ランダム偏光励起の光ポンピングによるアルカリ塩の核スピン偏極

Nuclear Spin Polarization of Alkali Salt by Optical Pumping of Atoms Confined to Random Scattering Medium

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Introduction

Spin Transfer — Photon

Optical pumping — Source of angular momentum → Alkali-metal atomic gas

Diffusion spin current — Flow of longitudinal spin angular momentum $\langle S_z \rangle$ $\langle I_z \rangle$ (Loss: atomic collision, wall relaxation)

Spin injection at surface — Nuclear dipole interaction → Solid (Ionic crystal $^6Li^+$, $^7Li^+$, $^{133}Cs^+$)

Spin diffusion — Spin capacitor

Development of universal method for hyper-polarization

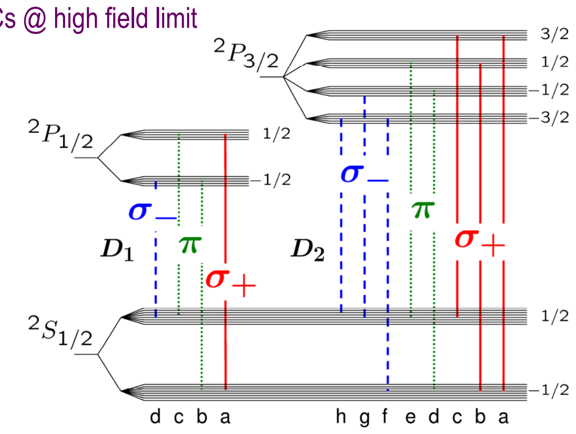
Improvement of boundary condition for polarized gas

Target of This Work

Enlarge the surface area of salt exposed to the polarized vapor without spoiling spin polarization

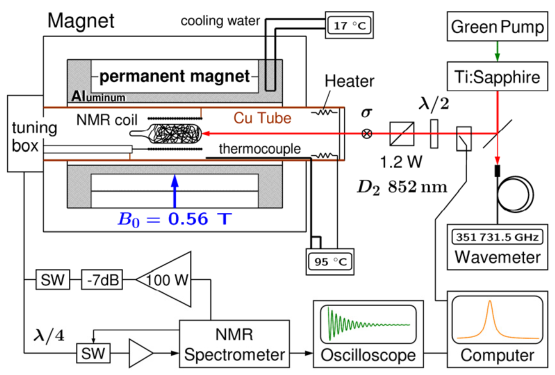
Energy Level

Cs @ high field limit



Zeeman splitting of electron state is larger than the hyperfine splitting. Eight nuclear-spin levels lies in each electronic manifold. Vertical lines show the transitions of the D_1 (D_2) line in the order of resonance frequency from right to left, correspondingly named from a to d (a to h). Each transition can be induced by the pump of any polarization due to the mixing between the direct product states.

Experimental Setup



Cs salts was solely NMR detected

Metal Knight shift → NMR frequencies far from that of salt nuclei

Atom Hyperfine structure

Continuous-wave pump light was routed into a permanent magnet. Linearly-polarized light by polarization beam-splitter and half-wave ($\lambda/2$) plate uniformly illuminated a cylindrical cell. Oven temperature was regulated by a resistive heater outside of magnet. Free-induction decay was observed by a solenoid coil sensing Cs salts in the glass cell. Trace of NMR line was Fourier transform of the transient signal.

Summary 1

Optical Pumping and Glass Wool

Surface area

Large surface area of salt was exposed to the optically-polarized atomic vapor

Thin layer of crystallites better matched the spin-diffusion length in salt

Light polarization

Glass-wool automatically converted the pump polarization as adapted for absorption cross section

Spin polarization near the surface

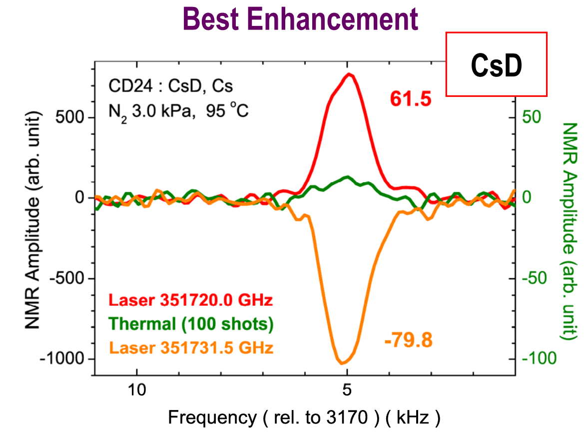
Alkali-metal atoms were well optically-polarized even in the close vicinity of salt surface

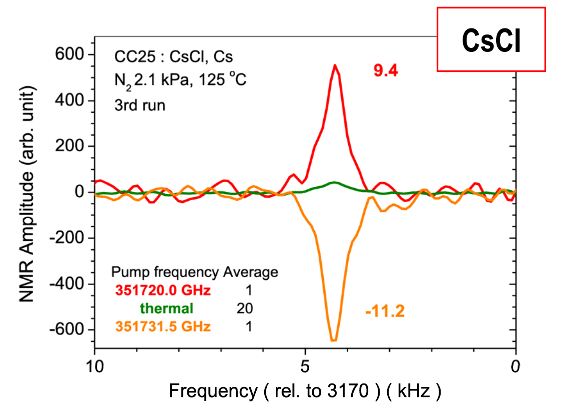
Effective optical path length

Glass-wool increased the effective optical path-length by scattering pump light in a small glass cell

Summary 2

Best Enhancement



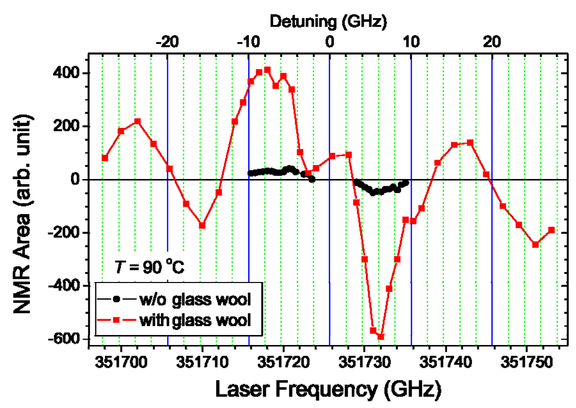


Enhancement Spectrum

Each point presents the area of NMR trace for Cs salts measured at various conditions

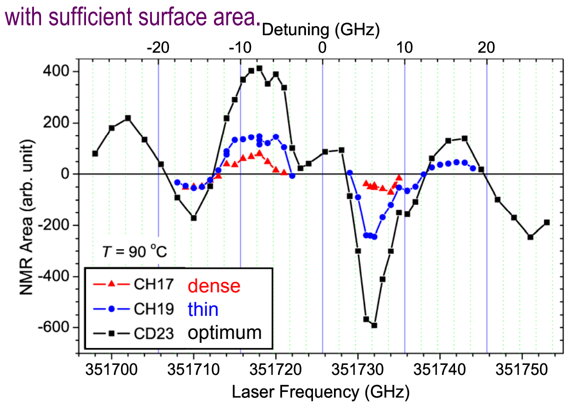
Enhancement by optical pumping with glass-wool

Optically enhanced signals of Cs salts formed on the quartz-glass wool (■) and on the sidewall w/o glass wool (●). The enhancement approached -80 for the glass-wool cells, as shown in summary 2.



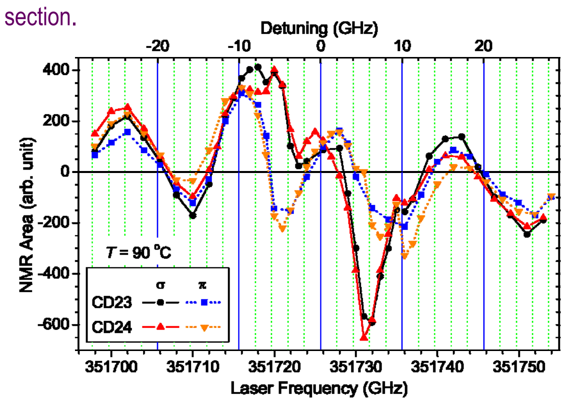
Glass-wool density

Signal intensity depends on the density of glass-wool because, at optimal density, pump light can percolate through the entire medium with sufficient surface area.



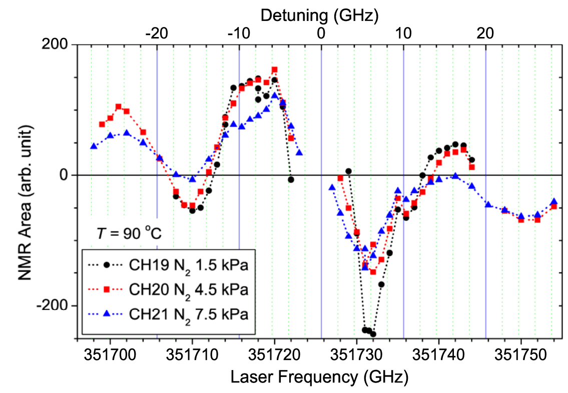
Light Polarization

Enhancement spectrum measured by σ pump (solid line) and π pump (dotted line). By the glass-wool, light polarization was automatically converted as adapted for strong absorption. See absorption cross section.



Buffer-gas pressure

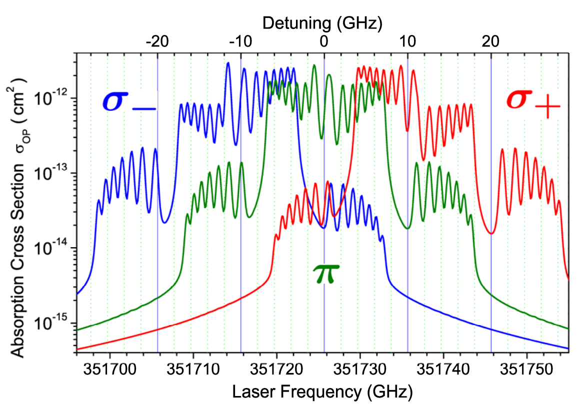
Pressure dependence of enhancement spectrum is similar to that of optical transitions, *i.e.* lower and broadened at high pressure.



Absorption Cross Section

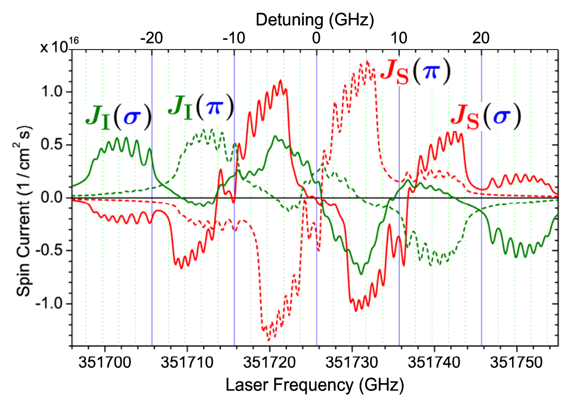
Calculated @ 1.5 kPa N_2 @ 0.56 T

Number density of atoms: 7.8×10^{12} /cm^3 @ 90℃



Spin Current

Numerical simulation: 1 W/cm^2, 90℃, 1.5 kPa N_2 @ 0.56 T



Light Polarization

▲ : Randomized polarization of light transmitting through the quartz-glass wool

● : Polarization of transmitted light without the glass wool