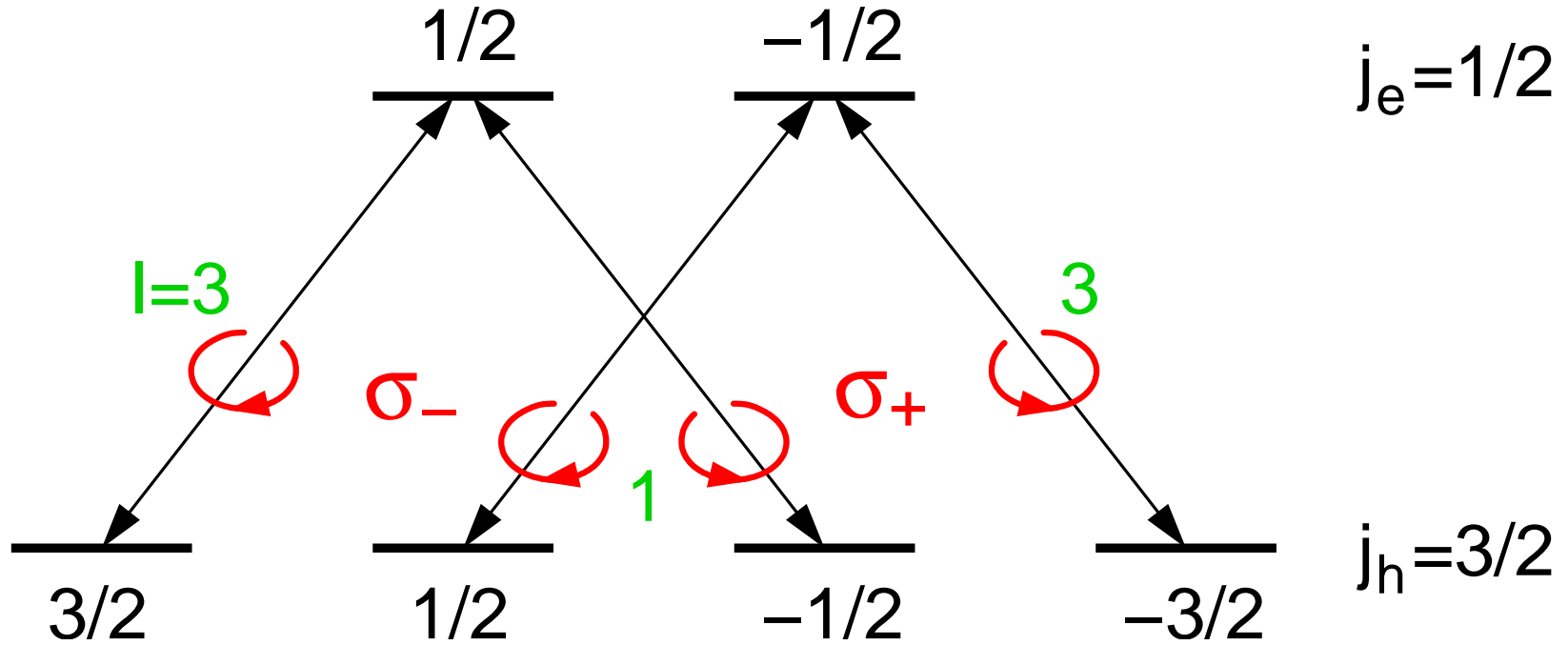


# Optical Spin Orientation



# Spin Relaxation Mechanisms

## (1) D'yakonov-Perel' (DP) mechanism

spin precession in random effective magnetic field due to

- +  $B = 0$  spin splitting
- + momentum scattering

## (2) Bir-Aronov-Pikus (BAP) mechanism

spin-flip scattering of electrons by holes due to

- + occupied (!) hole states
- + electron-hole exchange interaction  $\propto \boldsymbol{\sigma}_e \cdot \boldsymbol{\sigma}_h$
- + spin-orbit splitting of the valence band

## (3) Elliot-Yafet (EY) mechanism

spin-flip scattering of electrons due to

- +  $\mathbf{k} \cdot \mathbf{p}$  coupling between conduction and valence band states
- + spin-orbit splitting of the valence band
- + momentum scattering

# Spin Precession

- time evolution of a spin-1/2 state  $|\chi\rangle$

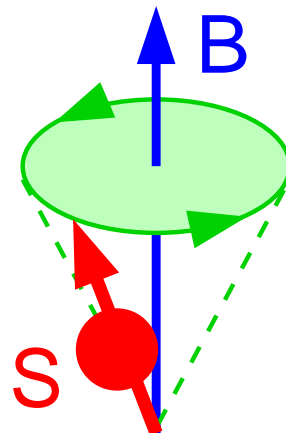
$$i\hbar \frac{d}{dt} |\chi\rangle = \frac{\hbar}{2} \boldsymbol{\sigma} \cdot \boldsymbol{\Omega} |\chi\rangle \quad \boldsymbol{\Omega} = \frac{\boldsymbol{\mathcal{B}}}{\hbar}$$

- consider  $\mathbf{S} \equiv \langle \chi | \boldsymbol{\sigma} | \chi \rangle$

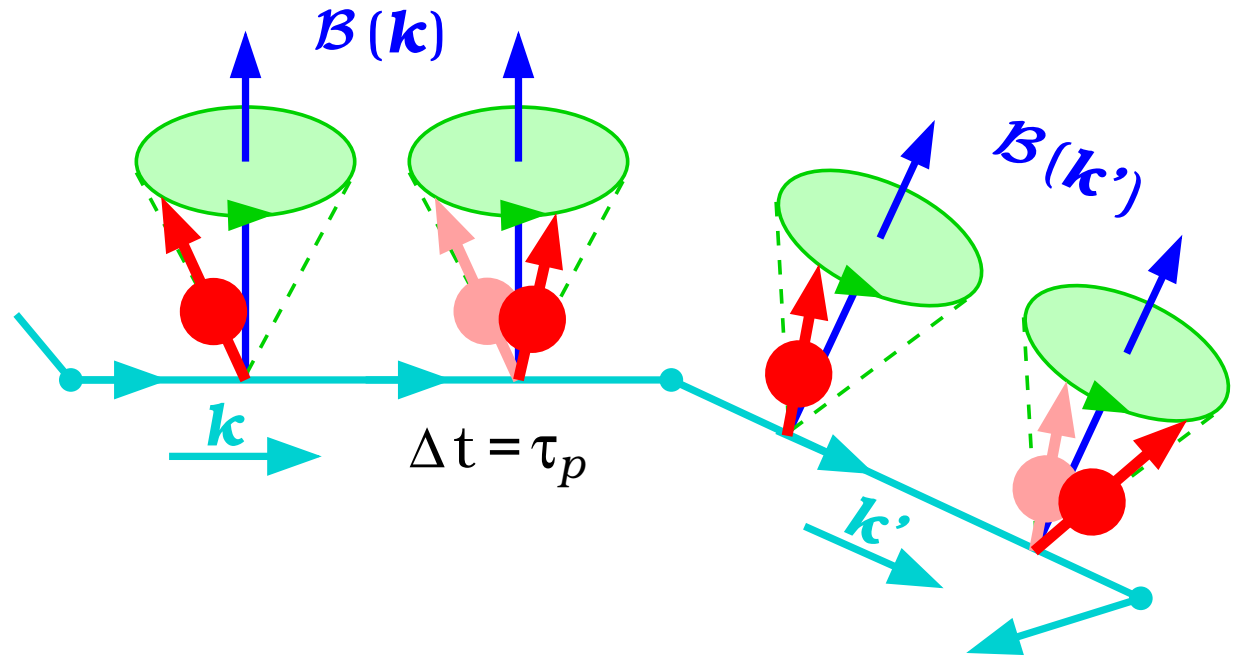
$$\begin{aligned} \dot{\mathbf{S}} &= \langle \dot{\chi} | \boldsymbol{\sigma} | \chi \rangle + \langle \chi | \boldsymbol{\sigma} | \dot{\chi} \rangle \\ &= \frac{i}{2} \langle \chi | [\boldsymbol{\sigma} \cdot \boldsymbol{\Omega}, \boldsymbol{\sigma}] | \chi \rangle \\ &= \langle \chi | \boldsymbol{\sigma} | \chi \rangle \times \boldsymbol{\Omega} \end{aligned}$$

$\Rightarrow$

$$\dot{\mathbf{S}} = \mathbf{S} \times \boldsymbol{\Omega}$$



# Dyakonov-Perel Spin Relaxation



random walk:

$$\Delta x^2(t) = l^2 n t$$

$l$  = step length  
 $n$  = # steps per time

random spin precession

$$\Delta \varphi^2(t) = (\Omega \tau_p)^2 \frac{1}{\tau_p} t = \Omega^2 \tau_p t$$

$\Omega = \frac{\mathcal{B}}{\hbar}$  = precession frequency

$\tau_p$  = momentum relaxation time

spin relaxation time  $\tau_s$

$$1 \stackrel{!}{\sim} \Delta \varphi^2(t = \tau_s) = \Omega \tau_p \tau_s$$

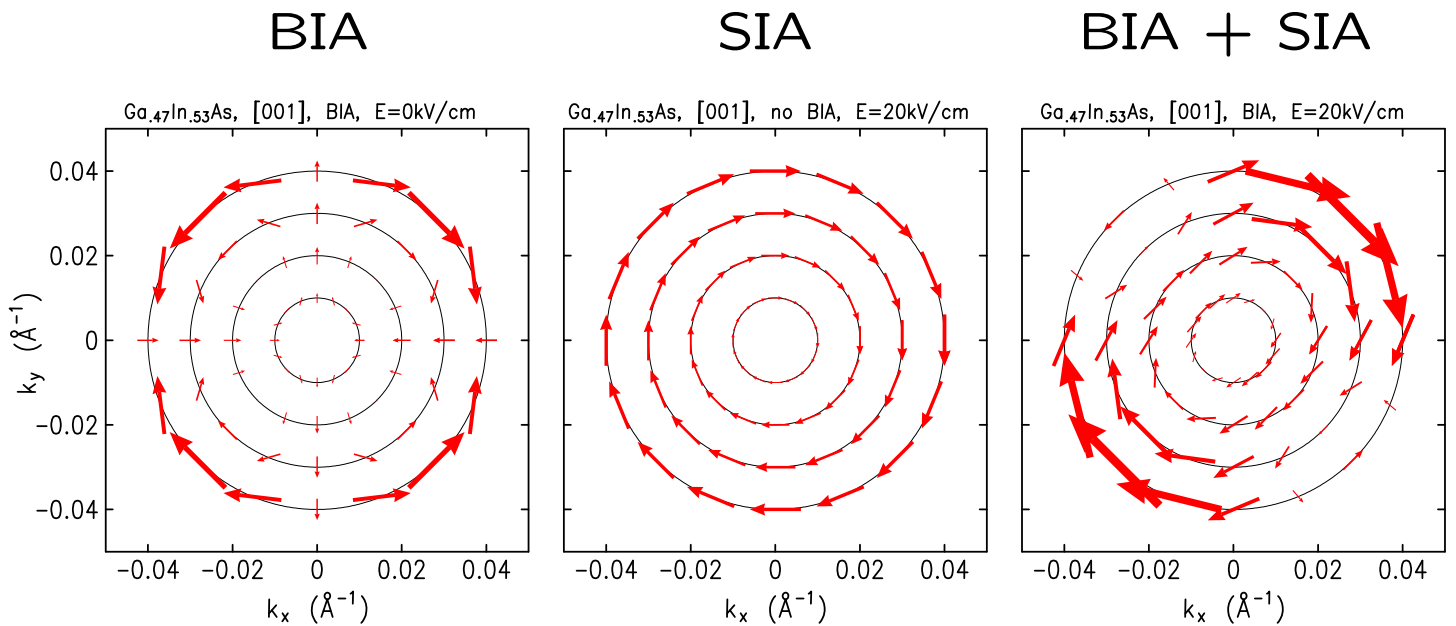
$\Rightarrow$

$$\frac{1}{\tau_s} \sim \Omega^2 \tau_p$$

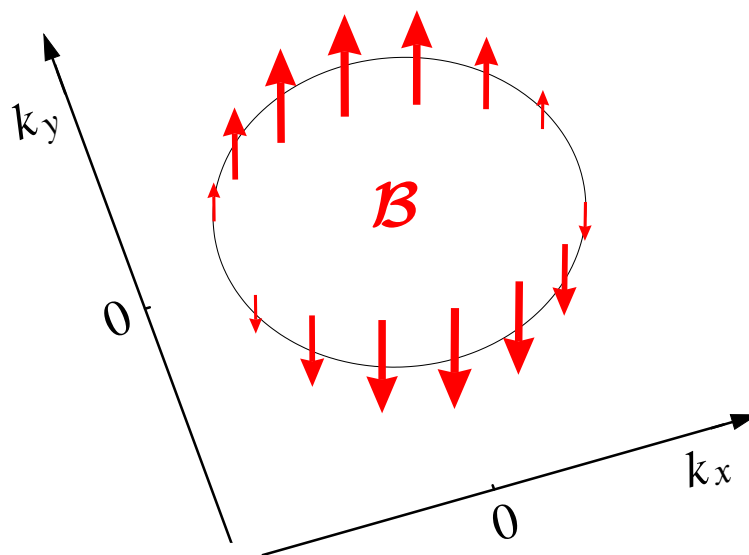
provided  $\tau_p \ll \tau_s$

# Tuning DP Spin Relaxation

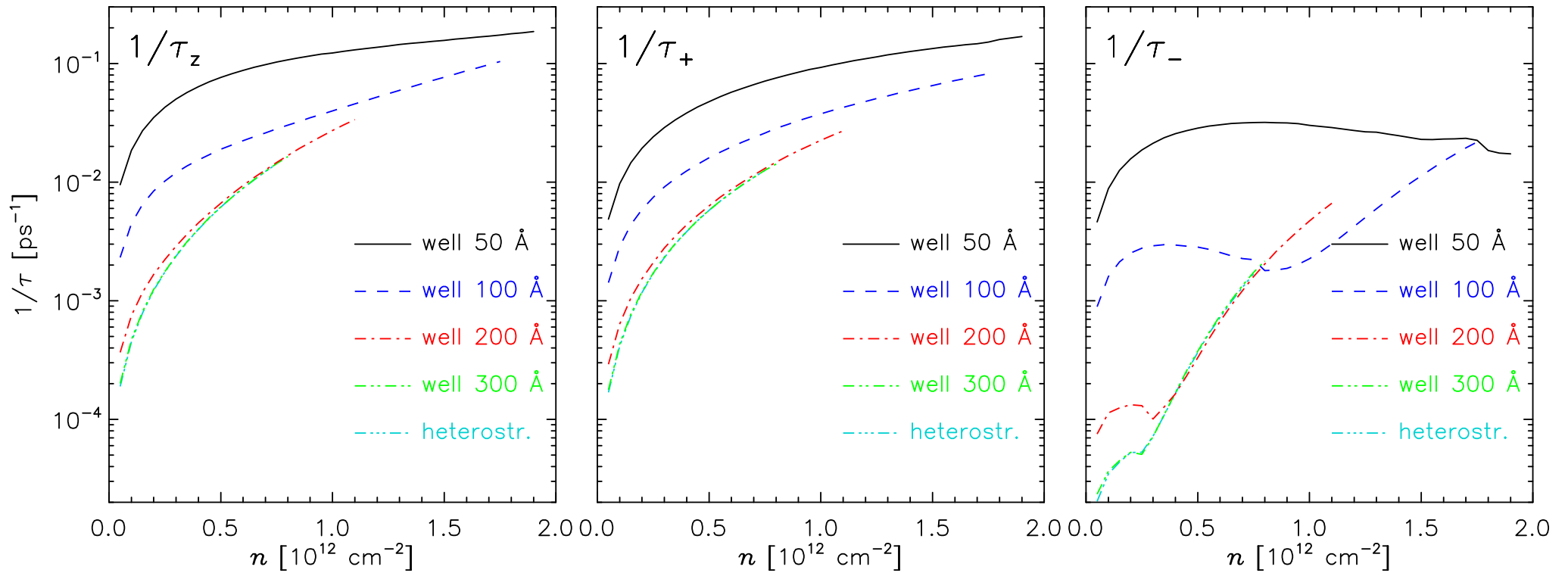
## (a) [001] surface



## (b) [110] surface



# Dyakonov-Perel Spin Relaxation (3)



symmetric (100)  
GaAs-Al<sub>0.35</sub>Ga<sub>0.65</sub>As QW,  
PRB **68**, 075322 (2003)