

Lysdetektorer

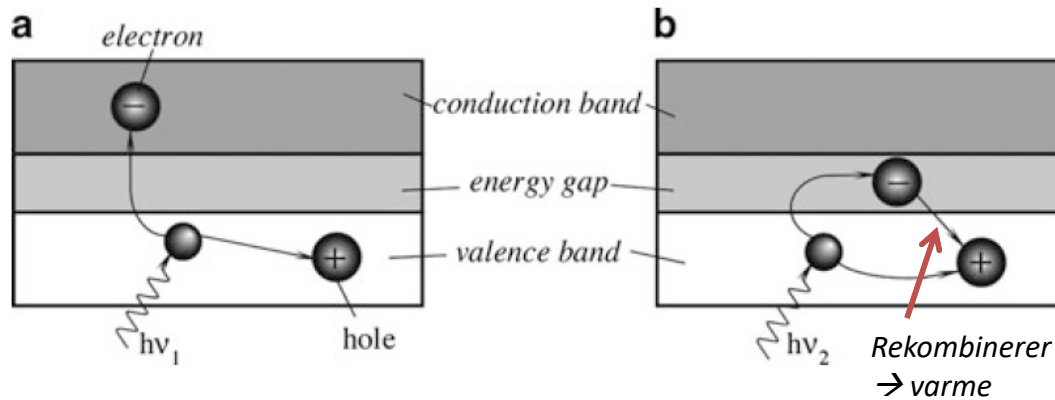


Fig. 14.1 Photoeffect in a semiconductor for high (a) and low (b) energy photons

- Absorpsjon av fotoner:
 - Kvanterespons
 - Termisk respons
- Kvantedetektor
 - UV \rightarrow MIR
 - Fotoeffekt (Einstein, Nobelpris 1921)
- Termisk detektor
 - MIR \rightarrow FIR

Material	Band gap (eV)	Longest wavelength (μm)
ZnS	3.6	0.345
CdS	2.41	0.52
CdSe	1.8	0.69
CdTe	1.5	0.83
Si	1.12	1.10
Ge	0.67	1.85
PbS	0.37	3.35
InAs	0.35	3.54
Te	0.33	3.75
PbTe	0.3	4.13
PbSe	0.27	4.58
InSb	0.18	6.90

Table 14.1 Band gaps and longest wavelengths for various semiconductors (after [1])

Fotoeffekt (kvantedetektorer)

- Alle sensorer som omdanner EM-stråling til ladningsbærere er kvantedetektorer:
 - Fotodioder
 - Fototransistorer
 - Fotoresistorer
- Noen detektorer kjøles for å redusere intern støy og for å få økt følsomhet ved lavere frekvenser

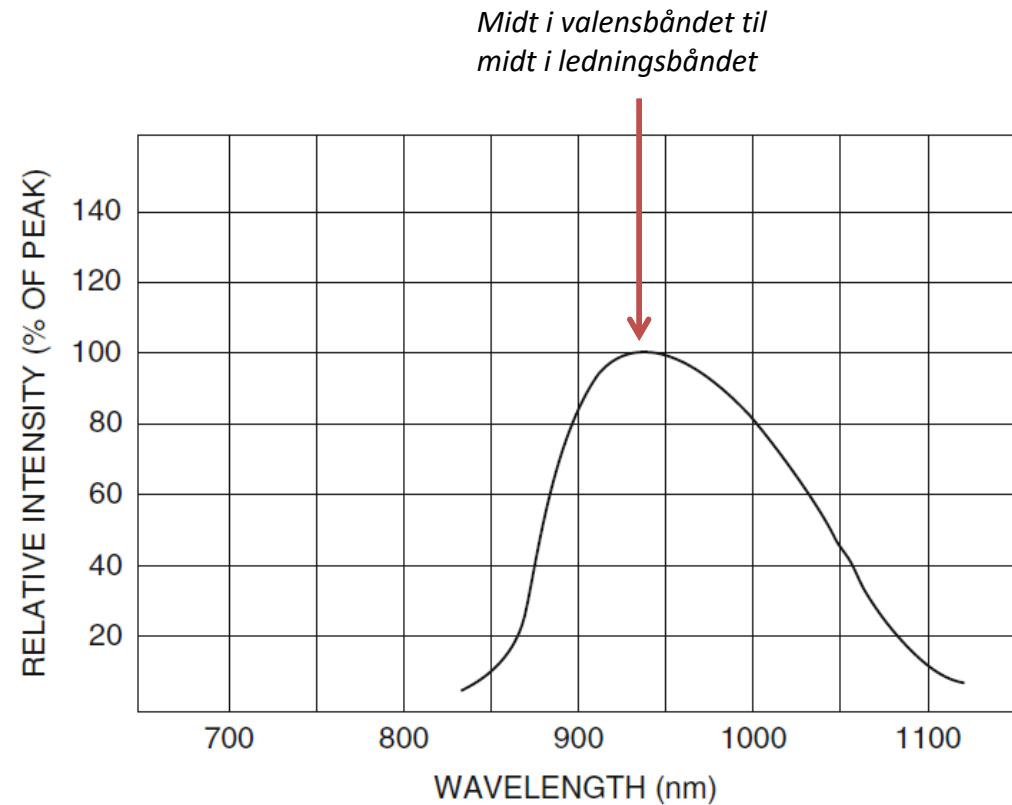
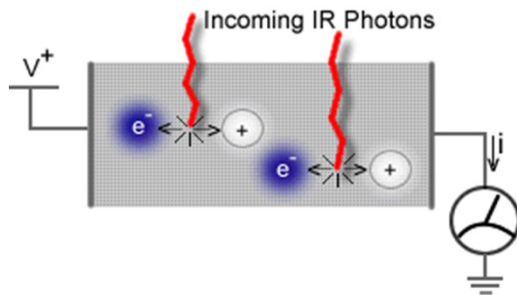
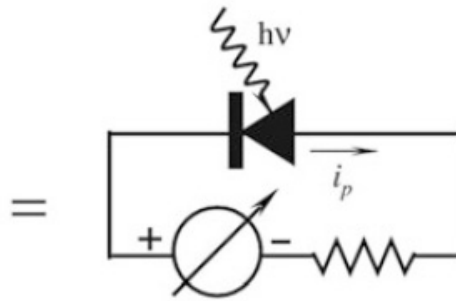
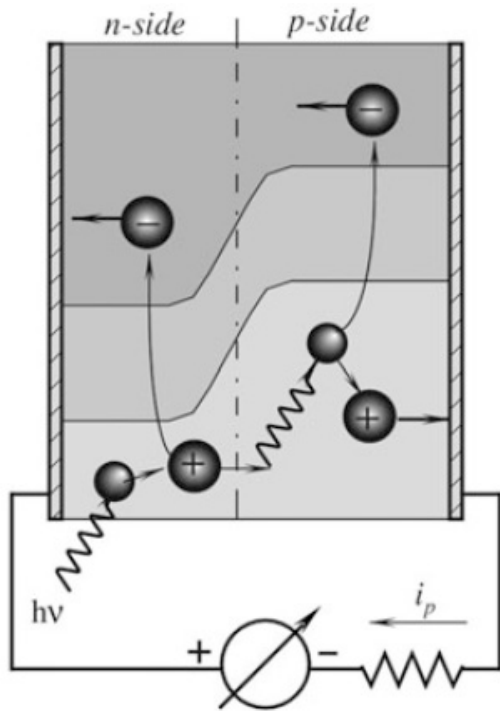


Fig. 14.2 Spectral response of an infrared photodiode



Ingen forspenning i photovoltaic mode

Fotodioder

- Diode forspent i lederetning
 - Strømbidrag fra fotoeffekt blir ubetydelig
- Forspent i sperreretning
 - Betydelig bidrag
- To typer:
 - Photovoltaic
 - Photoconductive

Fig. 14.3 Structure of a photodiode

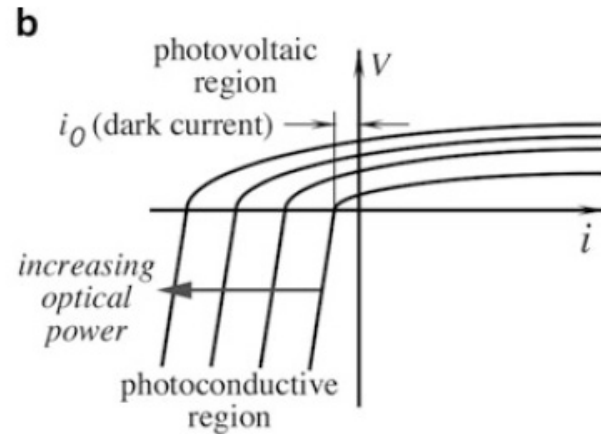
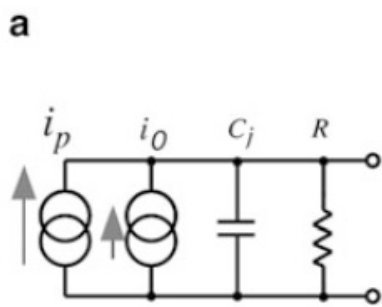


Fig. 14.4 An equivalent circuit of a photodiode (a) and its volt-ampere characteristic (b)



Fotodiode – photovoltaic mode (1)

- Stor indre kapasitans gir dårlig frekvensrespons
- Derfor bedre å bruke transresistansforsterker (neste slide)

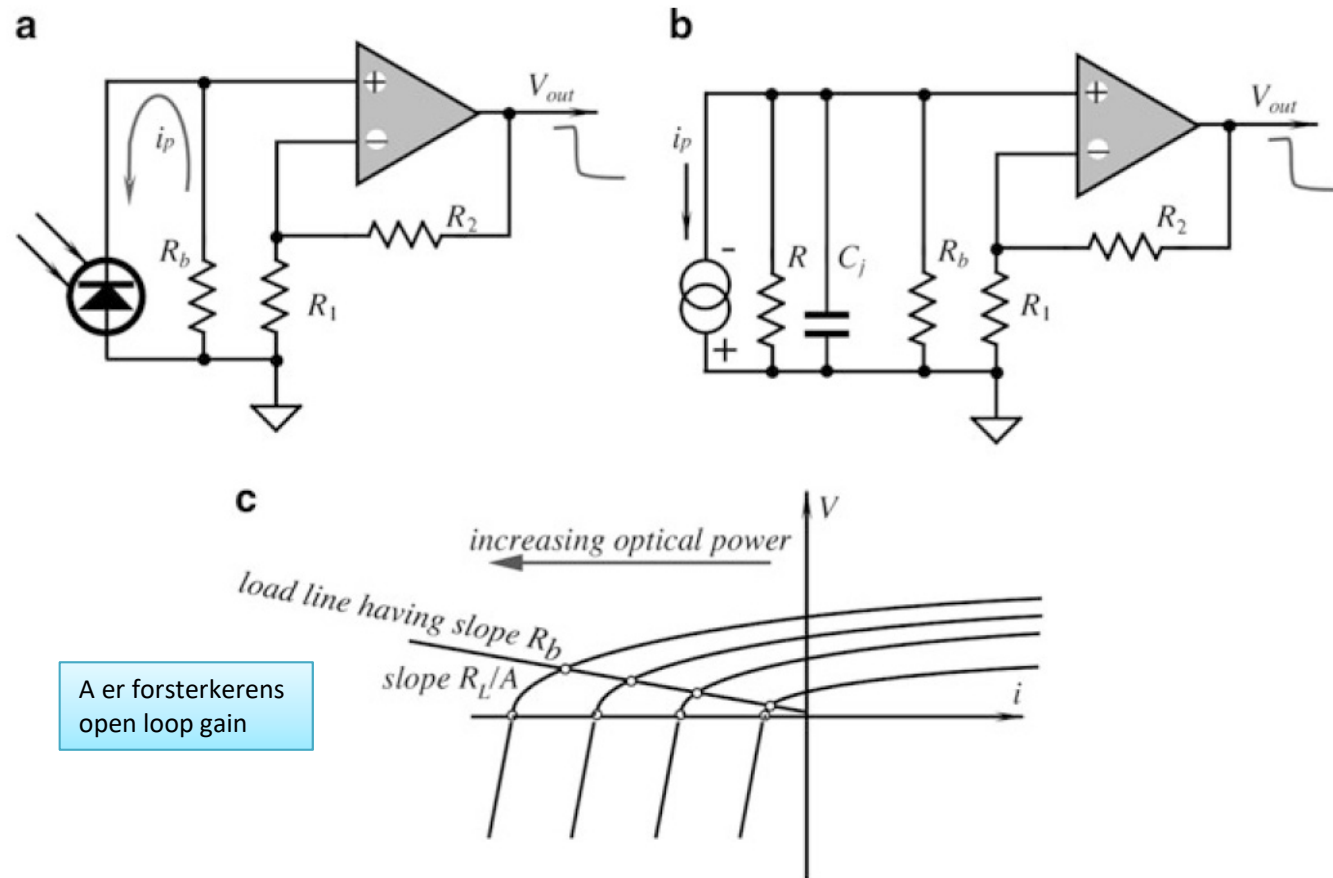


Fig. 14.5 Connection of a photodiode in a photovoltaic mode to a noninverting amplifier (a); equivalent circuit (b); and loading characteristic (c)

Fotodiode – photovoltaic mode (2)

- Kondensator C_L for å unngå ustabilitet ved HF hvor fasen dreies så mye internt at lasten tilsynelatende blir induktiv

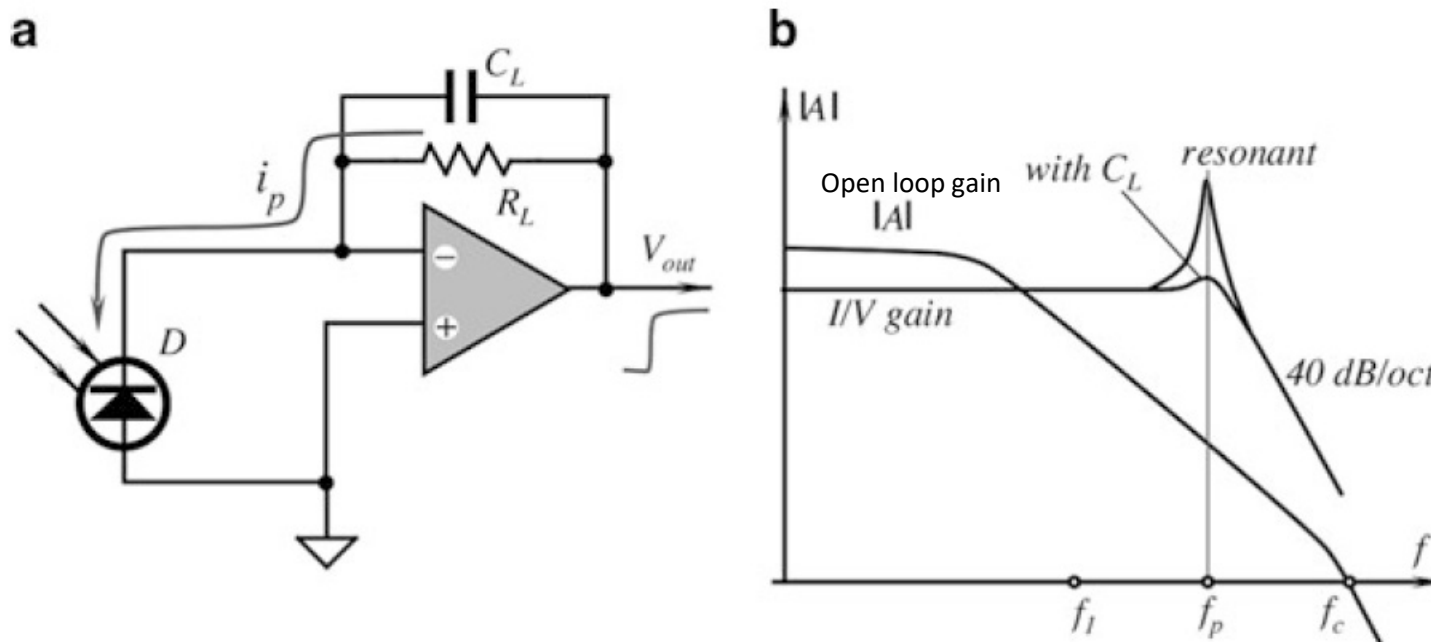


Fig. 14.6 Use of current-to-voltage converter (a) and the frequency characteristics (b)

Fotodiode – photoconductive mode

- Reverse bias \rightarrow load line i 3. kvadrant \rightarrow mer lineær

Fotodiode + interface-elektronikk
= lys-til-spennings-omformer

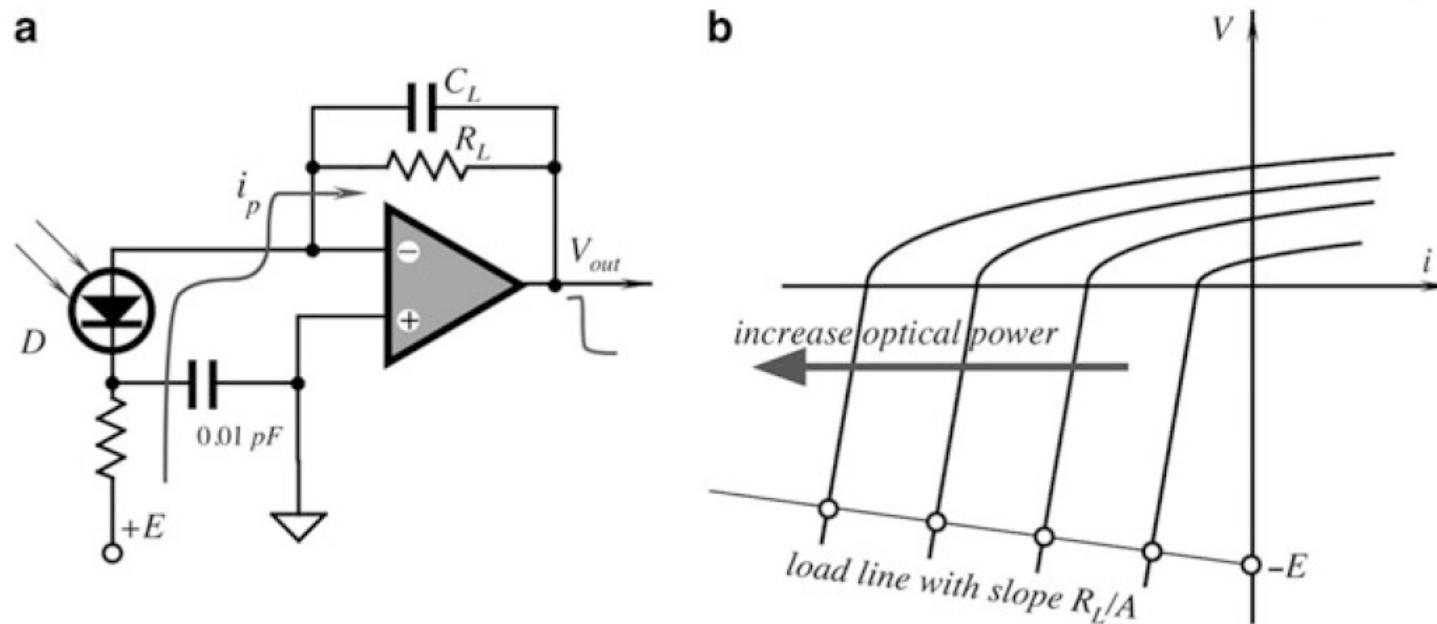
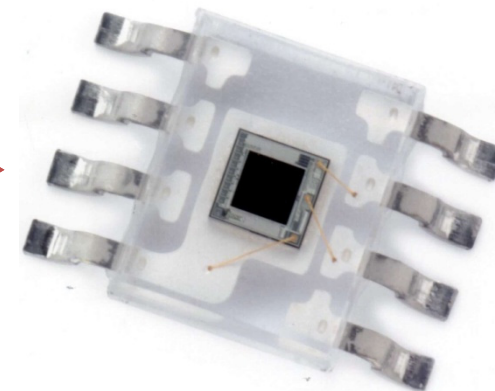


Fig. 14.8 Photoconductive operating mode. Circuit diagram (a) and load characteristic (b)

Fototransistor

- Strømforsterkning og høyere sensitivitet enn en diode

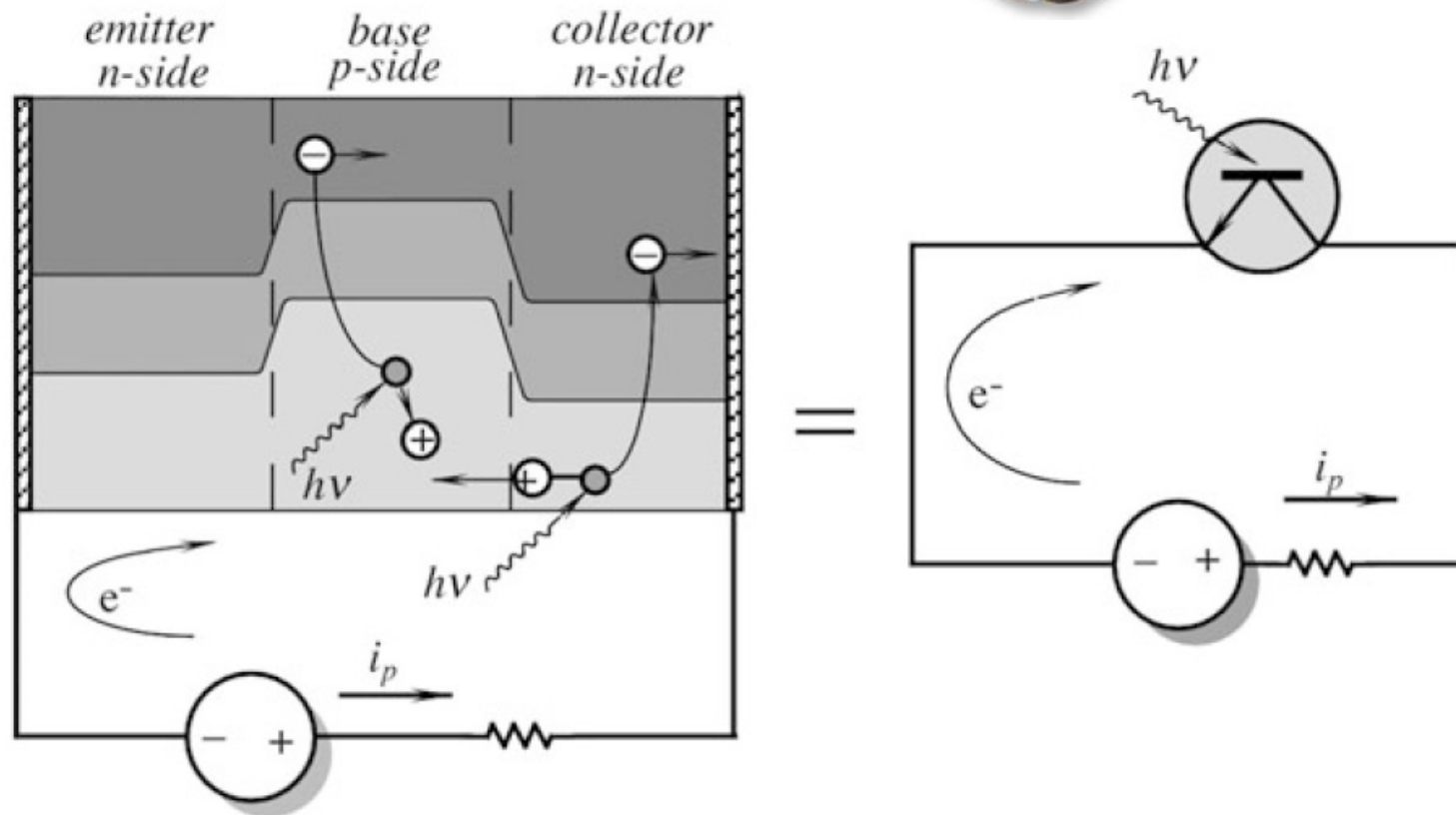


Fig. 14.9 Energy bands in a phototransistor

Fotoresistor

- Trenger ytre spenningskilde
- Lys skaper elektron-hull-par
- Dette gir ingen strøm per se, men endret resistans

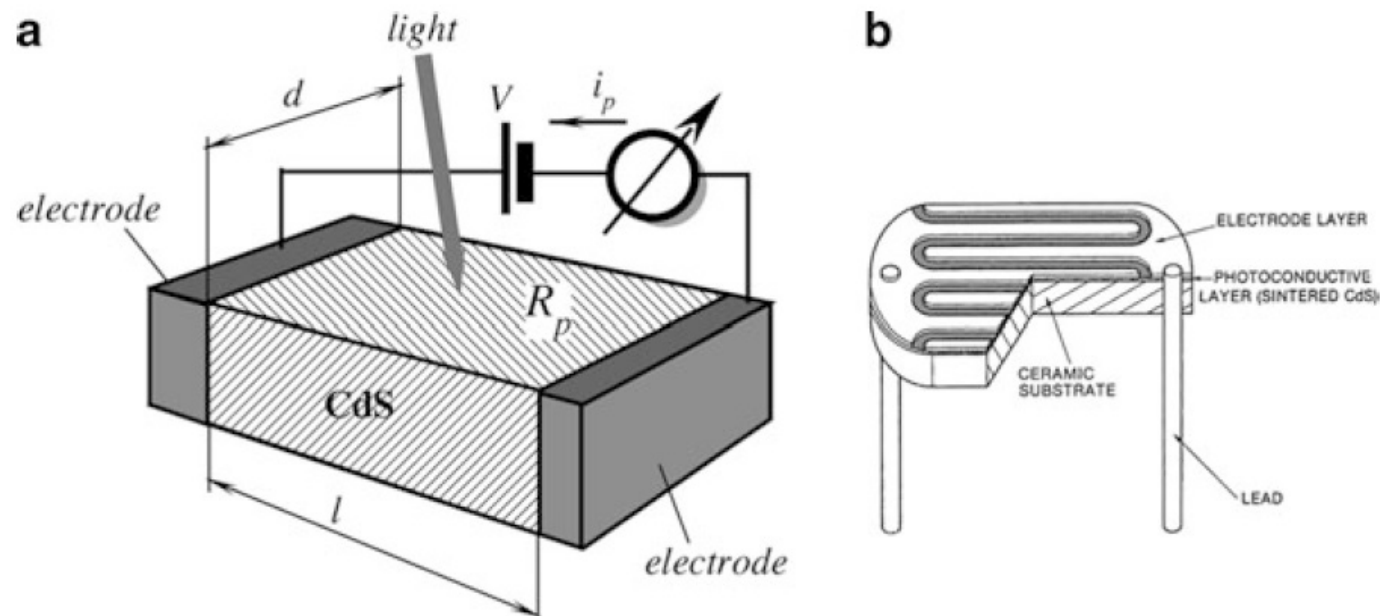
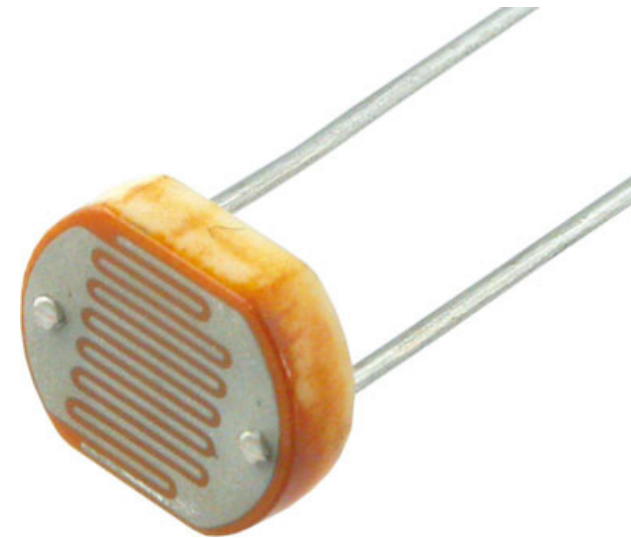


Fig. 14.11 Structure of a photoresistor (a) and a plastic-coated photoresistor having a serpentine shape (b)

Bildesensorer

- CCD eller CMOS
- CMOS-sensorer er mer komplette, og gir ut digitale verdier. Hvert pixel har egen forsterker og utlesning
- CCD gir bedre bildekvalitet og fanger 80 % av fotonene. Data leses av rad for rad

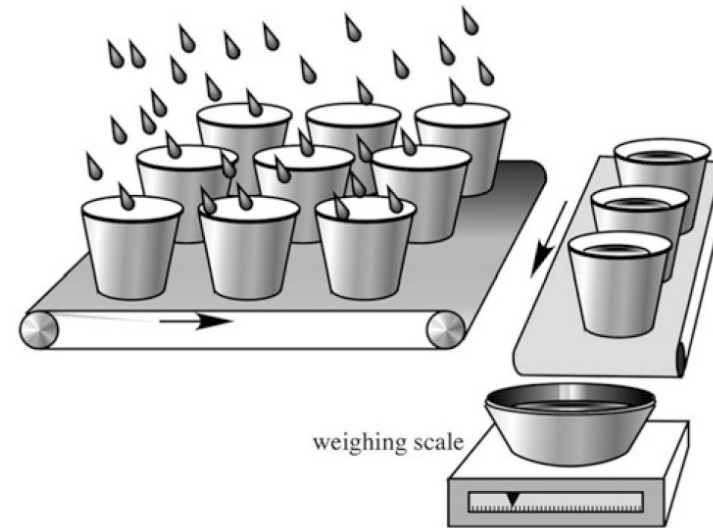
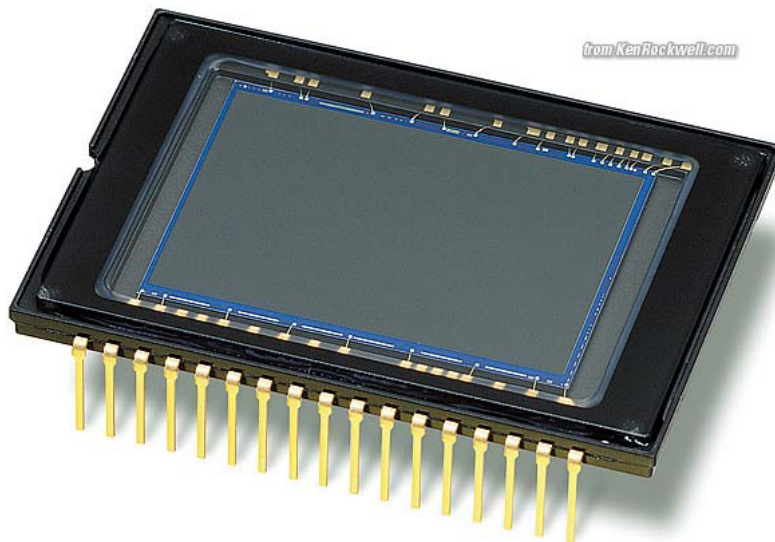


Fig. 14.16 Analogy of the CCD operation

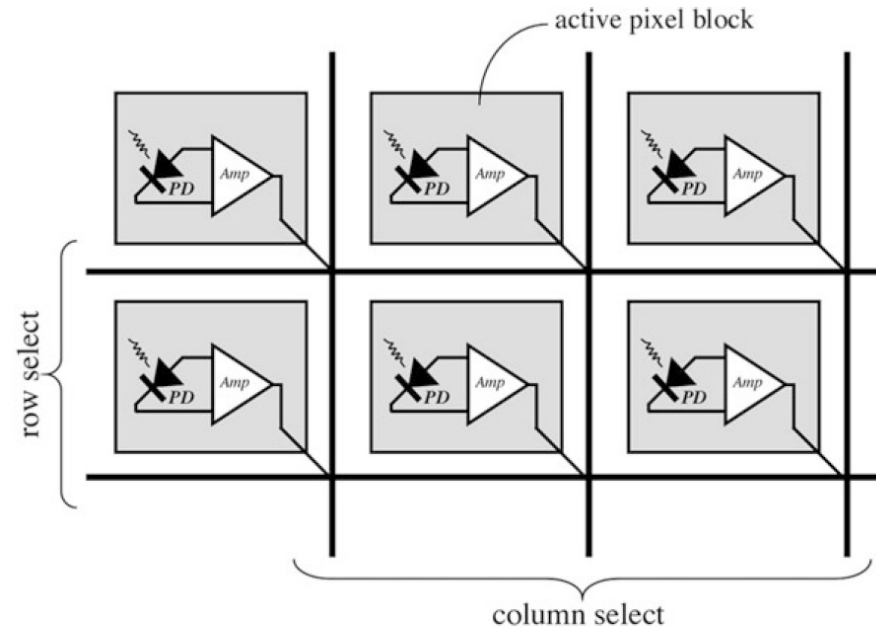


Fig. 14.17 Organization of a CMOS-imaging sensor

Les selv ...

Termiske detektorer

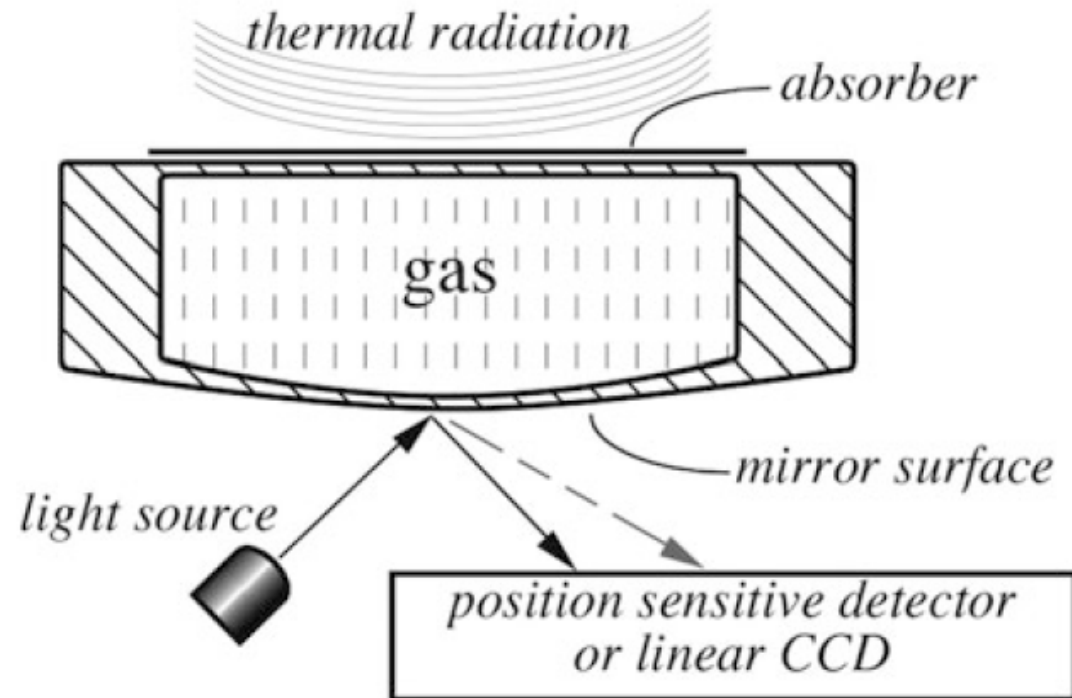
- Golay cells
- Thermopile sensors
- Pyroelectric sensors
- Bolometers
- Active Far-Infrared sensors
- Brukes for bølgelenger i MIR og oppover ($> 1 \mu\text{m}$)
- To typer:
 - Passive infrared (PIR): Omdanner stråling til varme
 - Active far-infrared (AFIR): Genererer selv varme og måler varmetap til omgivelser og objekter



Golay cells

Fig. 14.18 Golay cell detector for mid- and far-infrared radiation

- Breddbånd IR deteksjon
- Høy sensitivitet, men lite robust
- Kan lages i MEMS-teknologi



Thermopile -sensorer

- «Pile of thermocouples» for å øke sensitiviteten
- Lys i MIR og FIR –områdene
- Membran koblet til «hot junctions» varmes eller kjøles
- Kan bruke flere sensorer (=pixler) for thermal imaging

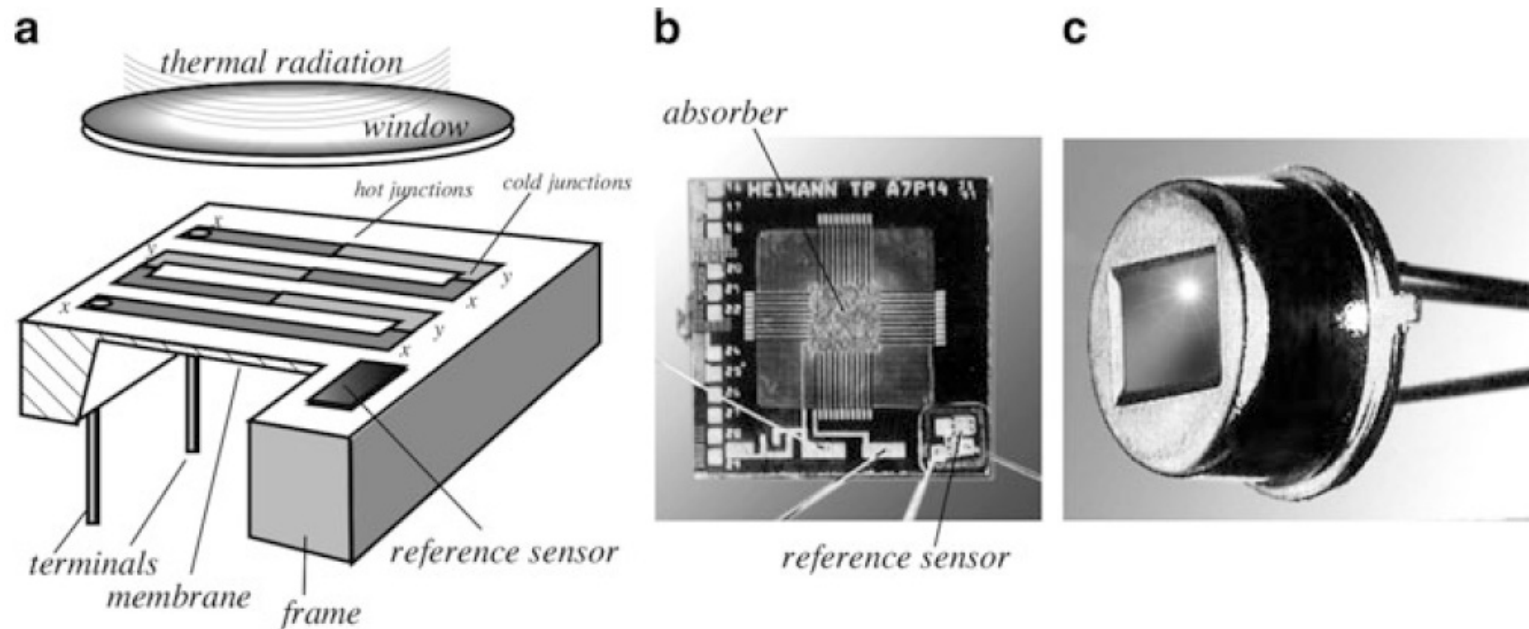


Fig. 14.19 Thermopile for detecting thermal radiation, equivalent schematic with a reference temperature sensor attached, x and y are different materials (a); micromachined thermopile sensor. Note the semiconductor reference temperature sensor on the silicon frame where the cold junctions are deposited, and the absorptive coating on the hot junctions in the center of the membrane (b); and sensor in a TO-5 packaging (c)

Pyroelektriske sensorer

- Pyroelektrisk effekt: Kondensator som lades pga oppvarming
- Reagerer kun på endringer i termisk stråling
- Tidskonstanten (C og R_b) i 14.23 a er veldig stor (2 sek typisk)
- Transresistans er raskere og dessuten uavhengig av kapasitansen i sensorelementet

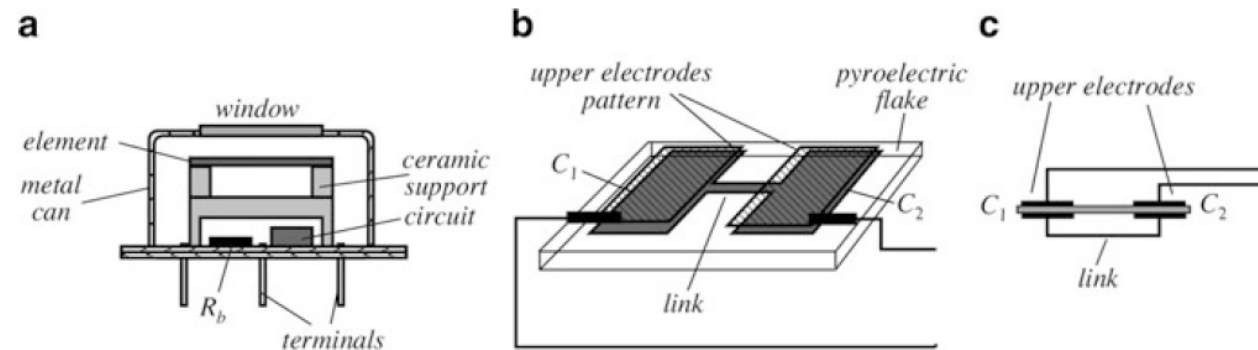


Fig. 14.22 A dual pyroelectric sensor assembled in a metal can (a); metal electrodes are deposited on the opposite sides of a pyroelectric plate (b); and equivalent circuit of a dual element (c)

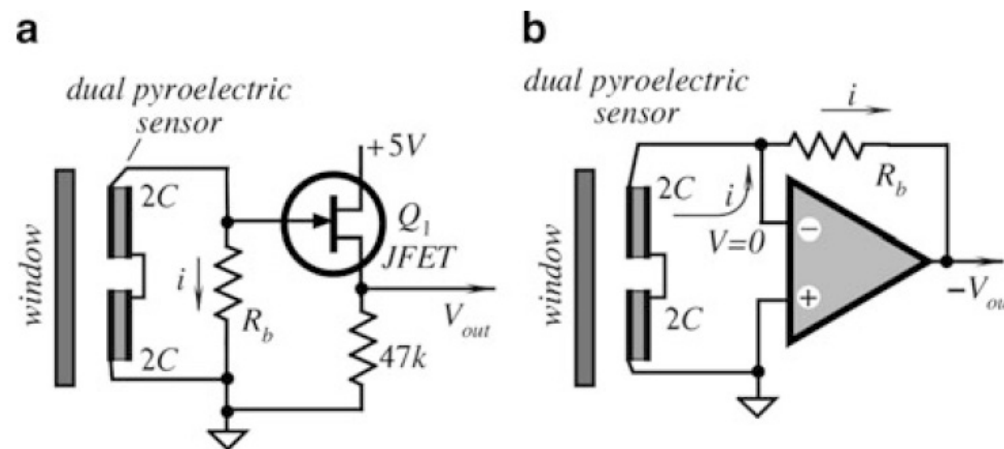
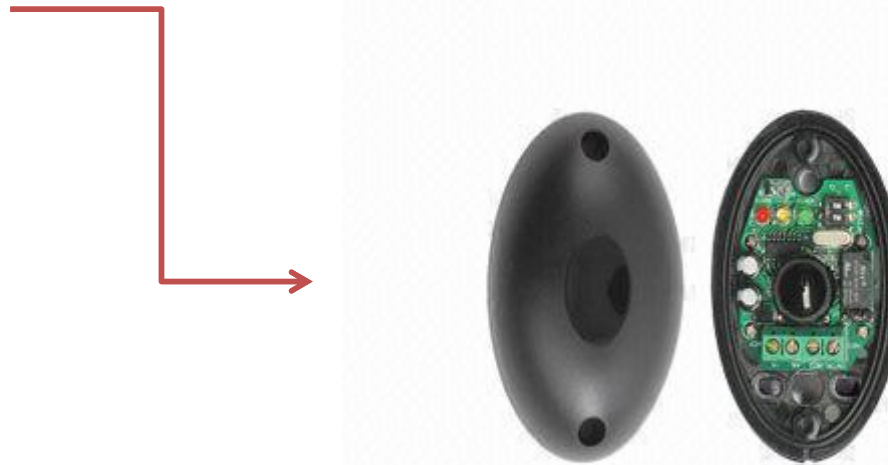


Fig. 14.23 Impedance converters for pyroelectric sensors voltage follower with JFET (a) and current-to-voltage converter with operational amplifier (b)

Bolometer / AFIR-sensor

- Bolometer: termistorer som brukes til å måle EM stråling over et bredt frekvensområde
- Active Far-InfraRed (AFIR) sensor: temperaturen på sensoren holdes konstant gjennom en aktiv krets. Som regel høyere enn omgivelsene, slik at sensoren avgir termisk energi (og denne måles)



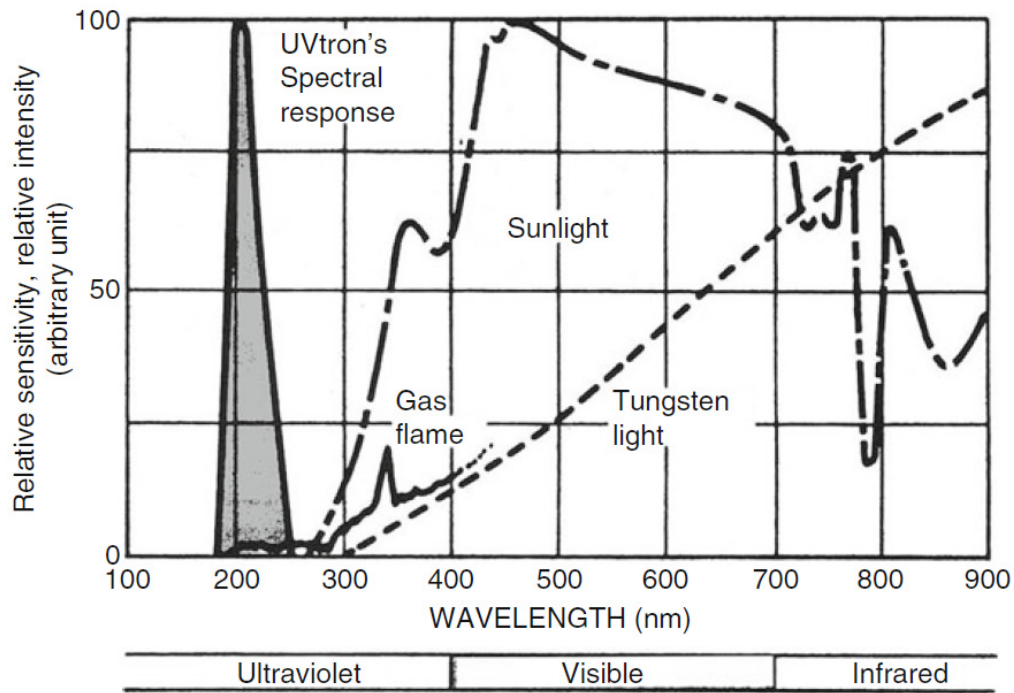
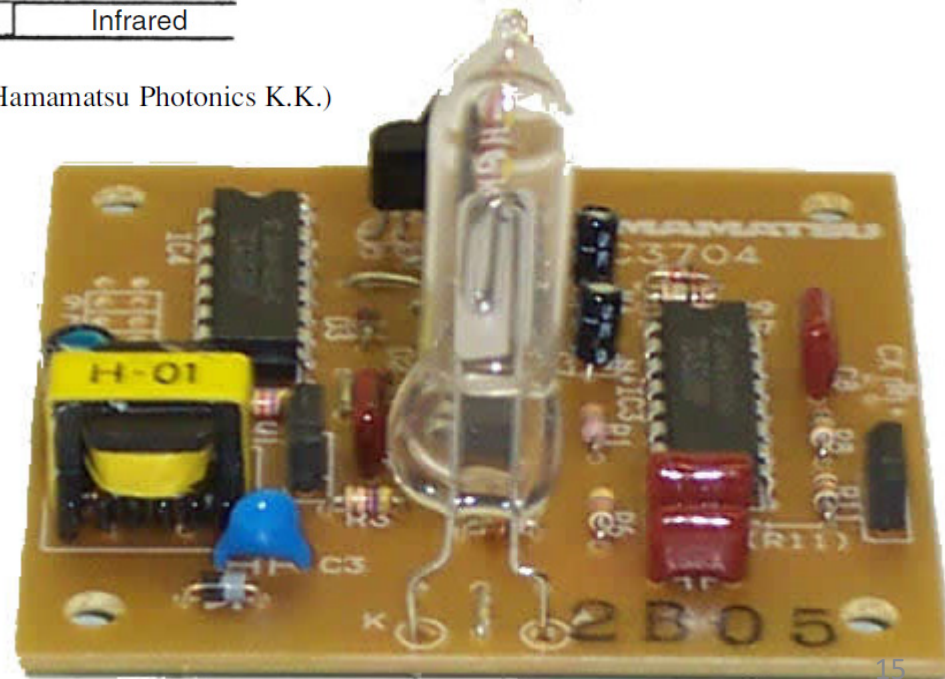


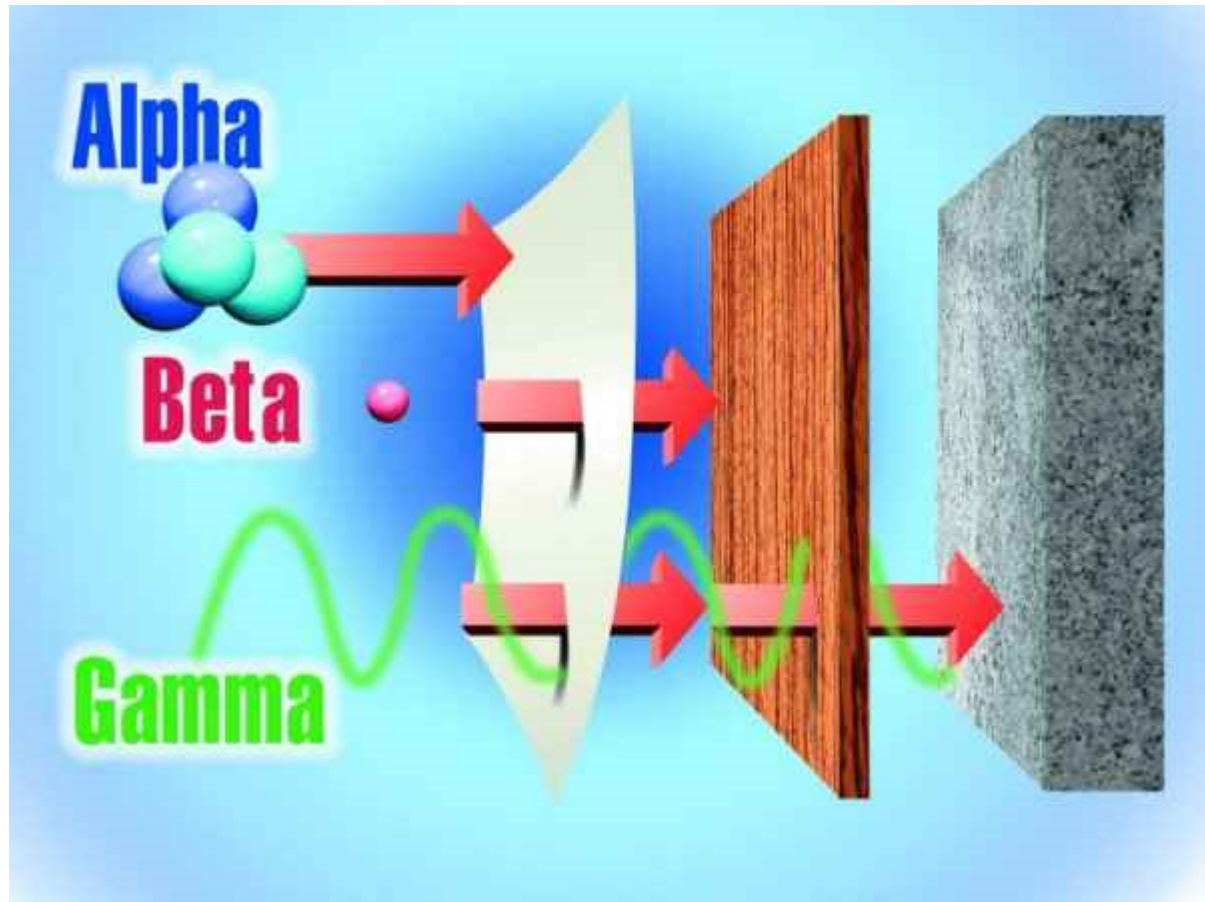
Fig. 14.31 Electromagnetic spectra of various sources (courtesy of Hamamatsu Photonics K.K.)

Gassflamme- detektor



Radiation

- Radioaktivitet:
Becquerel (Bq) =
antall
desintegrasjoner per
sekund
- Absorbert dose:
Grey (Gy) = J/kg



Scintillasjons-detektorer

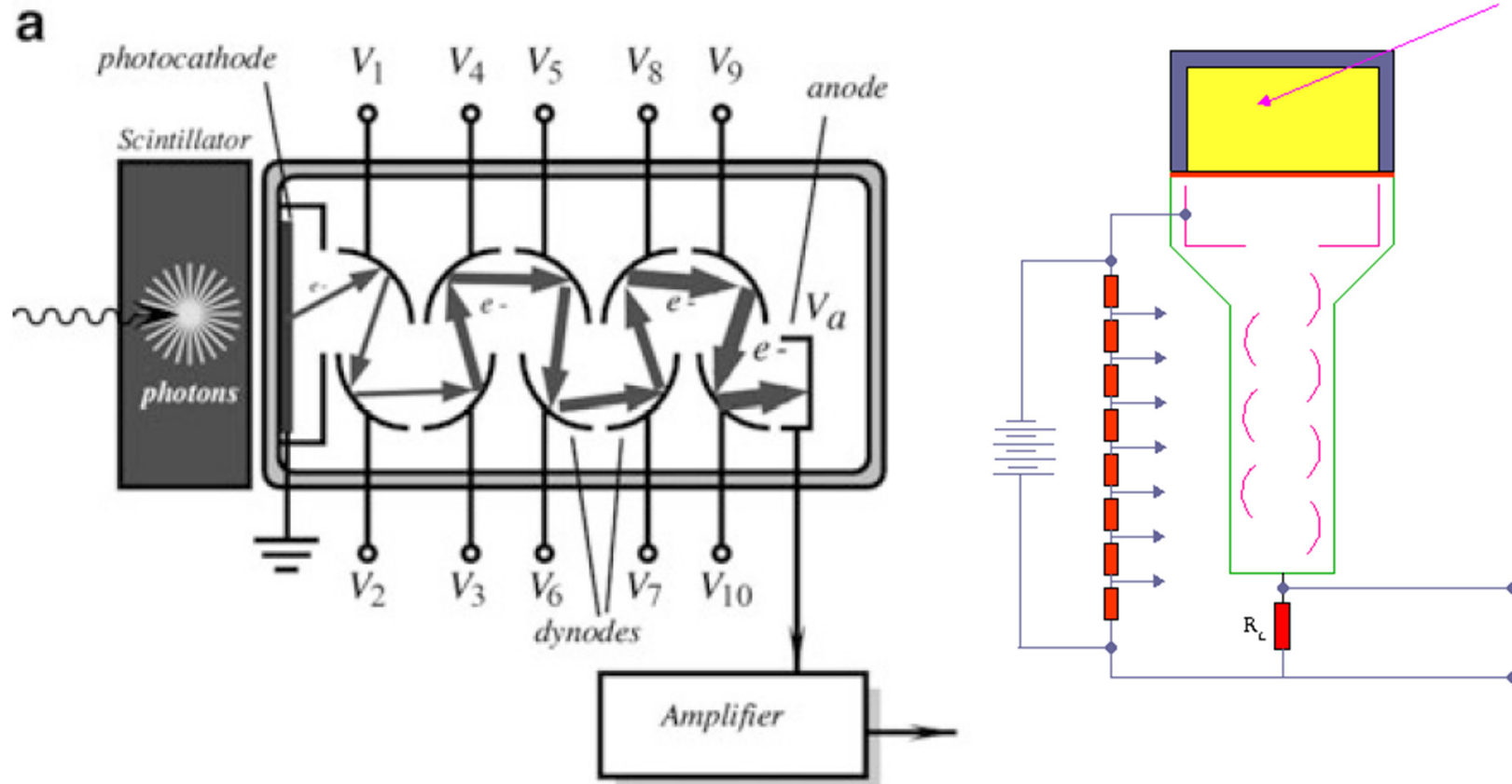


Fig. 15.1 Scintillation detector with a photomultiplier

Ioniseringsdetektorer

- Noen gasser / materialer danner ionepar ved ioniserende stråling
 - Ionekammer
 - Proporsjonal-kammer
 - Geiger-Müller-teller
 - Halvleder-detektorer

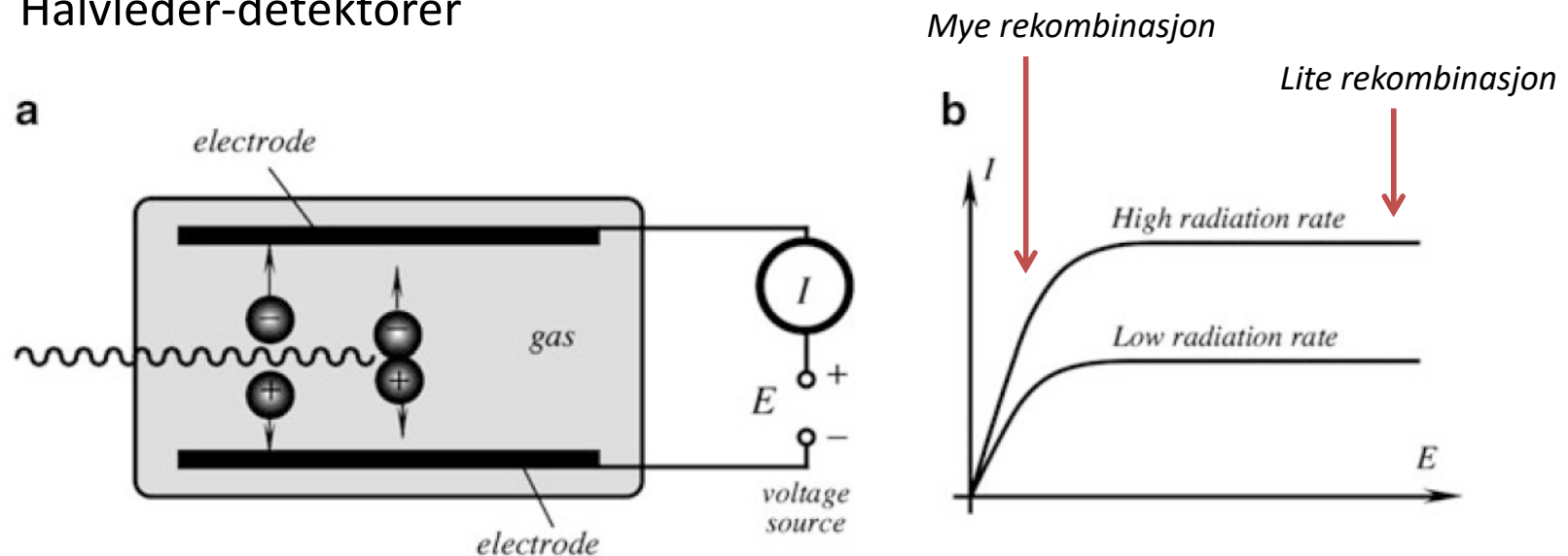


Fig. 15.3 Simplified schematic of an ionization chamber (a) and a current vs. voltage characteristic (b)

Proporsjonal-kammer

- Bruker høyere energi
→ ionene skaper
ytterligere ionepar
(Townsend avalanche)
- $> 10^6$ V/m

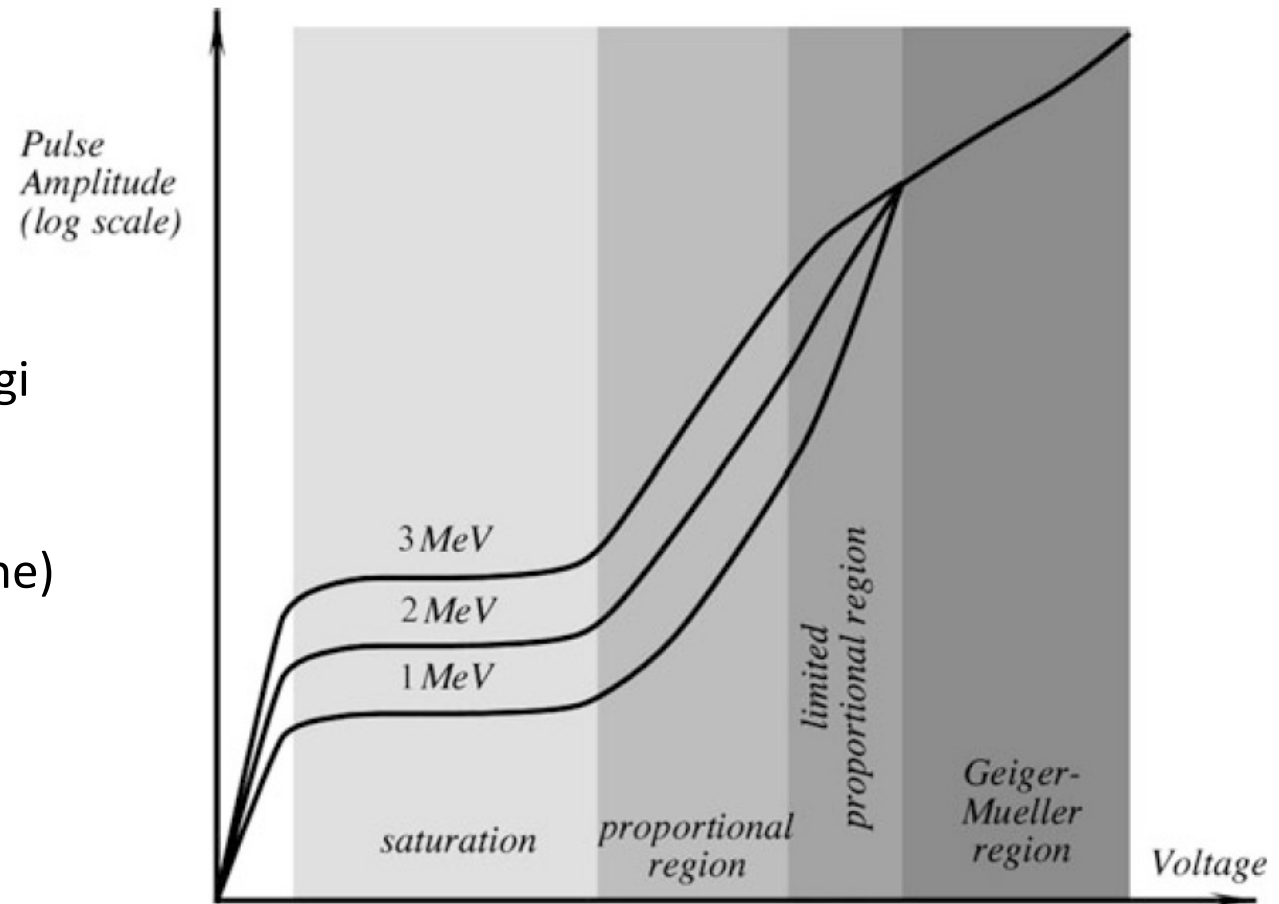
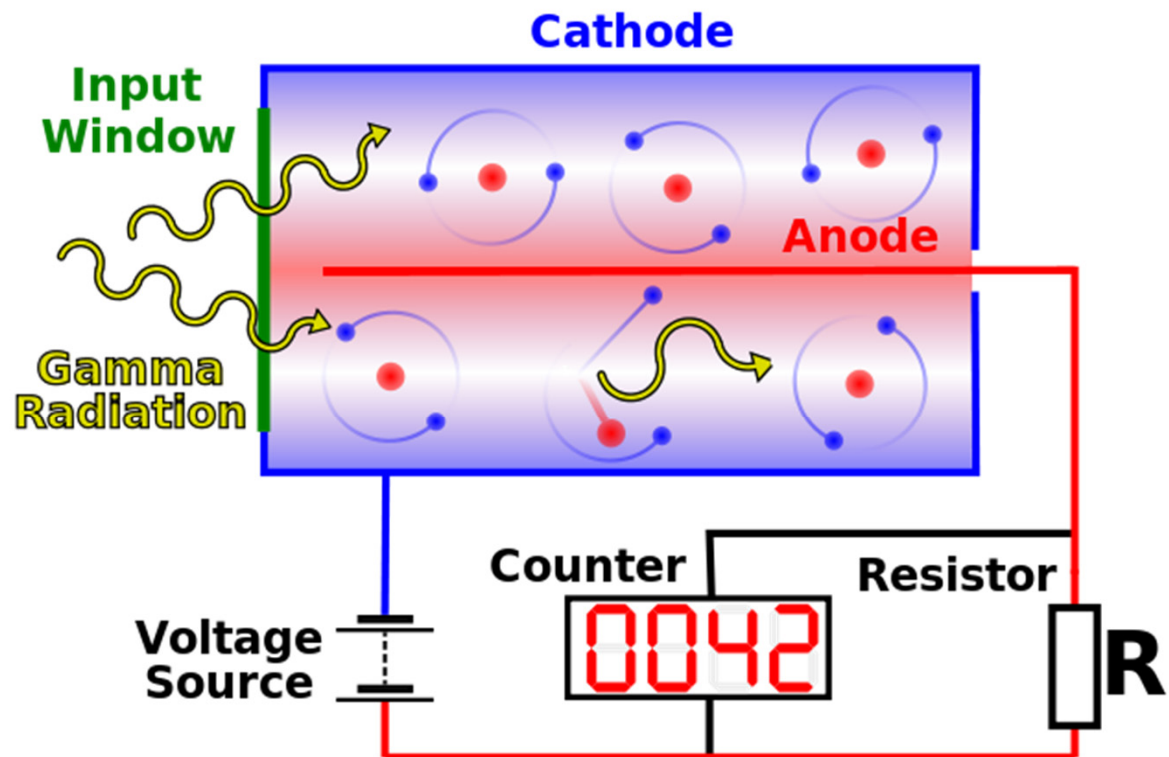


Fig. 15.4 Various operating voltages for gas-filled detectors (adapted from [2])

Geiger-Müller-teller

- Tynn-anodetråd i edelgass-kammer
- Svært høy spenning
- Townsend avalanche



Halvleder-detektorer

- PN-overganger forspent i sperreretning (for å kunne detektere små strømendringer)
- Stråling \rightarrow elektron-hull-par

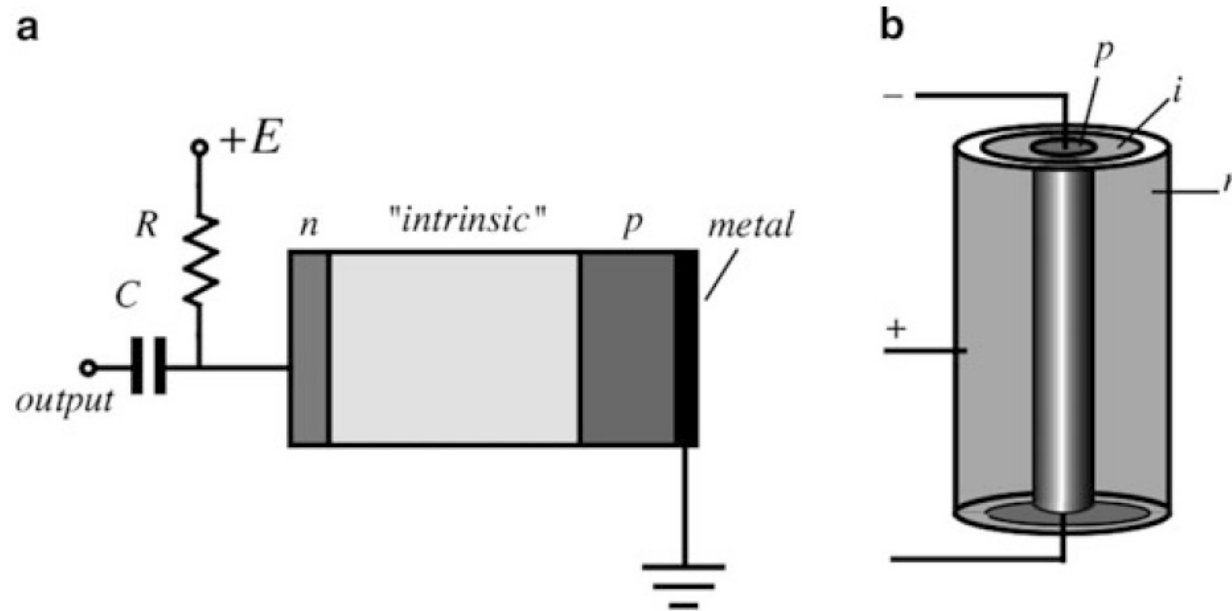


Fig. 15.6 Lithium-drifted pin-junction detector. Structure of the detector (a) and coaxial configuration of the detector (b)

Tåke- og boblekammer

- Tåkekammer: Mettet vann- eller alkoholdamp. Stråling (α eller β) \rightarrow ioner som fungerer som kondenserings-kjerner
- Boblekammer: Bruker væske i stedet (f.eks. flytende hydrogen) som er varmet nesten til kokepunktet. Som champagne eller øl.

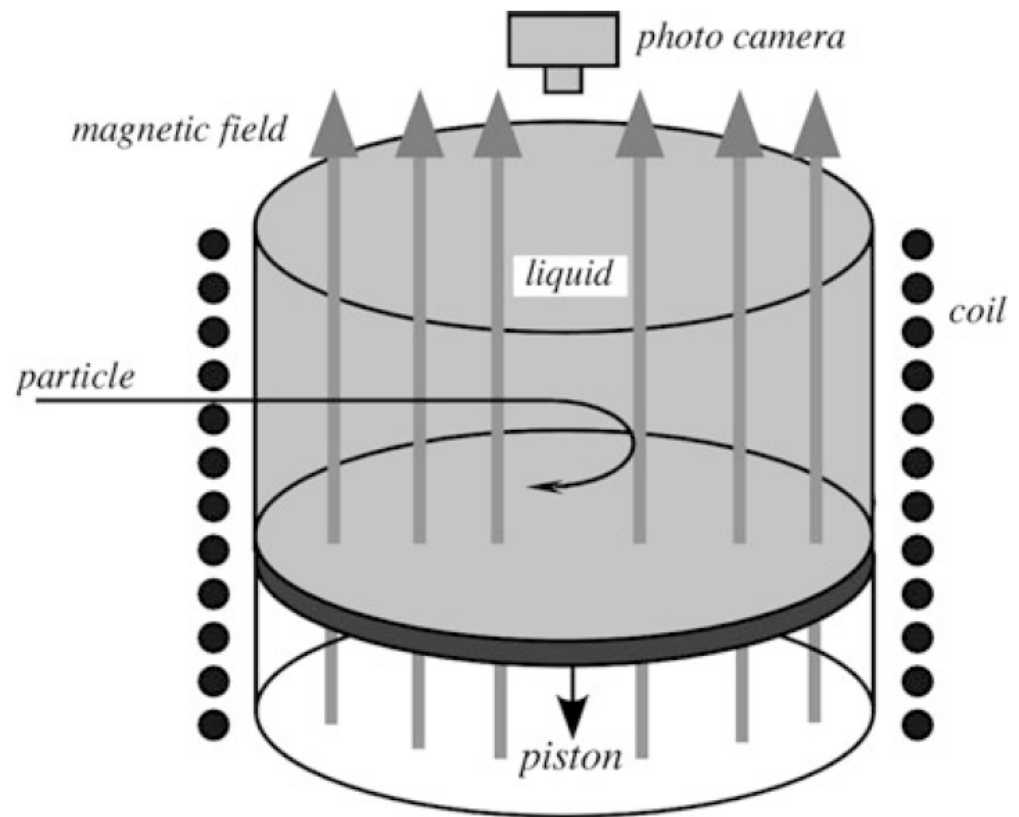


Fig. 15.7 Bubble chamber