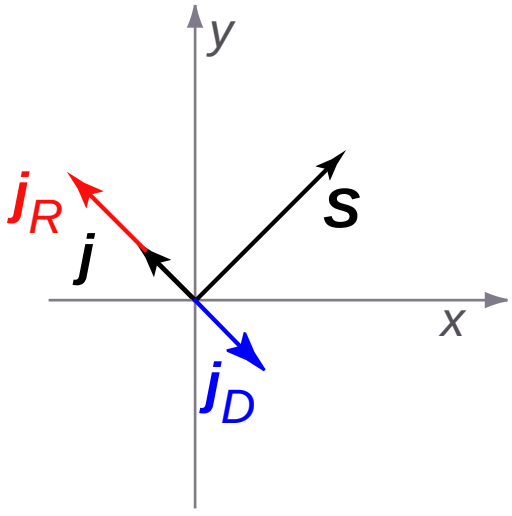
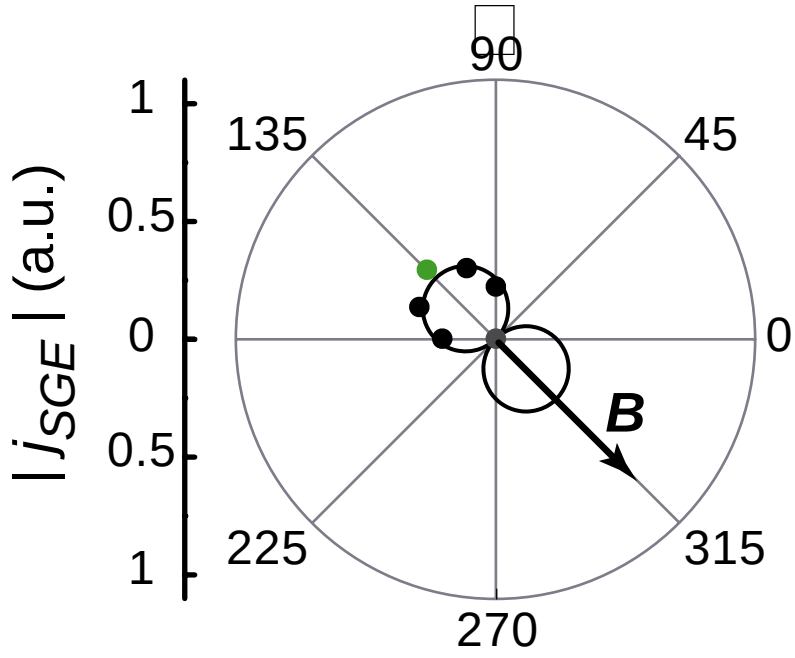
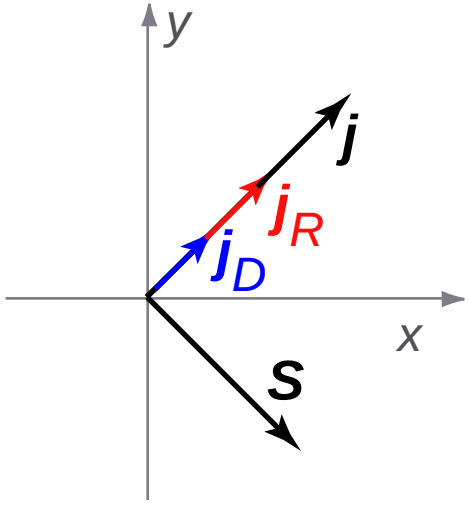
SGE, method -II

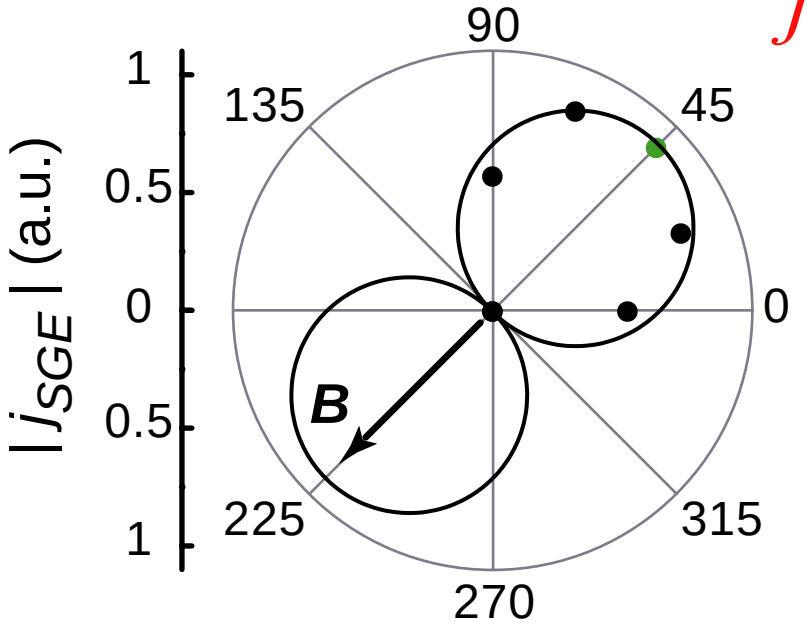




$j = j_D - j_R$

$j_R / j_D = \alpha / \beta = 2.15$

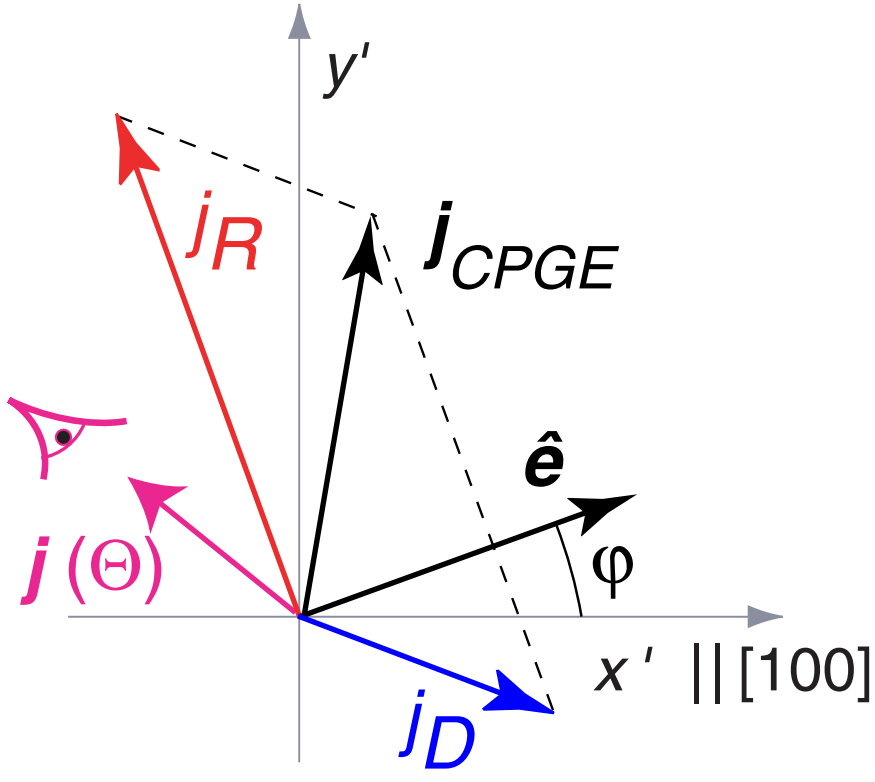


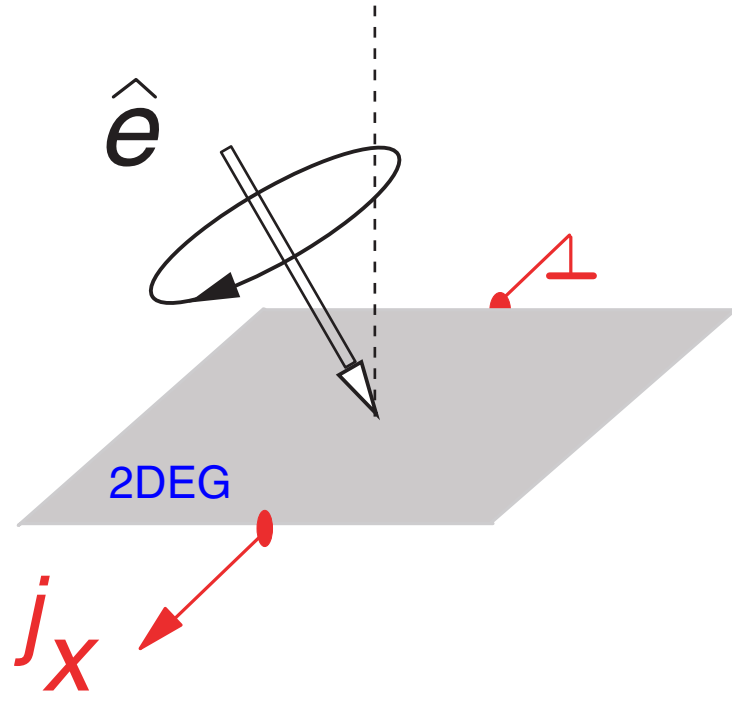


$j = j_D + j_R$

Experimental Details of CPGE

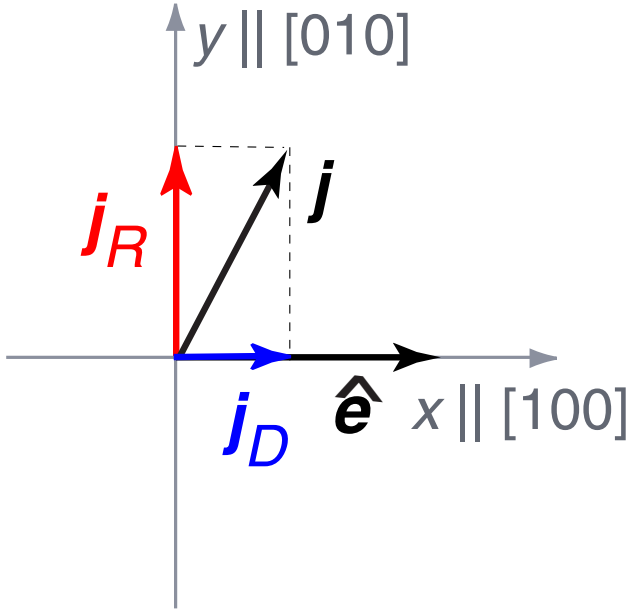
$$\vec{j}_{CPGE} = \begin{pmatrix} \beta & -\alpha \\ \alpha & -\beta \end{pmatrix} \hat{e}\, P_{circ}$$

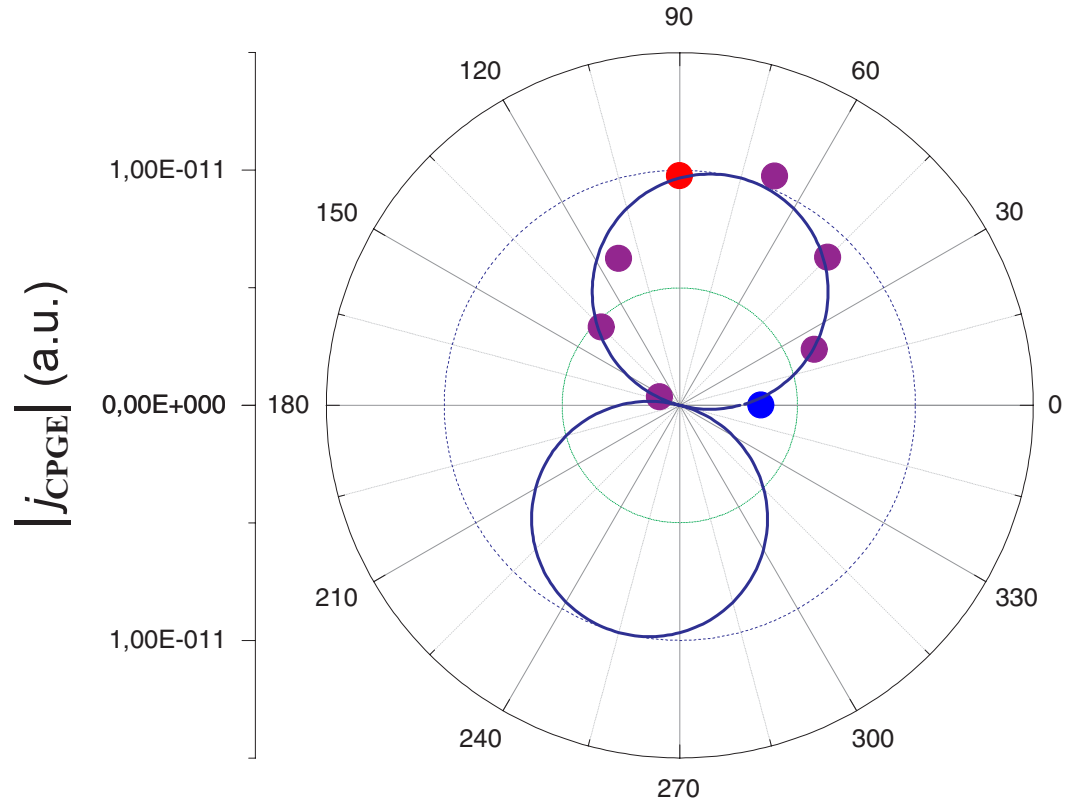




Experiments on the details of the band structure

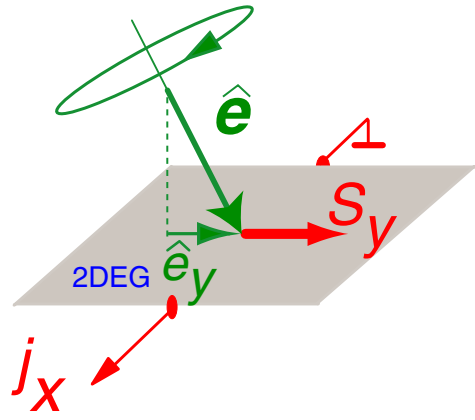
CPGE current: $\vec{j}_{CPGE} = \begin{pmatrix} \beta & -\alpha \\ \alpha & -\beta \end{pmatrix} \hat{e}\, P_{circ}$ $\quad j_R/j_D = \alpha/\beta$





InAs: $\alpha/\beta = 2.15$

Spin-galvanic effect at optical exitation



Circular Photogalvanic Effect

Phys. Rev. Lett. **86**, 4358 (2001)

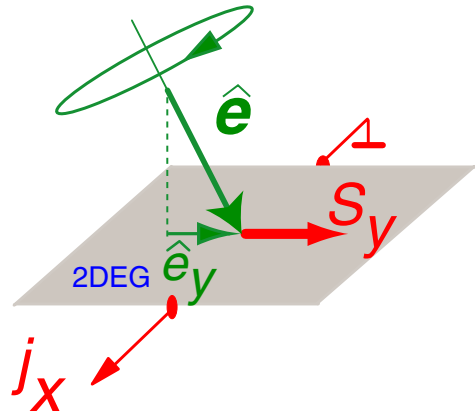
Spin-Galvanic Effect

Nature **417**, 153 (2002)

$$j_{x,\mathrm{CPGE}} = \gamma_{xy}\, \hat{e}_y E^2 P_{circ}$$

$$j_{x,\mathrm{SGE}} = Q_{xy} S_y \propto \hat{e}_y E^2 P_{circ}$$

Spin-galvanic effect at optical exitation



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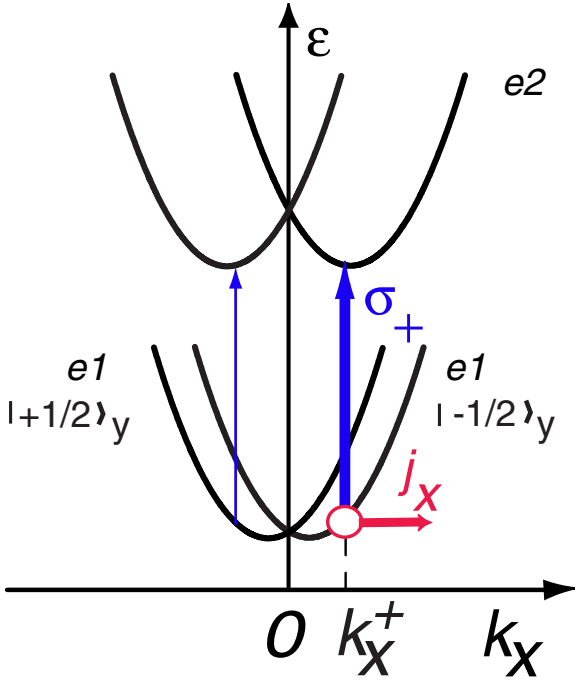

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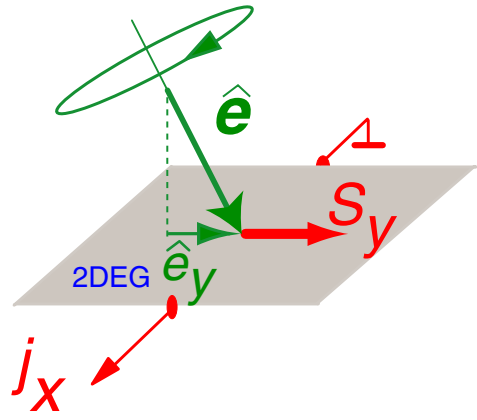

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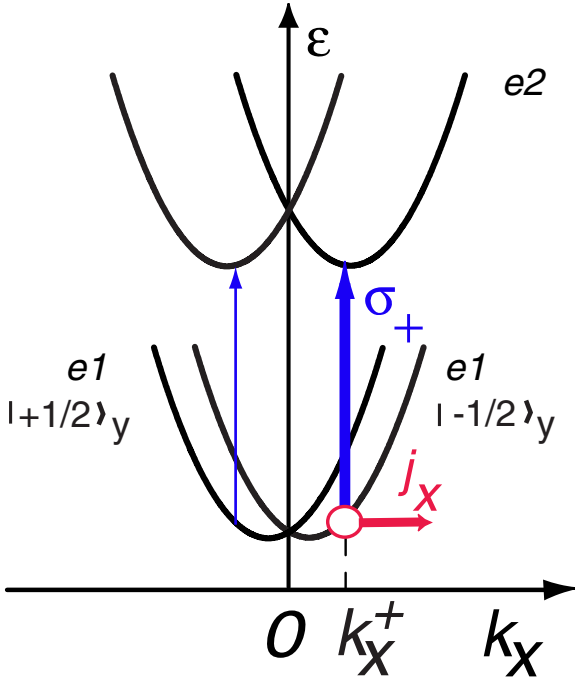
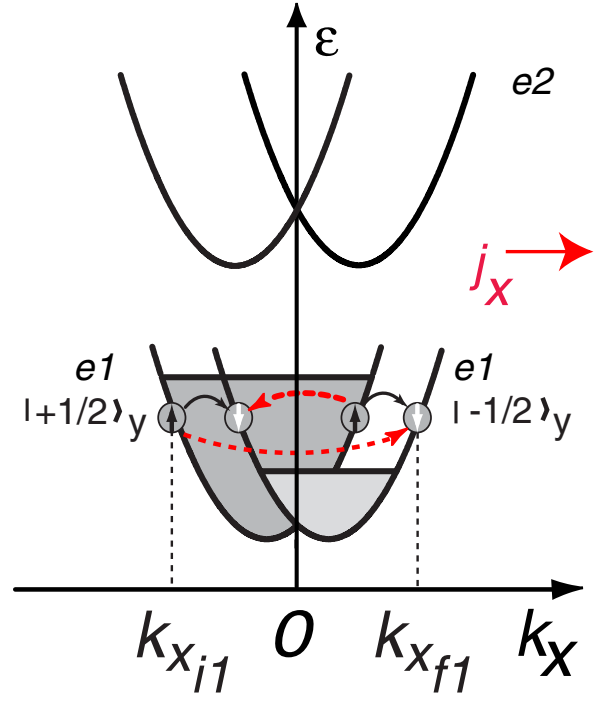
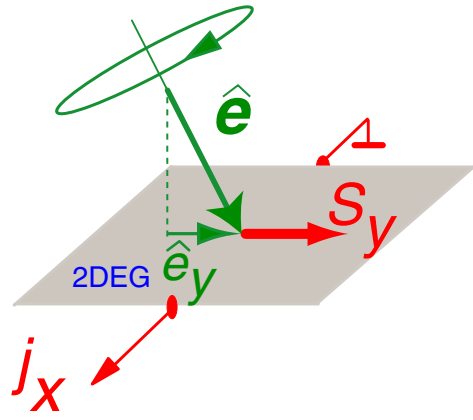




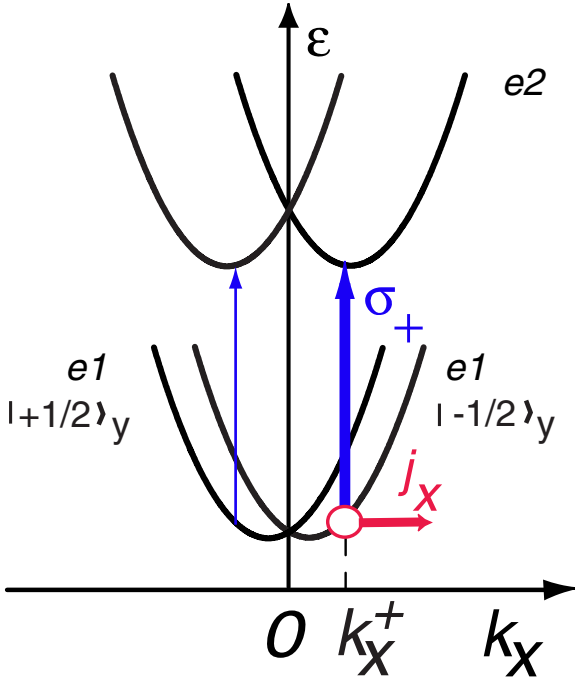
Spin-galvanic effect at optical exitation



Circular Photogalvanic Effect

Phys. Rev. Lett. **86**, 4358 (2001)

$$j_{x,\mathrm{CPGE}} \propto \tau_{p1} \frac{d\,\eta_{21}(\hbar\omega)}{d\,\hbar\omega}$$



$$j_{x,\mathrm{CPGE}} = \gamma_{xy}\, \hat{e}_y E^2 P_{circ}$$

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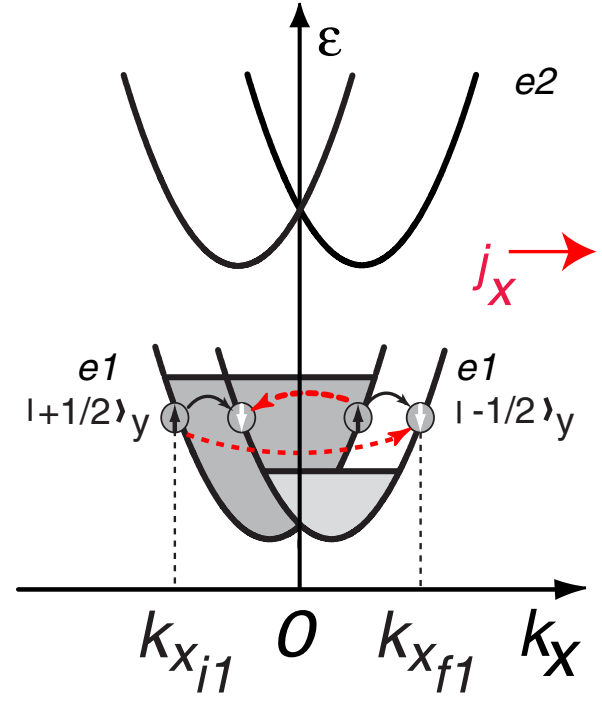
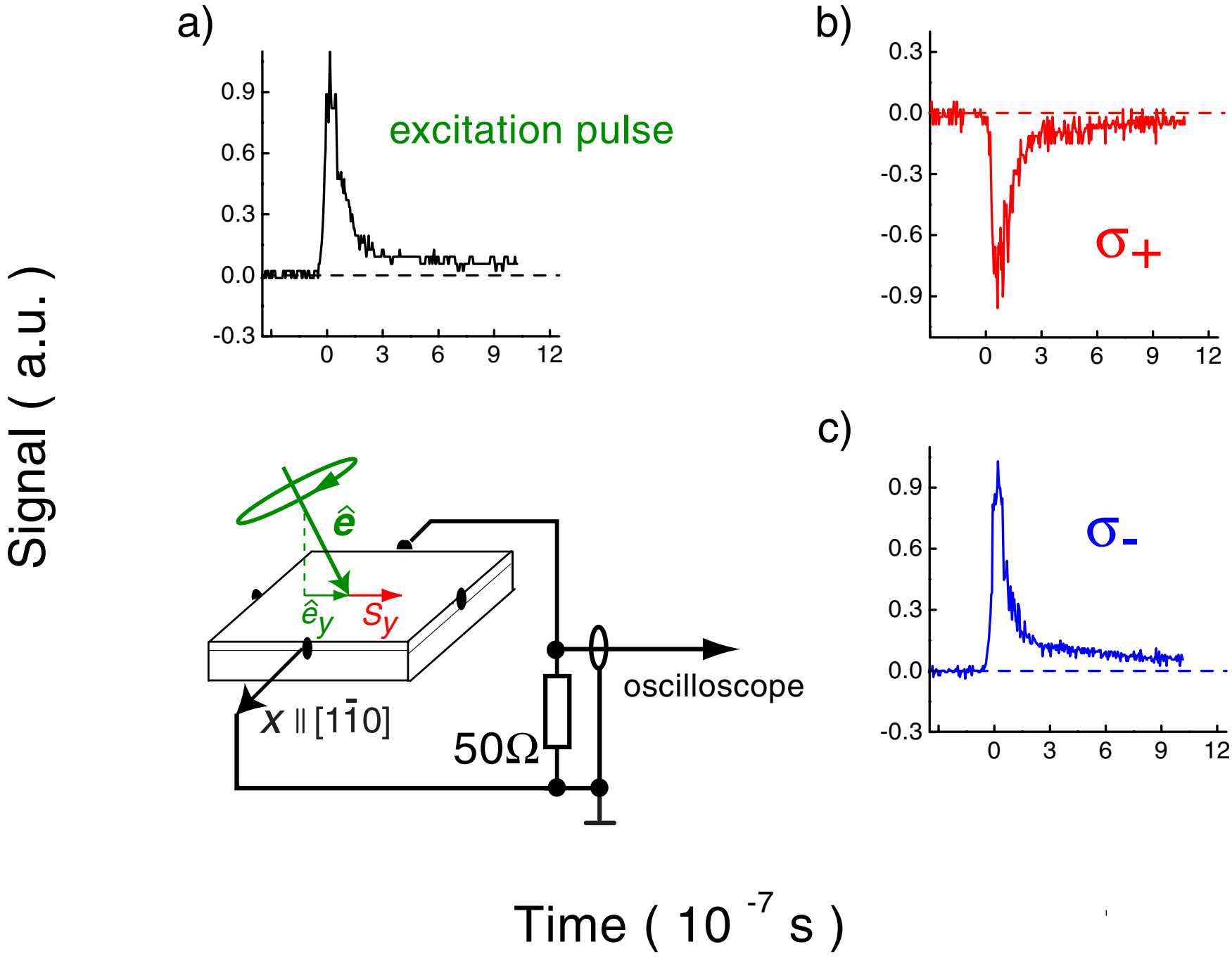
Spin-Galvanic Effect

Nature **417**, 153 (2002)

$$j_{x,\mathrm{SGE}} \propto \tau_{s1}\, \eta_{21}(\hbar\omega)$$

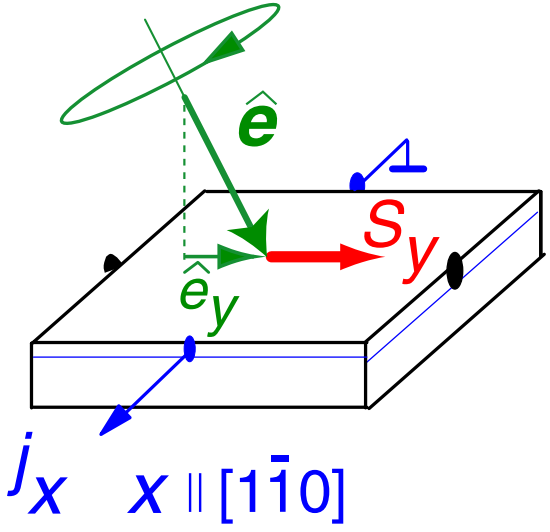


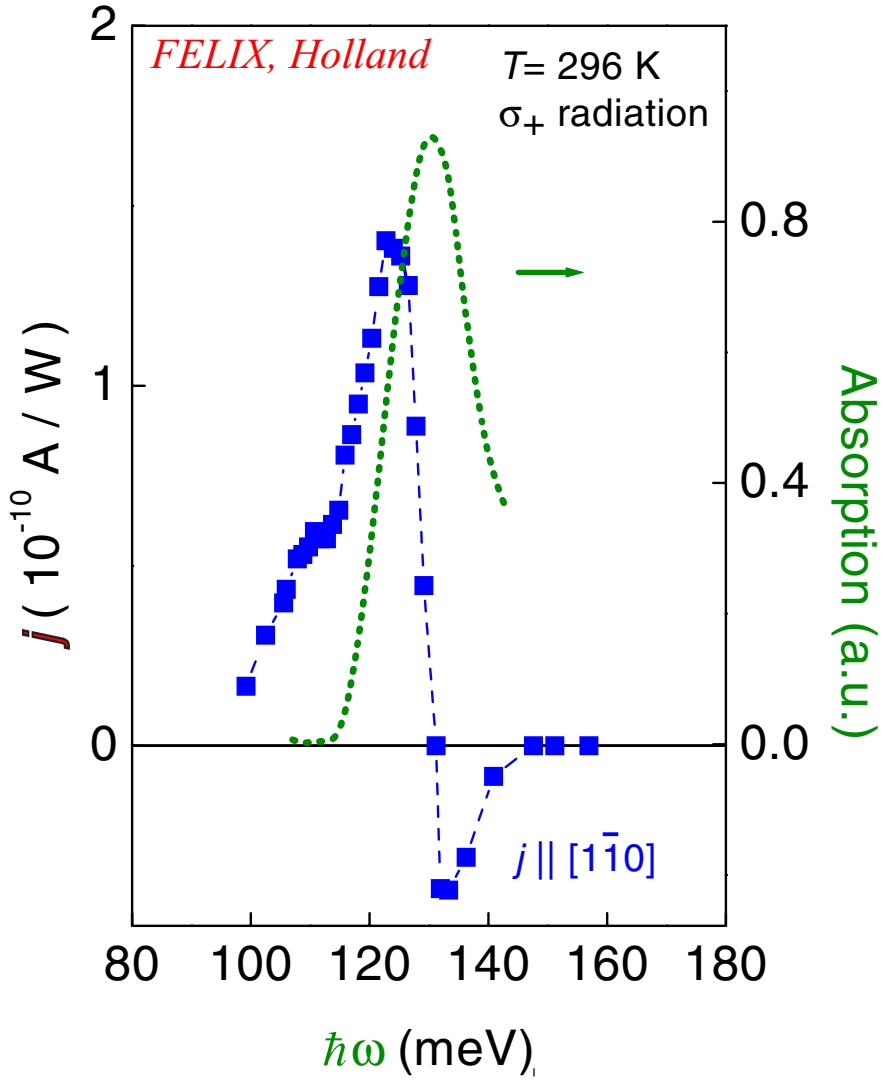
Spin galvanic effect at optical excitation



PRB (2003), cond-mat/0303193

Separation of CPGE and the spin-galvanic effect
(*e1-e2* transitions in *n*-type GaAs QWs)





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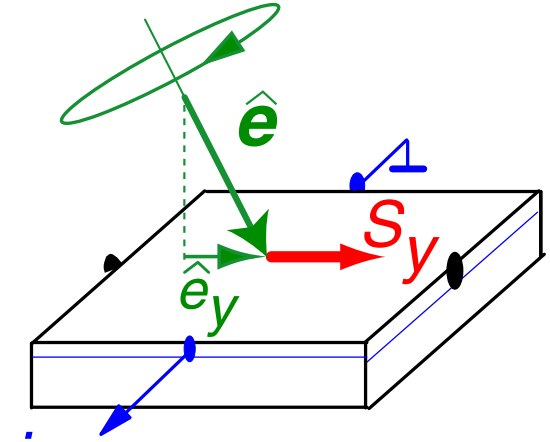
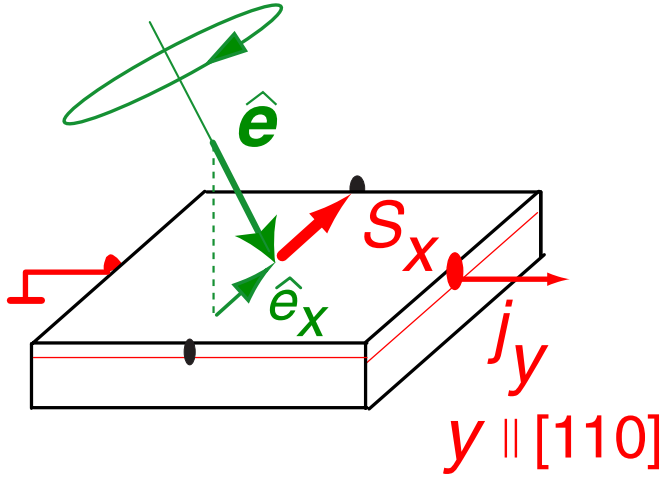
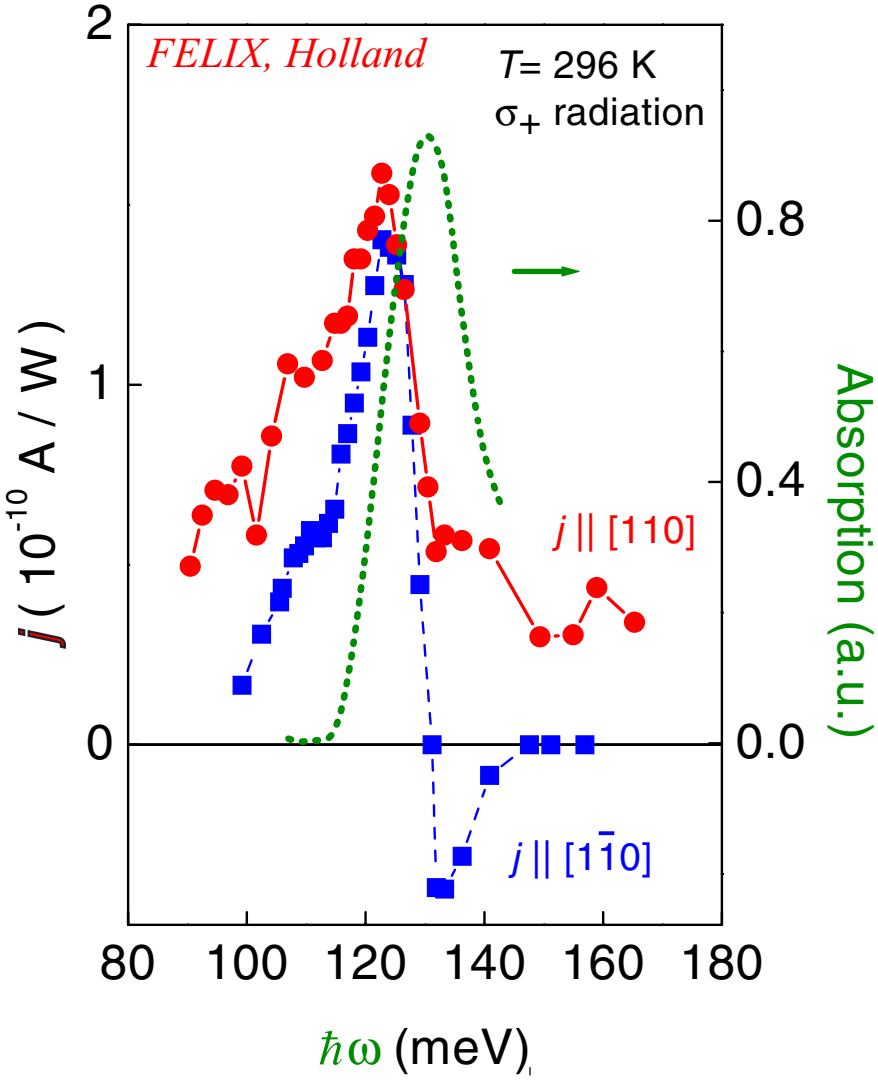






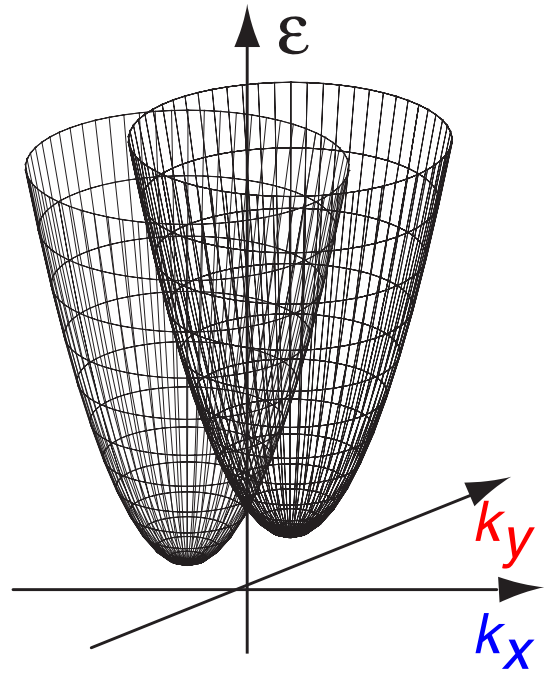
$$\hat{H}_{SO} = \sum_{lm} \beta_{lm} \sigma_l k_m$$

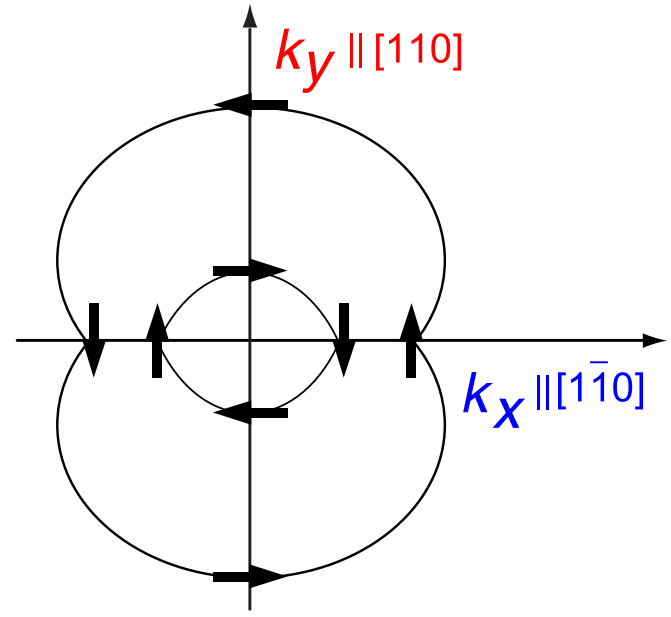
Rashba term

$$\alpha = (\beta_{xy} + \beta_{yx})/2$$

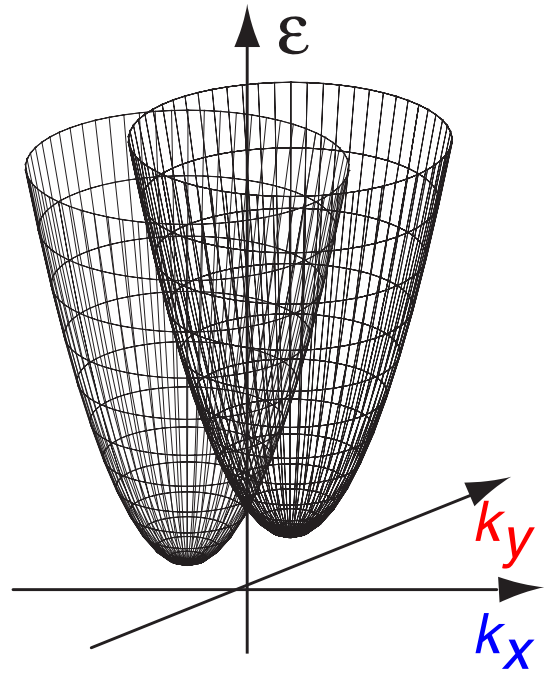
Dresselhaus term

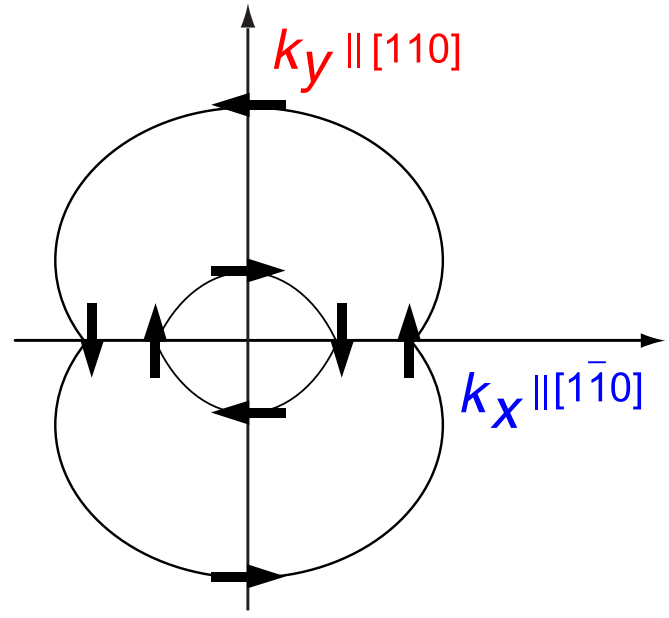
$$\beta = (\beta_{xy} - \beta_{yx})/2$$





$$\hat{H}_{SO}=\sum_{lm}\beta_{lm}\sigma_l k_m$$





Rashba term

$$\alpha = (\beta_{xy}+\beta_{yx})/2$$

Dresselhaus term

$$\beta = (\beta_{xy}-\beta_{yx})/2$$

[1$\bar{1}$0] $$j_x = \{A_{CPGE}[(\beta^{(1)} - \alpha^{(1)}) - (\beta^{(2)} - \alpha^{(2)})] + A_{SGE}(\beta^{(1)} - \alpha^{(1)})\} P_c \hat{e}_y$$

[110] $$j_y = \{A_{CPGE}[(\beta^{(1)} + \alpha^{(1)}) - (\beta^{(2)} + \alpha^{(2)})] + A_{SGE}(\beta^{(1)} + \alpha^{(1)})\} P_c \hat{e}_x$$

Applications

- Spin relaxation times at monopolar spin orientation due to infrared excitation

  - spin-sensitive bleaching (PRL **88**, 057401, 2002)
  - Hanle effect in spin-galvanic effect (*Nature* **417**, 153. 2002)

- Rashba and Dresselhaus spin splitting in the band structure

- In-plane symmetry of QWs (J. Phys.: Condens. Matter **15**, R935, 2003)

- Experimental demonstration of the monopolar spin orientation

- Fast room temperature infrared detectors of radiation helicity (Int. J. IMMW, 2003)

Summary

The experiments carried out on diverse types of quantum wells have shown, that a uniform non-equilibrium spin orientation in low symmetrical QWs gives rise to an electric current. Spin photocurrents offer a new access to investigation of QW band structure, in-plane symmetry and spin relaxation times.

review: J. Phys.: Condens. Matter **15**, R935, 2003

The End