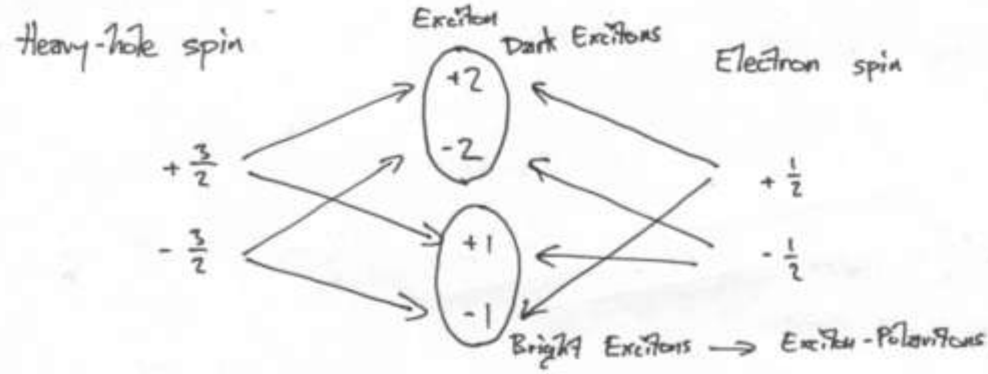
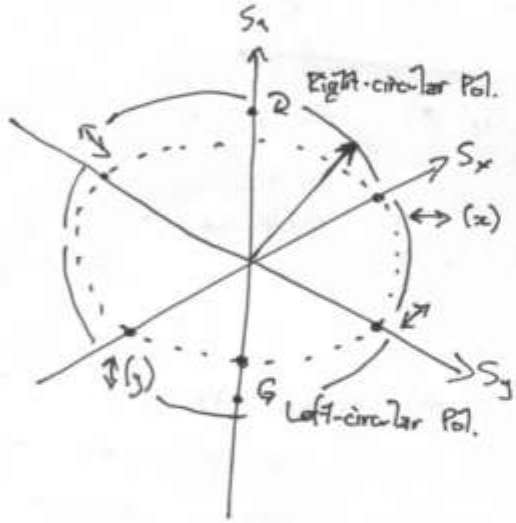
II - Spin Structure

Zinc blend structures, e.g., GaAs



— Pseudospin (Stokes') vector —



Spin density matrix

$$\underset{\approx}{\rho}_{\vec{k}} = \frac{N_{\vec{k}}}{2}\underset{\approx}{I} + \vec{S}_{\vec{k}} \cdot \underset{\approx}{\hat{\sigma}}$$

Coherent state: pseudospin lies on the sphere

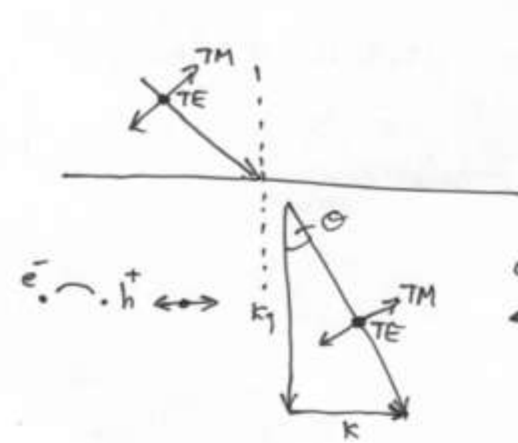
$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$

$$\sigma_y = \begin{pmatrix} 0 & -i \\ +i & 0 \end{pmatrix}$$

$$\sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

pseudovector!

TE-TM splitting



$$\sim \cos\theta = \sqrt{1-\sin^2\theta} = \sqrt{1-\frac{k^2}{k^2+k_z^2}}$$

$$\approx 1 - \frac{k^2}{2(k^2+k_z^2)} \approx 1 - \frac{k^2}{2k_z^2}$$

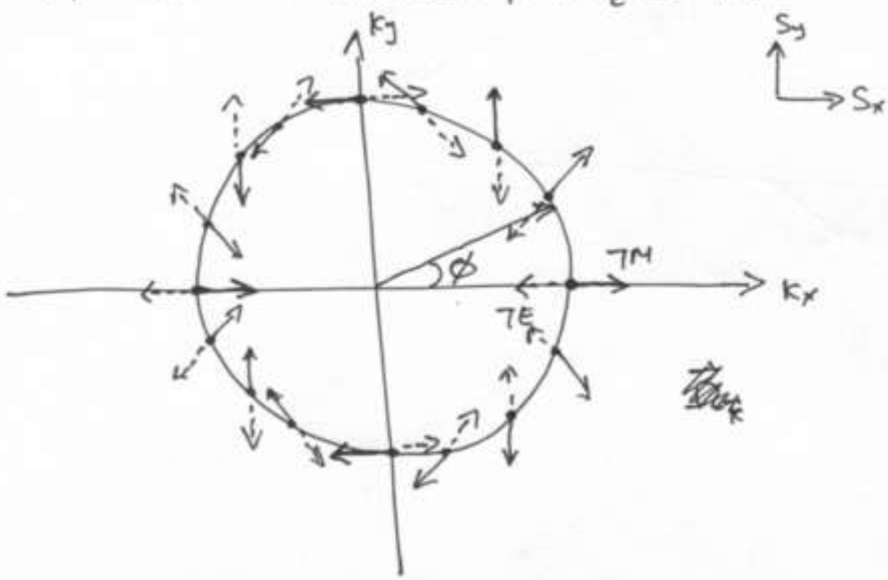
TE-TM splitting $\sim k^2$ for small angles

Exact k dependence is more complicated, but will not affect the results of this course

The orientation of TE & TM modes (eigenmodes) depends on orientation of k.

Pseudospin

Representation of TM modes for a given |k|



. pseudospin rotates at double the angle of the in-plane wavevector for TM states

Electrons in magnetic field:

$$\hat{\mathcal{H}}_e = \frac{\hbar}{2}\left(\hat{\sigma}.\vec{\Omega}\right)$$

operate on electron spin

$+\frac{1}{2} : \begin{pmatrix}1\\0\end{pmatrix}$

$-\frac{1}{2} : \begin{pmatrix}0\\1\end{pmatrix}$

TE-TM splitting for polaritons

$$\hat{\mathcal{H}}_{TE\text{-}TM,\vec{k}} = \frac{\hbar}{2}\left(\hat{\sigma}.\vec{\Omega}_{\vec{k}}\right)$$

operate on polariton pseudospin — Effective magnetic field

Right-circular pol. : $\begin{pmatrix}1\\0\end{pmatrix}$ &

left-circular pol. : $\begin{pmatrix}0\\1\end{pmatrix}$

Ω_k should be parallel to the pseudospin of TM states & anti-parallel to the pseudospin of TE states.

$$\Omega_{\vec{k}} = \Omega_0 |\vec{k}|^2 \left[\cos(2\phi)\hat{i} + \sin(2\phi)\hat{j} \right] \qquad \cos\phi = \frac{k_x}{|\vec{k}|}$$

$$\downarrow \qquad \sin\phi = \frac{k_y}{|\vec{k}|}$$

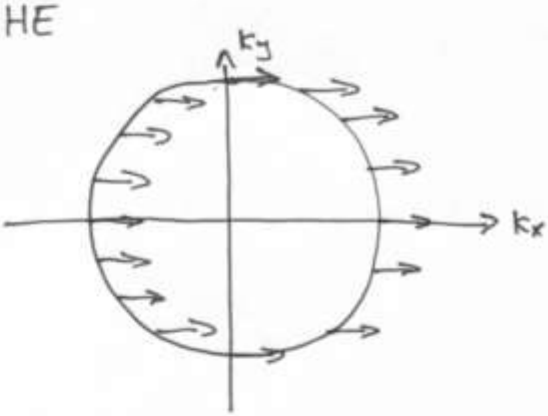
$$= \Omega_0 |\vec{k}|^2 \left[(\cos^2\phi - \sin^2\phi)\hat{i} + 2\sin\phi\cos\phi\,\hat{j} \right]$$

$$\therefore \hat{\mathcal{H}}_{TE-TM} = \frac{\hbar\Omega_0}{2} \begin{pmatrix} 0 & k_x^2 - k_y^2 - 2ik_xk_y \\ k_x^2 - k_y^2 + 2ik_xk_y & 0 \end{pmatrix}$$

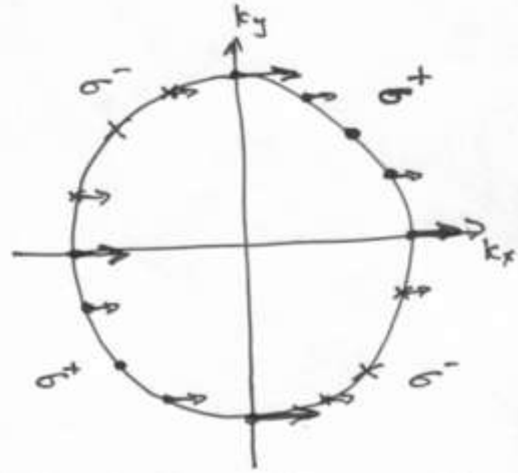
$$= \frac{\hbar\Omega_0}{2} \begin{pmatrix} 0 & (k_x - ik_y)^2 \\ (k_x + ik_y)^2 & 0 \end{pmatrix}$$

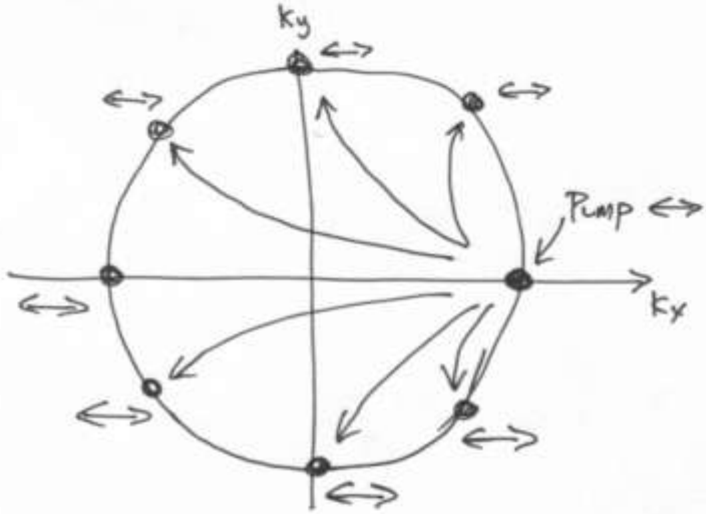
$$\frac{\partial \vec{S}_k}{\partial t} = \vec{S}_{\vec{k}} \times \vec{\Omega}_{\vec{k}} \qquad \text{pseudospin precession}$$

• OSHE



Influence of TE-TM splitting $\longrightarrow$





Rayleigh scattering

$\vec{k}$ can change direction

$|\vec{k}|$ conserved since the energy of polaritons is conserved

$$i\hbar\frac{\partial}{\partial t}\begin{bmatrix}\psi_+(\vec{k})\\ \psi_-(\vec{k})\end{bmatrix} = \left[E(k) - \frac{i\Gamma}{2} + \frac{\hbar}{2}\left(\hat{\sigma}\cdot\vec{\Omega}(\vec{k})\right)\right]\begin{bmatrix}\psi_+(\vec{k})\\ \psi_-(\vec{k})\end{bmatrix}$$

$$+ \int V(\vec{k}')\begin{bmatrix}\psi_+(\vec{k}-\vec{k}')\\ \psi_-(\vec{k}-\vec{k}')\end{bmatrix} d\vec{k}' + \begin{bmatrix}F_+(\vec{k})\\ F_-(\vec{k})\end{bmatrix} e^{-i\omega t}$$