All-electric quantum point contact spin-polarizer

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Device Properties

- InAs/InGaAs Quantum Well
- Large intrinsic SO-Coupling
  - $\mu \approx 5 \cdot 10^4 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$
  - $n \approx 1.2 \cdot 10^{12} \text{ cm}^{-2}$
- Wet-etched trenches
Quantized Conductance

- Asymmetric Potential → Plateau at 0.5G₀
- Spin Degeneracy lifted?
Temperature Dependence

- In plane B-field has no influence on plateau
- Feature can be seen up to $T \approx 13\, \text{K}$ and $V_{DS} \approx 1\, \text{mV}$
Behaviour in Magnetic Field

- Perpendicular B-field lifts plateau from 0.5 $G_0$ to $G_0$
- No direction dependence → Only indirect influence of B-field through $e^-$-density
Approach of Explanation

- Free $e^-$-approximation
- Neglect Rashba Coupling
- Landauer Formalism

\[
H = H_0 + H_{SO}
\]
\[
H_0 = \frac{\hbar^2 (k_x^2 + k_y^2)}{2m^*} + U(y)
\]
\[
H_{SO} = \beta \vec{\sigma} \cdot (\vec{k}_x \times \nabla U(y))
\]
Simulations

- No Plateau, asymmetric distribution of spin polarisation
- Add “by hand“ and additional interaction term

\[ H^\sigma = H_0^\sigma + \sum_{\text{int}}^\sigma (\vec{r}) \]

\[ H_0^\sigma = \frac{\hbar^2}{2m^*} \left( k_x^2 + k_y^2 \right) + U(y) + H_{SO} \]

\[ \sum_{\text{int}}^\sigma (\vec{r}) = \gamma n_{-\sigma} (\vec{r}) \]
Simulations

- „Proof“ of concept
- Only 25nm channel simulated
- $\Delta_{sp} \approx 43.5 \text{ meV}$
- $\gamma$ depends on the e- density
  $\rightarrow \gamma$ can be tuned with perpendicular B-field
No spin orbit coupling needed

- Strong repulsive interaction leads to increased asymmetry → Spin polarisation

- Strength of the initial lateral SO-Coupling is secondary

\[ P = \frac{G_+ - G_-}{G_+ + G_-} \]
Conclusion

• An asymmetric QPC potential gives rise to plateau at $0.5G_0$
• Not material dependent, initial spin balance needed

For an all electric spin polarizer, there has to be:
  Lateral spin orbit coupling
  Asymmetric confinement
  Strong repulsive Coulomb interaction

BUT:
• No DIRECT evidence!
Outlook – Direct evidence