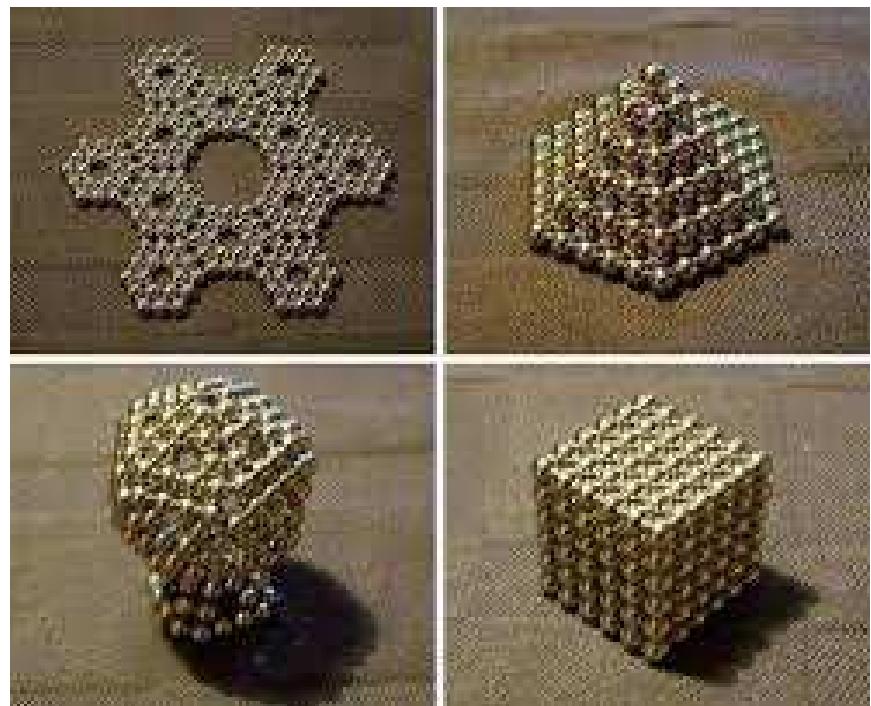


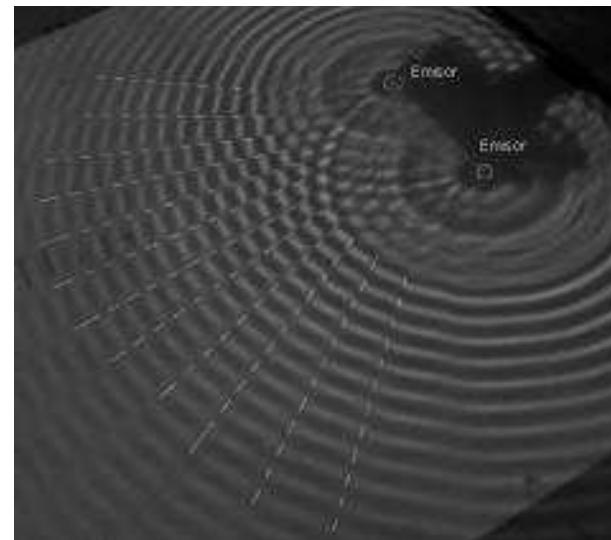
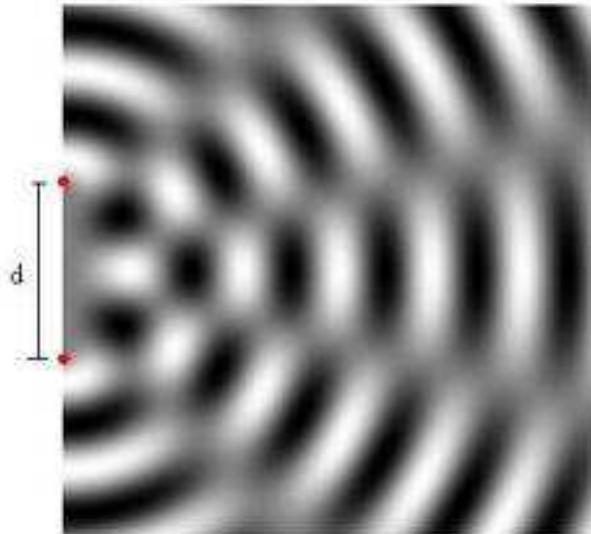
Fizika 112

17. Előadás

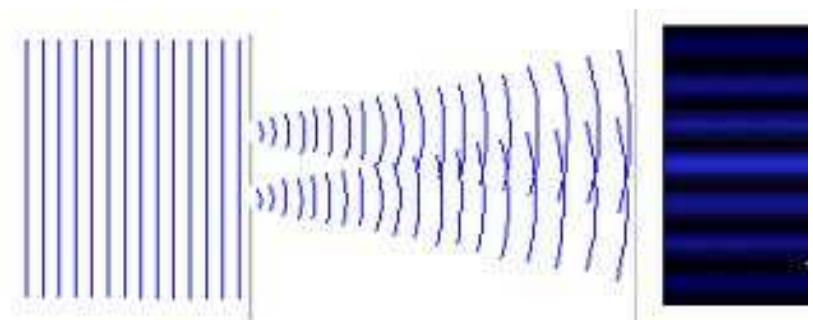
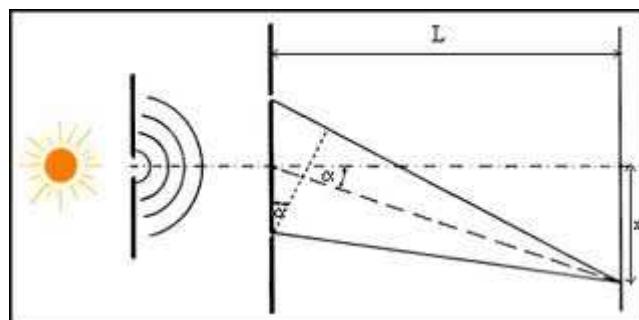


Interferencia I.

Előző félévben tanultuk: hang és vízhullámok → interferencia



EMH-ra kísérleti tapasztalat: fény interferenciája, mikrohullámú sütő (forgó tányér)

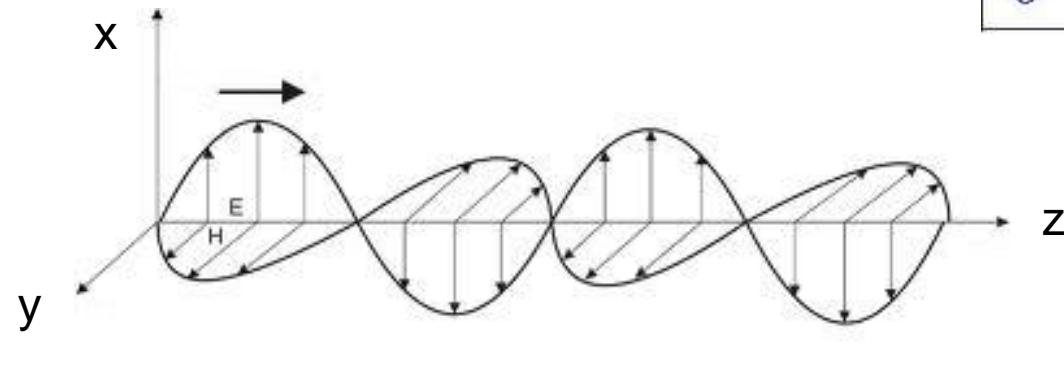
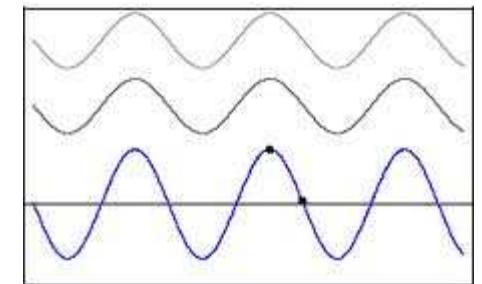


Interferencia II.

Láttuk:

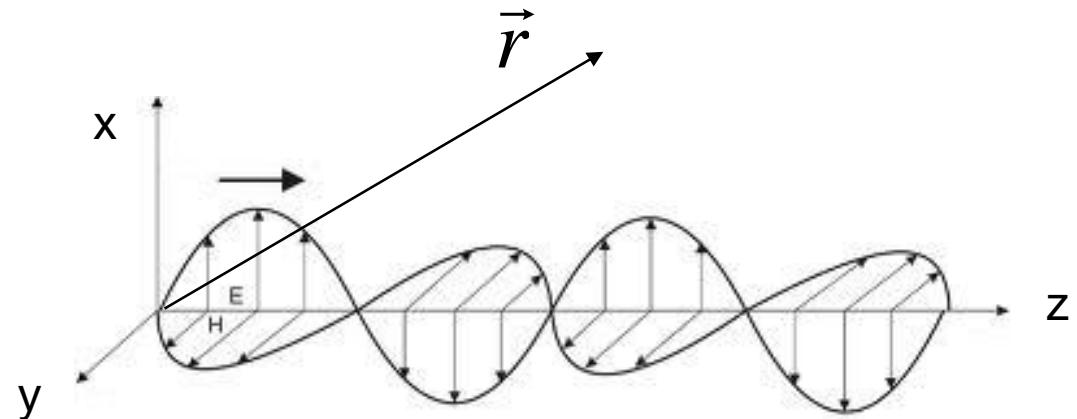
$$E_x(z,t) = E_{0x} \cos(\omega t - kz)$$

Szuperpozíció:



Általános irány:

$$E(\vec{r},t) = E_0 e^{i(\omega t - \vec{k}\vec{r})}$$



Interferencia III.

Intenzitás: $I \sim E^2$

$$E(\vec{r}, t) = E_0 e^{i(\omega t - \vec{k} \cdot \vec{r})}$$

$$I \sim EE^*$$

Két hullám interferenciája:

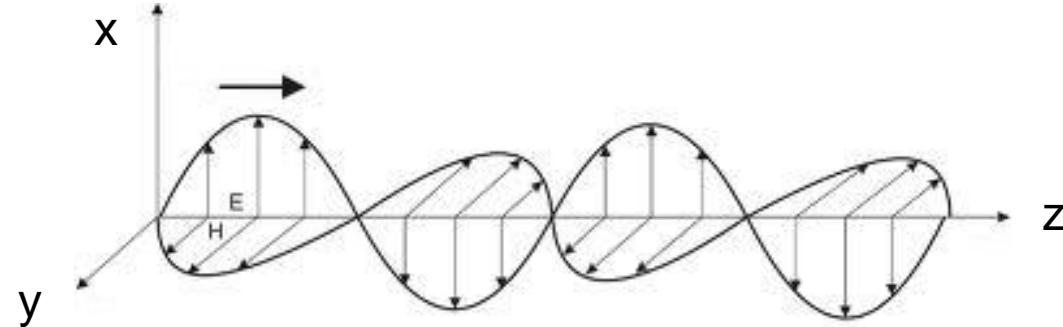
$$I \sim (E_1 + E_2)(E_1^* + E_2^*) = E_1 E_1^* + E_2 E_2^* + E_1 E_2^* + E_1^* E_2$$

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\left[\frac{2\pi}{\lambda}(\vec{k}_2 \cdot \vec{r}_2 - \vec{k}_1 \cdot \vec{r}_1)\right]$$

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos(\Delta\phi)$$

Interferencia IV.

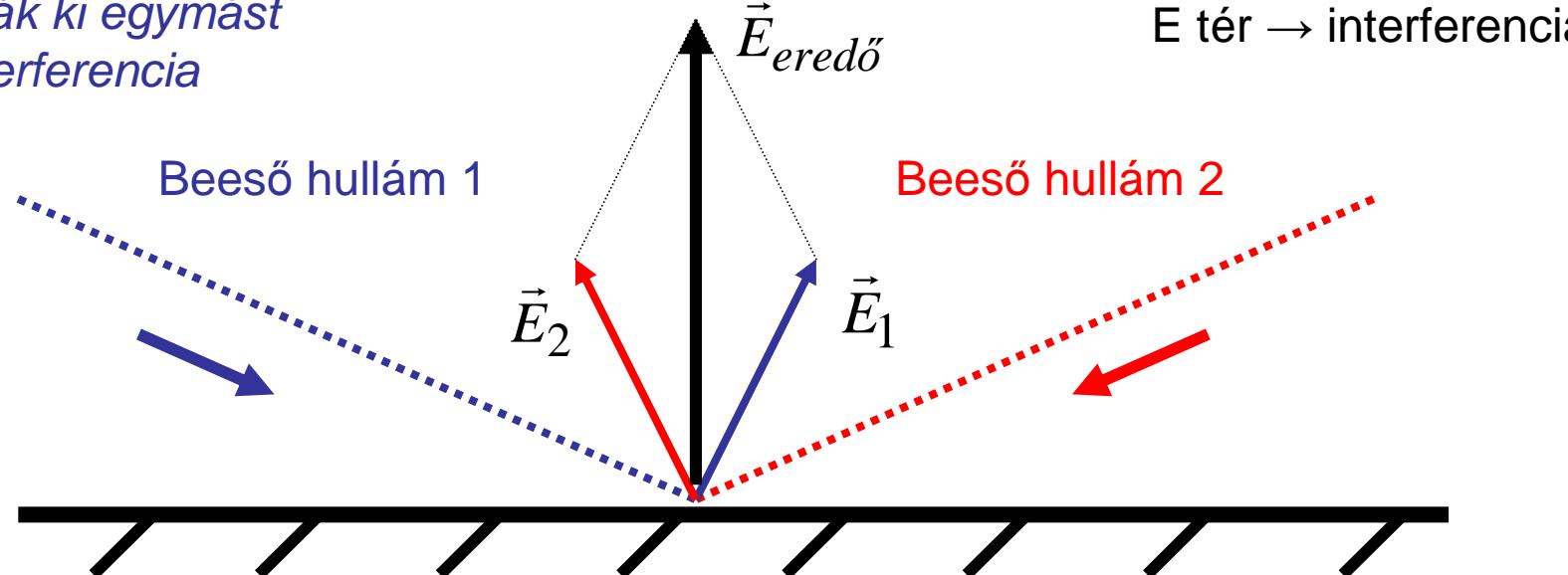
Polarizációs állapotok:



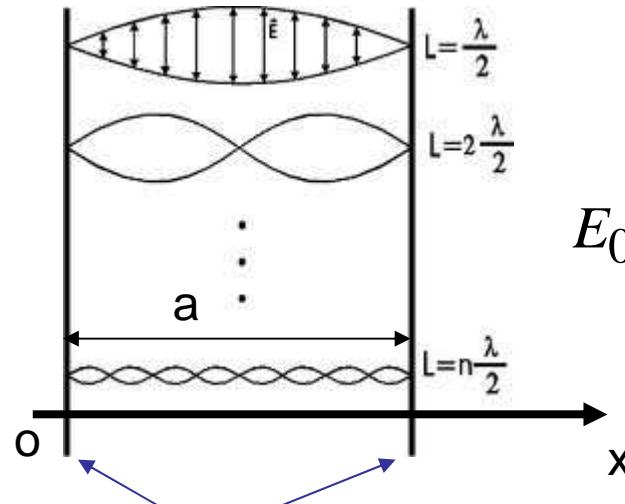
Lineárisan polarizált: polarizációs sík orientációja

Nem oltják ki egymást
nincs interferencia

Síkkal párhuzamos
E tér → interferencia



Hullámvezetők, módusok I.



Vezető-sík(lap)

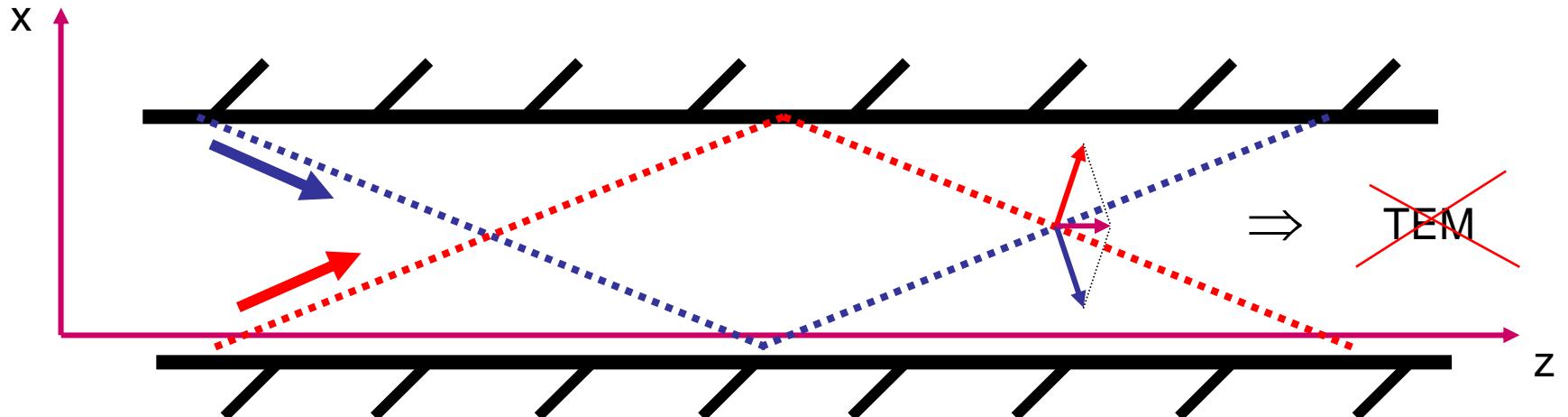
Határfeltételek: $E(x=0)=0$ és $E(x=a)=0$

Állóhullám:

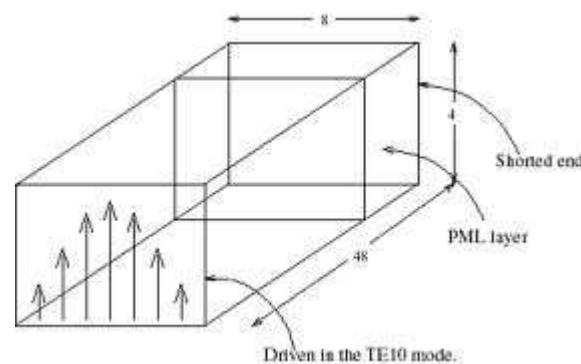
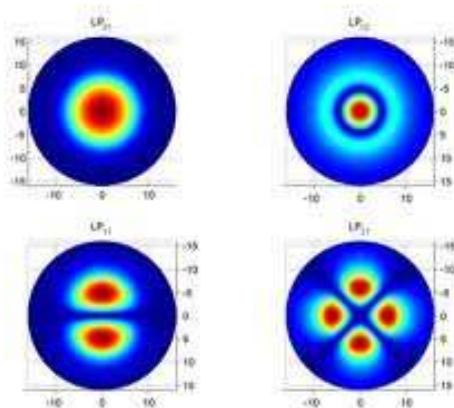
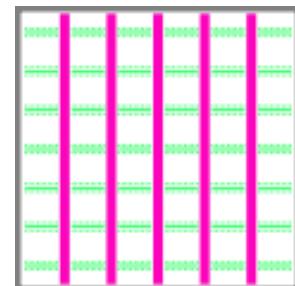
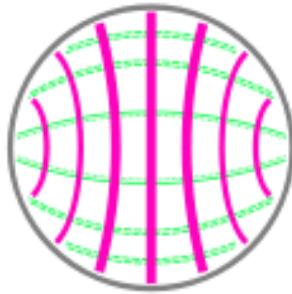
$$E_0 \sin(\omega t - kx) - E_0 \sin(\omega t + kx) = 2E_0 \sin(kx) \cos(\omega t)$$

$$k = n \frac{\pi}{a} \quad \text{ahol } n = 1, 2, 3, \dots$$

Ha a hullám a **z** tengely mentén halad:



Hullámvezetők, módusok II.



TE ($E_z = 0$) és TM ($H_z = 0$) módusok

Hullámvezetők, módusok III.

TM módus:

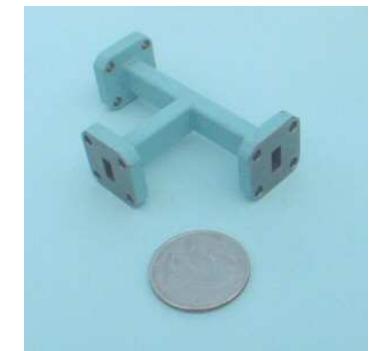
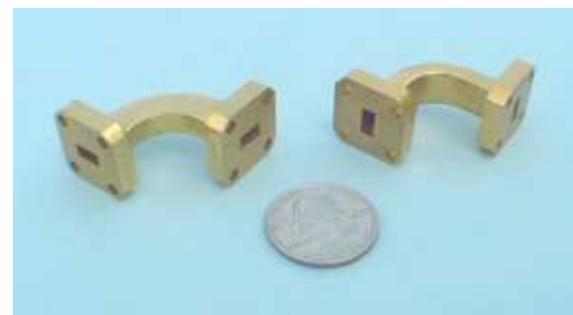
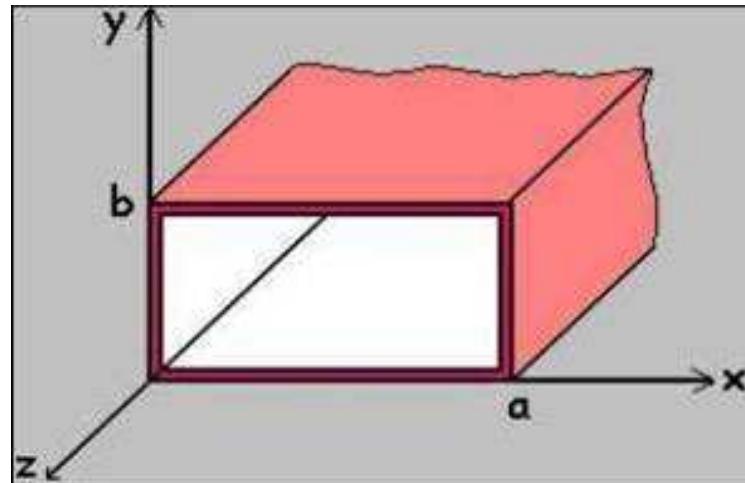
$$E_z = E_o \sin\left(\frac{m\pi}{a}x\right) \sin\left(\frac{n\pi}{b}y\right) e^{-j\beta z}$$

$$H_z = 0$$

TM_{mn}

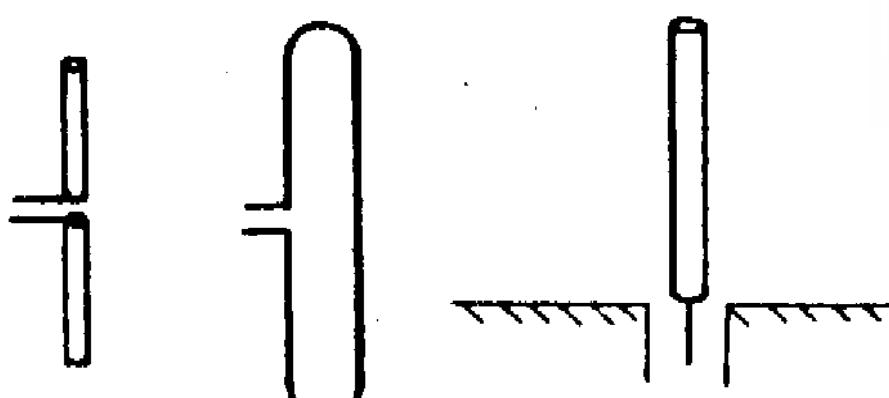
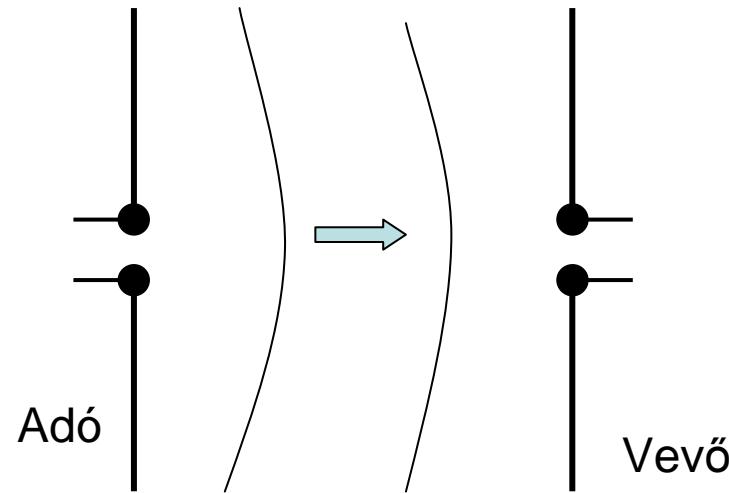
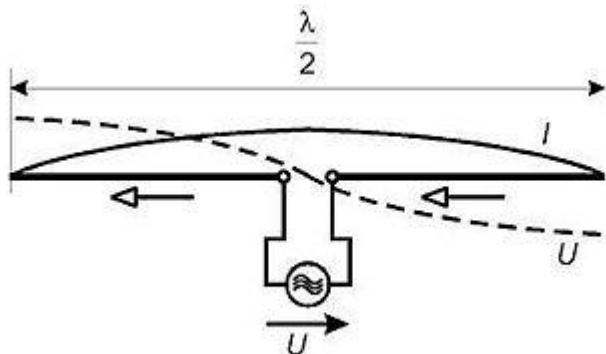
Levágási frekvencia:

$$\omega^2 \mu \epsilon > \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2$$



Antennák

Legegyszerűbb: Hertz-féle kísérlet

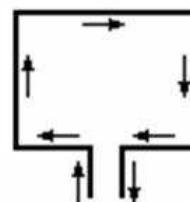


Egyenes
dipól

Hajlított dipól

Monopol

Féldipól



Keret-antennák

+ iránysugárzók

Stb.

Mobiltelefonok



Magyarországon:

1990- westel 450 MHz

1994- 900MHz

2003- 2.1 GHz, MMS

21Mbs néhány körzetben



Doppler – effektus I.

Hanghullámokra:



A megfigyelő mozog:

A forrás mozog:

$$f' = f_0 \left(1 \pm \frac{v}{v_h} \right)$$

$$f' = f_0 \frac{1}{1 \mp \frac{v}{v_h}}$$

Klasszikus mechanika:

Galilei transzformáció:

$$t = t' \quad \text{és} \quad x = x' + vt$$



15 February 1564 – 8 January 1642

Doppler – effektus II.

Hullám a K koord.rdsz.-ben: $\Psi(x,t) = A \cos(\omega t - kx) = A \cos\left(\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x\right)$

$$\Psi(x,t) = A \cos[\omega t' - k(x' + vt')] = A \cos\left[\frac{2\pi}{T}t' - \frac{2\pi}{\lambda}x' - \frac{2\pi}{\lambda}vt'\right]$$

$$\lambda = v_h T$$

$$\Psi(x,t) = A \cos\left[\left(\frac{2\pi}{T} - \frac{2\pi}{\lambda}v\right)t' - \frac{2\pi}{\lambda}x'\right] = A \cos\left[2\pi \underbrace{\frac{1}{T}\left(1 - \frac{v}{v_h}\right)}_{f'} t' - \frac{2\pi}{\lambda}x'\right]$$

$$f' = f_0 \left(1 - \frac{v}{v_h}\right)$$

Doppler – effektus III.

Galilei transzformáció → Maxwell-egyenletek **nem működik!!!**

Lorentz transzformáció → Maxwell-egyenletek **invariáns**

$$x = \gamma(x' + vt') \quad \text{és} \quad t = \gamma\left(t' + \frac{v}{c^2}x'\right)$$

$$K \rightarrow K' : v \rightarrow -v$$

$$x' = \gamma(x - vt) \quad \text{és} \quad t' = \gamma\left(t - \frac{v}{c^2}x\right)$$

ahol:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Doppler – effektus IV.

EMH: $E(x,t) = E_0 \cos(\omega t - kx) = A \cos\left(2\pi f t - \frac{2\pi}{\lambda} x\right)$

$$E(x,t) = A \cos\left[2\pi f \gamma\left(t' + \frac{v}{c^2} x'\right) - \frac{2\pi}{\lambda} \gamma(x' + vt')\right]$$

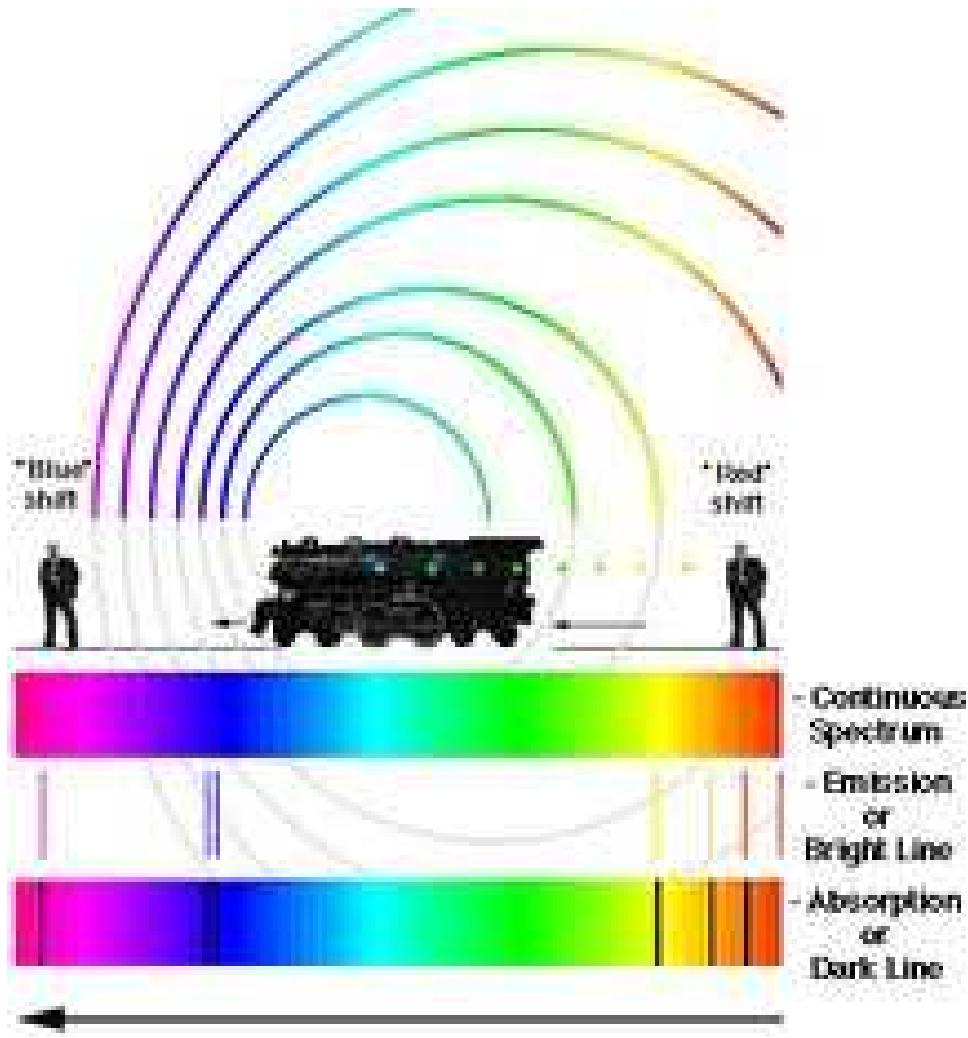
$$\frac{1}{\lambda} = \frac{f}{c}$$

$$E(x,t) = A \cos\left[2\pi f \underbrace{\sqrt{1 - \frac{v^2}{c^2}} t'}_{\text{red bracket}} - \frac{2\pi}{\lambda} \underbrace{\sqrt{1 - \frac{v^2}{c^2}} x'}_{\text{red bracket}}\right] = A \cos\left[2\pi f \underbrace{\sqrt{\frac{1 - \frac{v}{c}}{1 + \frac{v}{c}}} t'}_{\text{red bracket}} - 2\pi \underbrace{\frac{1}{\lambda} \sqrt{\frac{1 - \frac{v}{c}}{1 + \frac{v}{c}}} x'}_{\text{red bracket}}\right]$$

$$f' = f \sqrt{\frac{1 - \frac{v}{c}}{1 + \frac{v}{c}}} \quad \lambda' = \lambda \sqrt{\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}}$$

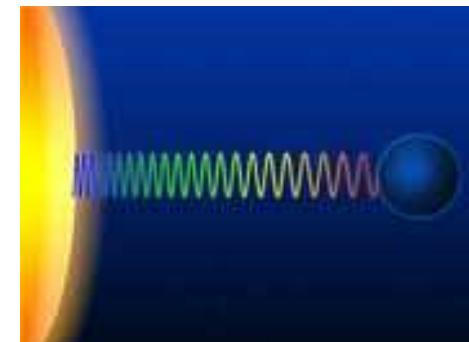
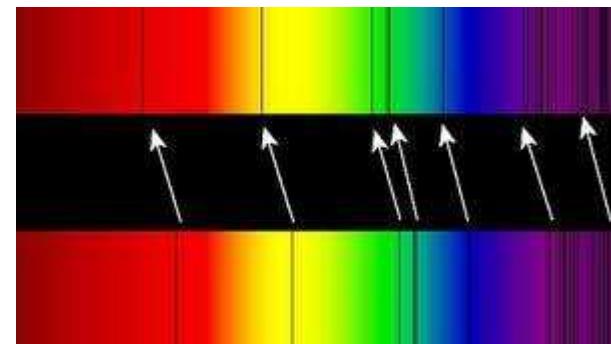
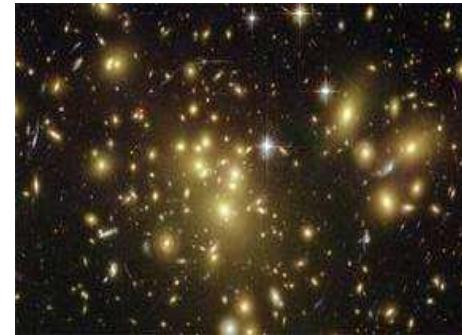
Doppler – effektus V.

Hubble-törvény: $v = H_0 s$



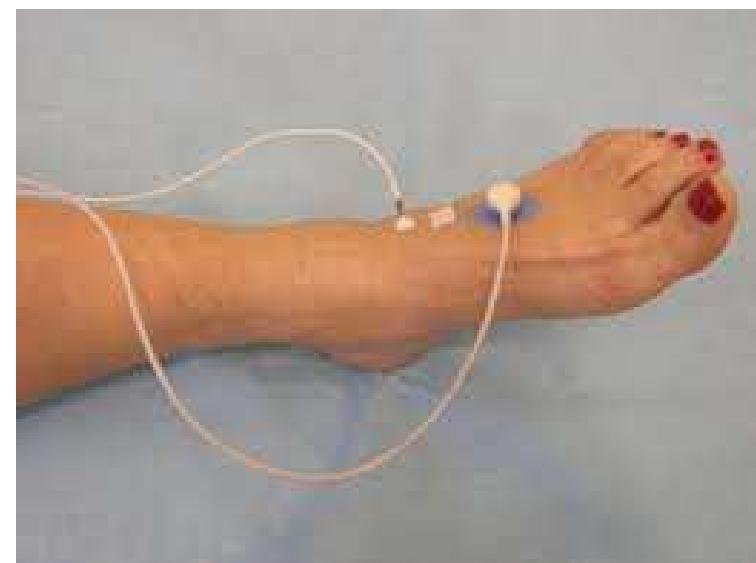
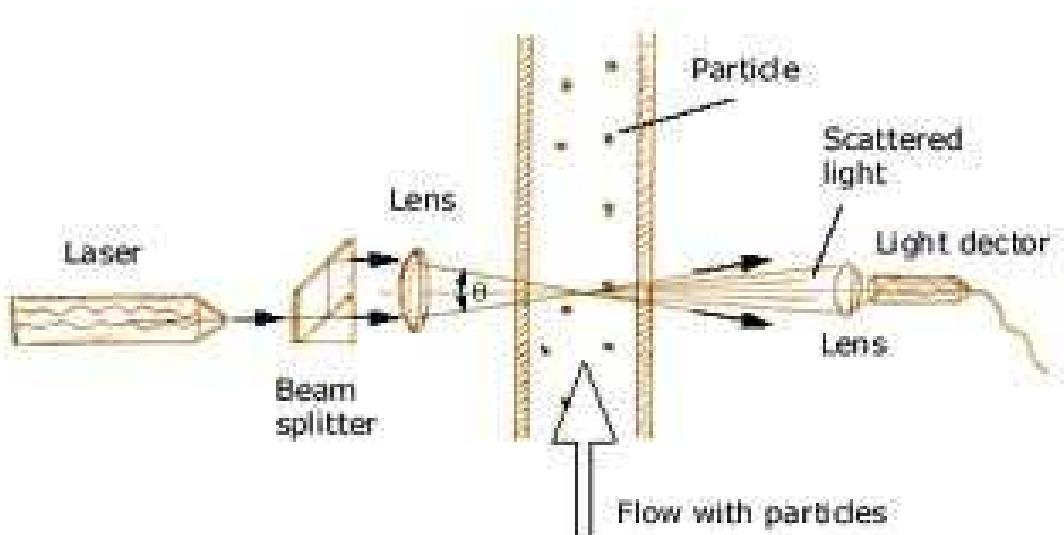
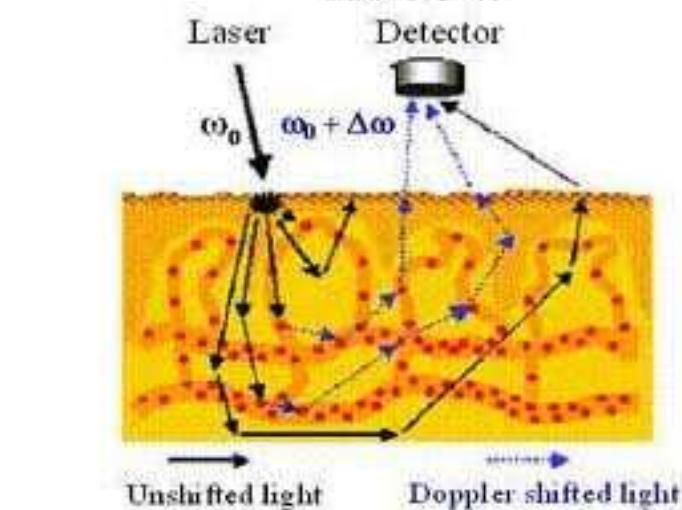
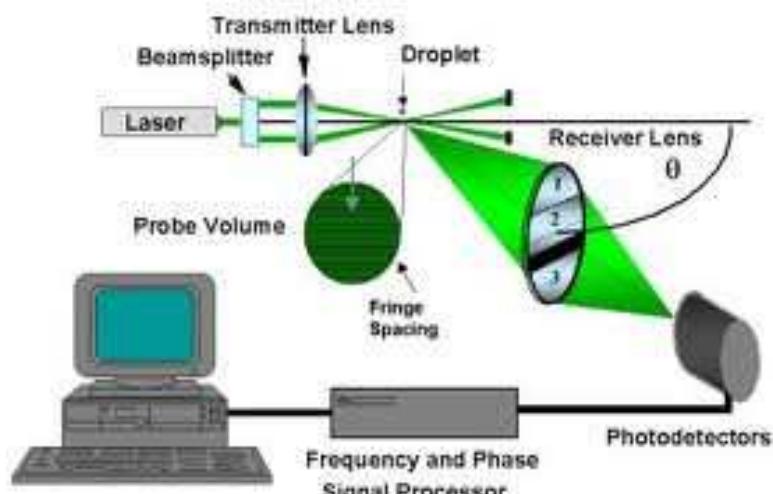
Parszek 1pc = 3,26 fényév

$$H_0 = 67.0 \pm 3.2 \text{ (km/s)/Mpc}$$



Doppler – effektus VI.

Lézer-Doppler-sebességmérés
véráram sebesség mérés



Doppler – effektus VII.

Lézer-Doppler-sebességmérés

