レーザー偏極気体原子を介したアルカリ塩へのスピン偏極移行

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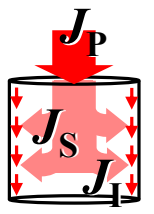
Motivation

Spin current (flow of angular momentum)

photon → alkali-metal (atomic gas) → noble-gas (spin capacitor) **more**

Loss of angular momentum due to atomic collision & wall relaxation



Hyper-polarization

Functional imaging of ion channels

$^{6}Li^{+}$, $^{7}Li^{+}$, $^{133}Cs^{+}$: small eQ electric quadrupole moment

Spin Transfer

High field pumping — 1

D_1 or D_2 pumping

Spin Current & atom diffusion — 2

N_2 pressure — broadening, quench, diffusion

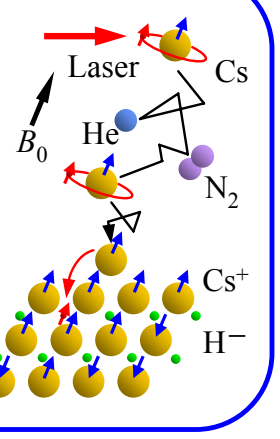
spin interaction collision

Spin injection through salt surface — 3

electron, S or I ?

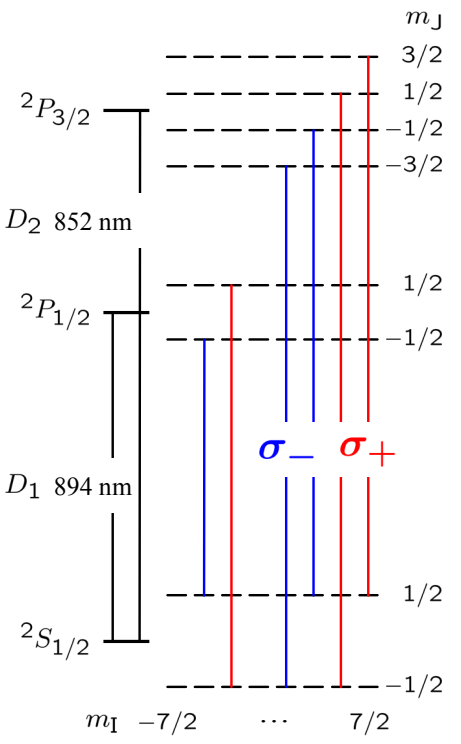
Spin diffusion in salt crystal — 4

nuclear dipole or ***F***-center mediated ?

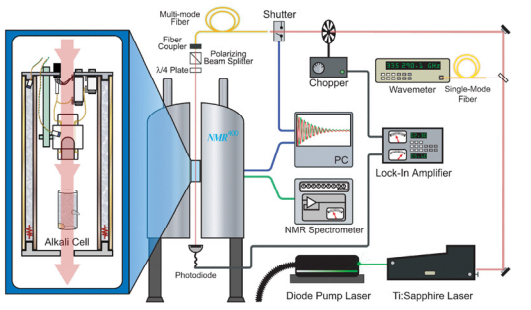


Energy Level

^{133}Cs ($I = 7/2$) **high field**



Experimental Setup



Metal 15.26 MHz @ 2.7 T (Knight shift)

Atom D_1 894 nm, D_2 852 nm
Hyperfine structure
→ NMR resonance far from that of solid nuclei

CsH salt on the side wall of glass cell

15.13 MHz @ 2.7 T

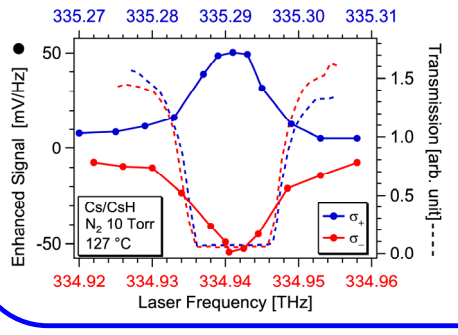
T_1 ~ 130 s @ 140 ℃

thickness ~ 10 μm,

Cs nuclei ~ 10^{20}

Enhancement Curve

NMR enhancement curve is identical to each atomic absorption
→ Photon angular momentum is transferred to solid through atomic Cs gas

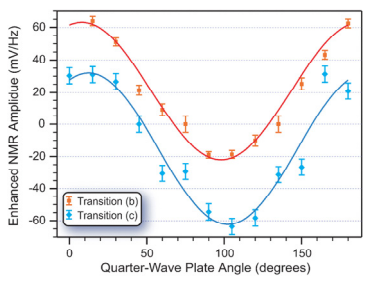


Transition (a) and (d)

D_1 @ 9.4T

Laser Polarization

Sign of NMR enhancement changes by laser polarization
→ Both electron and nuclear spin currents contribute to spin injection



Transition (b)

D_1 @ 2.7T

Spin Interaction Collision

***S*-damping** $(\gamma\ \mathbf{N}\cdot\mathbf{S})$

$$\langle \dot{S}_z \rangle = -\Gamma_{sd}\langle S_z \rangle - \langle \dot{I}_z \rangle$$

$$\langle \dot{I}_z \rangle = -2r^2\Gamma_{sd}\langle I_z \rangle$$

High field

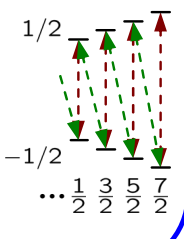
$$r = \frac{A}{2\hbar\omega_S} \ll 1$$

Hyperfine-shift $(\delta A\ \mathbf{I}\cdot\mathbf{S})$

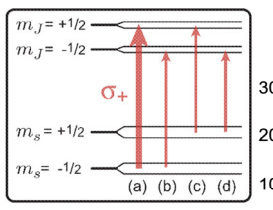
$$\langle \dot{S}_z \rangle = -\langle \dot{I}_z \rangle = -\Gamma_{hs}\langle \epsilon S_z - I_z \rangle$$

Spin-exchange between Cs atoms

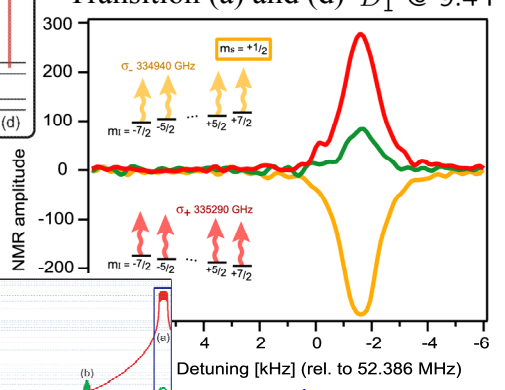
$$\langle \dot{S}_z \rangle = -\langle \dot{I}_z \rangle$$
$$= -2r^2\Gamma_{ex}\left[\langle \epsilon \rangle \langle S_z \rangle - \langle I_z \rangle\right]$$

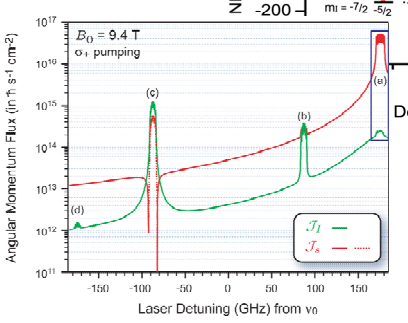


Enhancement of Spin Polarization



Transition (a) and (d) D_1 @ 9.4T



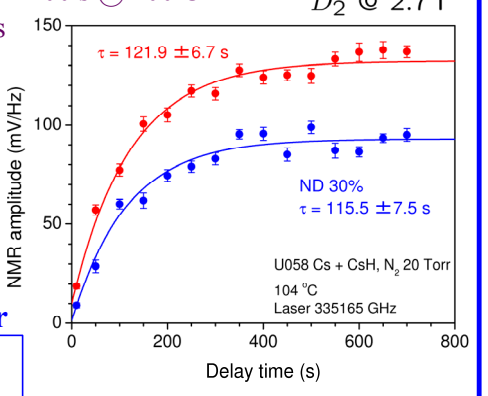


B_0

Spin relaxation time ~ 200 s @ 100℃

Spin-up time ~ 120 s

D_2 @ 2.7T

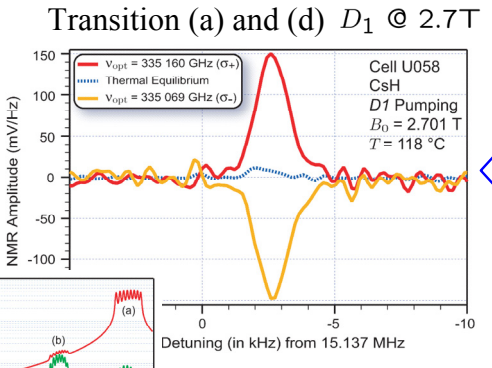


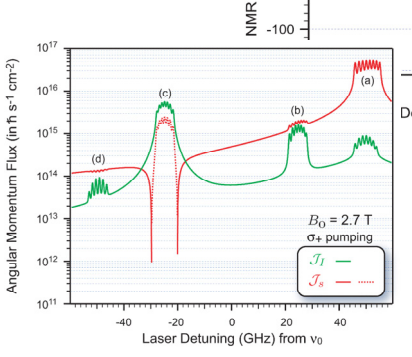
enhancement factor

$$\varepsilon = \frac{A_{pol}}{A_{th}} - 1$$

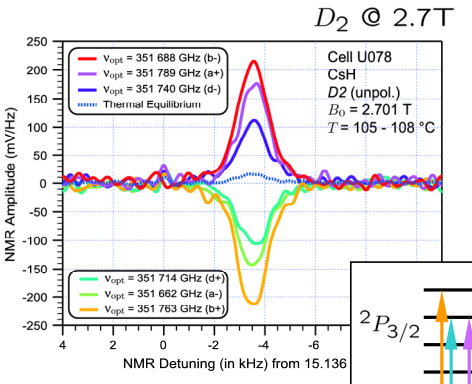
B_0	2.7	9.4
$\bar{\varepsilon}$	17.8	2.34
A_{pol}	48	22 (T)
	49.6	21.6 (ppm)

Transition (a) and (d) D_1 @ 2.7T



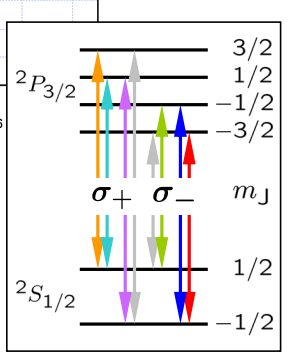


D_2 @ 2.7T



D_1 pumping D_2

Oscillator strength

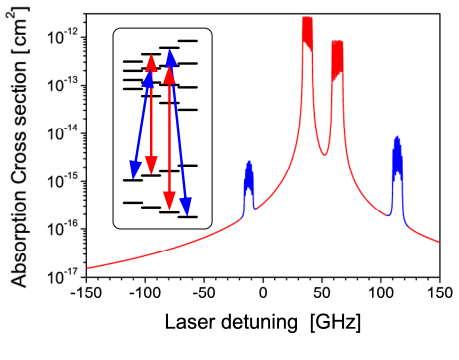


Spin Transfer from an Optically Pumped Alkali Vapor to a Solid, K. Ishikawa *et al.* Phys. Rev. Lett. **98**, 183004 (2007)

Spin Current induced by Optical Pumping & Atomic Collision

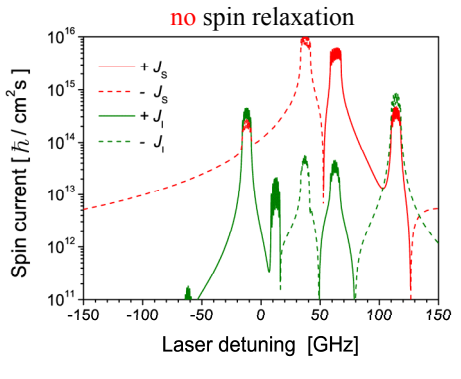
100 mW/cm², 100℃, 10 Torr N_2 @ 2.7 T

Optical transitions σ_+



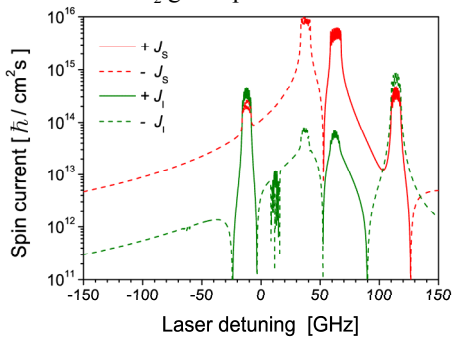
Γ_{op},

N_2 gas : quench, broadening, diffusion, no spin relaxation



Γ_{sd}
Γ_{hs}
Γ_{op}

N_2 gas : spin relaxation



Γ_{ex}
Γ_{op}
Γ_{sd}
Γ_{hs}

Spin-exchange between Cs atoms iterative calculation