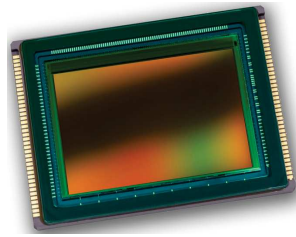
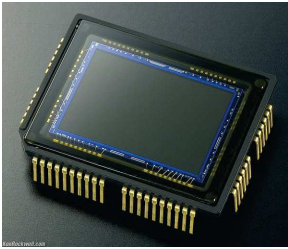
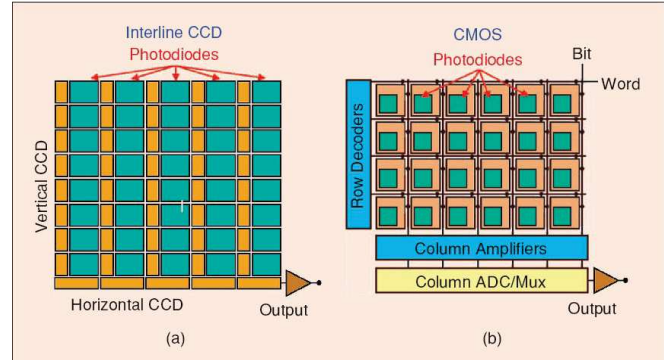


6. Optické snímače

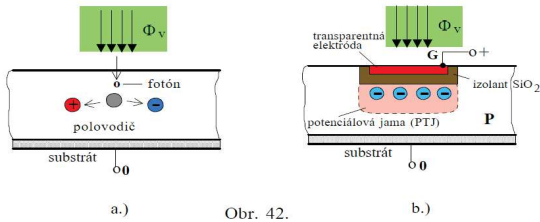
CCD a CMOS



6. Optické snímače



6.1. CCD prvky charge coupled device



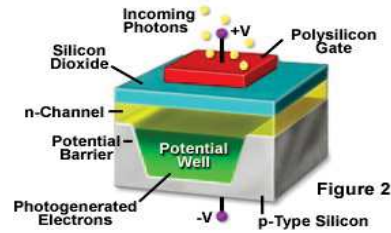
Obr. 42.

Uchovávame tzv. menšinové náboje, teda v P polovodiči elektróny. Tieto môžu vzniknúť :

- tepelnou generáciou - parazitný jav (**šum**)
- injekciou svetlom - vlastný snímací efekt
- injekciou z blízkeho PN prechodu - odovzdanie výstupného signálu

6.1. CCD prvky základná CCD bunka

Metal Oxide Semiconductor (MOS) Capacitor

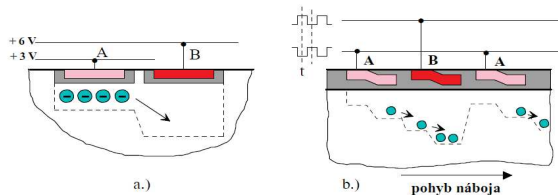


Charge-Coupled Device

- Invented at Bell Labs in 1970
- 2009 Nobel Prize in Physics
- Widely used in TV, medical, astronomy cameras
- Array of light sensitive MOS capacitors (pixels)
- Incoming light generates electrons which are captured in a potential well
- Electrodes, or gates, move the charge

From <http://learn.hamamatsu.com/articles/quantumefficiency.html>
Image from <http://www.microscopyu.com/articles/digitalimaging/ccdintro.html>

6.1. CCD prvky prenos náboja



Obr. 43.

Vyšší potenciál vytvorí hlbšiu PTJ, nosiče do nej prepadávajú.

Tvarované elektródy - tvarovaná PTJ

Elektródy A a B - výstupný register

6.1. CCD prvky

Množstvo nosičov závisí od intenzity osvetlenia E a od času t:

expozícia (osvit) e : (e býva označené tiež H)

$$e = E \cdot t \quad [lx \cdot s ; lx ; s ;]$$

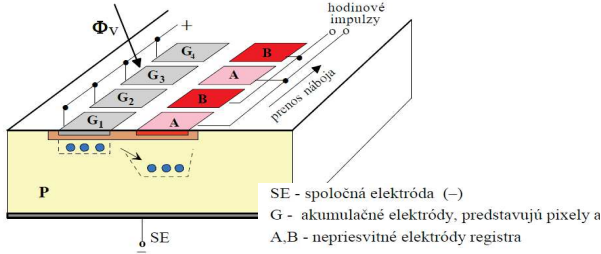
(6 - 2)

Poznámka: Doba existencie náboja v PTJ je asi $100 \text{ ms} + 10 \text{ s}$. (vyrovnanie tepelnu generáciou). Dlhé časy - problém, už cca $5 + 10 \text{ s}$ vyžadujú chladienie prvkov, napr. polovodičové, resp. softvérové potlačenie. (následné zosnimanie bez obrazu a odčítanie)

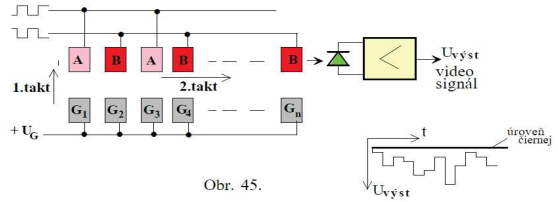
6.1. CCD prvky riadkový CCD senzor

Riadkový CCD senzor

1. Svetelný tok $\Phi_v \rightarrow$ náboj pod G_1, G_2, \dots
2. Po dobe expozície presun náboja pod A,B
3. Fázovo posunuté impulzy na A,B - vystavenie nábojov



6.1. CCD prvky riadkový CCD senzor



Obr. 45.

Video signál:

- poloha bodu - čas od začiatku prenosu
- osvetlenie bodu - amplitúda.

Počet pixelov - 128 (termovízia), po 6 - 10 tis (profi scannery...)
Rozmery : od 6 x 6 μm do 17 x 8 μm .

6.1. CCD prvky riadkový CCD senzor

Princíp elektronickej uzávierky

Doba snímania (pre 1728 pixelov) \rightarrow hodinové impulzy :

10 kHz \rightarrow doba snímania = 86 ms (1/12 [s])

10 MHz \rightarrow doba snímania = 86 μs (1/12000 [s])

Optimálne cca 10 ms (1/100 [s]), čomu zodpovedá 86 kHz.

Výhody: netreba mechanickú uzávierku - cena

Nevýhody: pomalé vysvitávanie - akumulujú svetlo aj počas vysvitávania (náchylnejšie na smearing, blooming)
rýchle vysvitávanie - nekvalitné (rýchle) odčítanie náboja

T/2 spôsobí posun o jedno miesto, resp. T vysvitie polovicu pixelov (párne - nepárne)

$E = 10 \text{ lx}$ dáva 0,2 V na výstupe.

Citlivosť na svetlo: ASA (DIN) a je 100 + 3200 ASA (21 + 36 DIN).

Poznámka: Horná hranica je už 6000 - 12000 ASA, diskutabilná je kvalita (malé snímače)

Rozlíšenie úrovni šedej 8 - 32 bitov \rightarrow 256 - 4,295. 10⁹ úrovni. (stand. 24 bit)

6.1. CCD prvky riadkový CCD senzor

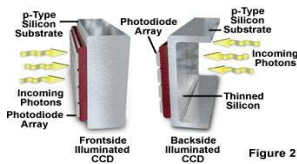
Použitie riadkových CCD :

- nepohyblivé obrázky (scannery...) - snímanie po riadkoch
- snímanie polohy (ako PSD)
- iné, napr. zaostrovacie systémy - vyhodnotenie kontrastu (krížový senzor, hrany)

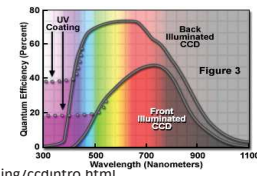
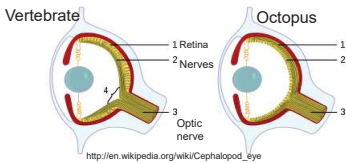
Ako zobrazovacie systémy potrebujú vysokokvalitnú optiku s vysokým rozlíšením pre malé ohniskové vzdialenosti (3 - 8 mm)

6.1. CCD prvky Front or Back Illuminated

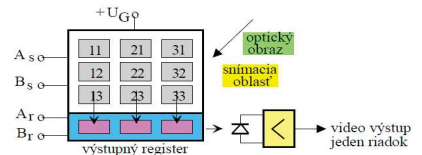
Frontside and Backside Illuminated CCDs



- Traditional, front-illuminated have wiring in front of photosensitive region
- This blocks some light, reducing QE
- Back-illuminated CCDs:
- Back side of the CCD is etched to 10-15 microns
- More fragile and costly, but higher QE



6.1. CCD prvky maticový CCD senzor: Full frame



Obr. 46.

Činnosť :

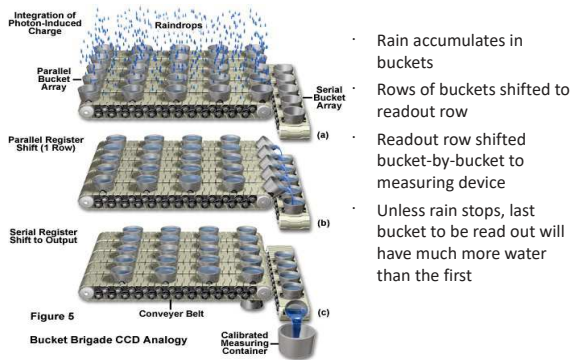
- obraz sa premietne na snímaciu časť \rightarrow pod elektródami náboj
- hodinové impulzy na A_1, A_2 (1 fáza), a B_1, B_2 (2 fáza) \rightarrow jeden riadok do výstupného registra.
- hodinové impulzy na A_1, B_1 \rightarrow obsah registra po pixeloch do výstupu.

- častejšie pre väčší formát (24 x 36 mm) - pridaný "bočný register"
- pri vysvitávaní by nemal reagovať na svetlo - zakrytie (mechanic, uzávierka)
- lacnejší

From <http://learn.hamamatsu.com/articles/quantumefficiency.html>

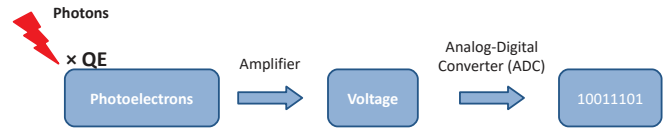
Image from <http://www.microscopyu.com/articles/digitalimaging/ccdintro.html>

Bucket brigade analogy for read out



- Rain accumulates in buckets
- Rows of buckets shifted to readout row
- Readout row shifted bucket-by-bucket to measuring device
- Unless rain stops, last bucket to be read out will have much more water than the first

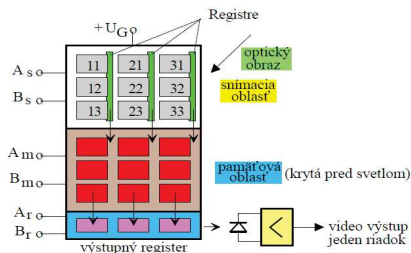
6.1. CCD prvky vyčítanie obsahu...



Bit Depth	Number of gray levels
8	28 = 256
10	210 = 1024
12	212 = 4096
14	214 = 16384
16	216 = 65536

6.1. CCD prvky maticový CCD senzor: frame transfer

- pridaná pamäť (rovnaká)
- pridaný zvislý register k stĺpcom v sn. časti (Al elektródy, krytý pred svetlom)
- úbytok plochy (citlivosť) – nad pixelom mikrošošovka (HAD)



6.1. CCD prvky snímanie farby

RGB systém

tri základné farby:

R (Red - červená), G (Green - zelená), B (Blue - modrá)

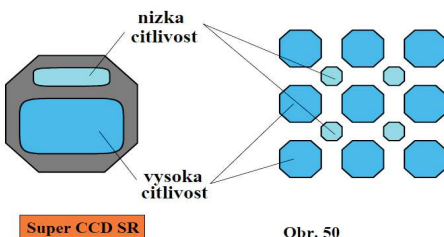
Poznámka: Jedna sa o aditívne miesanie farieb - svetiel.

Možnosti:

- postupne tri expozície cez tri filtre
- tri identické obrazy - tri senzory
- jeden "trojitý" maticový senzor + tzv. mozaikový filter.
- systém FOVEON

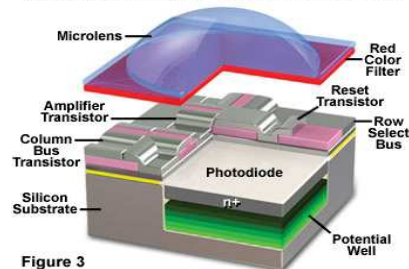
6.1. CCD prvky snímanie farby – dynamický rozsah

Zväčšenie dynamického rozsahu.



CMOS Detectors

Anatomy of the Active Pixel Sensor Photodiode

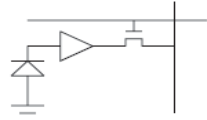


Complementary Metal Oxide Semiconductor

- Transistors in each pixel convert charge to voltage
- More can be done within a pixel meaning frame read out can be faster
- Fabricated much like microprocessors and RAM so are cheaper to make
- Used in webcams, phone cameras since they use less power

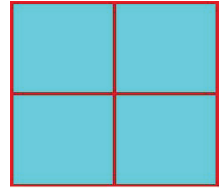
Active Pixel Image Sensor

- 3-4 transistors per pixel.
- Fast, higher SNR, but
- Larger pixel, lower fill factor.
- Lower voltage and lower power.



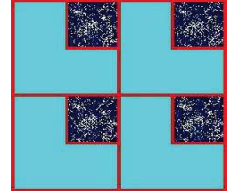
What is a Pixel?

- ◊ The smallest discrete component of an image or picture on a CRT screen is known as a pixel.
- ◊ Each pixel is a sample of an original image, where more samples typically provide more-accurate representations of the original.



What is Fill Factor?

- ◊ Fill factor refers to the percentage of a photo site that is sensitive to light.
- ◊ If circuits cover 25% of each photo site, the sensor is said to have a fill factor of 75%. The higher the fill factor, the more sensitive the sensor.



CMOS Detectors

Anatomy of the Active Pixel Sensor Photodiode

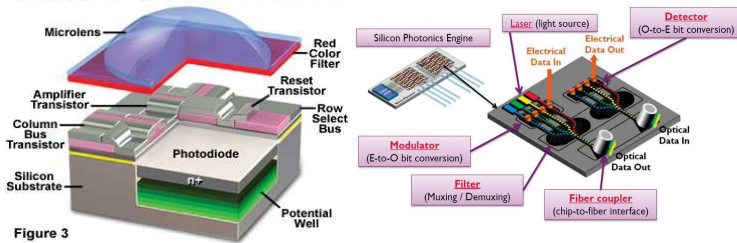
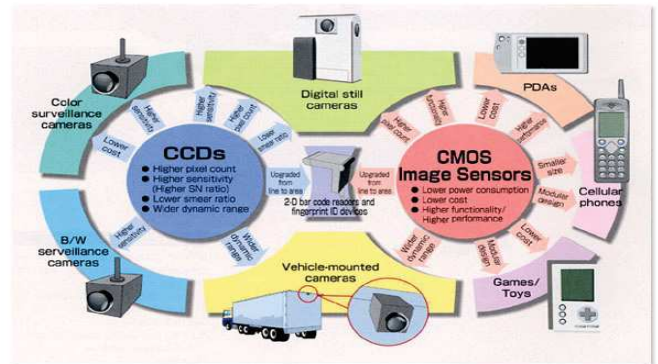


Figure 3

Image from <http://www.olympusmicro.com/primer/digitalimaging/cmosimagesensors.html>

6.1. CCD vs. CMOS

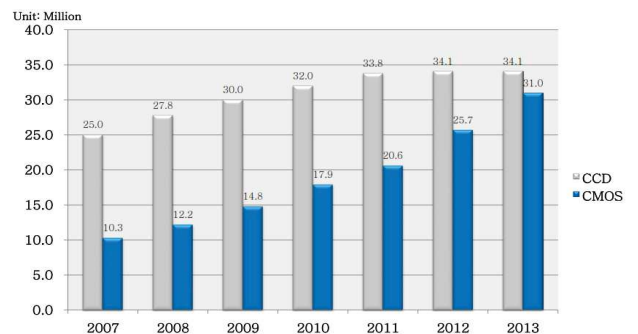


6.1. CCD vs. CMOS

- Create high-quality, low-noise images.
- Greater sensitivity and fidelity
- 100 times more power
- Require specialized assembly lines
- Older and more developed technology
- More susceptible to noise
- Light sensitivity is lower
- Consume little power
- Easy to Manufacture
- Cheaper

Picture quality, sensitivity and cost vs. Cost and battery life.

6.1. CCD vs. CMOS



6.1. Kamery v automobiloch case study



Audi A5 Sportback Driver assistance systems - overview of sensors

Front camera:

- adaptive cruise control (ACC)
- Stop&Go incl. Traffic jam assist
- Audi active lane assist
- Audi pre-sense front
- Audi pre-sense city
- Camera-based traffic sign recognition
- Collision avoidance assistant
- High beam assist
- Matrix LED headlights
- Predictive efficiency assistant
- Turn assist

Ultrasonic sensors at rear:

- Parking system rear
- Parking system plus
- Parking assist

Ultrasonic sensors at front:

- adaptive cruise control (ACC)
- Stop&Go incl. Traffic jam assist
- Parking system plus
- Park assist

Front radar sensors:

- adaptive cruise control (ACC)
- Stop&Go incl. Traffic jam assist
- Audi active lane assist
- Audi pre-sense front
- Collision avoidance assistant
- Distance display
- Predictive efficiency assistant
- Turn assist

Ultrasonic sensors at side:

- Audi active lane assist
- Parking assist

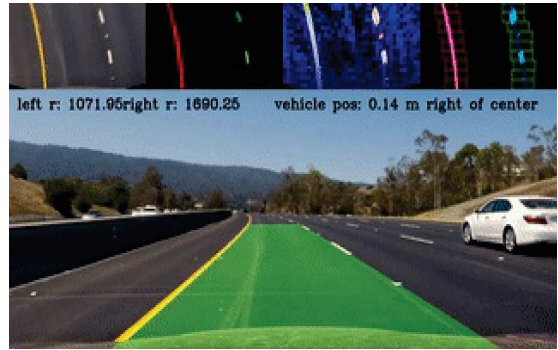
360° cameras:

- Parking system plus
- 360° cameras
- Parking assist with 360° cameras

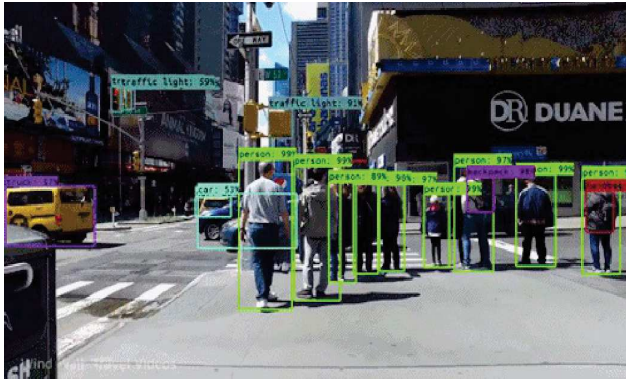
Rear radar sensors:

- adaptive cruise control (ACC)
- Audi active lane assist
- Audi pre-sense rear
- Audi side assist
- Exit warning
- Predictive efficiency assistant
- Rear cross traffic assist

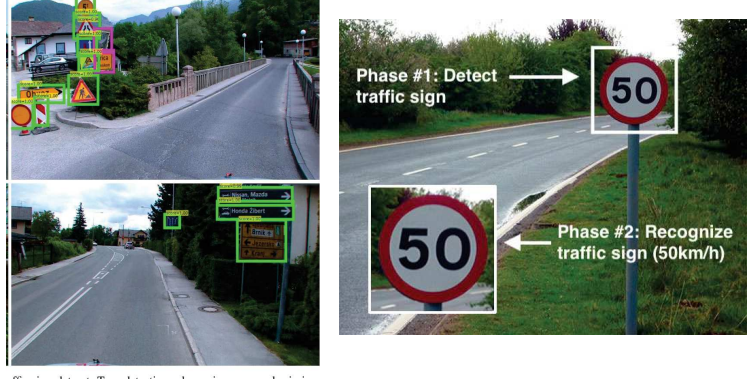
6.1. Kamery v automobiloch case study



6.1. Kamery v automobiloch case study



6.1. Kamery v automobiloch case study



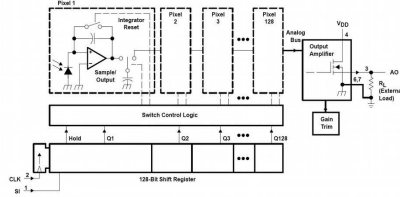
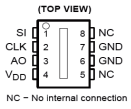
6.1. Kamery v automobiloch case study



Príklady

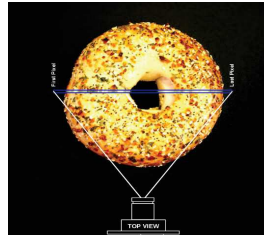
Riadkový CCD snímač

TAOS TSL 1401 CL

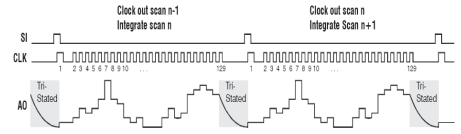


Riadkový CCD snímač

TAOS TSL 1401 CL



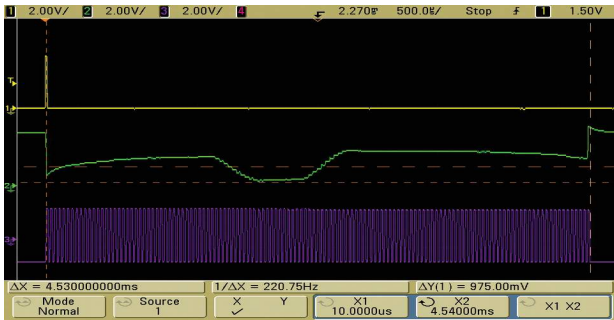
- 1 x 128 pixels
- 0 - 5 V output for each pixel
- 1 pixel / 1 clock pulse



Riadkový CCD snímač

TAOS TSL 1401 CL

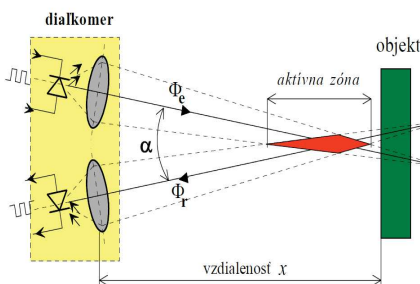
Optical distance sensors



6.2. Optické princípy

Optické diaľkomery

Optical rangefinder



malé α – dlhá úzka aktívna zóna (väčšie x)

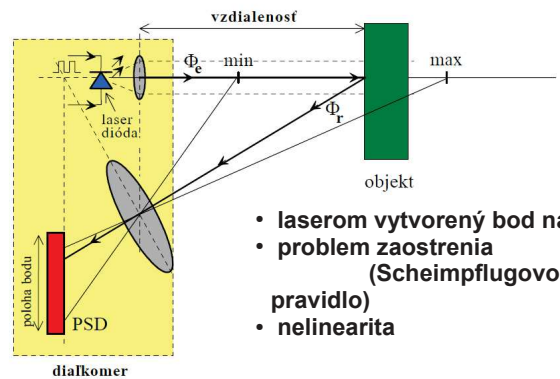
veľké α – krátka široká aktívna zóna → proximítne snímače

- amplitúda úmerná vzdialenosti
- poruchové vplyvy
- presnosť malá
- modulovaný svetelný tok
- optika (šošovky, zrkadlá)

Reflexný optický diaľkometer

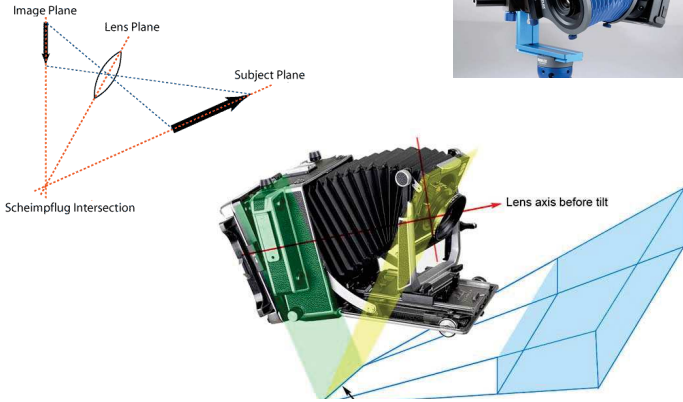
6.2. Optické princípy

Triangulačný diaľkometer

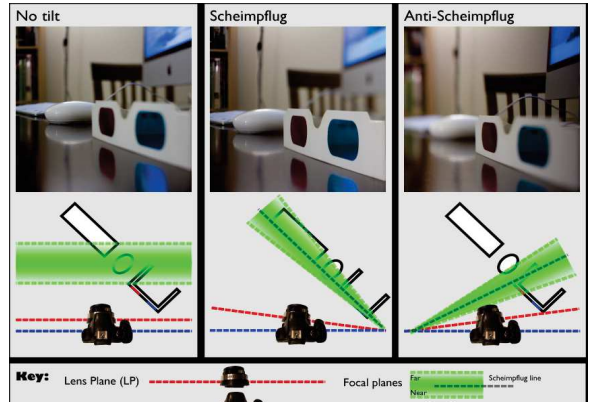


- laserom vytvorený bod na telese
- problém zaostrenia (Scheimpflugovo pravidlo)
- nelinearita

6.2. Optické princípy – Triangulačný diaľkomer Scheimpflugovo pravidlo



6.2. Optické princípy – Triangulačný diaľkomer Scheimpflugovo pravidlo

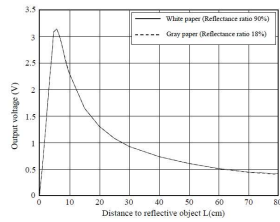


6.2. Optické princípy Triangulačný diaľkomer



SHARP GP2Y0A21YK0F

GP2Y0A21YK0F Distance Measuring Sensor Unit
Measuring distance: 10 to 80 cm
Analog output type

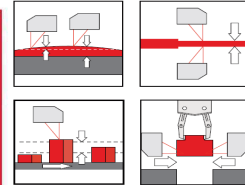


6.2. Optické princípy Triangulačný diaľkomer



Intelligent
Laser-Optical
Displacement
Measurement

Compact CMOS CCD Sensor
optoNCDT 1401



CMOS CCD technology

- range 5 m (10, 50, 100, 200 mm)
- resolution 0.01 % FSO (1 μ m static, 3 μ m dynamic 1kHz)
- 1000 readings per second
- Output 4 ... 20 mA and RS232
- Fast adaption to varying surface properties
- Compact self-contained sensor