Magnetic and optic sensing

Magnetic sensors

Literature

Physics of Semiconductor Devices

S.M. Sze, Kwok K. Ng

Available as eBook on
http://www.lub.lu.se/en/search/lubsearch.html

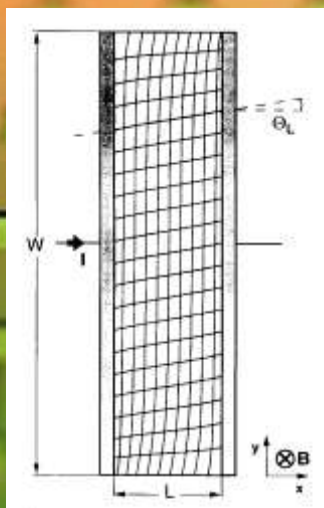
This lecture chapters 14.4
Magnetic Sensors

Magnetic sensors

- Digital Compass
- Current sensor
- Position, acceleration
- Rotational velocity
- Flow (Ferrofluids)
- Biosensors (antibody labeled microbeads)

Lorentz deviation

- mangentoresistans -

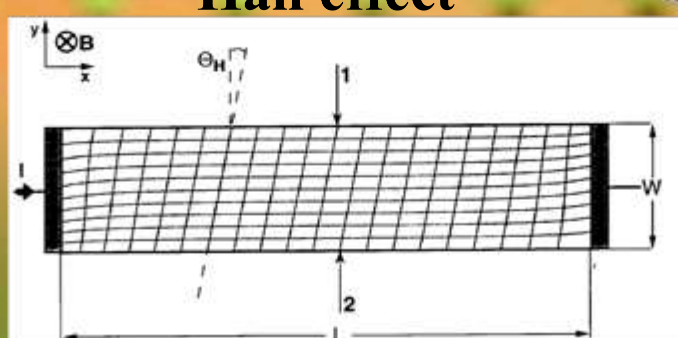


Lorentz force: $\mathbf{F} = -qv \times \mathbf{B}$

$(\rho_{nB} - \rho_n)/\rho_n = (r_n \mu_n B)^2$

magnetoresitive effect small for silicon
ex. $\rho_{nB} \approx 1.02\ \rho_n$ at B = 1 Tesla

Hall effect



$V_H = V_1 - V_2 = R_H \frac{IB}{t}$

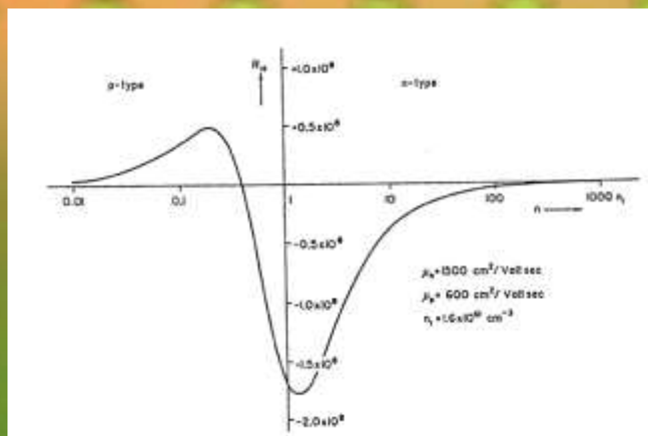
Hall coefficient: $R_H = -r_n/qn$

Where r_n electron diffraction coefficient and n density of free electrons (holes).

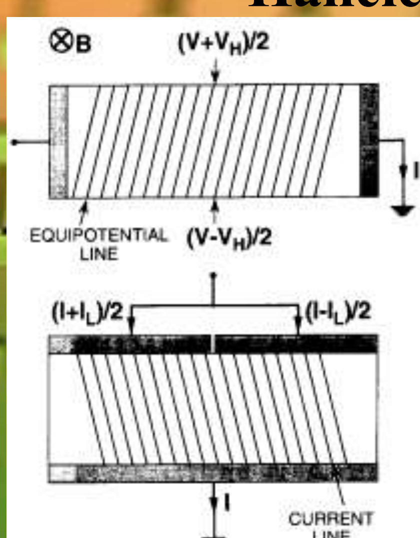
Low dopant levels yields high Hall coefficient;

Relative coefficient of sensitivity is: $R_H/t = V_H/IB$

Hall coefficient for semiconductors



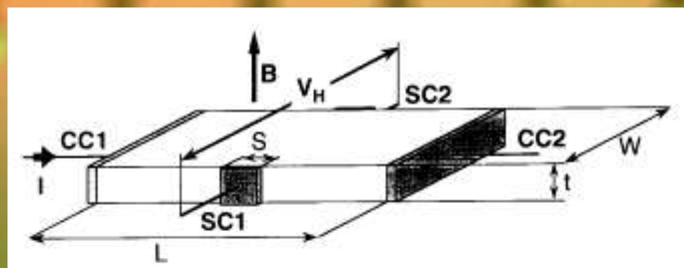
Operative modes for Hallelement



Hall voltage mode

Lorentz current mode

Hall element

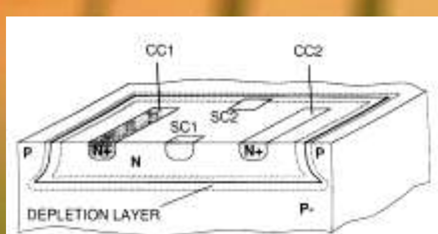


CC1 = current contact 1
CC2 = current contact 2
SC1 = sensor contact 1
SC2 = sensor contact 2

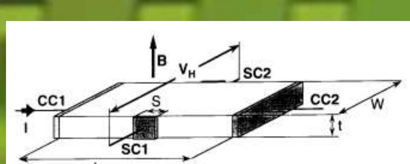
Relative sensitivity factor: $R_H/t = V_H/IB$

Silicon integrated Hallelement

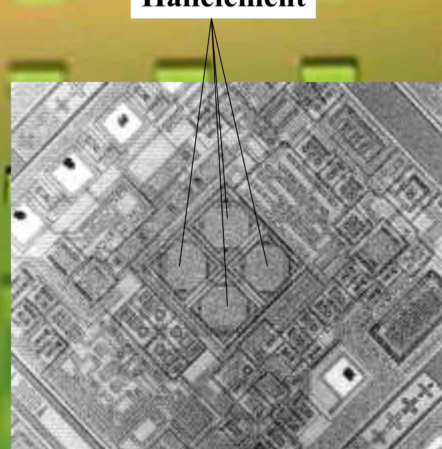
-Vertical sensitivity-



Jfr.

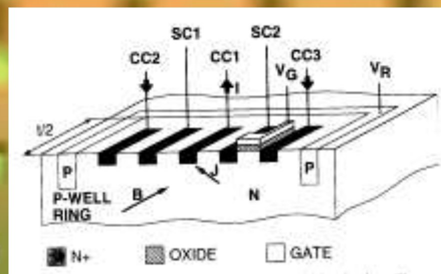


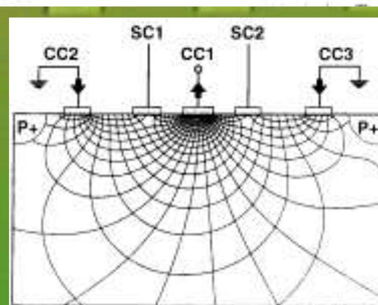
Hallelement



Vertical Hall Device - VHD

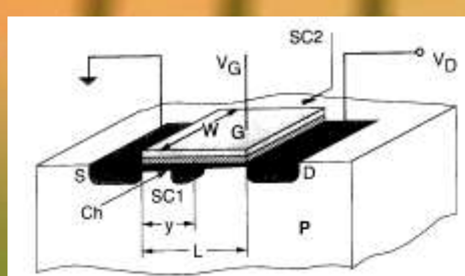
-Horisontal sensitivity





Popovic 1984

Hall MAGFET



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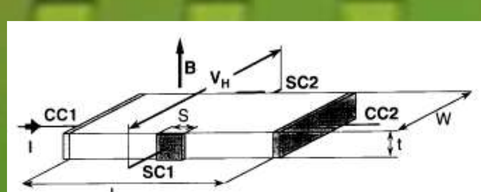


- Higher sensitivity
- Faster
- Smaller

$V_H = G\ I_D\ B\ r_{nch}/Q_{ch}$

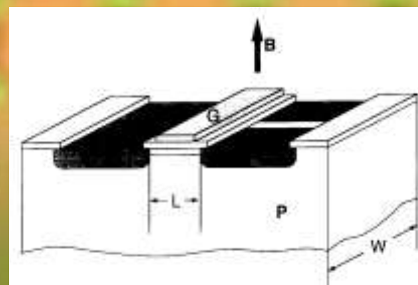
Jmfr

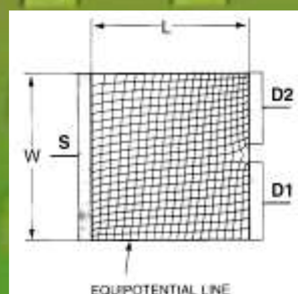
$V_H = -I\ B\ r_n/qnt;$

$S_I = r_{nch}/Q_{ch} =$

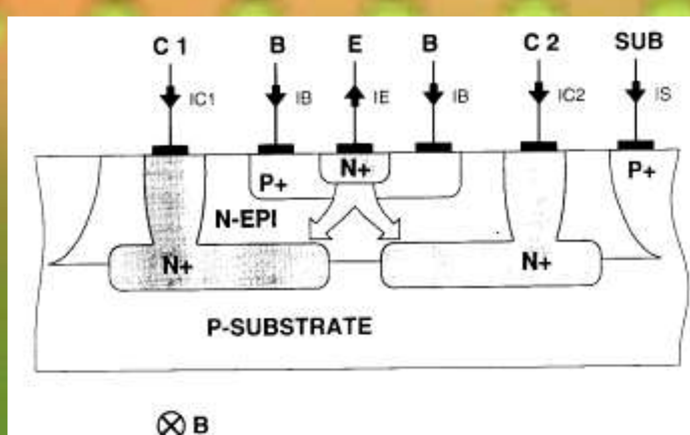
$r_{nch}/(V_G - V_T)$

Dual drain MAGFET





Dual collector vertical magnetotransistor



$I_{C1}-I_{C2} = G\ r_n \mu_n (L/W_E)\ I_{co}\ B$

Optical Sensors

Optical Sensors

- Heat
- IR
- Position
- Velocity (Rotational velocity)
- Flow
- Chemical Sensors
  - Absorbance
  - Luminescence

Literature

Physics of Semiconductor Devices

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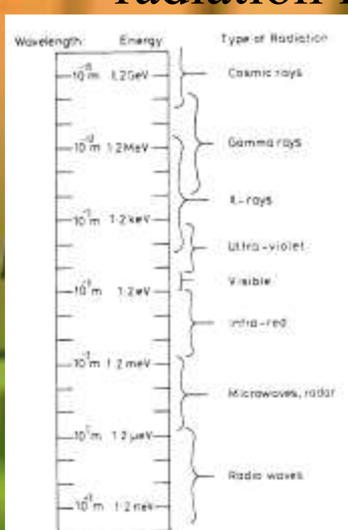
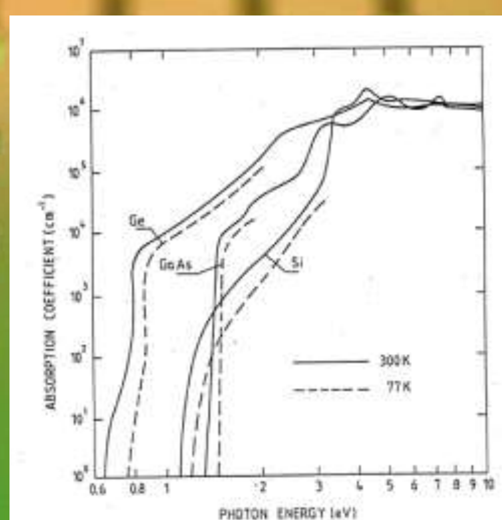
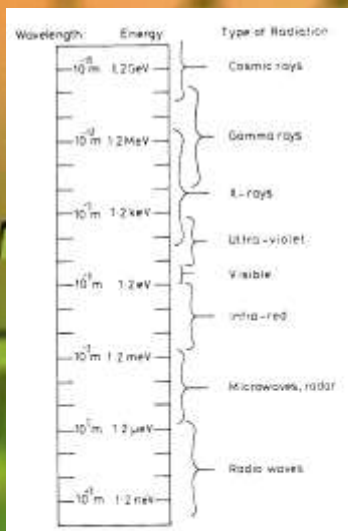
This lecture chapters 13.2-5
Photodetectors

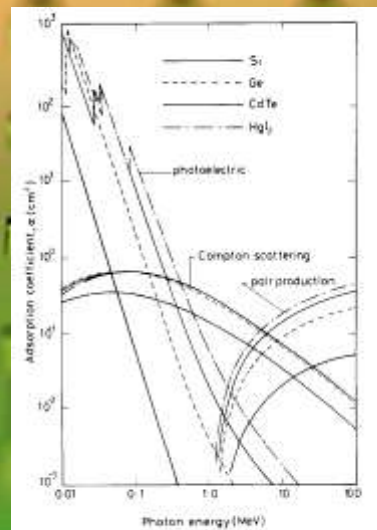
Absorption coefficient of radiation in semiconductors



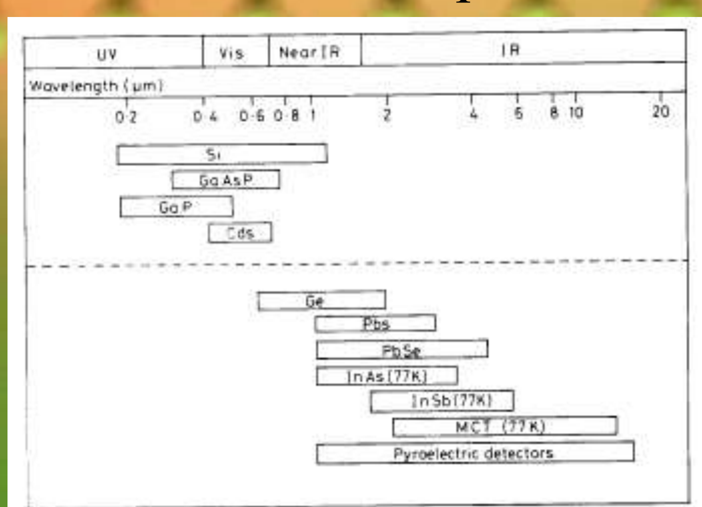


Absorption coefficient of radiation in semiconductors

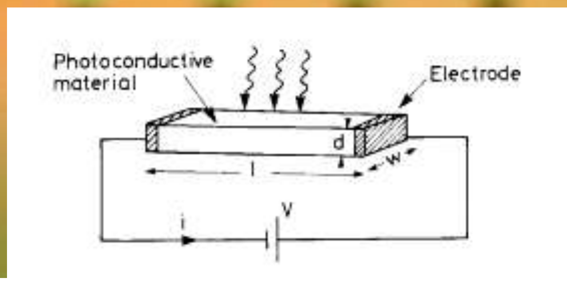




Usable wavelengths for semiconductor based optical senors



Photoconductive cell



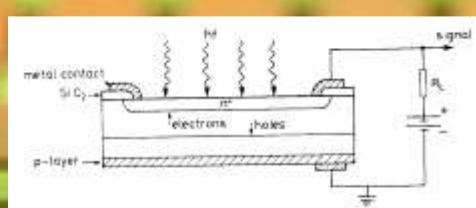
$R = l/(\sigma dw)$

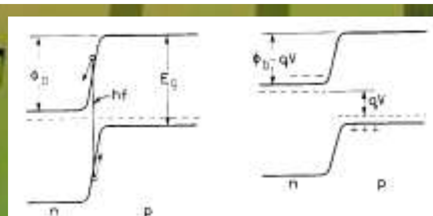
$\Delta\sigma = eN_t(\mu_n\tau_n+\mu_p\tau_p)$

μ is the mobility for holes (p) resp. electrons (n) and
τ is particle mean lifetime.
N_t is the number of charge carriers generated per second:

$$N_t = \eta\Phi(1-e^{-\alpha d})$$

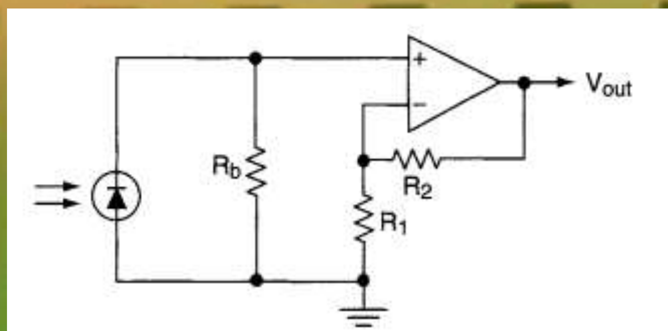
Photo diode





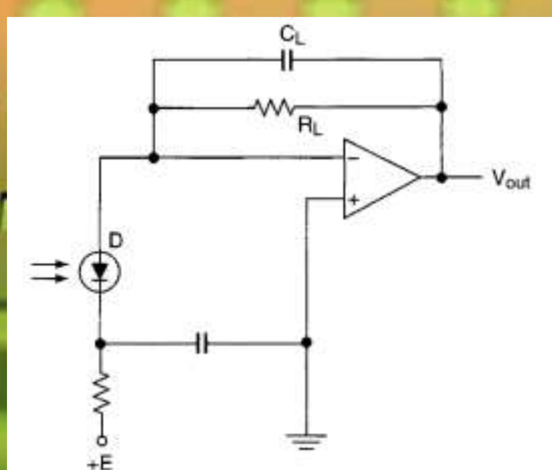
Electron-/hole pairs formed in the intrinsic region of the reversed potential pn-junction generates the photocurrent.

Photovoltaic mode



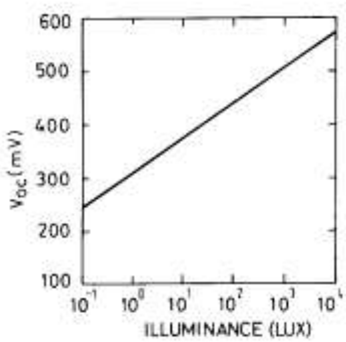
$$V_{oc} = \frac{kT}{q} \ln\left(\frac{I_L}{I_S} + 1\right)$$

Photoconductive mode

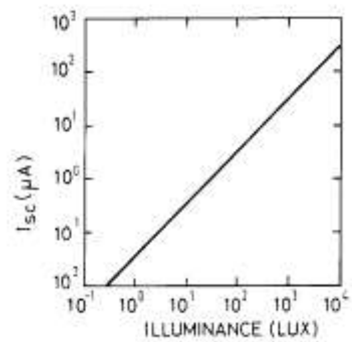


Characteristics of pn-photodiode

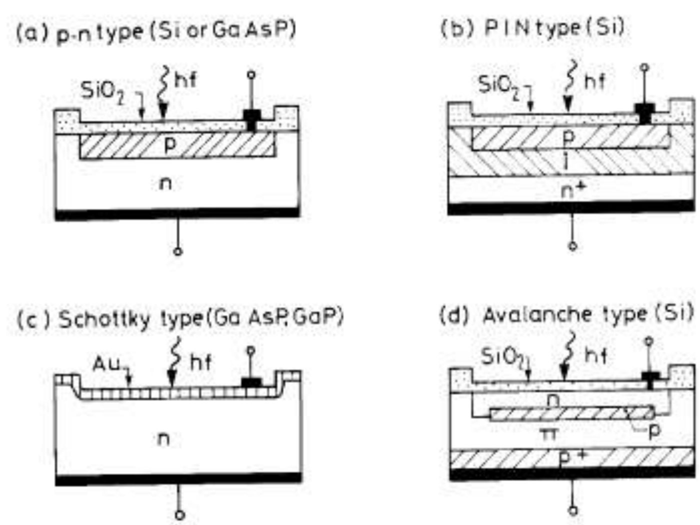
Open circuit
Photovoltaic mode

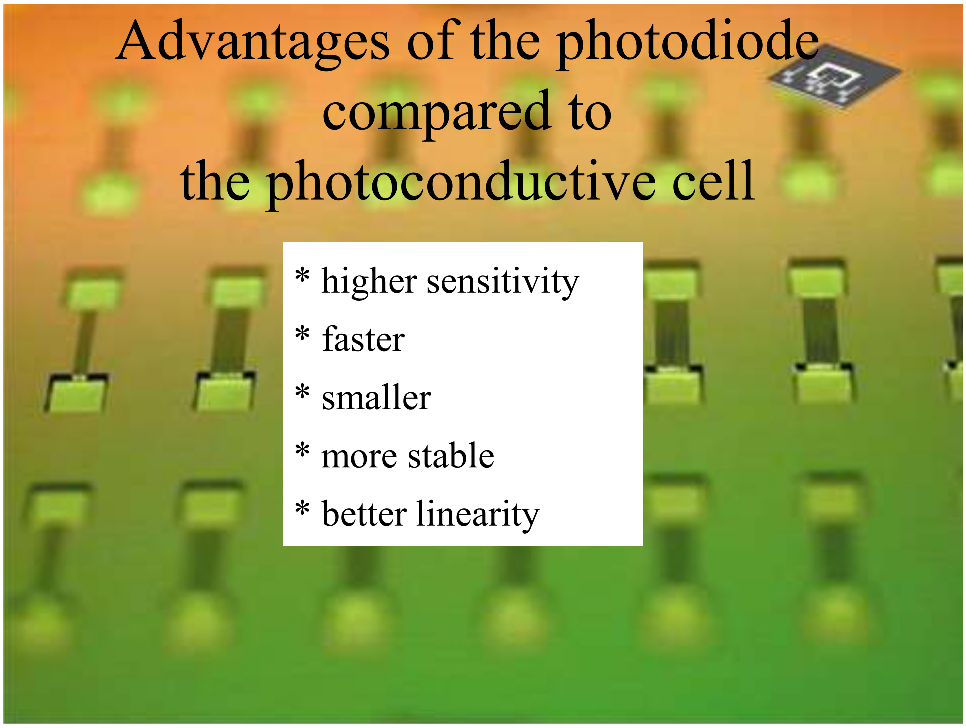


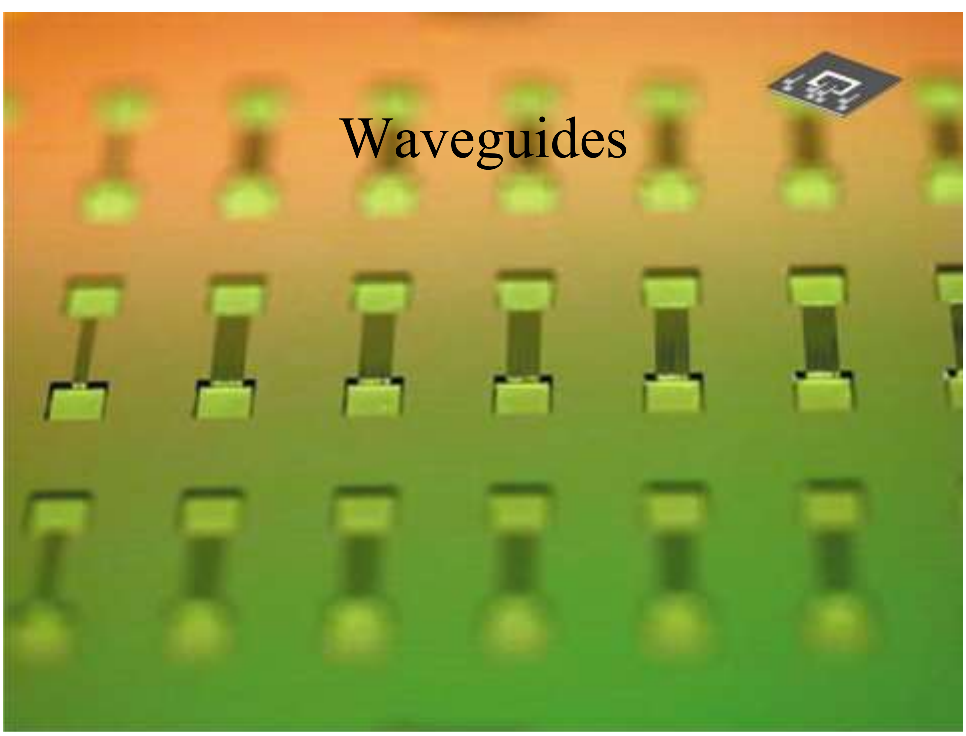
Short circuit
Photoconductive mode



Variations of the photodiode



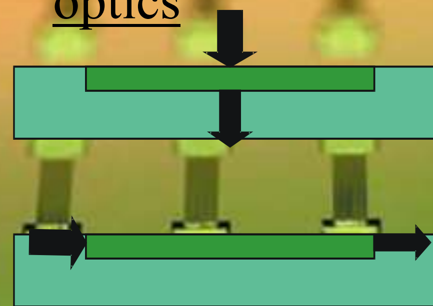

Advantages of the photodiode
compared to
the photoconductive cell
* higher sensitivity
* faster
* smaller
* more stable
* better linearity


Waveguides

Free-space optics versus integrated optics

a) Free-space optics

b) Integrated optics

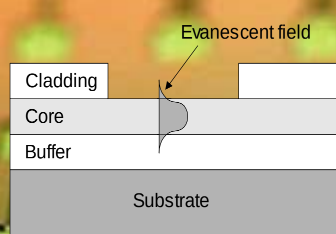


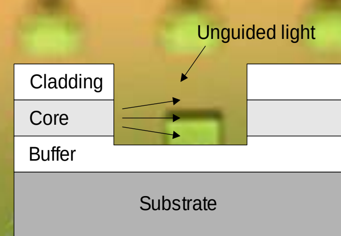
- Increased optical path length. Lambert-Beers law:

$A = abc$ (molar absorptivity, path length, concentration)

- Rugged and alignment-free operation of the devices

Detector configurations



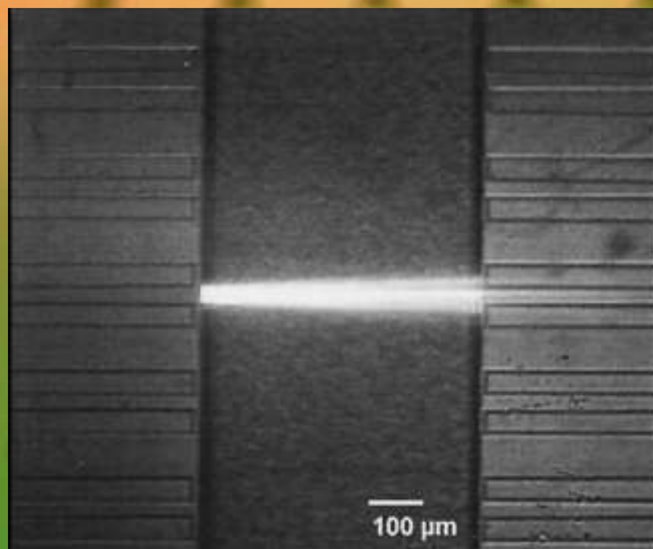


Evanescent wave sensing

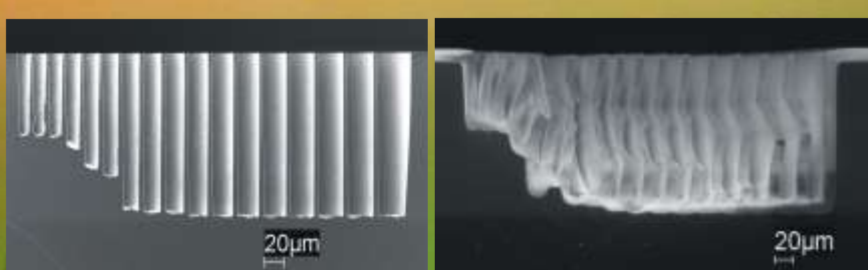
- Probes the surface of the core layer
- Light is guided in the detection region

Free-space wave sensing

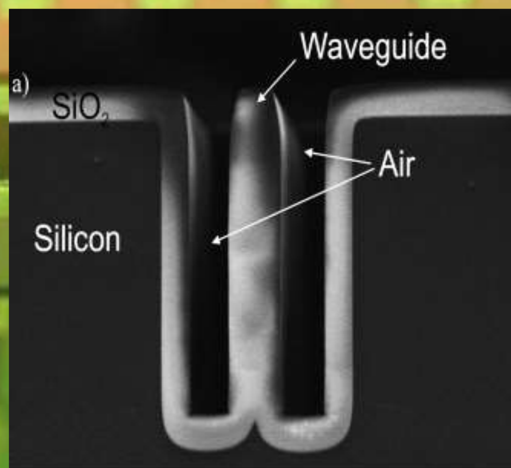
- Probes the bulk of the solution
- Light is unguided in the detection region



High-aspect ratio electrically insulated channels

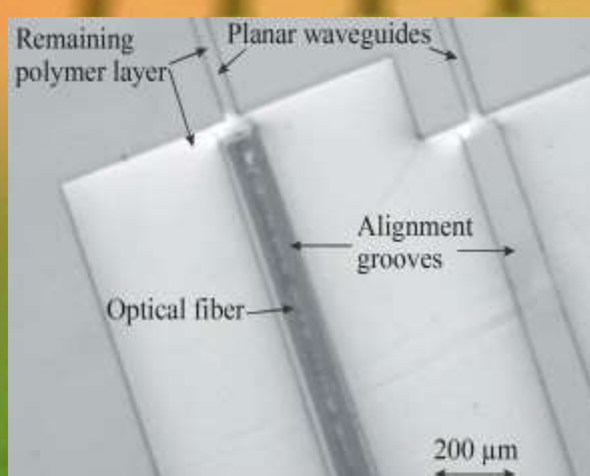


- Anisotropic KOH etching of <110> silicon
- Thermal oxidation of silicon channels walls

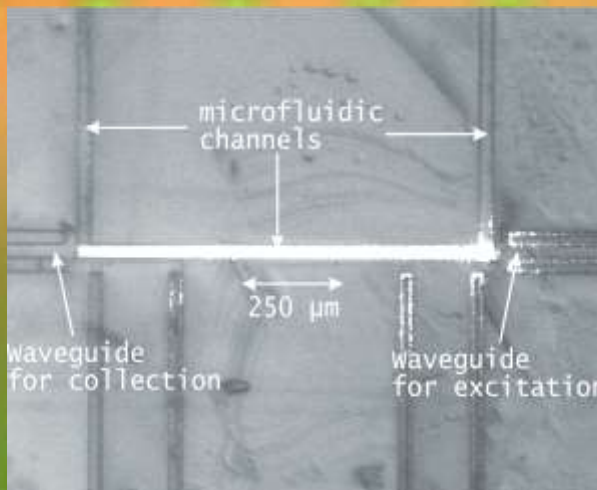


Klaus B. Mogensen, *Electrophoresis* 2004

Integrated fiber coupler

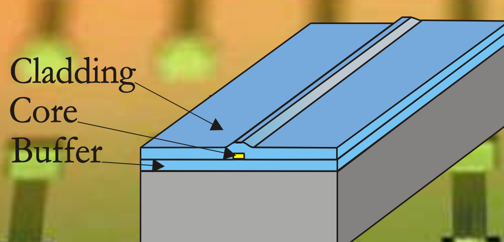


Chemical absorbance cell



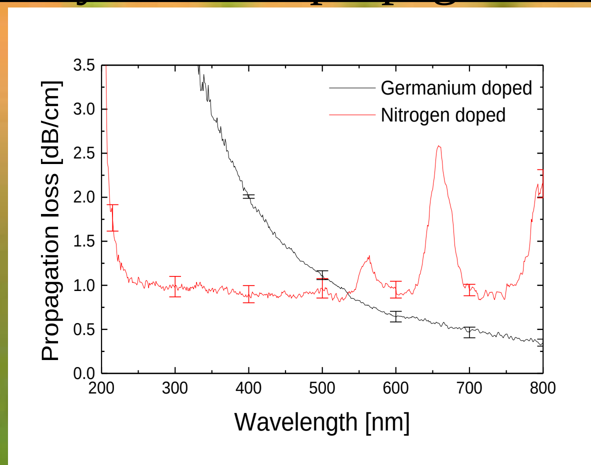
- 1000 µm absorbance length
- 30 µm channel width

Fabricated multimode waveguides



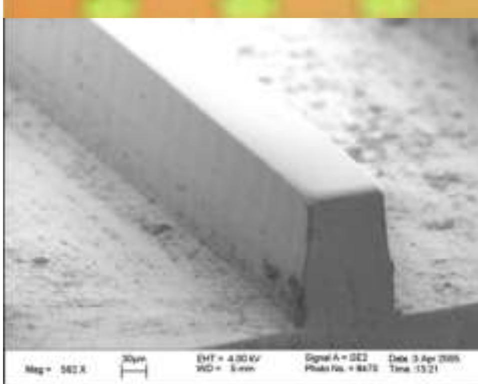
Width: 24 µm	Nitrogen doped	Germanium doped
Buffer	10 µm wet oxide	10 µm wet oxide
Core	4 µm SiO_xN_y	4 µm $SiGe_xO_y$
Cladding	7 µm SiO_x	5 µm BPSG

Spectrally resolved propagation loss



- Calculated with cut-back method with 5 different lengths

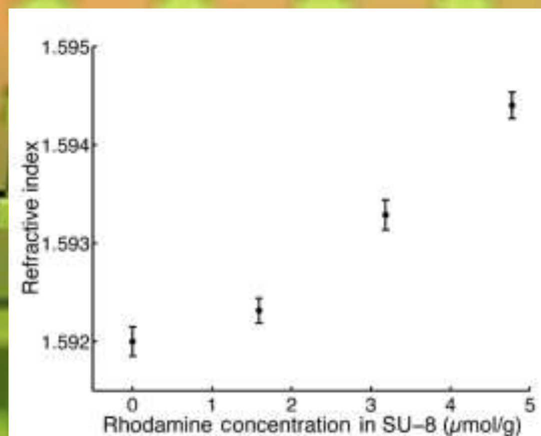
Polymer waveguides



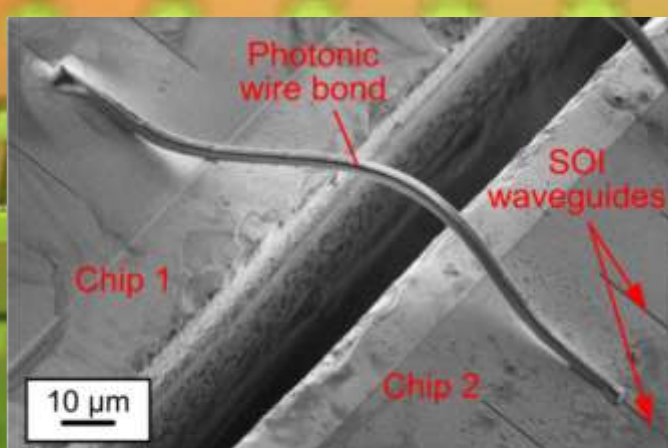
- Spin-coated or thermally bonded thin films with different refractive index
- Structured with litography or milling

Bundgaard & Geshke 2006

Polymer waveguides



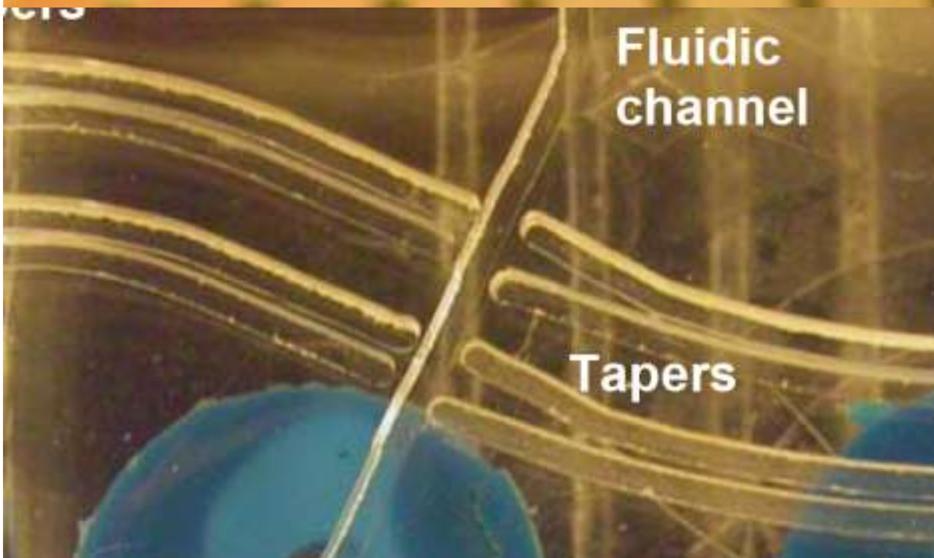
Optical wire bond



- 3D printed optical waveguide chip-to-chip optical interconnect

N. Lindenmann et al.2011

Tapers

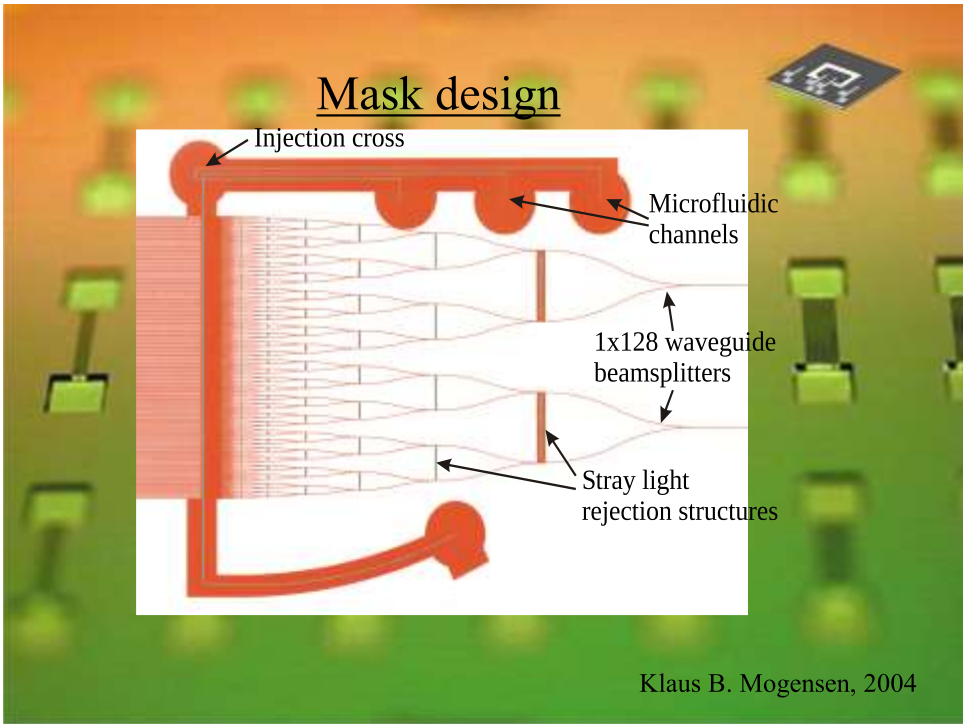


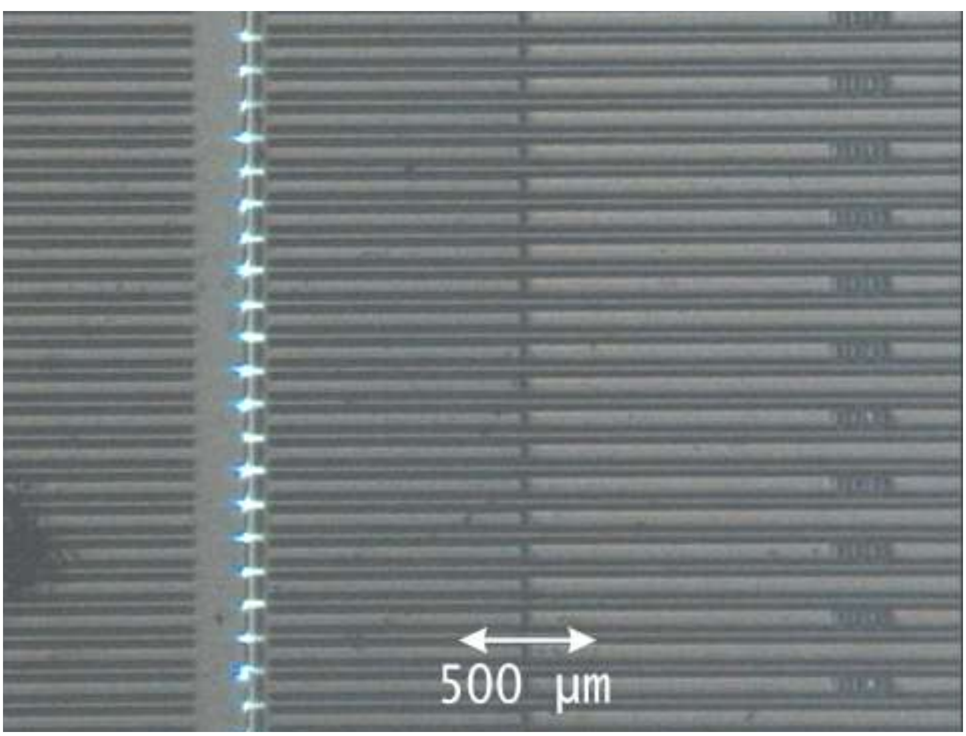
Perozzelli, 2005

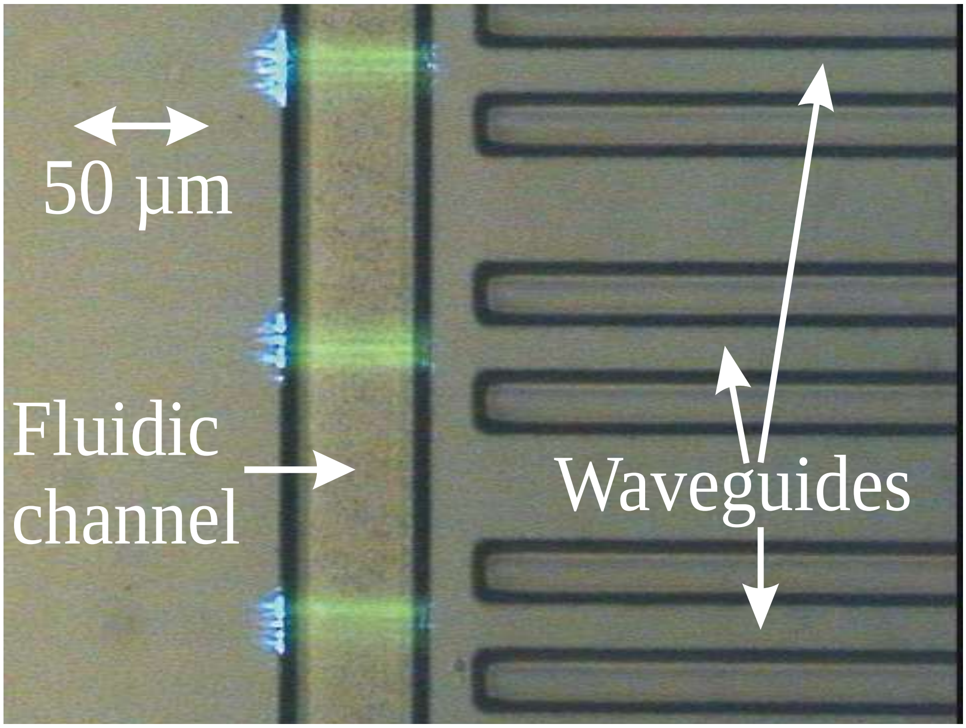
Lenses

Sperical lenses in PDMS
moulded from isotropically etched silicon

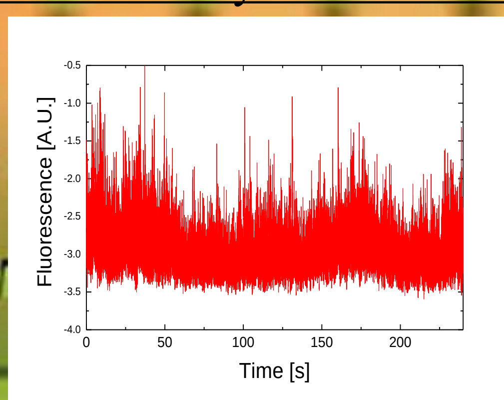
Perozzelli, 2005


Mask design
Injection cross
Microfluidic channels
1x128 waveguide beamsplitters
Stray light rejection structures
Klaus B. Mogensen, 2004


500 µm

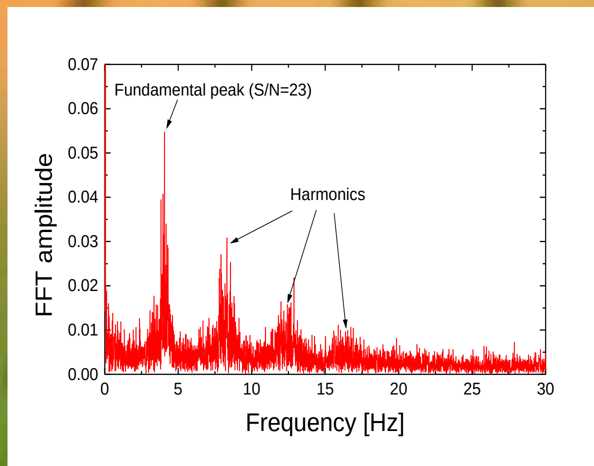


Particle velocity measurements



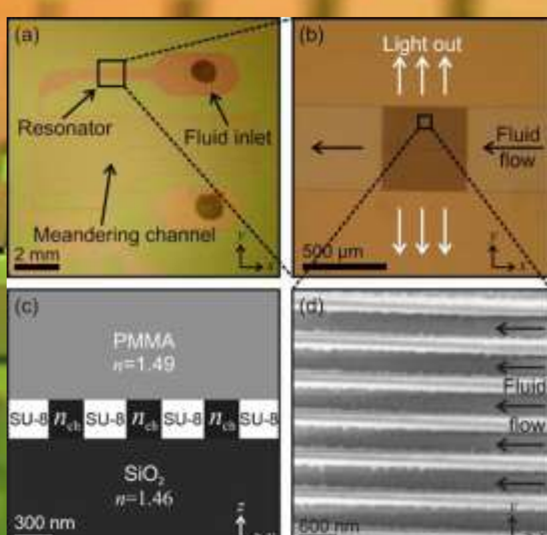
- 1.0 µm fluorescent beads (1,000 fold dilution in 0.1x TBE)
- Field strength: 111 V/cm

Fourier transformation



• Fundamental peak at 4.1±0.5 Hz (410±50 μm /s)

Laser-on-chip



Dye laser
(Rhodamine 6G)

Laser light is formed in a Bragg resonator (b)

Pumped with external 532 nm Nd:YAG laser

Gersborg-Hansen and Kristensen, 2006

Laser-on-chip