

1. Elektromagnetische Welle im Vakuum

$$E_x = 0; \quad E_y = 30 \cos\left(2\pi * 10^8 t - \frac{2\pi}{3} x\right); \quad E_z = 0$$

(a) $\omega = 2\pi * 10^8 \text{ 1/s}$

$$f = \frac{\omega}{2\pi} = \underline{\underline{10^8 \text{ 1/s}}}$$

(b) $k = \frac{2\pi}{3}$

$$\lambda = \frac{2\pi}{k} = \underline{\underline{3 \text{ m}}}$$

(c)

Direction: $\underline{\underline{\hat{x}}}$

(d) $B_0 = \frac{E_0}{c}$

$$\underline{\underline{\vec{B} = 10^7 \cos\left(2\pi * 10^8 t - \frac{2\pi}{3} x\right) \hat{z}}}$$

2. Photonen-Ping-Pong

	$\vec{E}_1(t) = E_0 \begin{pmatrix} \cos(\omega t) \\ 0 \\ 0 \end{pmatrix}$	$\vec{E}_2(t) = E_0 \begin{pmatrix} \cos(\omega t) \\ \sin(\omega t) \\ 0 \end{pmatrix}$	$\vec{E}_3(t) = E_0 \begin{pmatrix} a \cos(\omega t) \\ b \sin(\omega t) \\ 0 \end{pmatrix}$
(a)	$w_{rms} = \frac{\epsilon_0 E_0^2}{2}$	$w_{rms} = \epsilon_0 E_0^2$	$w_{rms} = \frac{\epsilon_0 E_0^2 (a^2 + b^2)}{2}$
	$I_{rms} = \frac{c \epsilon_0 E_0^2}{2}$	$I_{rms} = c \epsilon_0 E_0^2$	$I_{rms} = \frac{c \epsilon_0 E_0^2 (a^2 + b^2)}{2}$
	Linear Polarization	Circular Polarization	Elliptical Polarization

$$(b) \vec{F} = \frac{d\vec{p}}{dt} = \frac{P}{c} = \epsilon_0 E_{\text{rms}}^2 A$$

$$F_1 = \epsilon_0 E_{\text{rms}}^2 A$$

$$F_2 = 2F_1 = 2\epsilon_0 E_{\text{rms}}^2 A$$

$$F_3 = \frac{F_1 + F_2}{2} = \frac{3}{2} \epsilon_0 E_{\text{rms}}^2 A$$

(c) pair Wave with largest E_{rms} with F_2

$\Rightarrow \underline{\underline{F_2 + \vec{E}_2}}$ generate the highest mean Force \vec{F}

3. Stehende Wellen

$$\vec{E}(\vec{r}, t) = \text{Re} \left(\vec{E}_0 e^{i\vec{k}\vec{r} - i\omega t} \right)$$

(a)

$$\vec{E}_1(x\hat{x}, t) = \text{Re} \left(\vec{E}_0 e^{ik_x x - i\omega t} \right)$$

$$\vec{E}_2(-x\hat{x}, t) = \text{Re} \left(\vec{E}_0 e^{-ik_x x - i\omega t} \right)$$

$$\begin{aligned} \vec{E} = \vec{E}_1 + \vec{E}_2 &= \text{Re} \left(\vec{E}_0 \left[e^{ik_x x - i\omega t} + e^{-ik_x x - i\omega t} \right] \right) = \\ &= \text{Re} \left(\vec{E}_0 e^{-i\omega t} \right) * 2 \cos(k_x x) \end{aligned}$$

$$\text{For } x = (2n + 1) \frac{\pi}{2k_x}, n \in \mathbb{N}: \quad \cos(k_x x) = 0 \quad \Rightarrow \quad \vec{E} = 0$$

$\Rightarrow \vec{E}$ describes a standing Wave with $\lambda = \pi$

(b)

$$\vec{E}_1(x\hat{x}, t) = \text{Re} \left(\vec{E}_0 e^{ik_x x - i\omega t} \right)$$

$$\vec{E}_2(y\hat{y}, t) = \text{Re} \left(\vec{E}_0 e^{ik_y y - i\omega t} \right)$$

$$\begin{aligned} \vec{E} = \vec{E}_1 + \vec{E}_2 &= \text{Re} \left(\vec{E}_0 \left[e^{ik_x x - i\omega t} + e^{ik_y y - i\omega t} \right] \right) = \\ &= \text{Re} \left(\vec{E}_0 e^{-i\omega t} \left[e^{ik_x x} + e^{ik_y y} \right] \right) \end{aligned}$$

$\Rightarrow \vec{E}$ does not describe a standing Wave

(c) $\vec{r}_1 = \cos\left(\frac{\pi}{10}\right)\hat{x} + \sin\left(\frac{\pi}{10}\right)\hat{y}$

$$\vec{E}_1(x\hat{x}, t) = \text{Re} \left(\vec{E}_0 e^{ik_x x - i\omega t} \right)$$

$$\vec{E}_2(\vec{r}_1, t) = \text{Re} \left(\vec{E}_0 e^{i\vec{k}\vec{r}_1 - i\omega t} \right)$$

$$\begin{aligned} \vec{E} = \vec{E}_1 + \vec{E}_2 &= \text{Re} \left(\vec{E}_0 \left[e^{ik_x x - i\omega t} + e^{i\vec{k}\vec{r}_1 - i\omega t} \right] \right) = \\ &= \text{Re} \left(\vec{E}_0 e^{-i\omega t} \underbrace{\left[e^{ik_x x} + e^{i\vec{k}\vec{r}_1} \right]}_{> 0 \Rightarrow \text{no Root}} \right) \end{aligned}$$

$\Rightarrow \vec{E}$ does not describe a standing Wave

(d) $\omega_1 = 2\omega_2$

$$\vec{E}_1(\hat{x}, t) = \text{Re} \left(\vec{E}_0 e^{i\vec{k}\hat{x} - i\omega_1 t} \right)$$

$$\vec{E}_2(-\hat{x}, t) = \text{Re} \left(\vec{E}_0 e^{-i\vec{k}\hat{x} - i\omega_2 t} \right)$$

$$\begin{aligned} \vec{E} = \vec{E}_1 + \vec{E}_2 &= \text{Re} \left(\vec{E}_0 \left[e^{ik_x x - i2\omega_2 t} + e^{-ik_x x - i\omega_2 t} \right] \right) = \\ &= \text{Re} \left(\vec{E}_0 e^{-i\omega_2 t} \underbrace{\left[e^{ik_x x - i\omega_2 t} + e^{ik_x x} \right]}_{\text{time dependent Root}} \right) \end{aligned}$$

$\Rightarrow \vec{E}$ does not describe a standing Wave

$$\underbrace{\hspace{10em}}_{> 0 \Rightarrow \text{no Root}}$$