < h \cdot \nu$ => creation of electron-hole-pairs e.g. GaAs E_g=1.4eV (870 nm) InGaAs E_g=0.4 .. 1.4eV (870 nm .. 3.2 µm)
- interaction with the lattice phonons for $E_g < h \cdot \nu$

Relaxation processes



- recombination of electron-hole-pairs in direct semiconductors (e.g. GaAs): relaxation time τ_1 ~ 1 ns => not suitable for THz-signals
- faster recombination in e.g. low temperature grown GaAs or InGaAs: => due to defects in the lattice relaxation times τ_2 ~ 200 fs - 500fs

Photomixing in semiconductors



two monochromatic plane waves at a fixed position z=0

total electric field from the superposition of the two monochromatic waves

time dependent optical intensity of the mixed two monochromatic waves

$\mathbf{E_1}(t) = E_1 \cdot \cos(2\pi \cdot f_1 \cdot t)$

$\mathbf{E_2}(t) = E_2 \cdot \cos(2\pi \cdot f_2 \cdot t)$

with frequency f_1 and frequency $f_2 = f_1 + \Delta f$, Δf ~ 1 THz

from e.g. two tunable diode lasers

$\mathbf{I} = |\mathbf{E_1}(t) + \mathbf{E_2}(t)|^2$
~ $\cos^2(\pi \cdot \Delta f \cdot t)$
(difference frequency component, "slow" envelope of the optical power)

Conclusions:

- for a vanishing carrier density in the nodes of the optical intensity => relaxation time $\tau_2 < 1/(2\Delta f)$
- high absorption coefficient α of optical power => direct semiconductor: e.g. GaAs or InGaAs
- high carrier mobility μ for efficient terahertz emission and detection needed

According to the periodic illumination of the semiconductor (photoconductor) carriers (electrons, holes) are generated:

$n \sim \alpha \cdot I$

n - carrier density
α - absorption coefficient
I - intensity of the optical signal

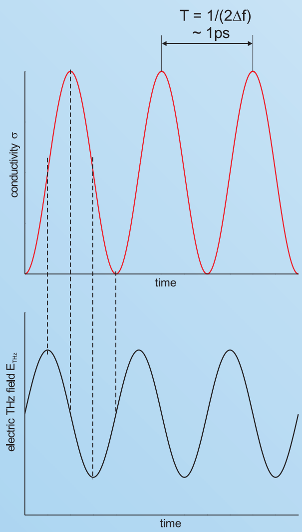
With an applied electric field at the electrodes the current density is given by

$j = \sigma \cdot E_{bias} \approx e \cdot n \cdot \mu \cdot E_{bias}$

e - elementary charge
σ - conductivity
μ - carrier mobility
E_{bias} - applied electric field

For the emitted terahertz field yields:
$E_{THz} \sim \partial j / \partial t$

j - current density,
E_{THz} - terahertz electric field strength



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