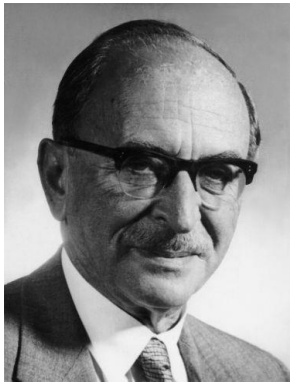
Modern fizika alkalmazásai a mérnöki gyakorlatban

10. előadás

Holográfia

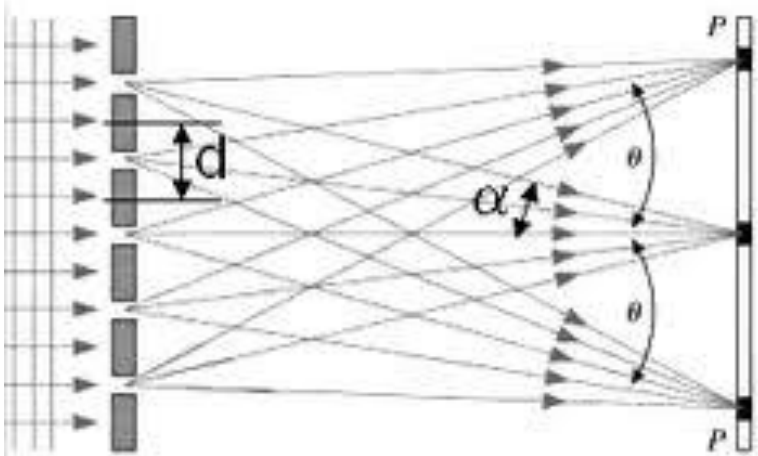


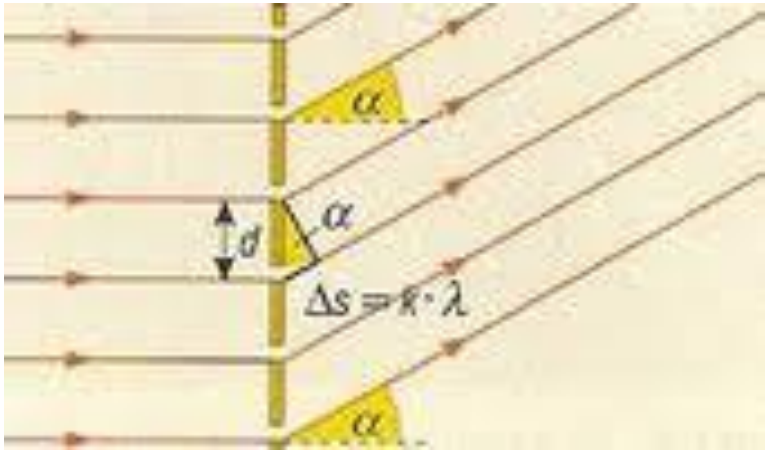
Gábor Dénes (Dennis Gabor): a Hungarian electrical engineer and physicist, he invented the holography.

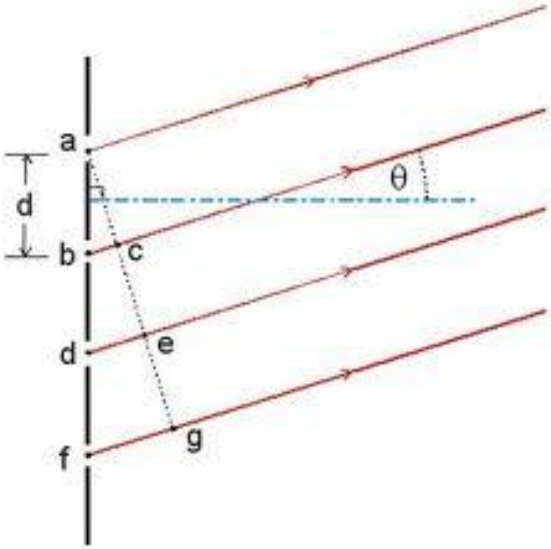
He received the 1971 Nobel Prize in Physics.

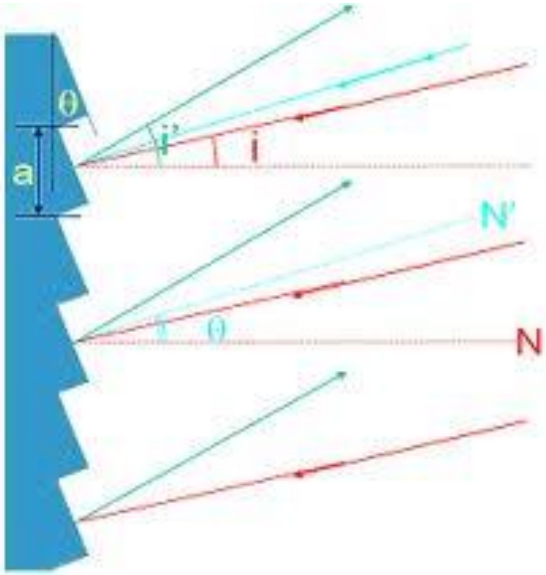
Diffrakció, optikai rács

Optikai rács







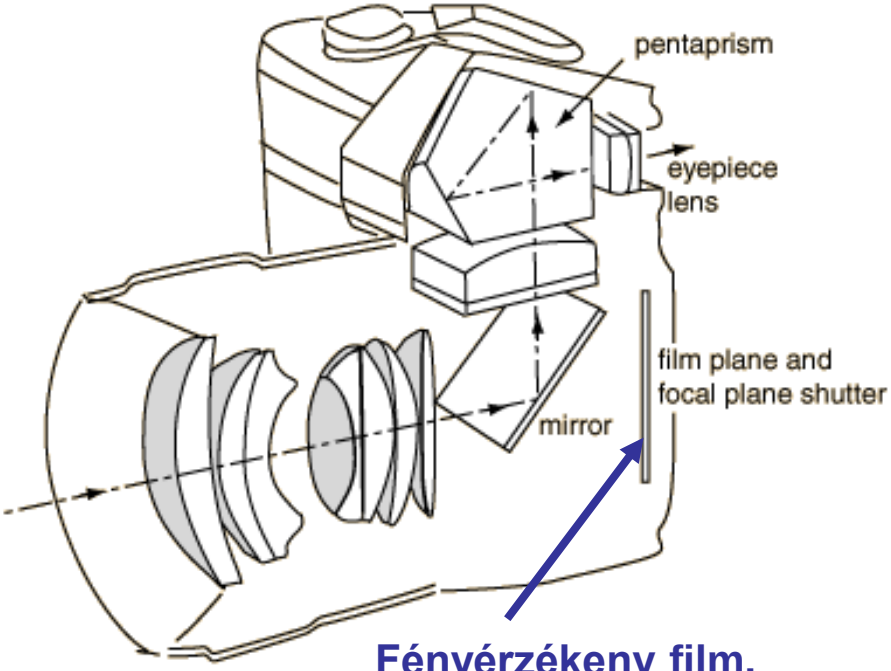


Erősítés: $d\sin\theta = n\lambda$

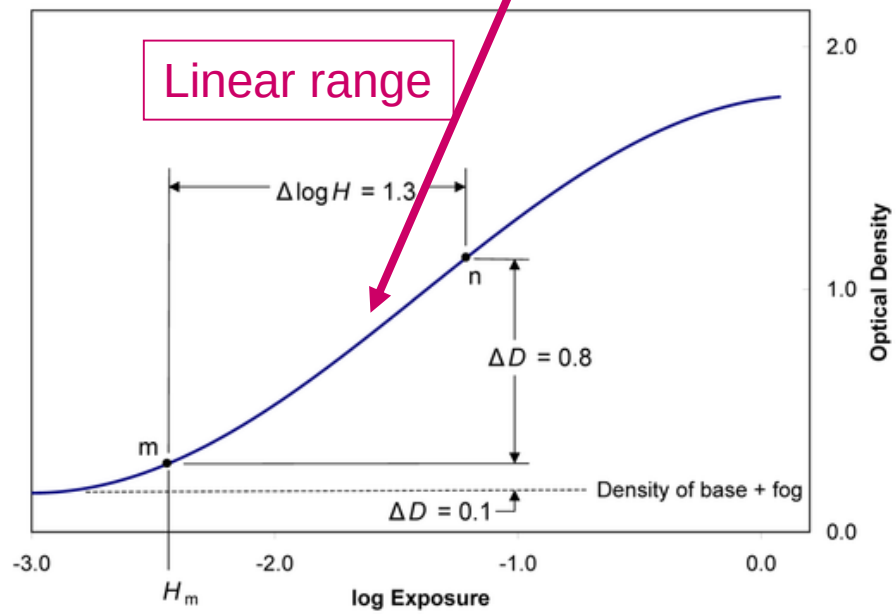
Fényképezés

The transmission of the photoplate (or film):

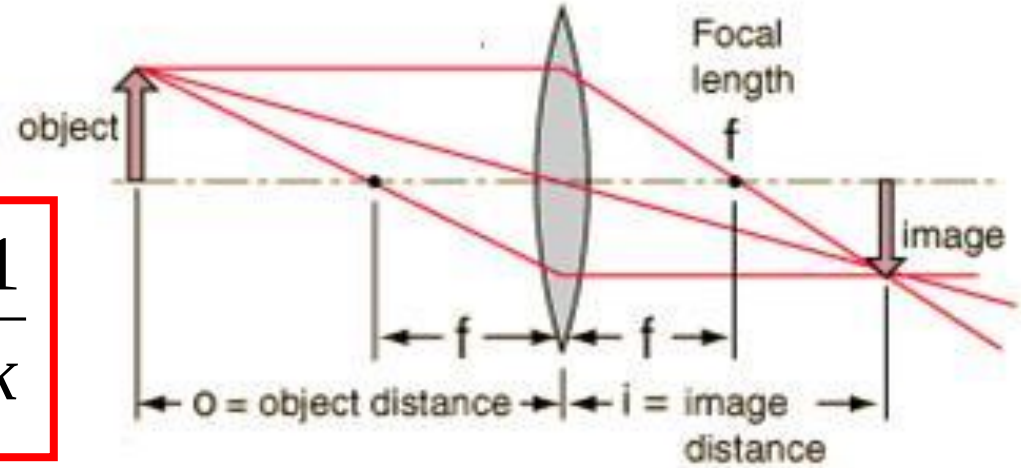
$$h(x, y) = h_o + t \cdot I(x, y)$$



Fényérzékeny film.



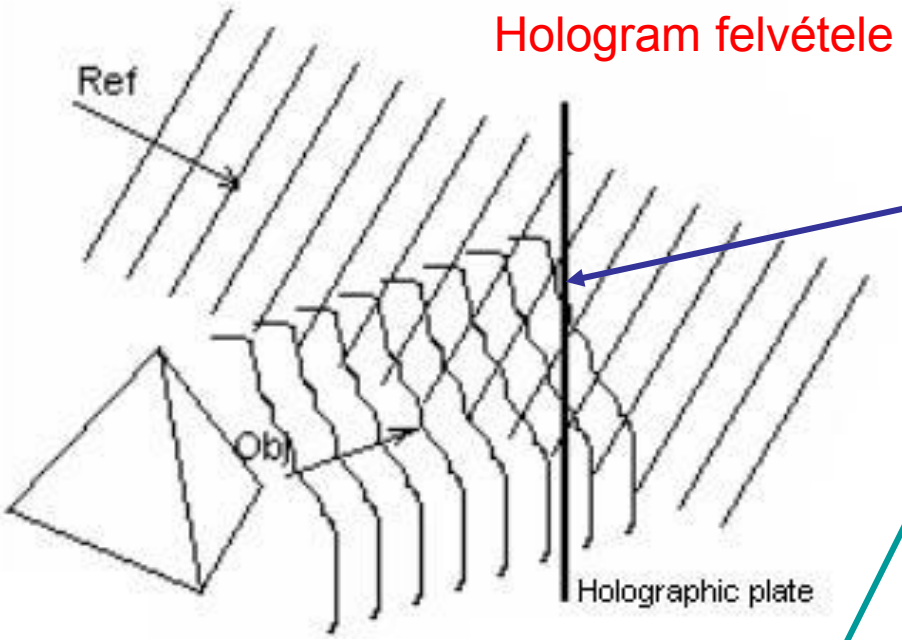
$$\frac{1}{f} = \frac{1}{t} + \frac{1}{k}$$



Holográfia I.

Hagyományos holográfia (amplitúdó hologram)

Hologram felvétele



Expozíció (megvilágítás)

$$I = I_o + I_r + E_o E_r^* + E_r E_o^*$$

+ előhívás (fotokémiai folyamat)

Rekonstrukció (3D-kép visszaállítása)

A hologram transzmissziója:

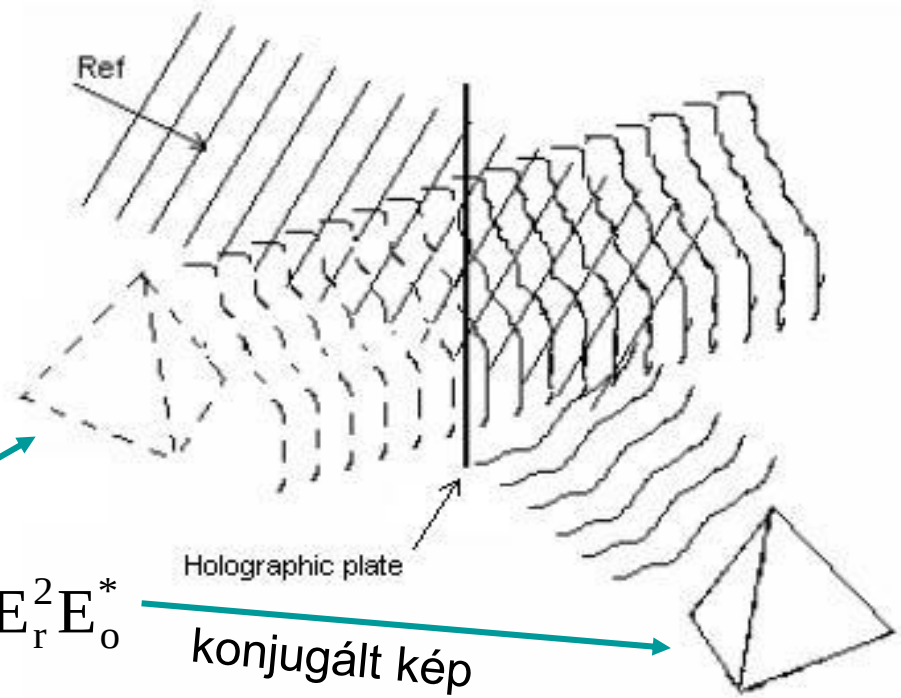
$$h(x, y) = h_o + t \cdot I(x, y)$$

Rekonstrukció:

$$E_r h = h_o E_r + E_r t(I_o + I_r) + E_o |E_r|^2 + E_r^2 E_o^*$$

valódi kép

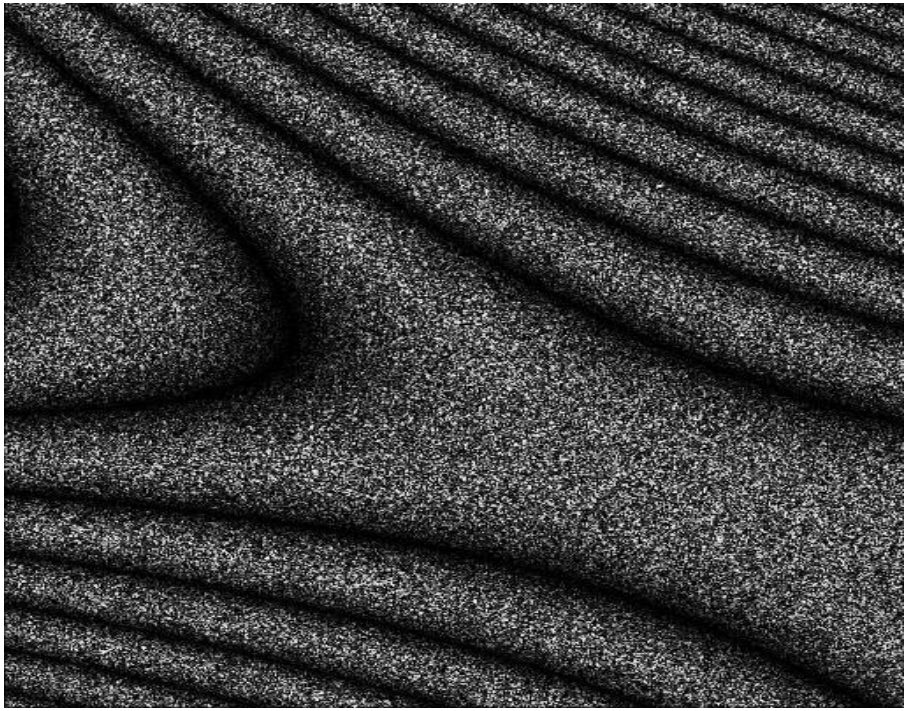
konjugált kép



Holográfia II.

Hologram:
A rögzített interferencia mintázat:

Amplitúdó-hologram



A hologram jellemzése:

D =Io/Ir

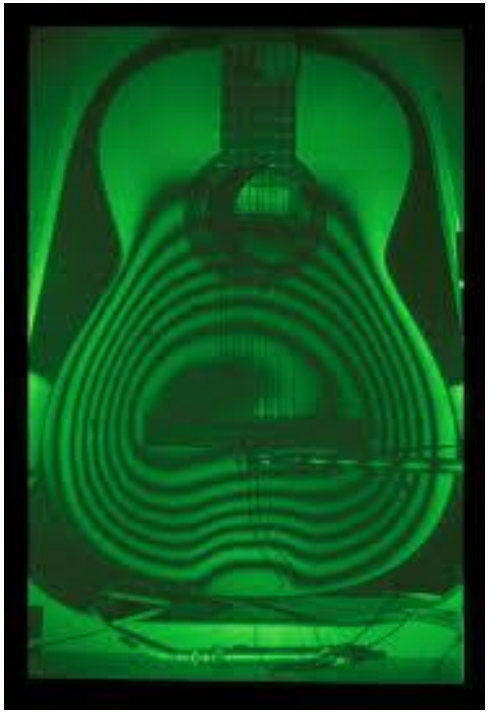
Io = rekonstruált tárgyhullám intenzitása
Ir = referencia hullám intenzitása

D ~ 5 %

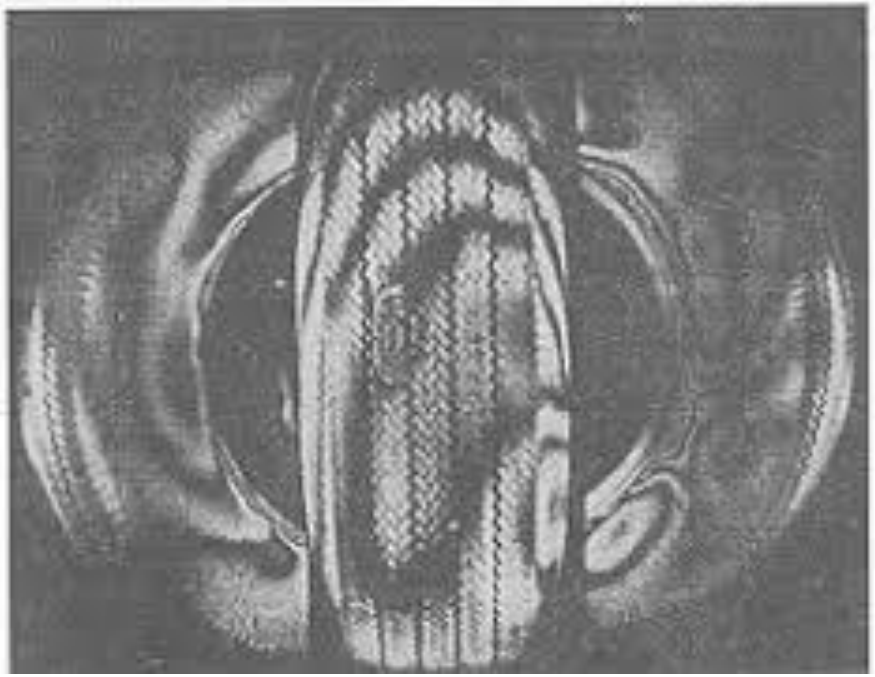
Holográfia III.

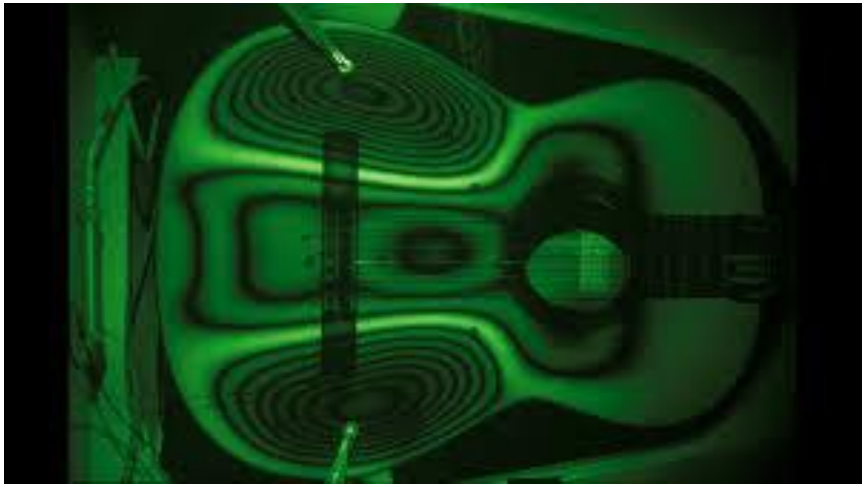
Két-expozíciós hologram

Rezgési módusok mérése holografikus módszerrel



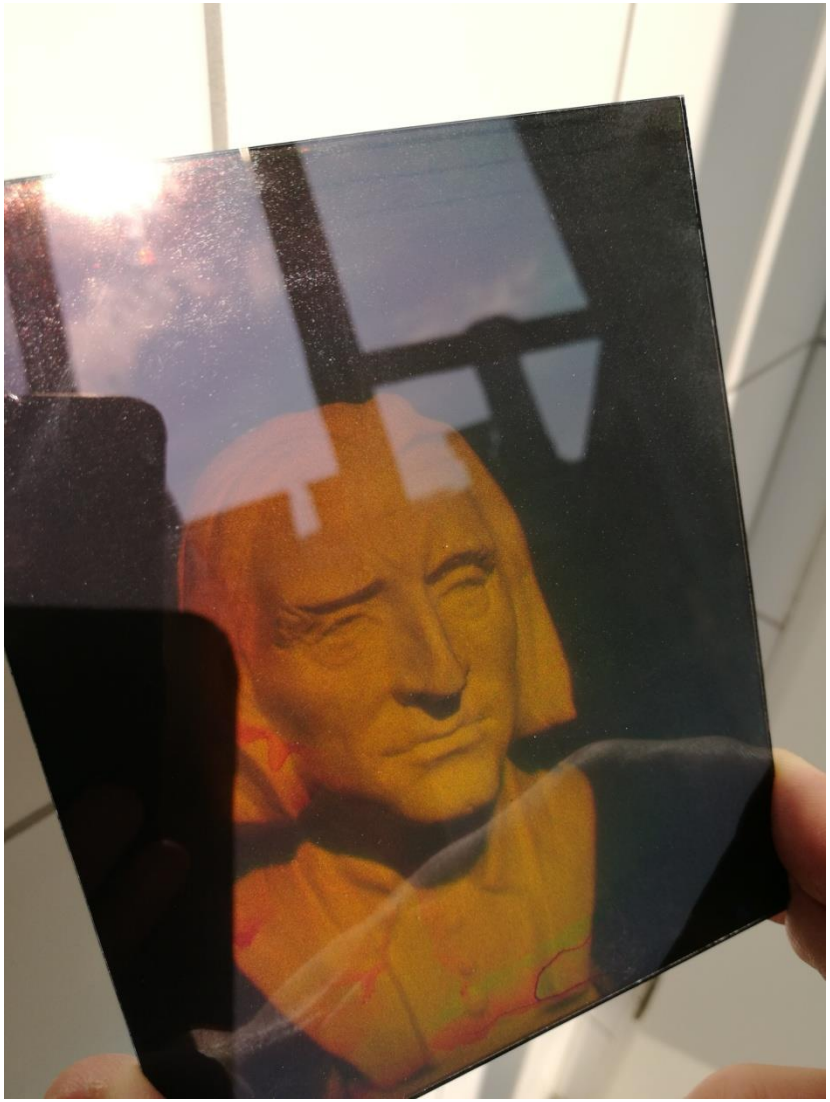
15. ábra. Hologram segítségével végzett roncsolásmentes vizsgálat. A kettős expozícióval készült hologram az abroncs két hibáját teszi láthatóvá. (Ralph Grant és a GCO szívességéből, Ann Arbor, Michigan)



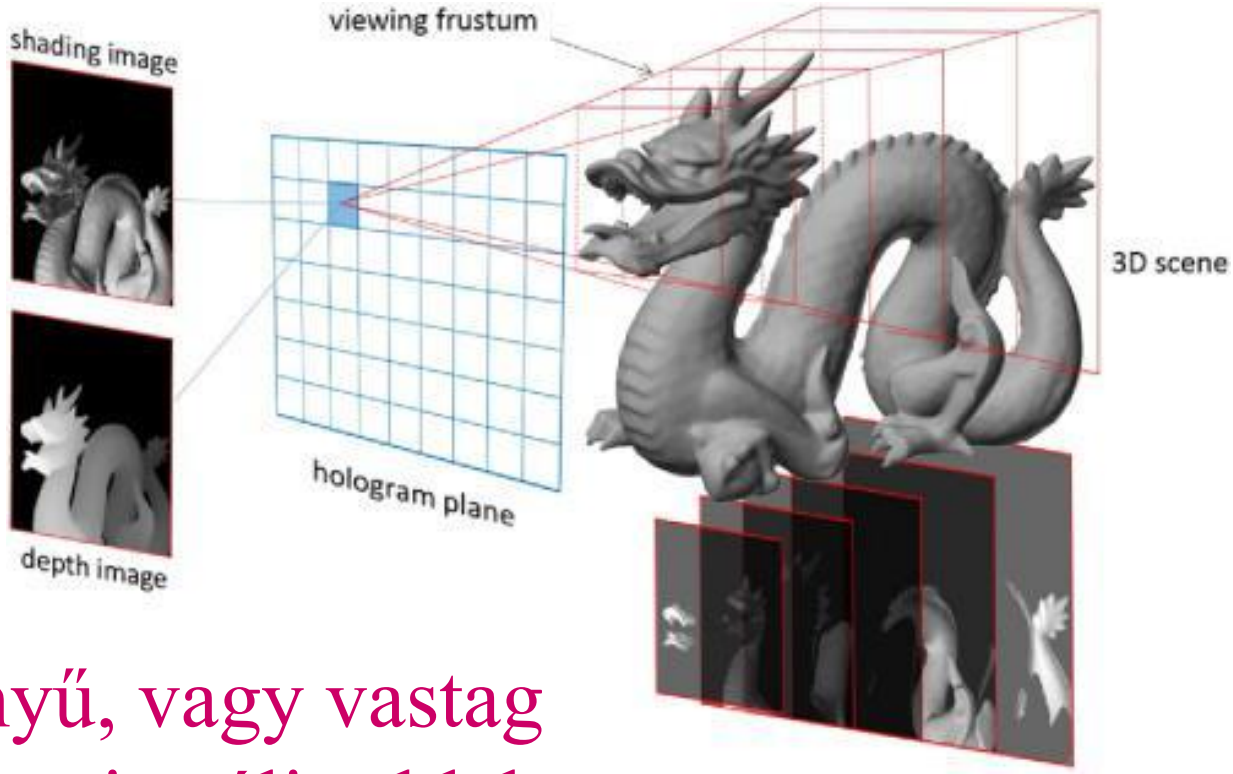


Holográfia IV.

Fehér fényű, vagy vastag hologram, vagy reflexiós hologram



Holográfia V.



Fehér fényű, vagy vastag hologram: virtuális ablak

Holográfia VI.

Hologram ?

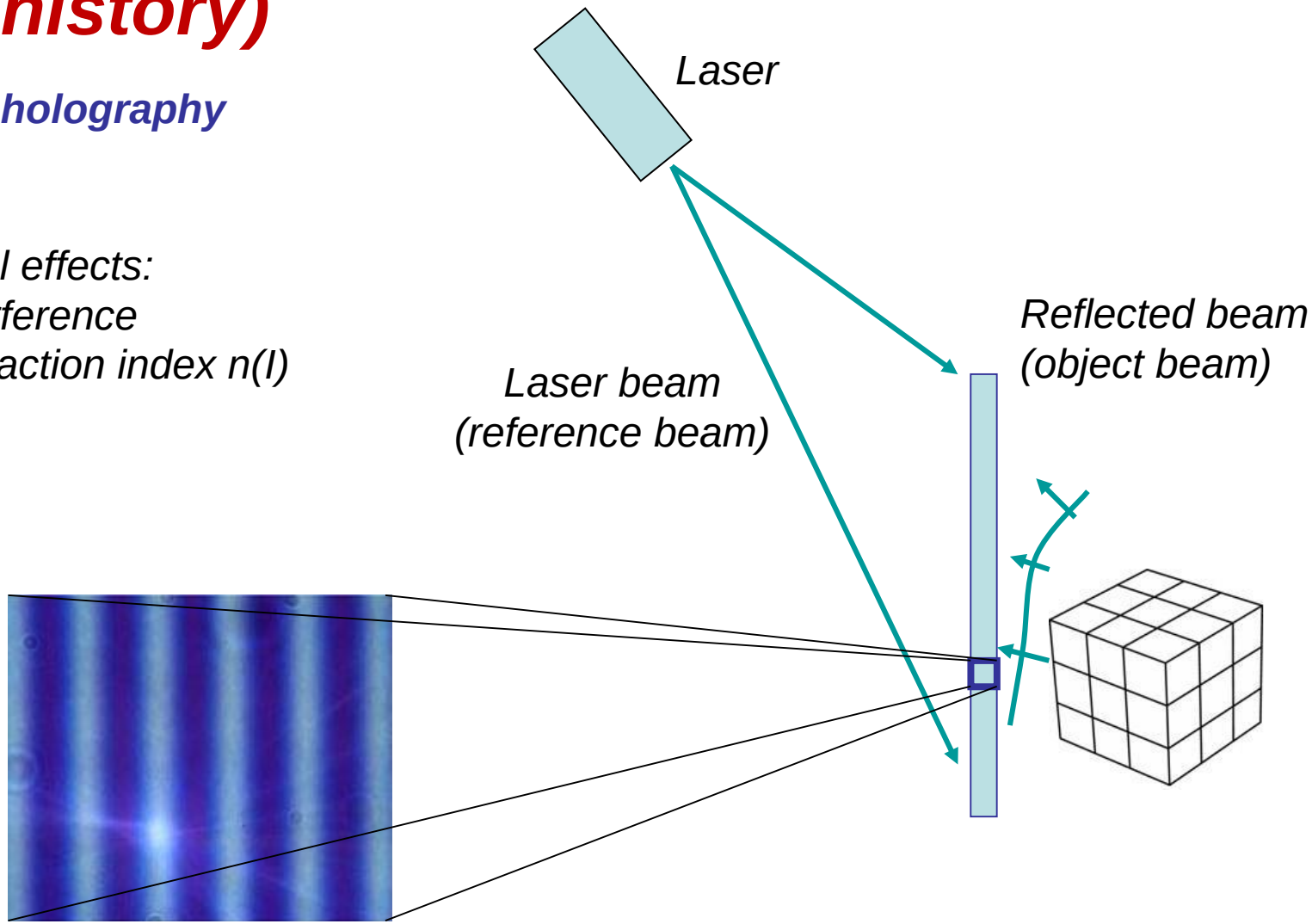
Holográfia VII.

How to record a white-light hologram ? (Short history)

1. Classical holography

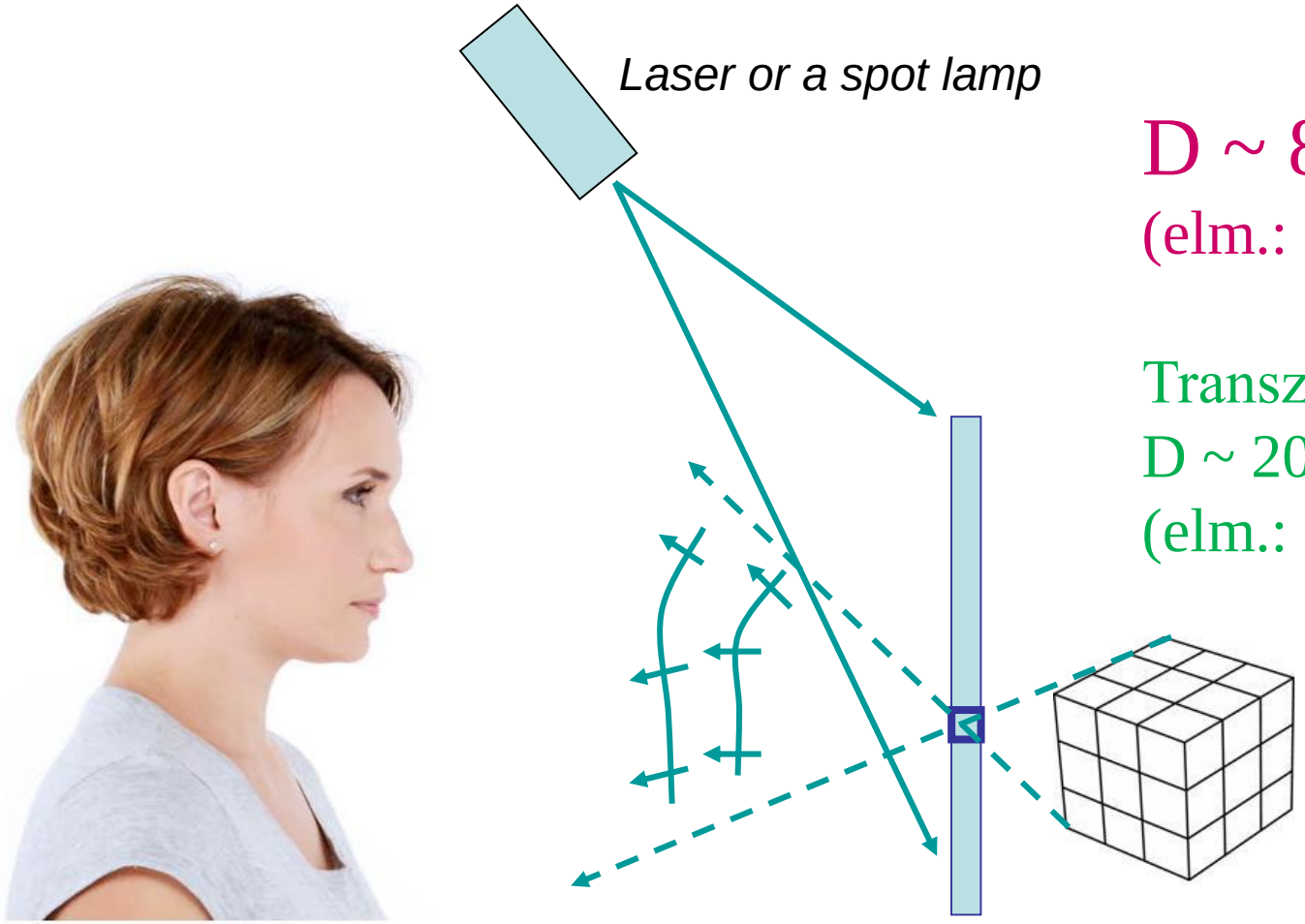
Physical effects:

1. *Interference*
2. *Refraction index n(I)*



Holográfia VIII.

How to use a white-light hologram for object reconstruction?



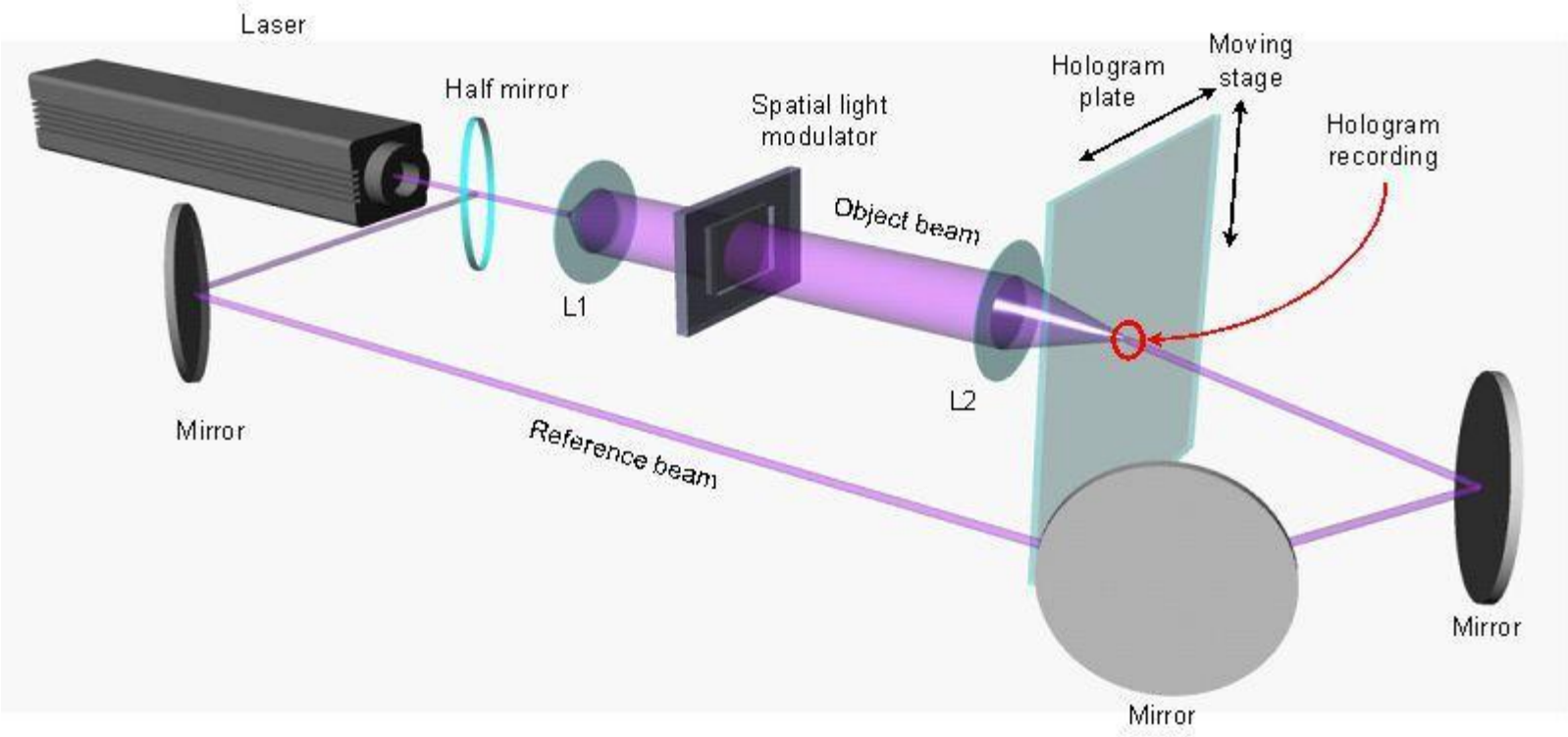
D ~ 80 %
(elm.: 100%)

Transzmissziós:
D ~ 20 %
(elm.: 32%)

Holográfia IX.

How to record a white-light hologram ? (Short history)

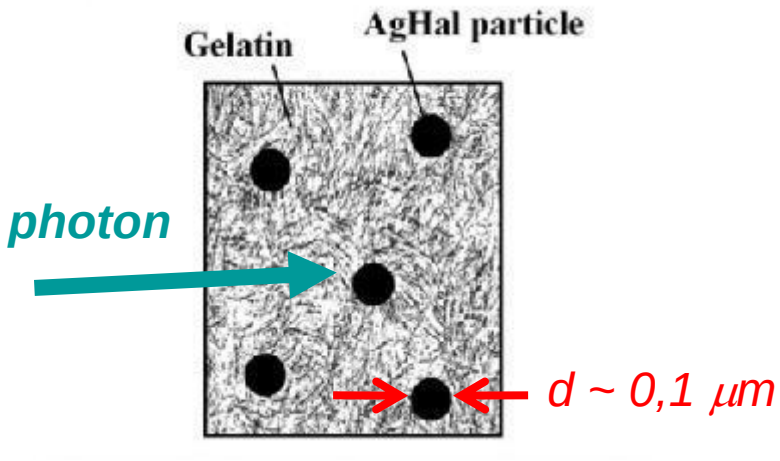
2. Printig of holographic stereogram



Holográfia X.

Holomaterials

1. Silver halide photo-plate



Normal developer

Special developer (bleacher)

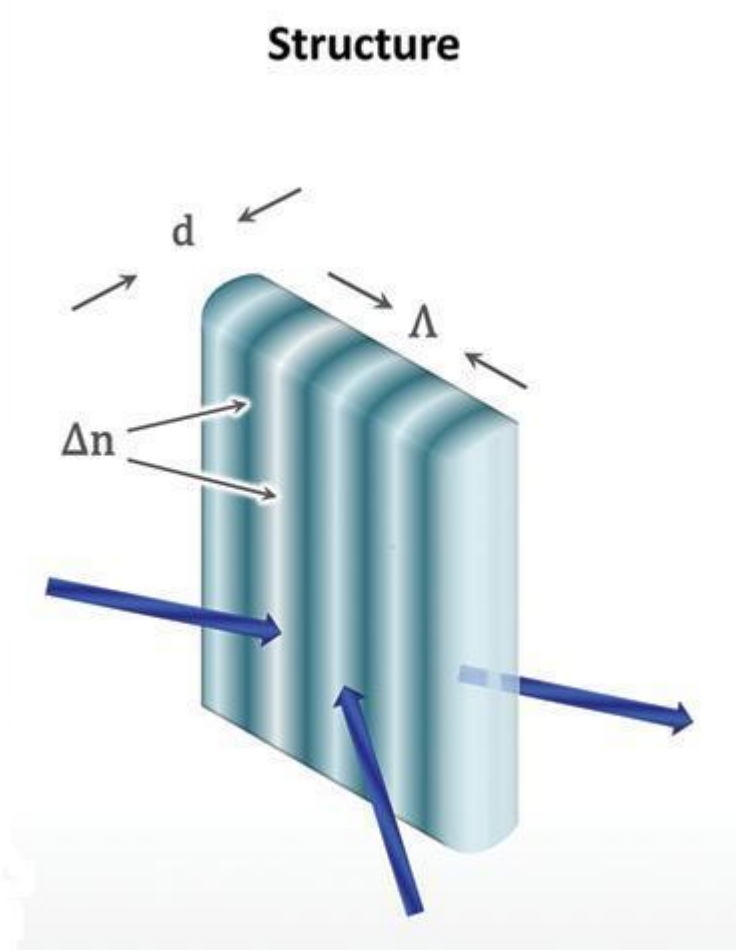
Ronald Reagan-12x18", Hologram on glass, H. Bjelkhagen and F Unterseher

Advantiges: high resolution, separate exposure at different wavelength, short term exposure (~ps)

Disadvantiges: chemical process (appl. developer ~10 min)

Holográfia XI.

2. Photopolymer

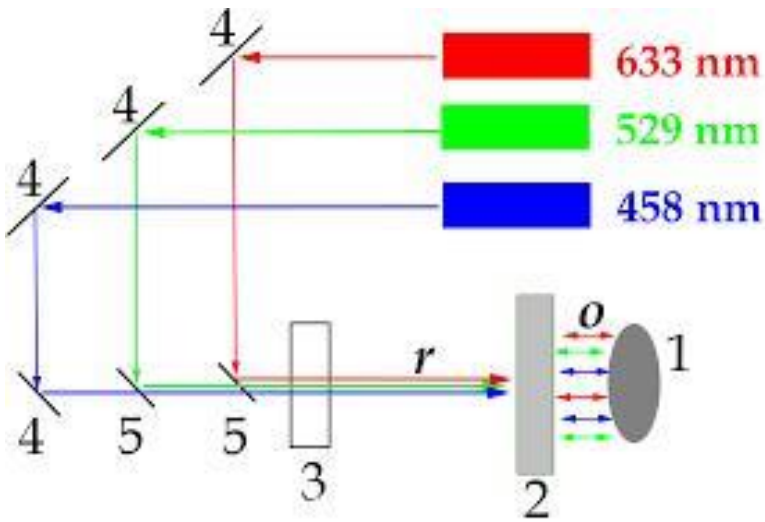


No developer!!!

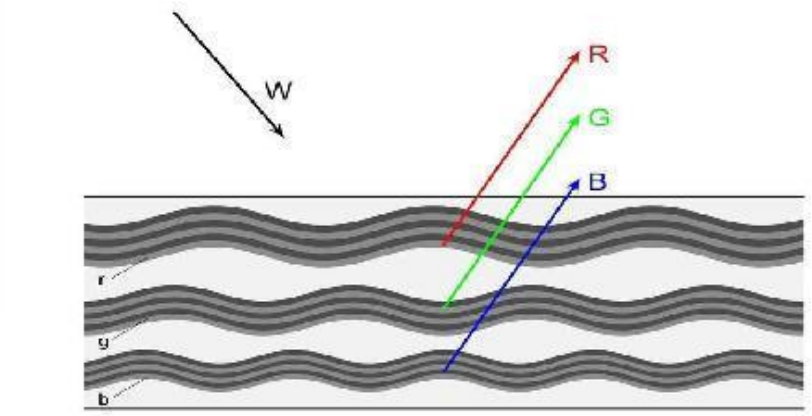
Advantiges: no chemical process is required
Disadvantiges: slow exposure (~0,5 μs),
simultaneous exposure in all wavelength

Holográfia XII.

Multicolor reflection hologram



Exposure (record of hologram)



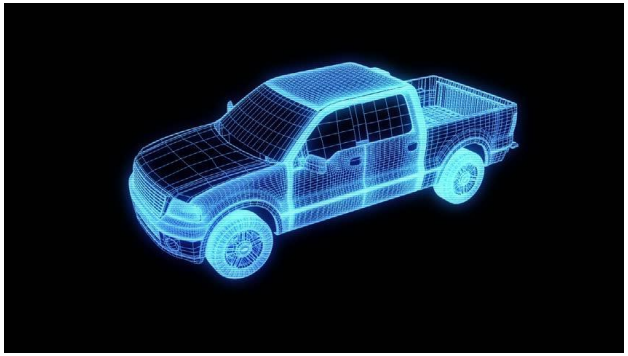
Reconstruction

Holográfia XIII.

Quantitative and pure data synthesis

Holo_studio (holo-camera): greenbox technology

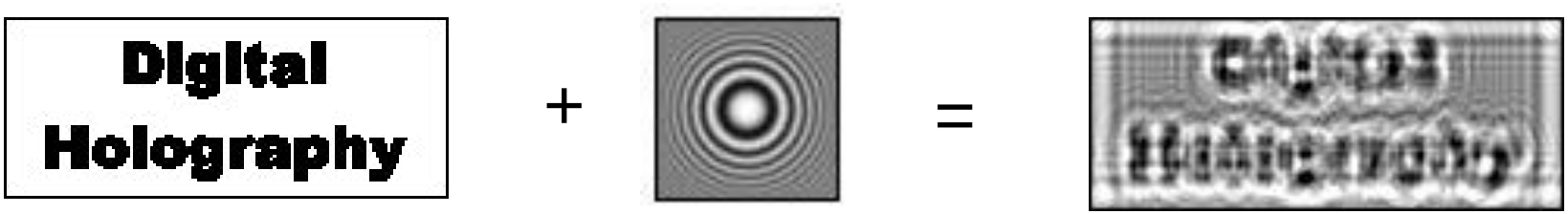
Rendering the 3D image



Advantiges: useful for full parrallax
Disadvantiges: - too much calculation
- difficulties
- long term, etc.
- additional texture

Holográfia XIV.

Digitális holográfia



Hagyományos hologram-lemez felbontása: 5000 vonal/mm

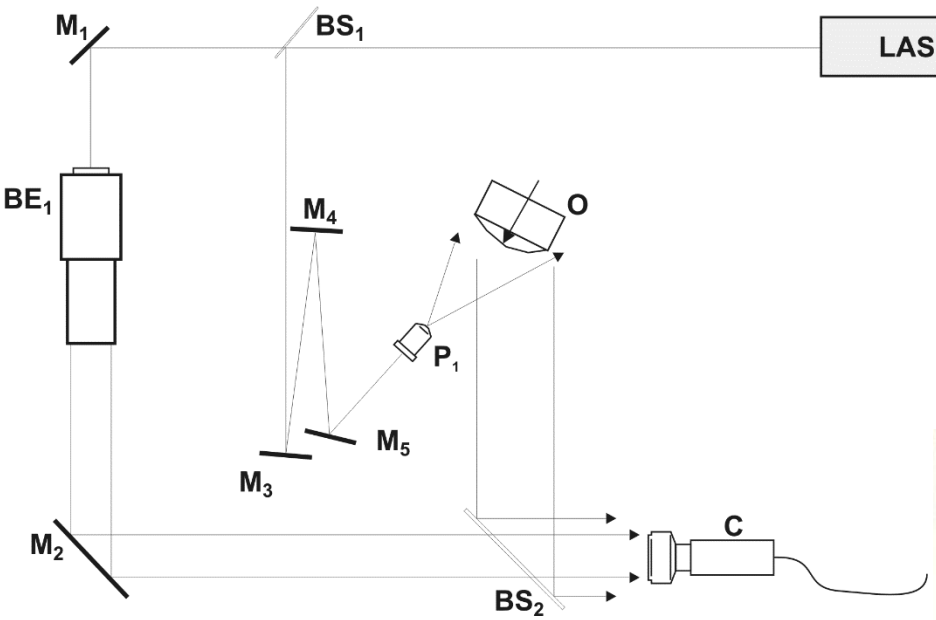
Camera	Chip type	Number of pixels	Pixel size [μm²]	Frames per second	Dynamic range	Θmax for λ=633nm
Roper Sci. MegaPlus 1.4i	FT	1017* 1035	6.8 * 6.8	6.9	8 bit	2.7°
Roper Sci. Megaplus 16.8i	FT	4096* 4096	9 * 9	0.47	8 bit	2.0°
Roper Sci. Megaplus ES 1.0	IT	1008* 1018	9 * 9	30	8 or 10 bit	2.0°
Roper Sci. Megaplus 4.0	IT	2048* 2048	7.4 * 7.4	30	8 or 12 bit	2.45°
Hamamatsu C8484-01	PSI	1344* 1024	6.45 * 6.45	8.3	12 bit	2.81°
Duncan DT1100	PS	1392* 1040	4.65 * 4.65	12	8 or 12 bit	3.9°

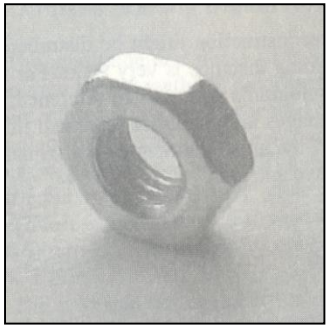
FT: full frame: interline transfer, PSI: progressive scan interline, PS: progressive scan

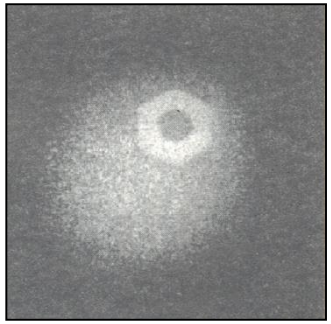
Holográfia XV.

Digitális holográfia

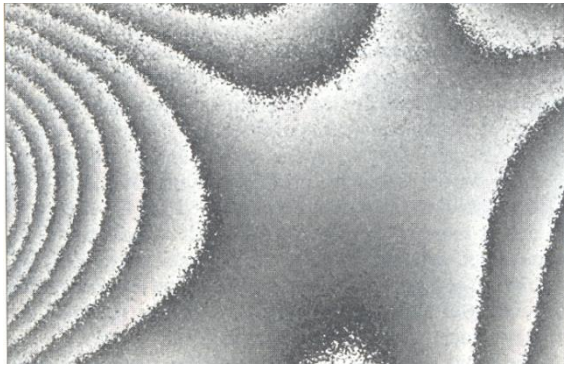
”In-line” elrendezés

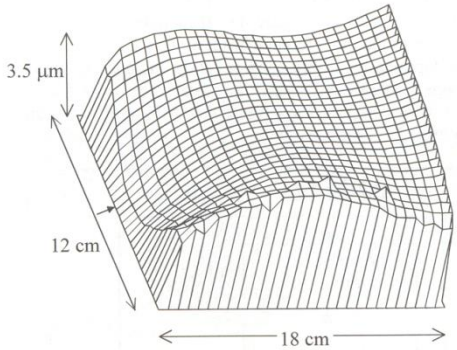


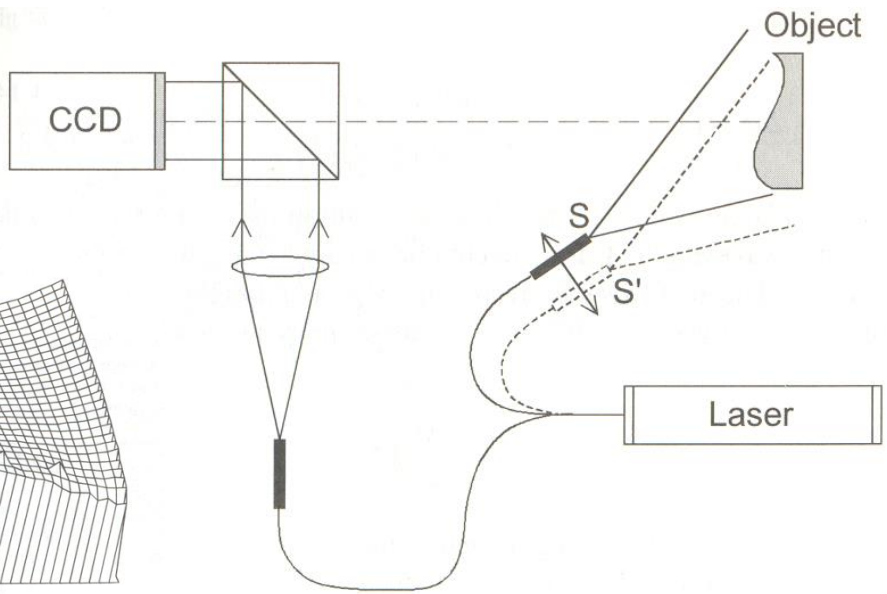




Alakmérés:

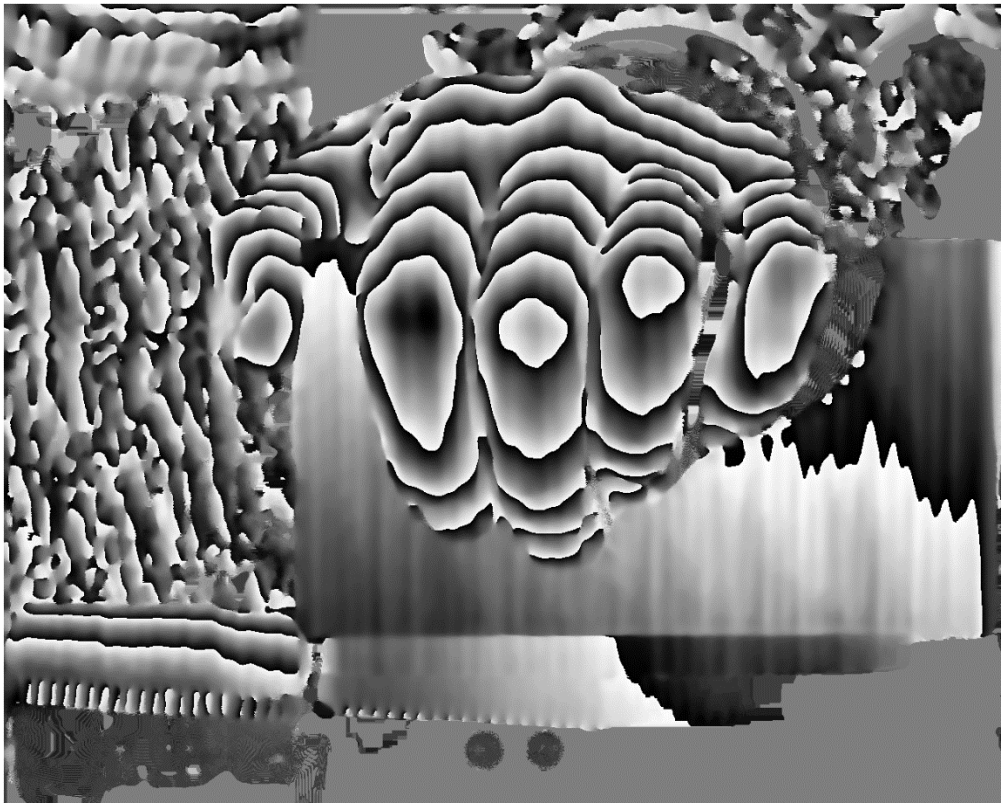


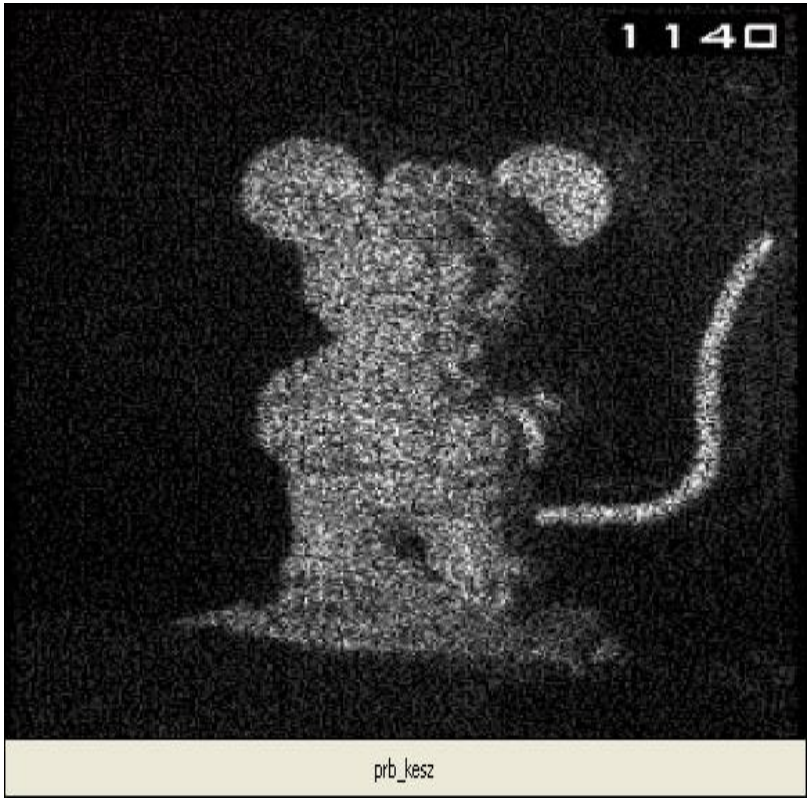




Holográfia XVI.

Digitális holográfia

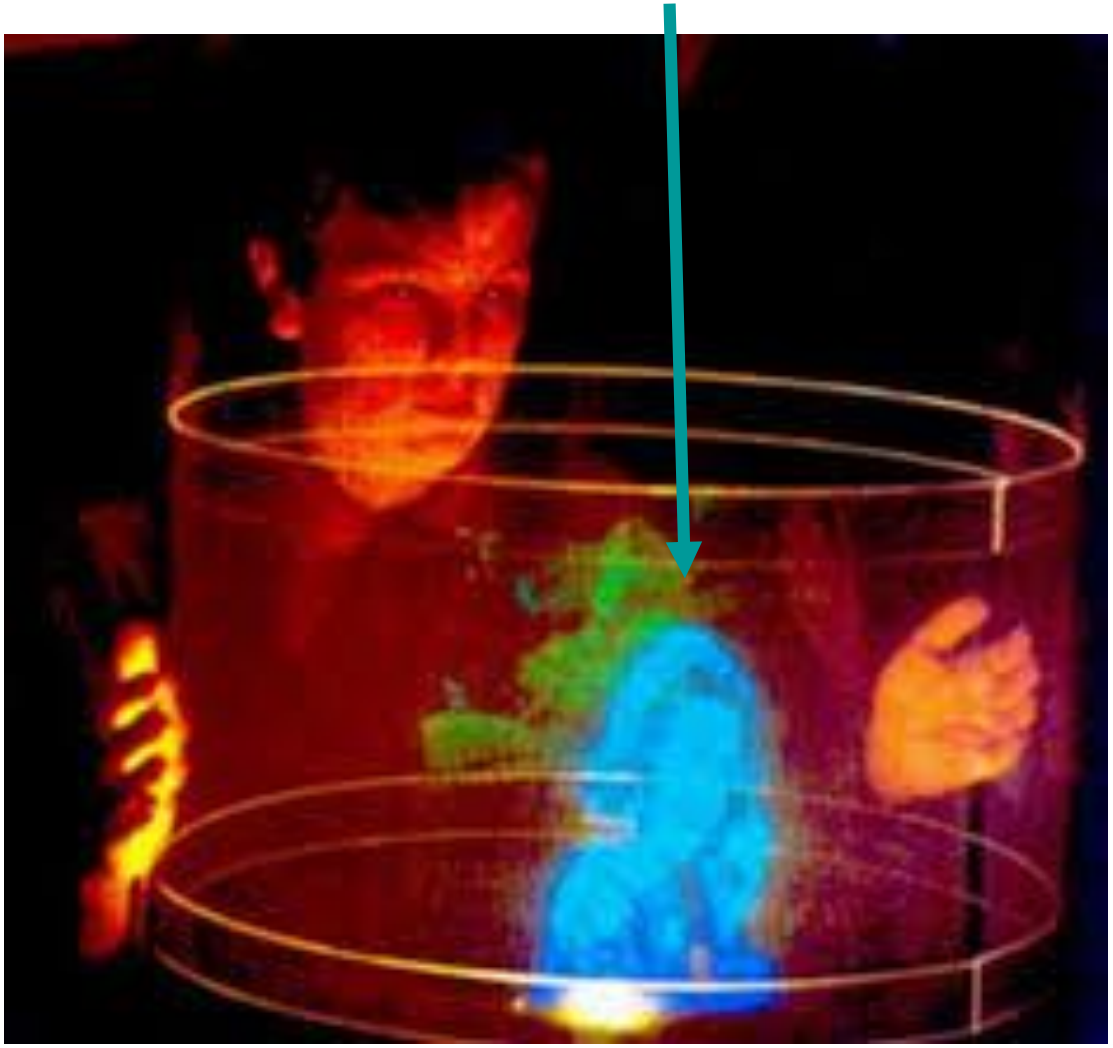




Holográfia XVII.

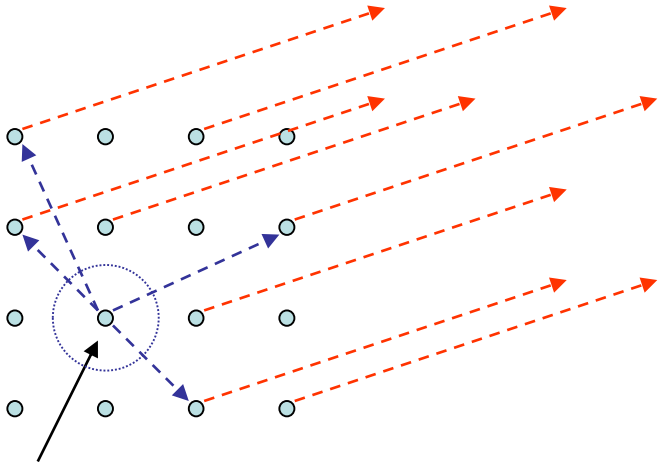
Digitális holográfia

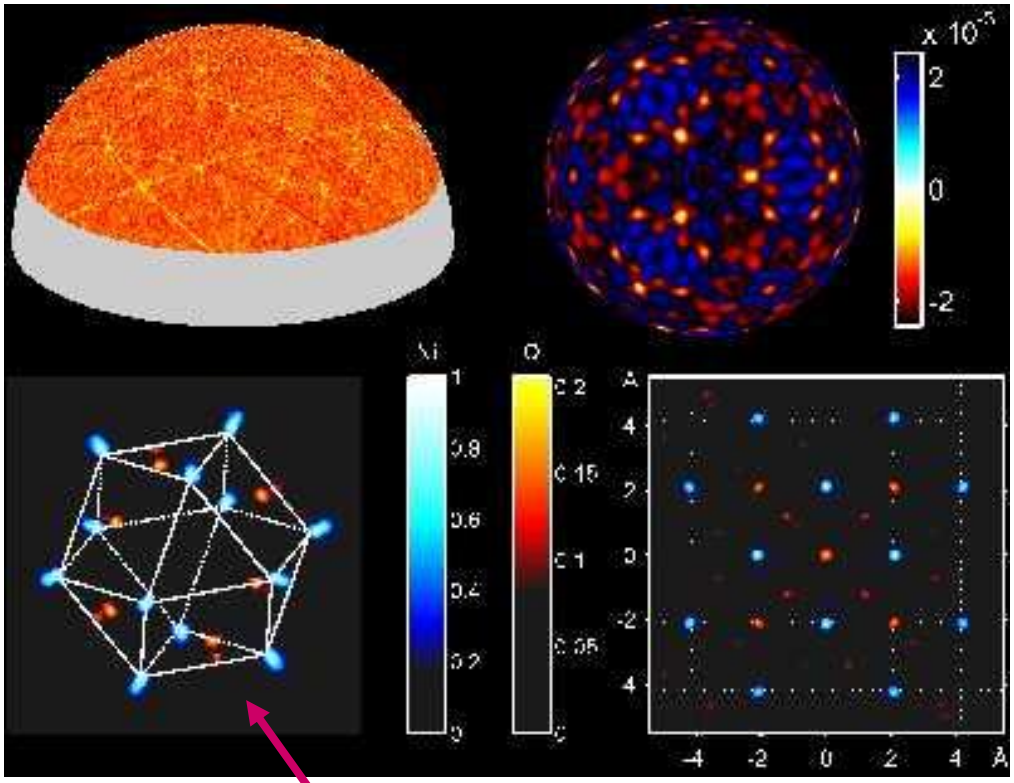
A computer-generated hologram:



Holográfia XVIII.

X-ray, neutron, electron holography
Source: an atom





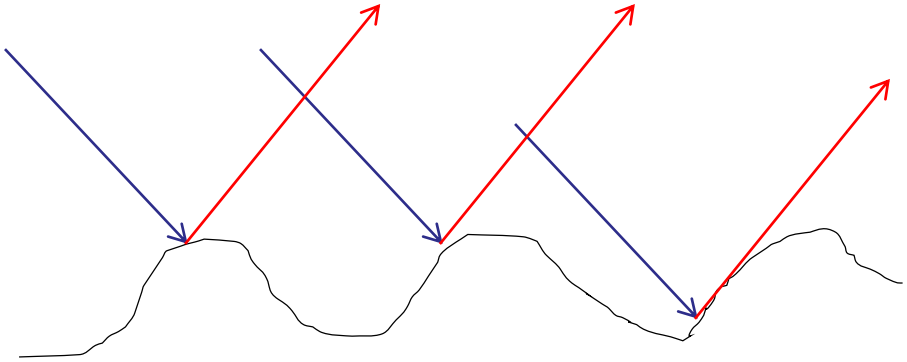
Reference wave: primary wave
(the original wave)

Object wave: secondary waves
scattered from the neighbor atoms

Computer generated reconstruction

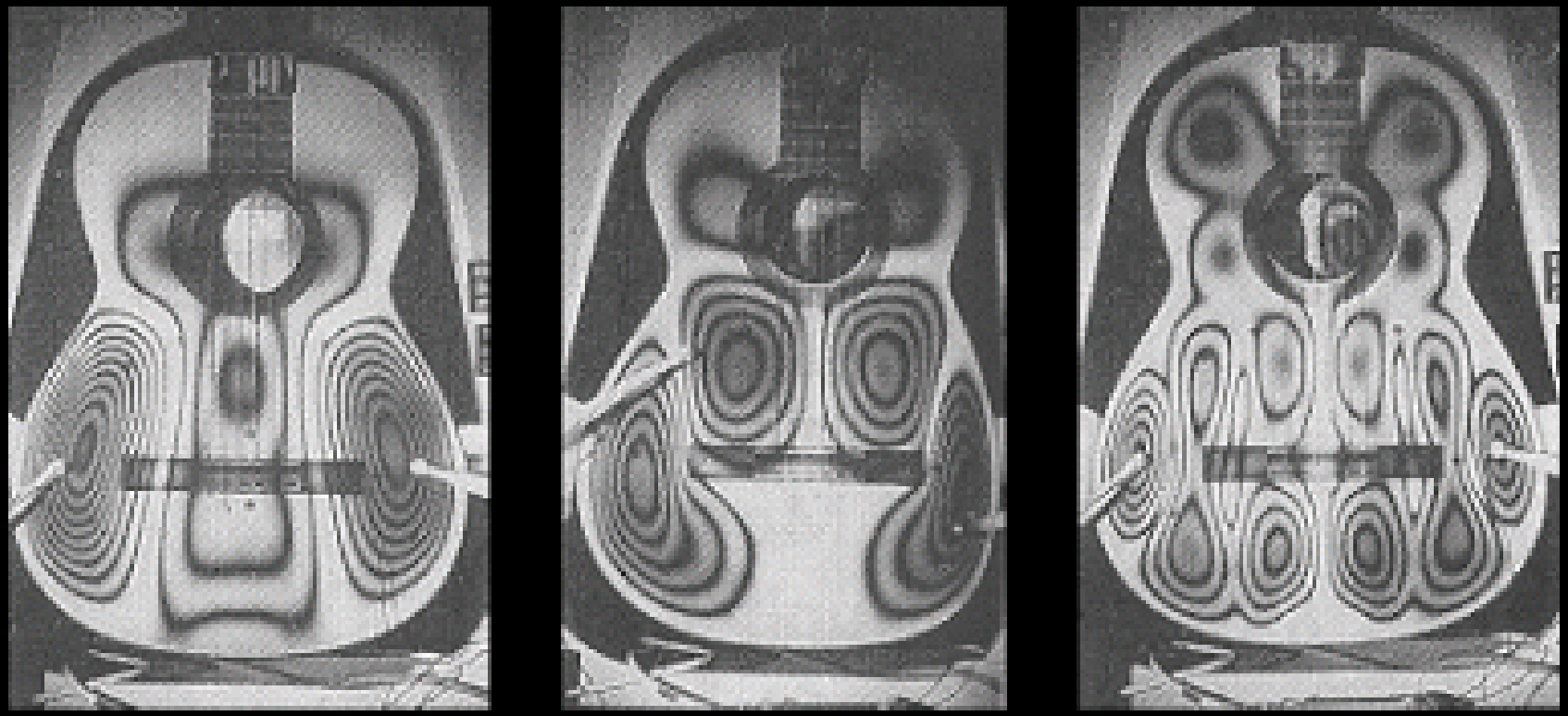
Holográfia XIX.

Biztonságtechnikai hologramok (holografikus matrica)



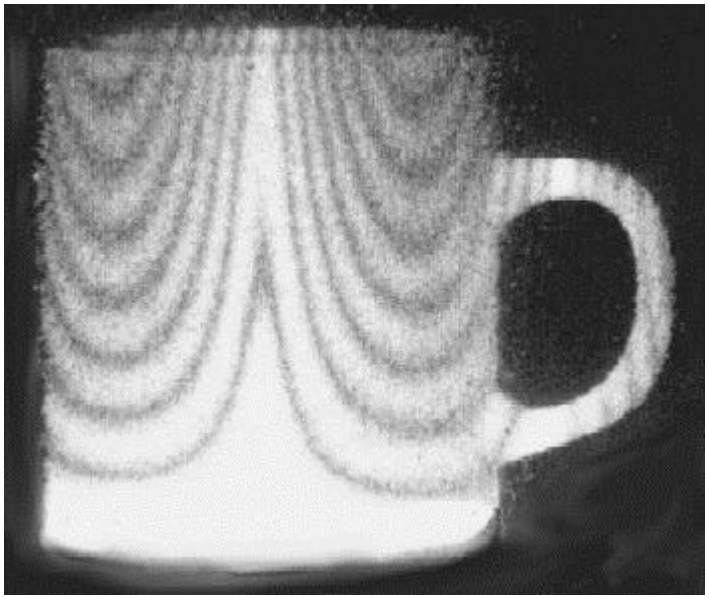
Holográfia XX.

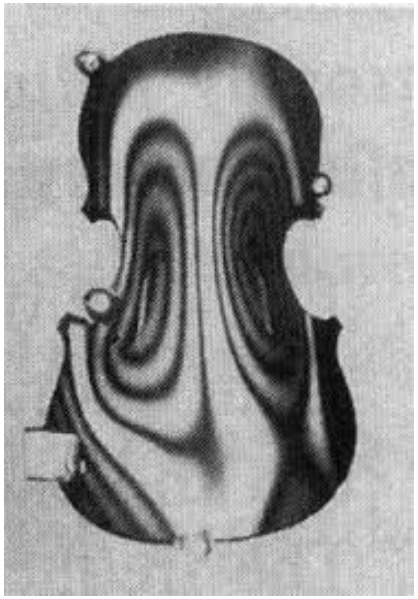
Rezgés és deformáció vizsgálata

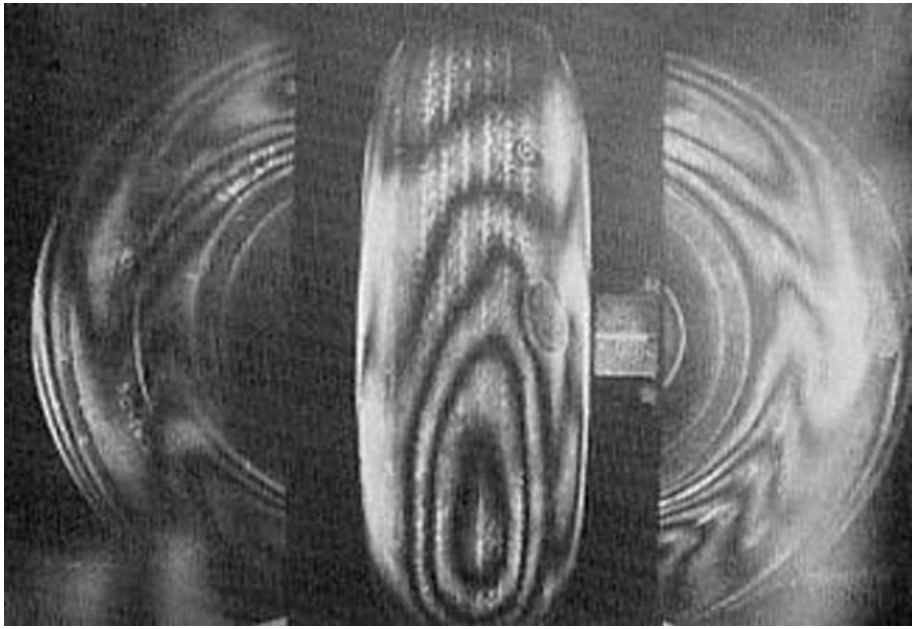


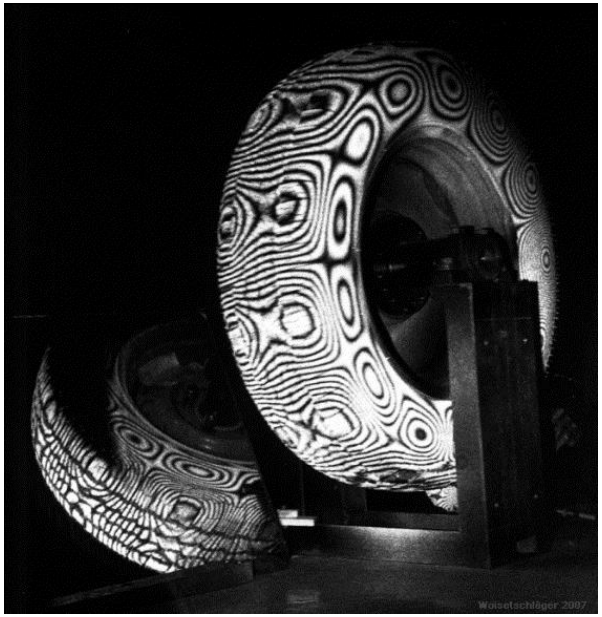
Time-averaged holographic interferograms at 553, 731, and 1174 Hz.
(Fletcher 220)

Holográfia XXI.







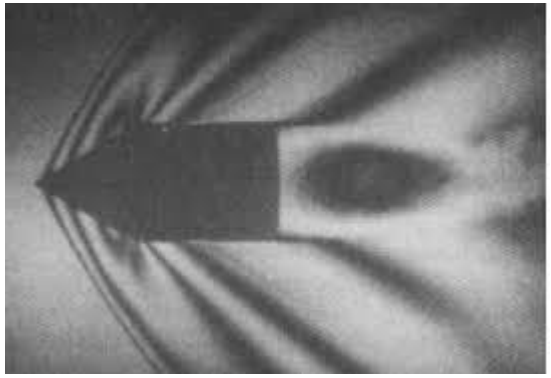


Holográfia XXII.

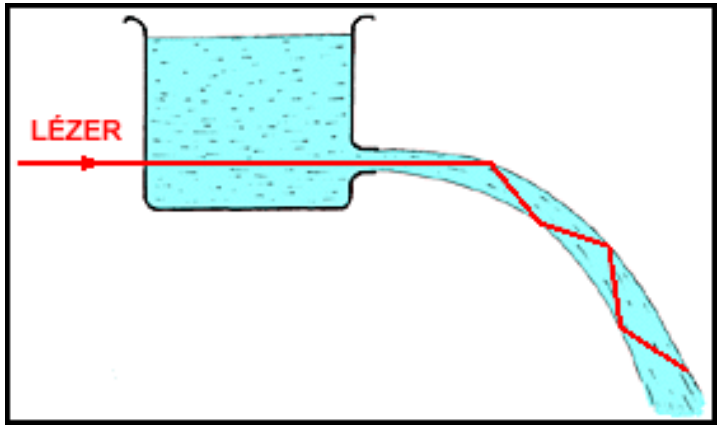
(a)

(b)

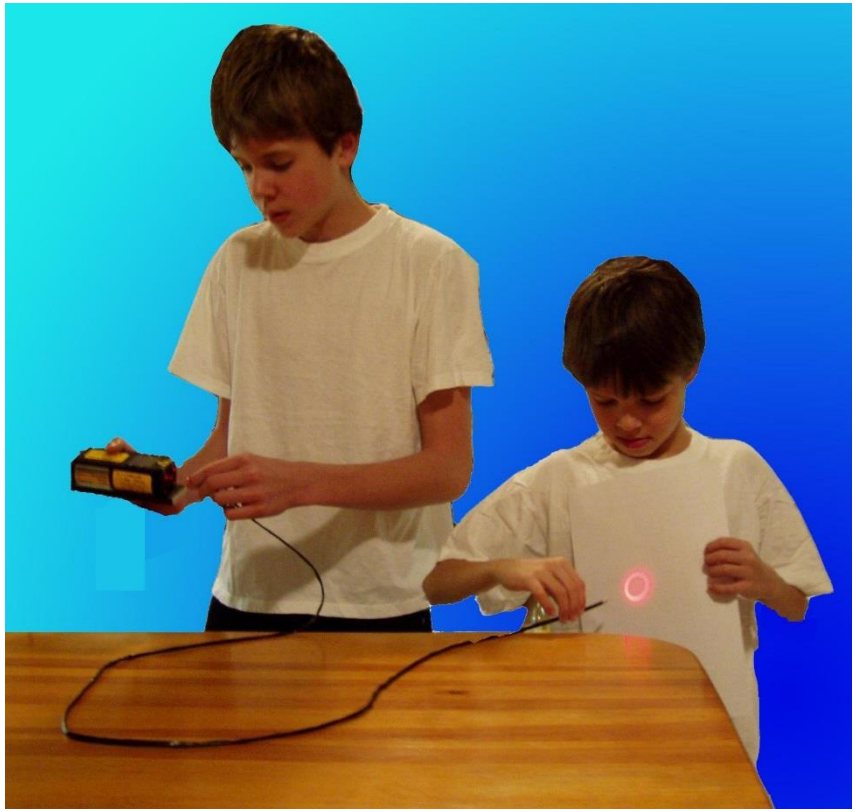
(c)

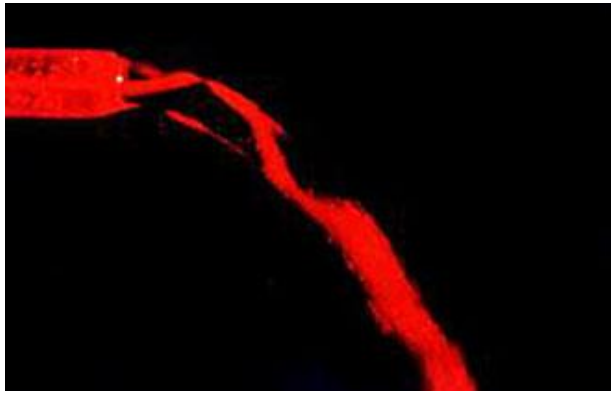


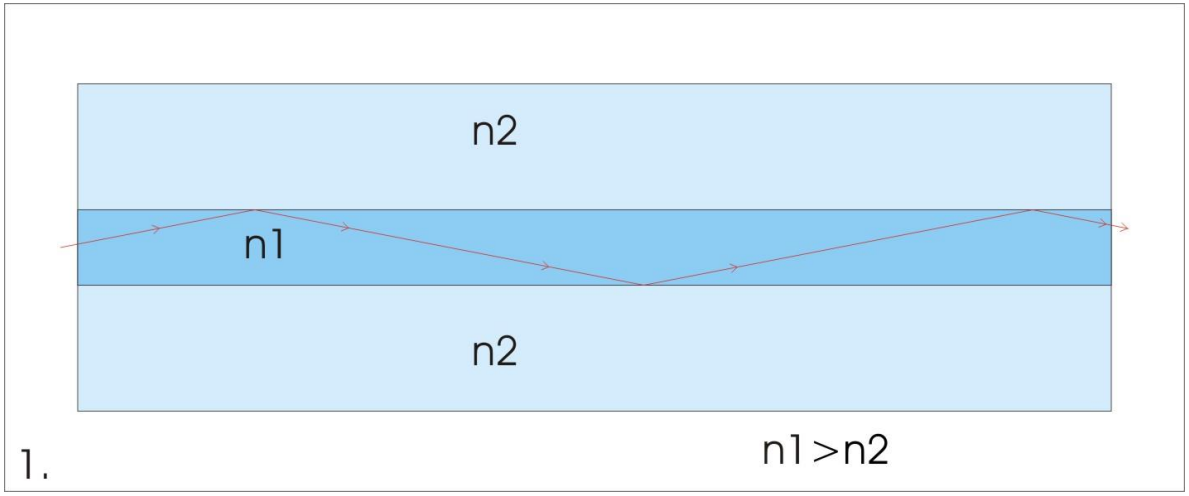
Optikai adatátvitel I.



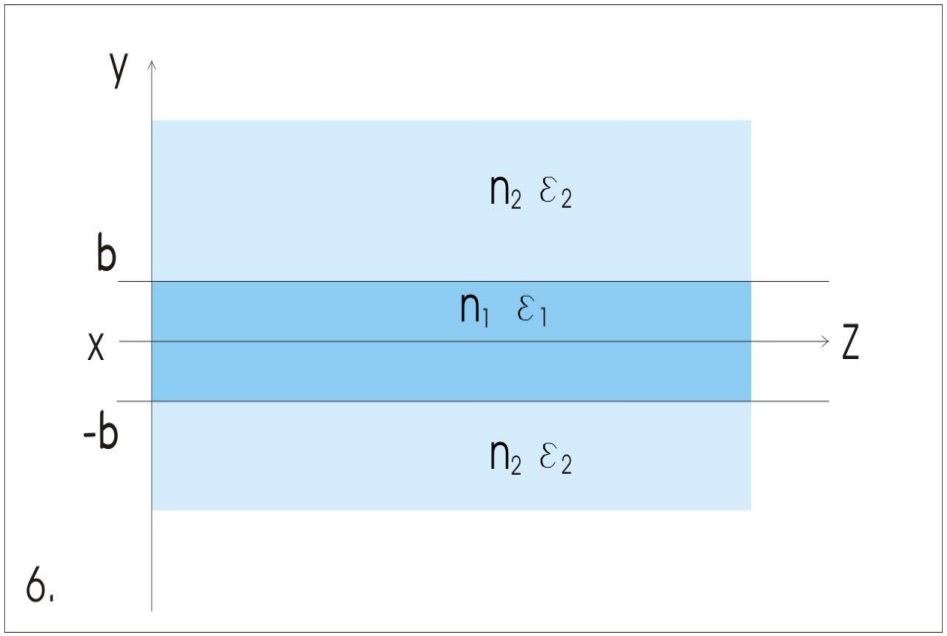
? teljes visszaverődés ?







Optikai adatátvitel II.



Feltételek:

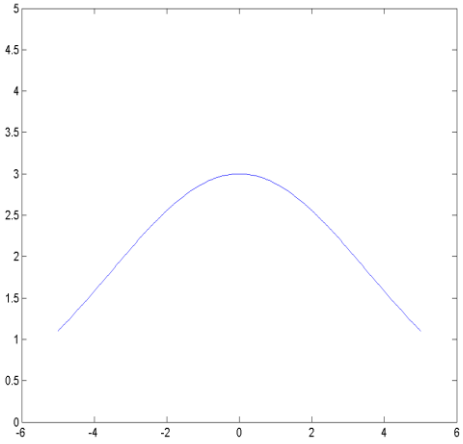
x: ∞ :

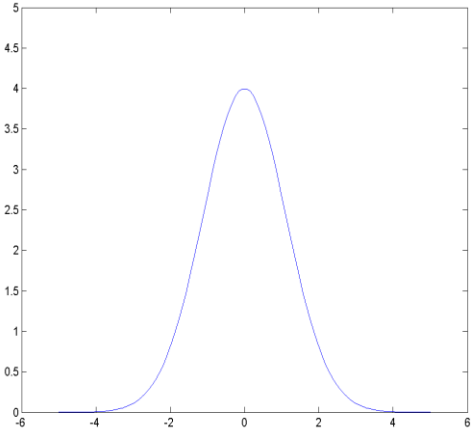
z: terjedés iránya

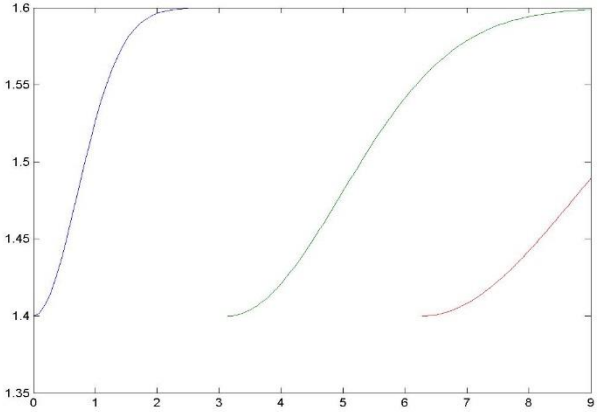
$$\varepsilon_1 > \varepsilon_2$$

Időfüggés: exp[i(ωt-βz)]

$$V = bk_o\sqrt{\varepsilon_1 - \varepsilon_2}$$

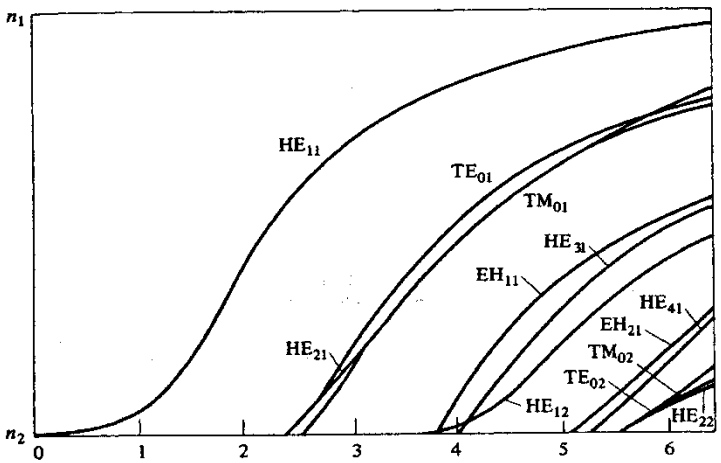


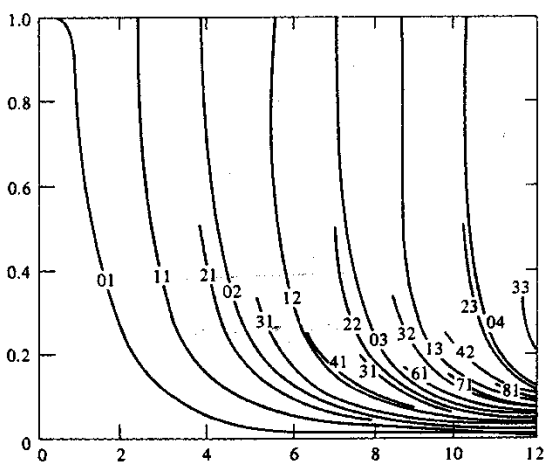


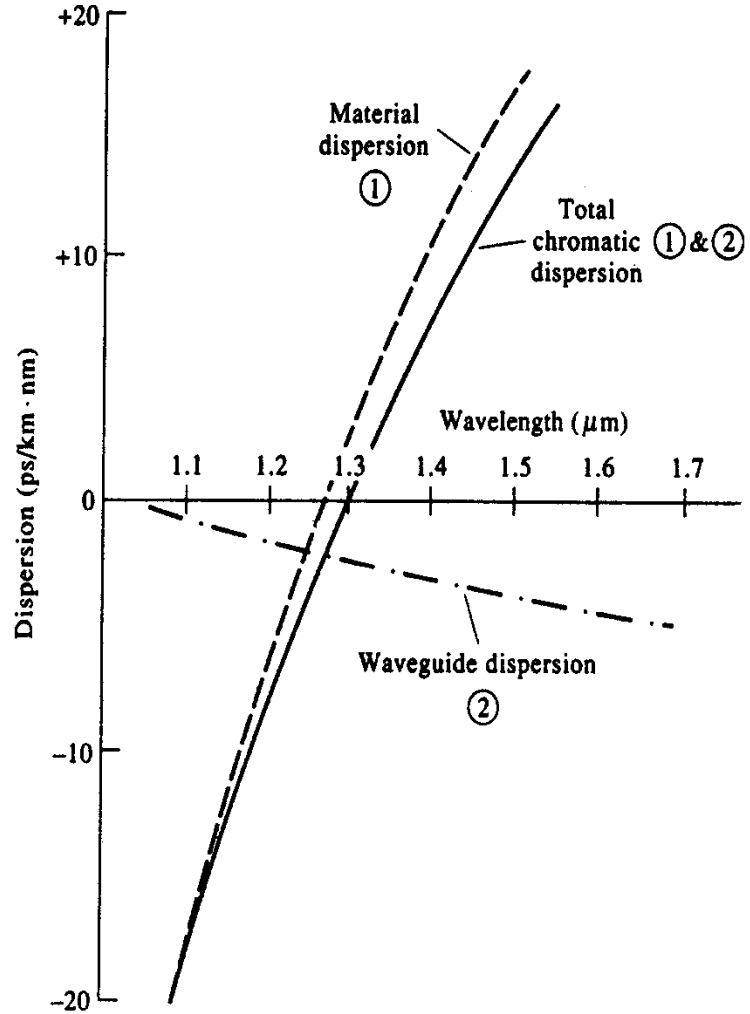


Optikai adatátvitel III.

Módusdiszperzió

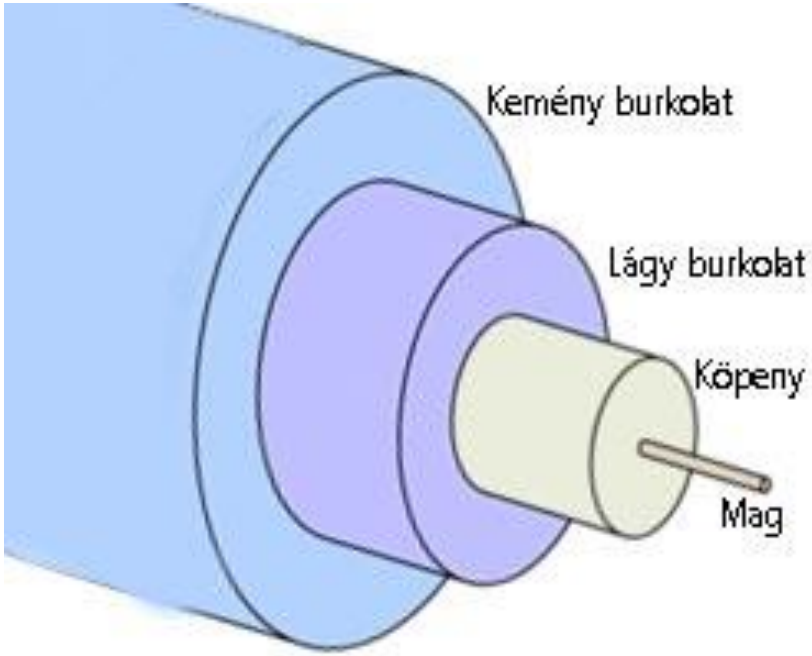


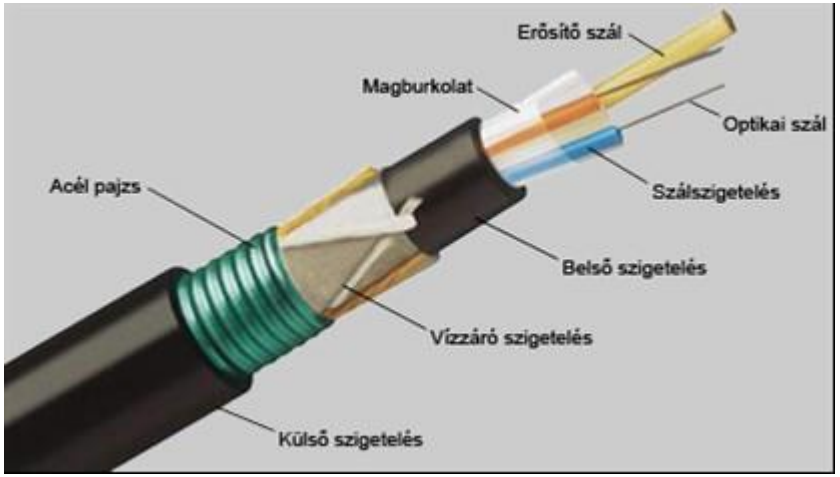


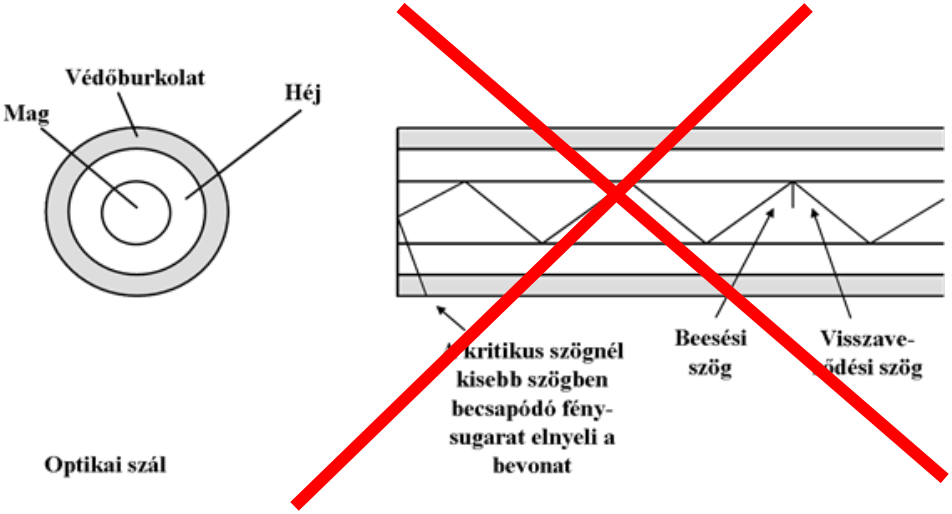


$$telj.hányad = \frac{magban}{köpenyben}$$

Optikai adatátvitel IV.

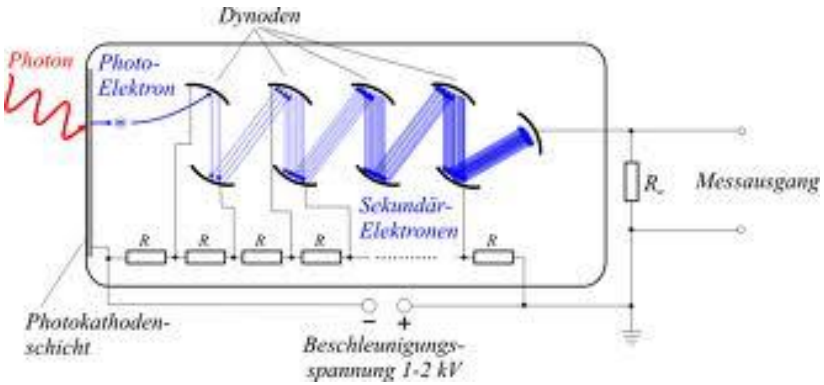


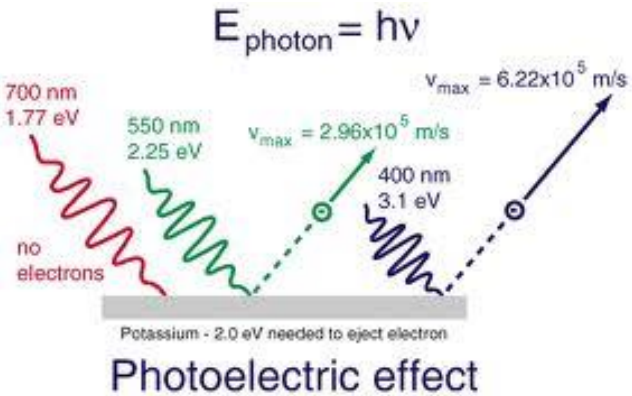




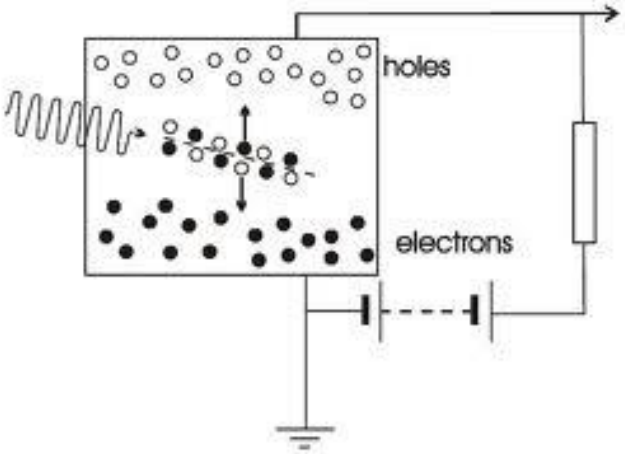
Detektorok

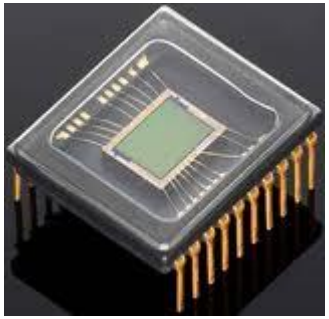
Fotóelektronsokszorozó (photomultiplier)

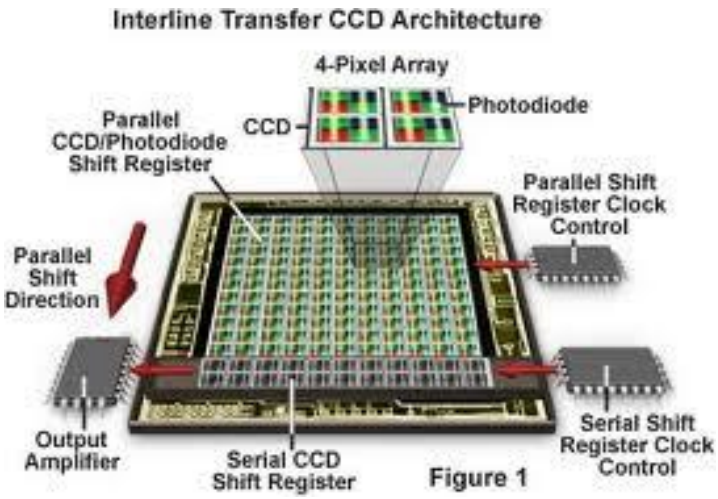




Félvezető detektorok





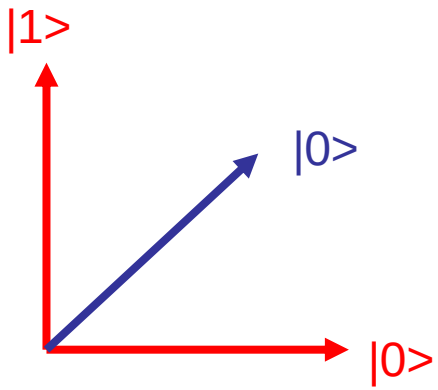


A foton polarizációs állapota

Malus-törvény: $I = I_0 \cos^2 \Theta$

Polarizációs állapot mérése.

Polarizátor transzmissziójának valószínűsége: $P = \frac{I}{I_0}$



|0> =a |0> + b|1>

$$a = b = \frac{1}{\sqrt{2}}$$

Mérés:

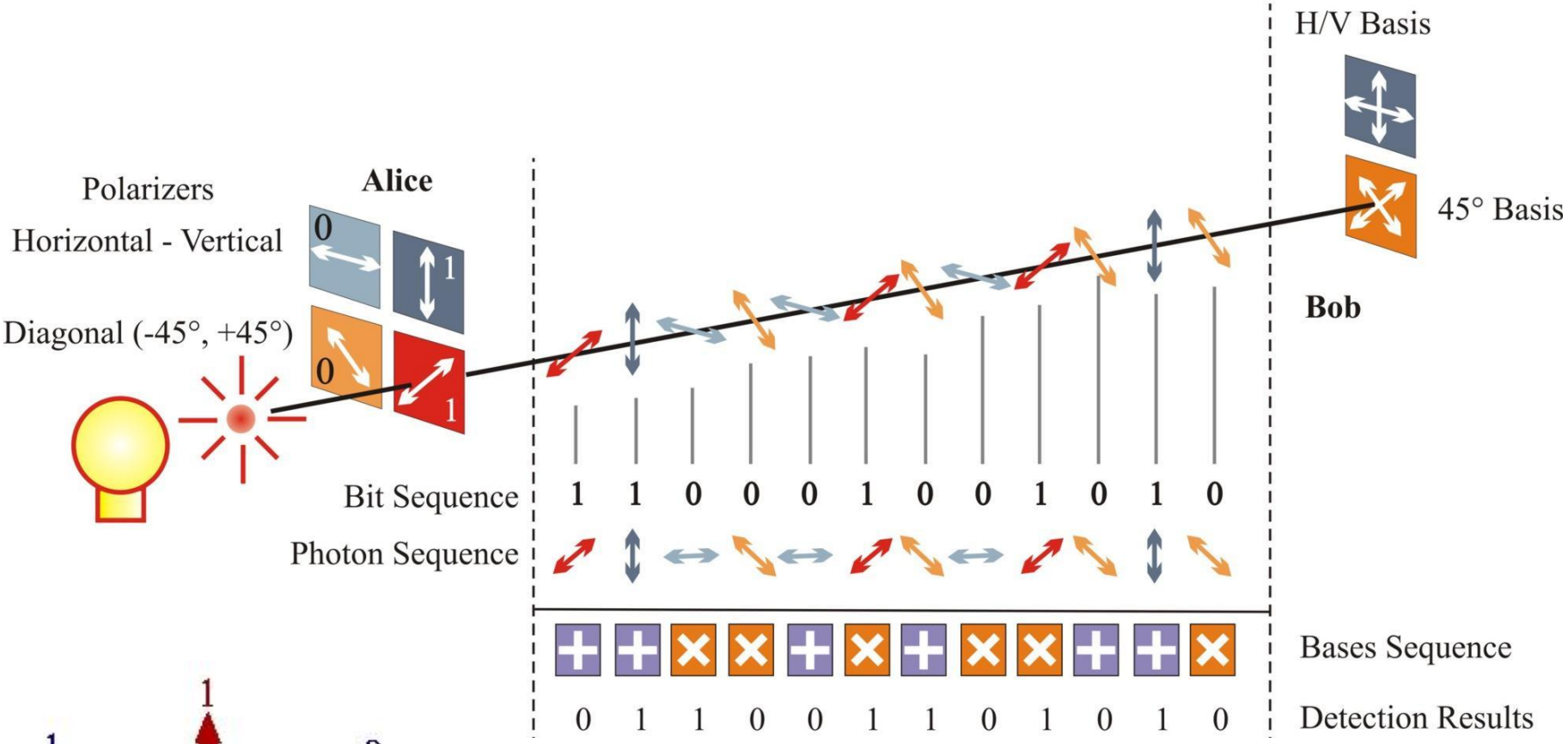
Foton - állapot: |0>
Bázis állapotok : |0> & |1>

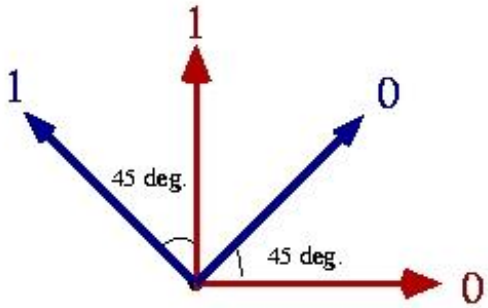
A |0> állapot mérésének valószínűsége: $a^2=½$

A |1> állapot mérésének valószínűsége : $b^2=½$

Kvantumkriptográfia

A BB84 protokoll:





(see *C.H. Bennett and G. Brassard "Quantum Cryptography: Public Key Distribution and Coin Tossing", Proceedings of IEEE International Conference on Computers Systems and Signal Processing, Bangalore India, December 1984, pp 175-179.*)