2.3 평면파의 편파 전자기학 2(cheng 7-2.3)에서 강의하였음(beam project 강의)

Polarization of Planewave ; Electric, Magnetic filed 분포(Planewave)

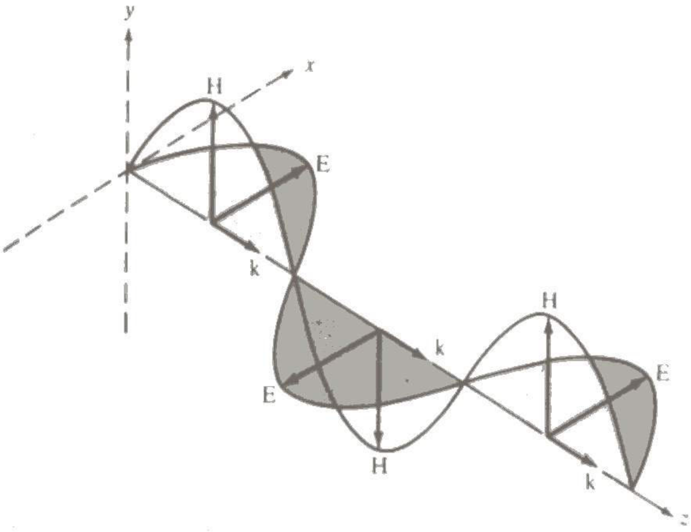
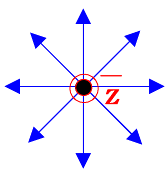


FIGURE 2-2
Electric and magnetic field distributions in a train of plane electromagnetic waves at a given instant in time.

그림 평면파의 전계와 자계의 필드분포

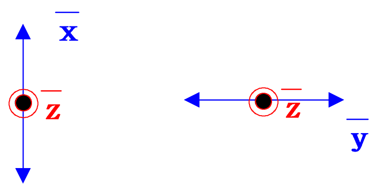
- Transverse wave(TEM)
- E, H, k : orthogonal vector
- linearly polarized
- Polarization vector= E_x (전계의 방향이 분극방향)



편파않 된 light(전자파)

(전계기준)

전계가 비대칭일 때 편광되었다고 함.



$\left.\begin{array}{l}\bar{x} \text{ 방향 편광} \\ \bar{y} \text{ 방향 편광}\end{array}\right\}$ 선형 편광

ex) TEM파의 linear polarized 설명

sol) 전계가 $\bar{x}$ 방향 이나 $\bar{y}$ 방향과 일치

·$\overline{\mathrm{x}}$ 방향 편파인 경우 전계

$$\mathrm{E}(z) = E_1(z)\,\overline{\mathrm{x}} = E_{10}\,e^{-jkz}\,\overline{\mathrm{x}}$$

순시식; $\therefore \mathrm{E}(z,\,t) = \Re e\,[E_1(z)\,\overline{\mathrm{x}}\,e^{j\omega t}]$

$$= \Re e\,[E_{10}\,e^{-jkz}\,e^{j\omega t}\,\overline{\mathrm{x}}]$$

$$= \Re e\,[E_{10}\,e^{j(\omega t - kz)}\,\overline{\mathrm{x}}]$$

$$= \Re e\,[E_{10}\,\{\cos(\omega t - kz) + j\sin(\omega t - kz)\}\,\overline{\mathrm{x}}]$$

$$= E_{10}\cos(\omega t - kz)\,\overline{\mathrm{x}}$$

※ Polarization의 일반적인 state 고찰

· 또 다른 polarized wave을 포함하여 고찰

- 앞에서 wave에 orthogonal($\overline{\mathrm{y}}$ 방향)

-$\mathrm{E}(z,\,t) = E_{20}\cos(\omega t - kz + \delta)\,\overline{\mathrm{y}}$

where, $\delta = \theta$: waves의 상대적인 위상천이(relative phase difference)

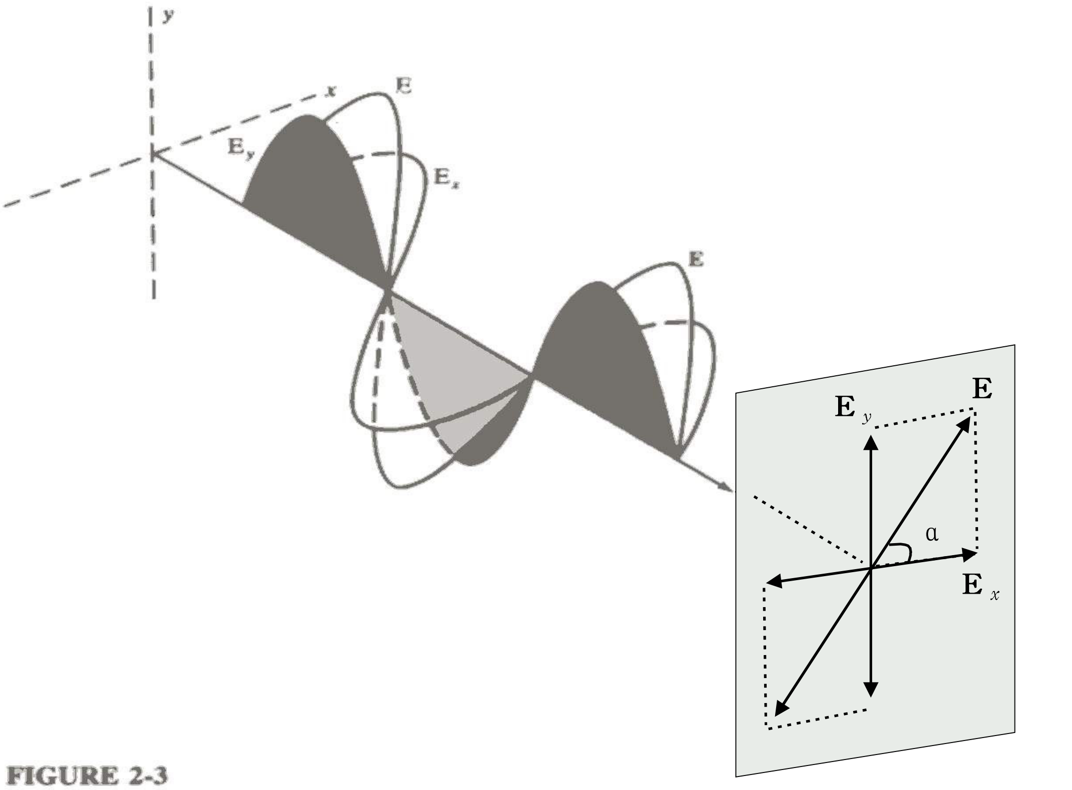


FIGURE 2-3
Addition of two linearly polarized waves having zero relative phase between them.

· 결과적으로, if $\delta = 0$ or $\delta = n\pi$

$$\mathrm{E}(z,\, t) = E_1(z,\, t)\,\bar{\mathrm{x}} + E_2(z,\, t)\,\bar{\mathrm{y}}$$

→ in phase

→ polarization vector가 angle 조성

→ 순시각

$$\phi = \alpha = \tan^{-1}\frac{E_{20}}{E_{10}} \quad : \bar{\mathrm{x}} \text{ 에 대하여} \qquad (7\text{-}29)(2\text{-}56)$$

→ magnitude

$$E = (E_{10}^2 + E_{20}^2)^{1/2}$$

· 역으로 2개의 직교 plan wave는 하나의 polarized wave로 combine(결합)이 가능.

· 또 임의의 polarized wave는 2개의 독립된 직교 plane wave로 분해가능.

⇒ ex) 7-2

※ $\mathrm{E}(z) = E_1(z)\,\bar{\mathrm{x}} + E_2(z)\,\bar{\mathrm{y}}$ 에서

1) $E_2(z)$ 가 $E_1(z)$ 와 $\pi/2$ 의 위상차가 뒤지는 경우

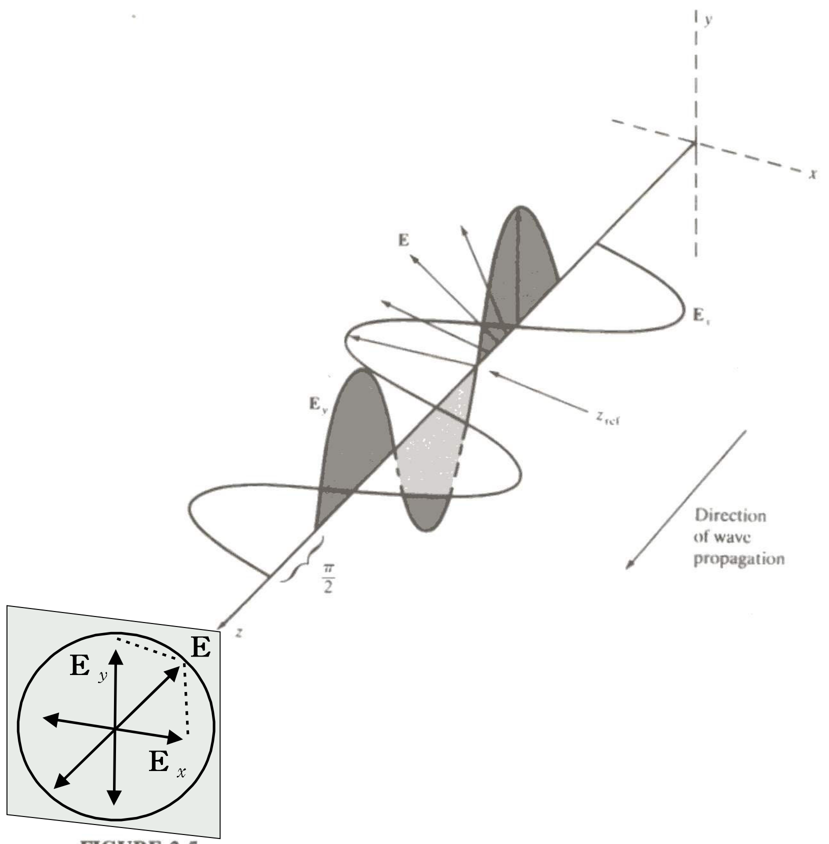


FIGURE 2-5
Addition of two equal-amplitude linearly polarized waves with a relative phase difference $\delta = \pi/2 + 2m\pi$ results in a right circularly polarized wave.

$$\mathrm{E}(z) = E_1(z)\,\overline{\mathrm{x}} + E_2(z)\,\overline{\mathrm{y}} \qquad (7\text{-}26)$$

$$= E_{10}\,e^{-jkz}\,\overline{\mathrm{x}} - j\,E_{20}\,e^{-jkz}\,\overline{\mathrm{y}}$$

순시식은

$$\mathrm{E}(z,\ t) = \Re e\,[E_1(z)\,e^{j\omega t}\overline{\mathrm{x}} + E_2(z)\,e^{j\omega t}\overline{\mathrm{y}}]$$

$$= \Re e\,[\{E_{10}\,e^{-jkz}\overline{\mathrm{x}} - j\,E_{20}\,e^{-jkz}\overline{\mathrm{y}}\}\ e^{j\omega t}]$$

$$= \Re e\,[\{E_{10}\,e^{j(\omega t - kz)}\overline{\mathrm{x}} - j\,E_{20}\,e^{j(\omega t - kz)}\overline{\mathrm{y}}\}]$$

$$= \Re e\,[\{E_{10}\cos(\omega t - kz) + j\sin(\omega t - kz)\}\,\overline{\mathrm{x}}$$

$$- j\,E_{20}\{\cos(\omega t - kz) + j\sin(\omega t - kz)\,\overline{\mathrm{y}}\}]$$

$$= E_{10}\cos(\omega t - kz)\,\overline{\mathrm{x}} + E_{20}\sin(\omega t - kz)\,\overline{\mathrm{y}}$$

E_{10} 와 E_{20} 위상차 $= \pi / 2$

$$= E_{10}\cos\left(\omega t - kz\right)\overline{\mathrm{x}} + E_{20}\cos\left(\omega t - kz - \frac{\pi}{2}\right)\overline{\mathrm{y}}$$

where,

t 의 변화에 대한 $\mathrm{E}(z, t)$ 의 고찰은 $z = 0$ 로 놓고 보아야 좋음

$$\mathrm{E}(0,\ t) = E_{10}\cos\omega t\ \overline{\mathrm{x}} + E_{20}\sin\omega t\ \overline{\mathrm{y}} \qquad (7\text{-}27)$$

$$= E_1(0,\ t)\,\overline{\mathrm{x}} + E_2(0,\ t)\,\overline{\mathrm{y}}$$

· ωt : $0 \quad \rightarrow \quad 2\pi$ 증가시

$\rightarrow \mathrm{E}(0, t)$ 는 반시P 방향으로 회전 $\begin{cases} \mathit{Right\ \ Hand\ \ Circularly\ \ Polarized} \\ :\ \mathit{RHCP\ \ wave} \end{cases}$

$\Rightarrow\ E_{10} = E_{20}$: 원형궤적($\mathit{Circularly\ \ Poloarized\ \ wave}$)

$\Rightarrow\ E_{10} \neq E_{20}$: 타원형궤적($\mathit{Elliptically\ \ Poloarized\ \ wave}$)

where,

$$\cos\omega t = \frac{E_1(0,\ t)}{E_{10}}$$

$$\sin\omega t = \frac{E_2(0,\ t)}{E_{20}} = \sqrt{1 - \cos^2\omega t} = \sqrt{1 - \left[\frac{E_1(0,\ t)}{E_{10}}\right]^2}$$

위식을 정리하면

$$\therefore \quad \left[\frac{E_2(0,\ t)}{E_{20}}\right]^2 + \left[\frac{E_1(0,\ t)}{E_{10}}\right]^2 = 1 \quad (7\text{-}28)\text{타원방정식}$$

· $E_{10} = E_{20}$ 인 경우 $\mathrm{E}(0, t)$ 가 $\overline{\mathrm{x}}$ 축과 이루는 각

$$\alpha = \tan^{-1}\frac{E_{20}}{E_{10}} = \omega t \qquad (7\text{-}29)$$

→ 전계 E가 반시계방향으로 일정한 각속도 ω로 회전하는 것

2) 이제 $E_2(z)$ 가 $\pi/2$ 의 위상차가 앞서는 경우

(7-26) : $\mathrm{E}(z) = E_1(z)\overline{\mathrm{x}} + E_2(z)\overline{\mathrm{y}}$ (7-30)

$$= E_{10}e^{-jkz}\overline{\mathrm{x}} + jE_{20}e^{-jkz}\overline{\mathrm{y}}$$

(7-27) : $\mathrm{E}(0, t) = E_{10}\cos\omega t\,\overline{\mathrm{x}} - E_{20}\sin\omega t\,\overline{\mathrm{y}}$ (7-31)

$$= E_1(0, t)\overline{\mathrm{x}} + E_2(0, t)\overline{\mathrm{y}}$$

역시, Elliptically Polarized wave 임.

; Left Hand Circulaly Polarized wave(LHCP wave)

3) 임의의 위상차 δ가 있는 경우(page 371 문제 7-6)

$$E_1(z)\overline{\mathrm{x}} = E_{10}\cos(\omega t - kz)\overline{\mathrm{x}} \qquad (a\text{-}1)$$

$$E_2(z)\overline{\mathrm{x}} = E_{20}\cos(\omega t - kz + \delta)\overline{\mathrm{y}} \qquad (a\text{-}2)$$

$$\frac{E_2(z)}{E_{20}} = \cos(\omega t - kz)\cos\delta - \sin(\omega t - kz)\sin\delta \qquad (a\text{-}3)$$

한편 식(a-1)의 양변에 cos δ 을 곱하면

$$\frac{E_1(z)}{E_{10}}\cos\delta = \cos(\omega t - kz)\cos\delta \qquad (a\text{-}4)$$

식 (a-3)에서 식 (a-4)을 빼면

$$\frac{E_2(z)}{E_{20}} - \frac{E_1(z)}{E_{10}}\cos\delta = -\sin(\omega t - kz)\sin\delta \qquad (a\text{-}5)$$

또한

$$\sin^2(\omega t - kz) = 1 - \cos^2(\omega t - kz) \qquad (a\text{-}6)$$

$$= 1 - \left[\frac{E_1(z)}{E_{10}}\right]^2$$

where, 식 (a-1)에 의해

$$\cos(\omega t - kz) = 1 - \frac{E_1(z)}{E_{10}}$$

식 (a-5)을 제곱하여 식 (a-6)을 대입하면

$$\left[\frac{E_2(z)}{E_{20}} - \frac{E_1(z)}{E_{10}}\cos\delta\right]^2 = \sin^2(\omega t - kz)\sin^2\delta \qquad \text{(a-7)}$$

$$= \left[1 - \left(\frac{E_1(z)}{E_{10}}\right)^2\right]\sin^2\delta$$

전개하며,

$$\left[\frac{E_2(z)}{E_{20}}\right]^2 + \left[\frac{E_1(z)}{E_{10}}\right]^2\cos^2\delta - 2\left[\frac{E_2(z)}{E_{20}}\right]\left[\frac{E_1(z)}{E_{10}}\right]\cos\delta$$

$$= \sin^2\delta - \left[\frac{E_1(z)}{E_{10}}\right]^2\sin^2\delta$$

$$\left[\frac{E_1(z)}{E_{10}}\right]^2[\cos^2\delta + \sin^2\delta] + \left[\frac{E_2(z)}{E_{20}}\right]^2 - 2\left[\frac{E_2(z)}{E_{20}}\right]\left[\frac{E_1(z)}{E_{10}}\right]\cos\delta = \sin^2\delta$$

$$\left[\frac{E_1(z)}{E_{10}}\right]^2 + \left[\frac{E_2(z)}{E_{20}}\right]^2 - 2\left[\frac{E_2(z)}{E_{20}}\right]\left[\frac{E_1(z)}{E_{10}}\right]\cos\delta = \sin^2\delta \qquad \text{(a-8)}$$

여기서, $\delta = \pm\frac{\pi}{2}$, $\pm\frac{3\pi}{2}$, … 이면, 식 (1-8)은 다음과 같다.

$$\therefore \quad \left[\frac{E_2(0,\,t)}{E_{20}}\right]^2 + \left[\frac{E_1(0,\,t)}{E_{10}}\right]^2 = 1 \qquad \text{(7-28)}$$

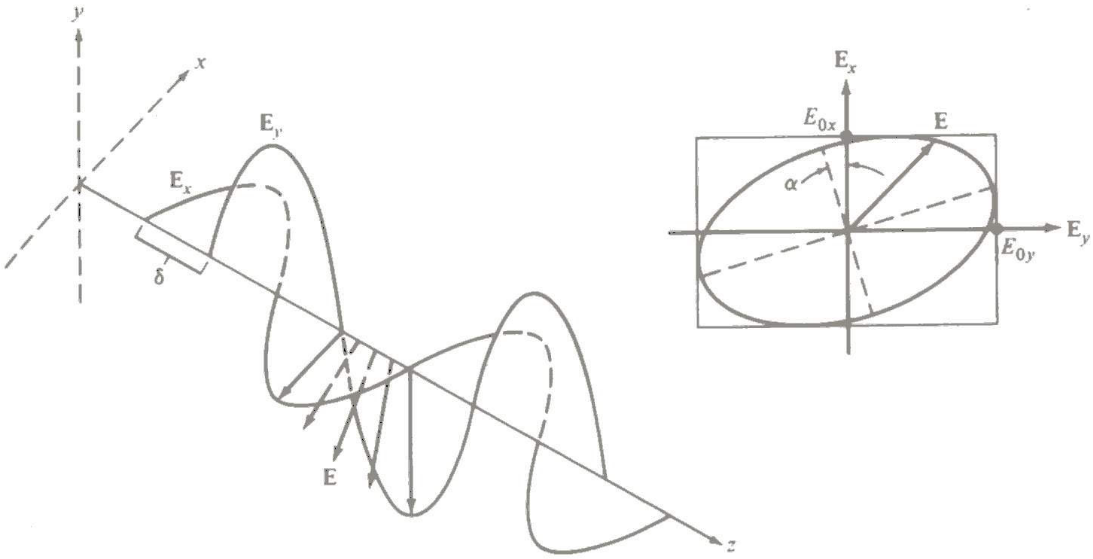


FIGURE 2-4
Elliptically polarized light results from the addition of two linearly polarized waves of unequal amplitude having a nonzero phase difference δ between them.