Spin relaxation of a quantum impurity system with spin-orbit coupling

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Introduction and background

Spin-orbit coupling

SO-coupling is originated from a relativistic particle in an electromagnetic field

Ex.) Spin-Hall effect

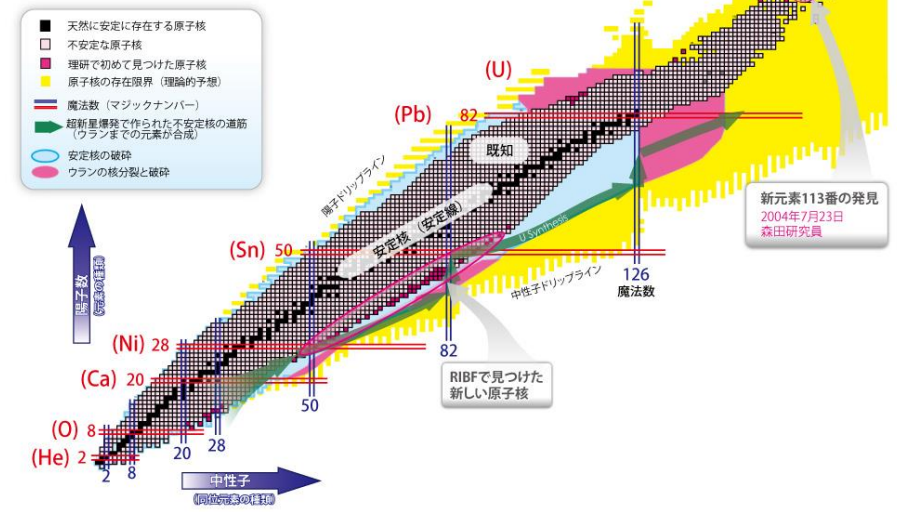$$H_{so} = \boldsymbol{s} \cdot (\boldsymbol{\alpha} \times \boldsymbol{p})$$

$$\boldsymbol{\alpha} = -\frac{e}{2m^2} \boldsymbol{\nabla}\phi$$

In general, it's small

The coupling appears in various system

Condensed matter

Nuclear physics
Ex.) magic number of a nucleus

Nuclide chart

https://www.nishina.riken.jp/researcher/archive/illust.html

SO-coupling is intrinsic in a system

It's tunable in cold atom system
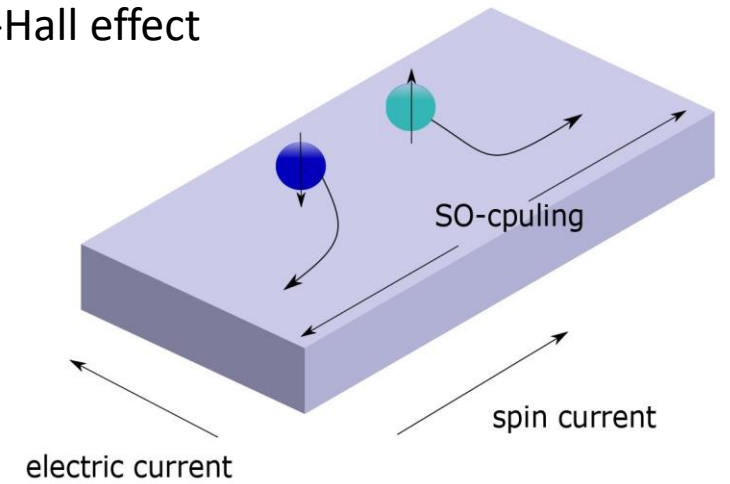
SO-coupling in ultra-cold atom system

Lin, YJ., Jiménez-García, K. & Spielman, I. Spin–orbit-coupled Bose–Einstein condensates. Nature 471, 83–86 (2011).
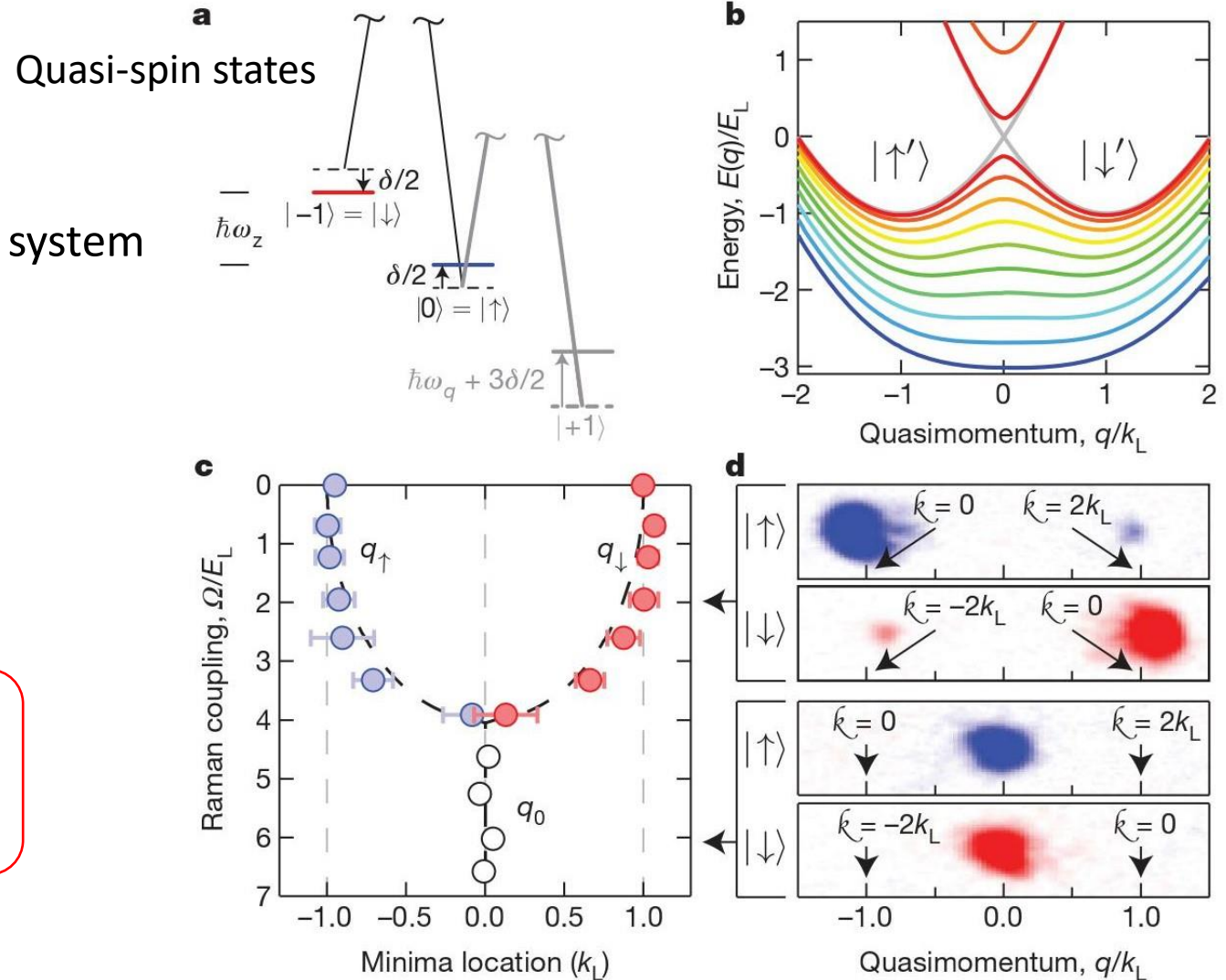
Neutral

Quasi-spin states

The coupling is realized by lasers in ultra-cold atom system

2D SO-coupling
(Rashba and Dresselhaus type)

The strength is tunable

We focus spin dynamics (spin relaxation) from SO-coupling

Introduction and background

The spin relaxation mechanism by SO-coupling

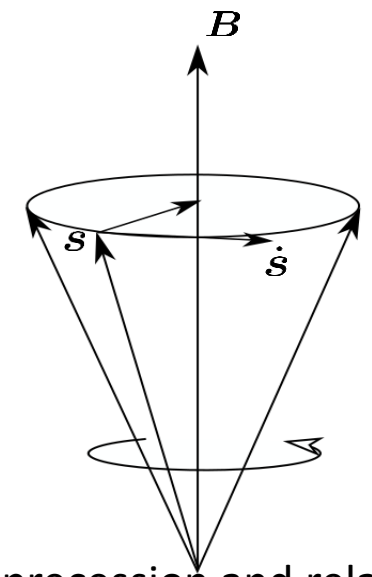Ex.) NMR (magnetic field + spin-spin interaction)

Spin relaxation ・・・ A transition with spin-flip

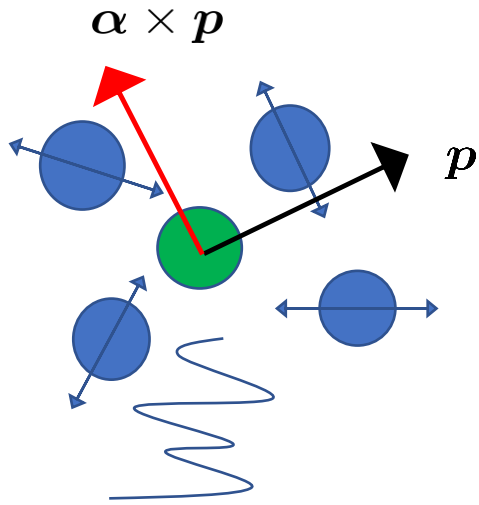Bias (magnetic field) + Interaction between spin and other degrees of freedom

Spin precession and relaxation in the magnetic field

The mechanism by SO-coupling

$$H_{so} = \boldsymbol{s} \cdot (\boldsymbol{\alpha} \times \boldsymbol{p})$$

M. I. D'yakonov, V. I. Perel, 1971b, Fiz. Tverd. Tela 13, 3581, [Sov. Phys. Solid State 13, 3023-3026 (1971)].

$\boldsymbol{\alpha} \times \boldsymbol{p}$

$\boldsymbol{p}$

$$\boldsymbol{b}_{eff}(t_1) = \boldsymbol{\alpha} \times \boldsymbol{p}(t_1)$$

$$\boldsymbol{b}_{eff}(t_2)$$

Momentum is time-dependent due to scattering

In the case that the momentum relaxation scale is shorter than the spin precession time scale