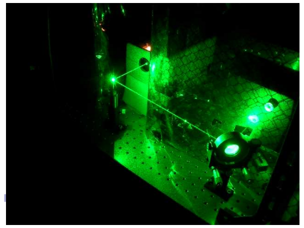
DESIR Workshop, 2010 5/26-28 Leuven, Belgium



"*OROCHI*" experiment

Nuclear laser spectroscopy in superfluid helium for measurements of spins and moments in exotic nuclei

Tokyo Institute of Technology

Takeshi Furukawa

Asahi Labo.
Applied Nuclear Physics Laboratory

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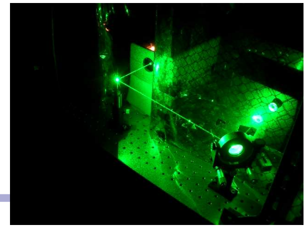
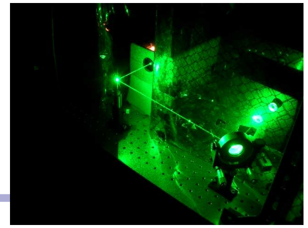


Contents

- **What is "OROCHI" ?**
  - Nuclear laser spectroscopy in superfluid helium
  - For the measurement of rare isotopes
  - not a precision but sensitive to detect photons
- **Present status**
  - off-line development
    - with Rb, Cs, Ag, and Au stable isotopes
- **Future prospect**
  - on-line experiment with Rb beam @ RIKEN
  - off-line development for In and Tl isotopes

New Laser Spectroscopy

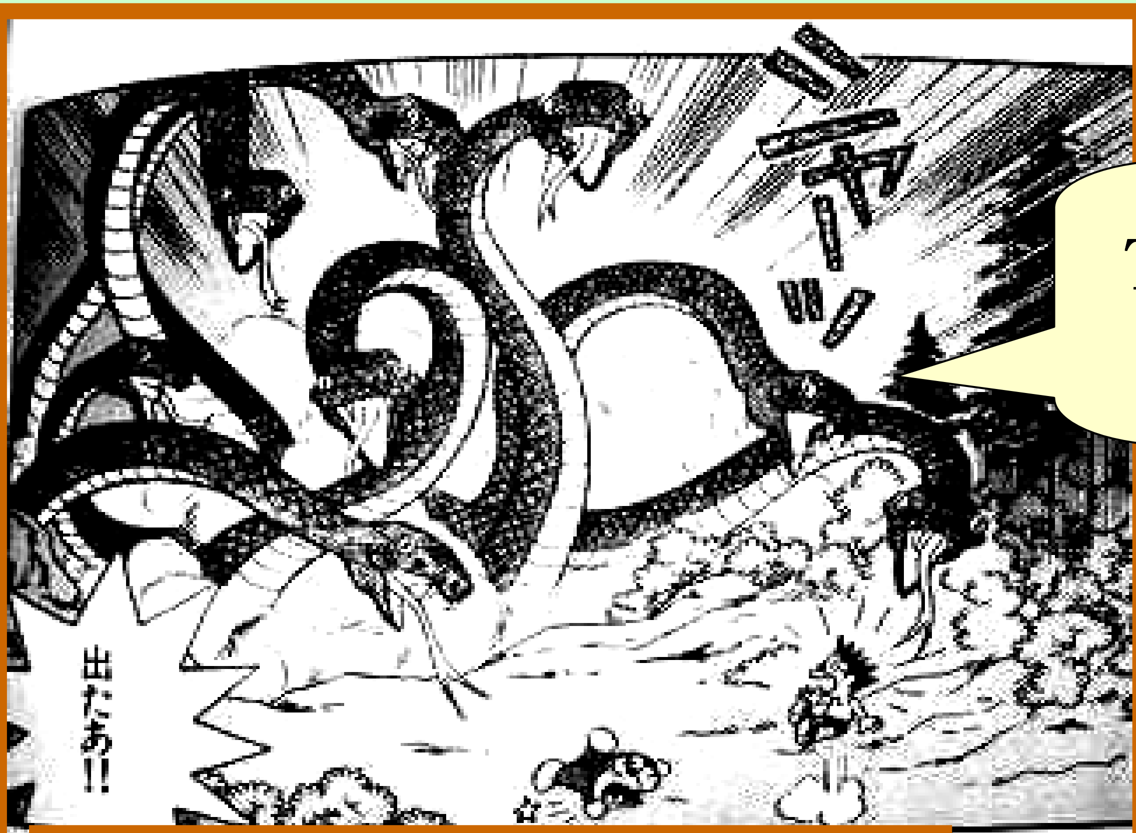


to measure the nuclear spins & moments in exotic nuclei…

"laser spectroscopy for radioisotope(RI) atoms in superfluid helium (He II)"

"OROCHI"

Helium as Ion-catcher



from "DRAEMON" vol. 22, by FUJIKO, F. Fujio

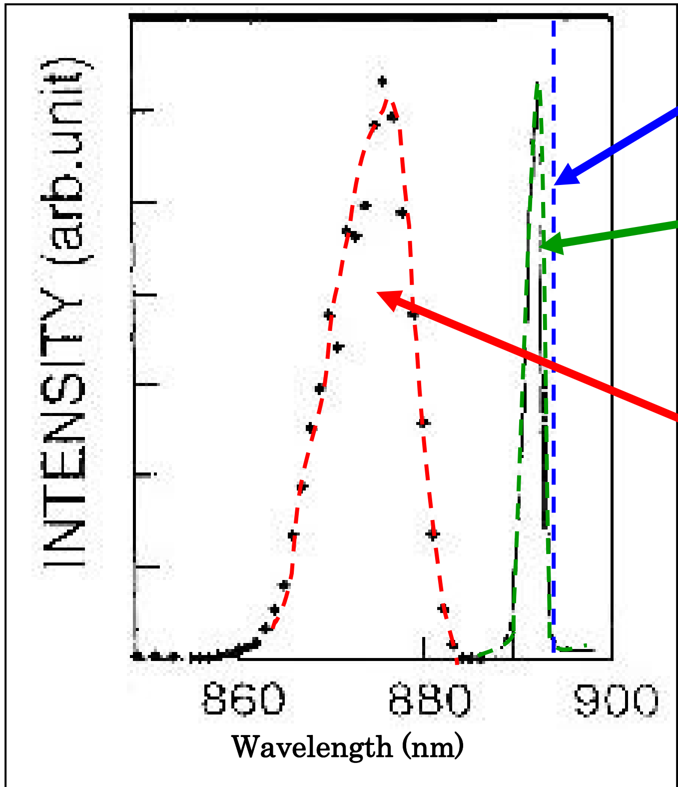
This is Japanese "OROCHI" snake

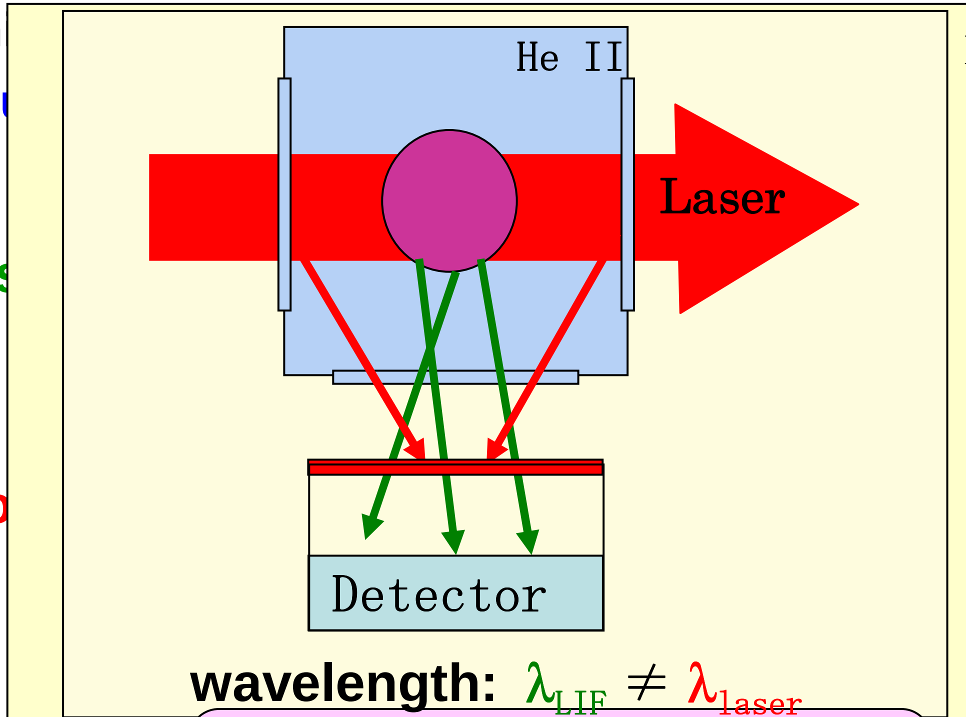
Advantage in He II

We use He II **to reduce the b.g. photons.**

Atomic absorption line in He II (① largely blue-shifted
② widely broadened

^{133}Cs D1 atom

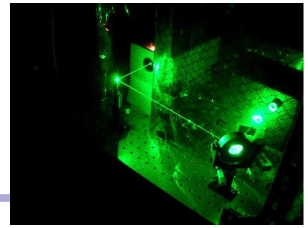




Suspress background count

Reduction: $10^{-10} \sim 10^{-13}$

Double resonance spectroscopy



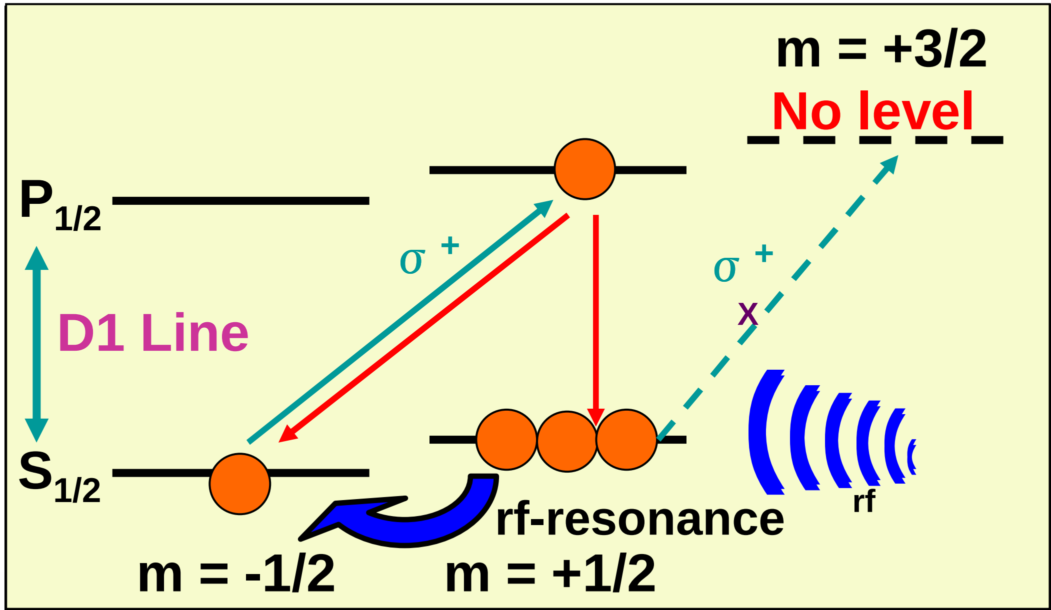
measurement of atomic sublevel structure

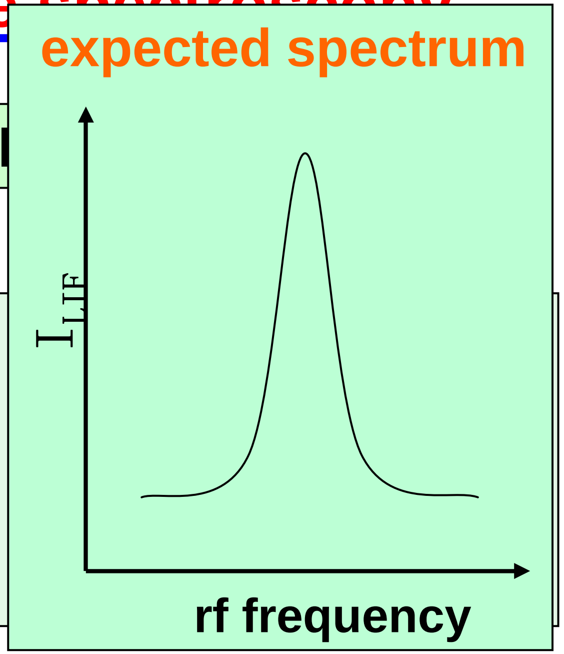
: Double resonance spectroscopy

In the case of Zeeman splitting in al

1st step: optical pumping

2nd step: double resonance





mission photons in optical pumpi

(Laser Induced Fluorescence, LIF)

decreased gradually

$[I_{LIF}] \propto 1 - P_z$

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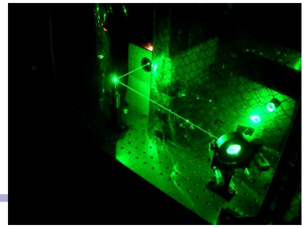
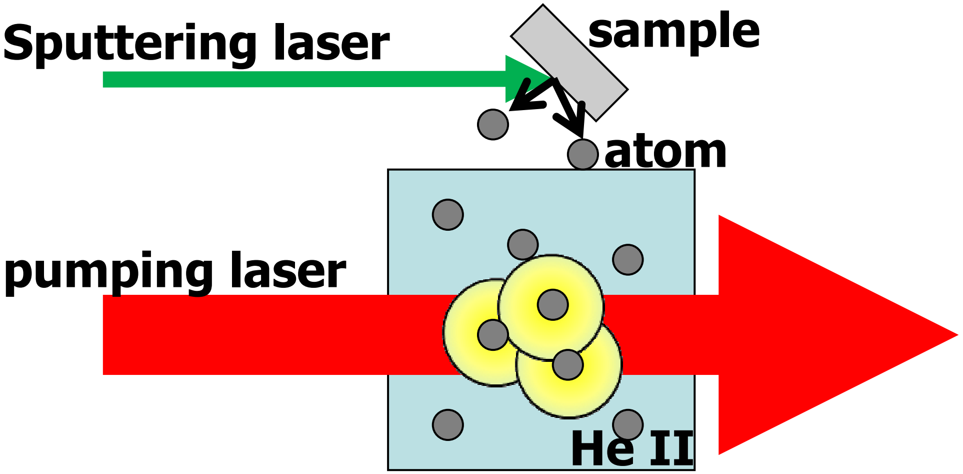
Off-line development

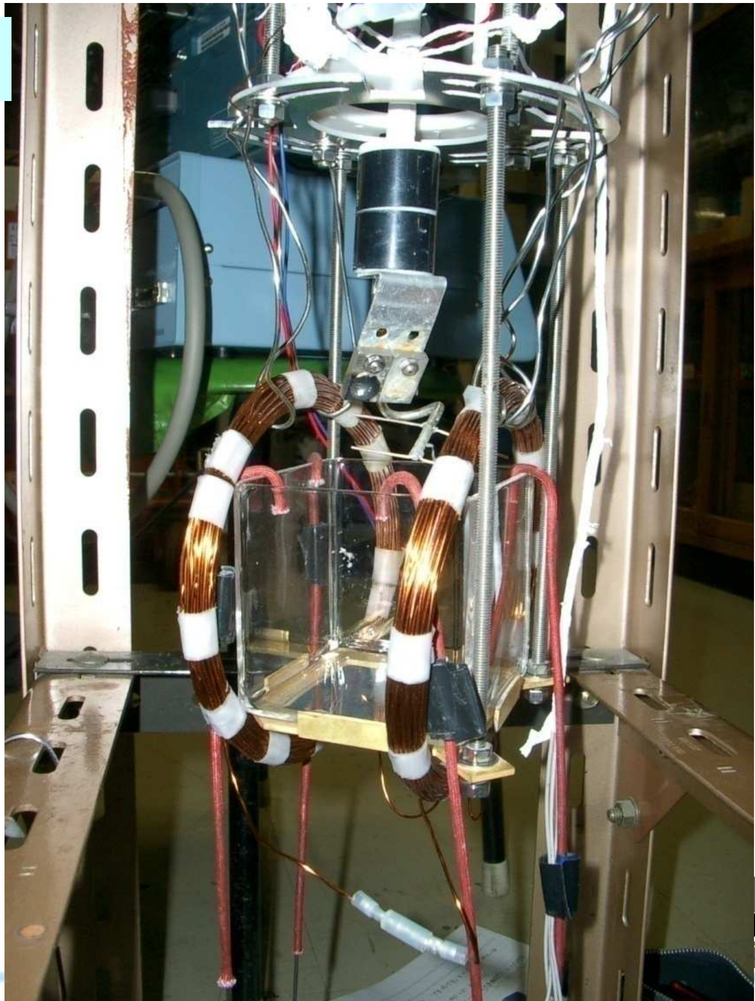


To confirm the feasibility of OROCHI

with stable isotope: Rb, Cs, Ag, Au, ….

Atoms introduced with laser sputtering



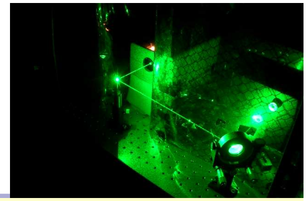


Optical pumping

→ **Double resonance**

→ **Photons detection**

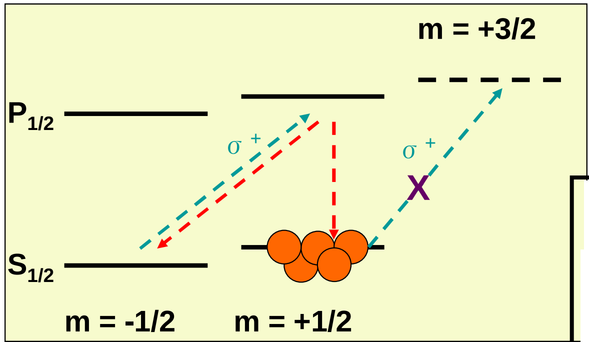
Optical pumping in He II



T. Furukawa *et al.*, Phys. Rev. Lett. 96, 095301 (2006)

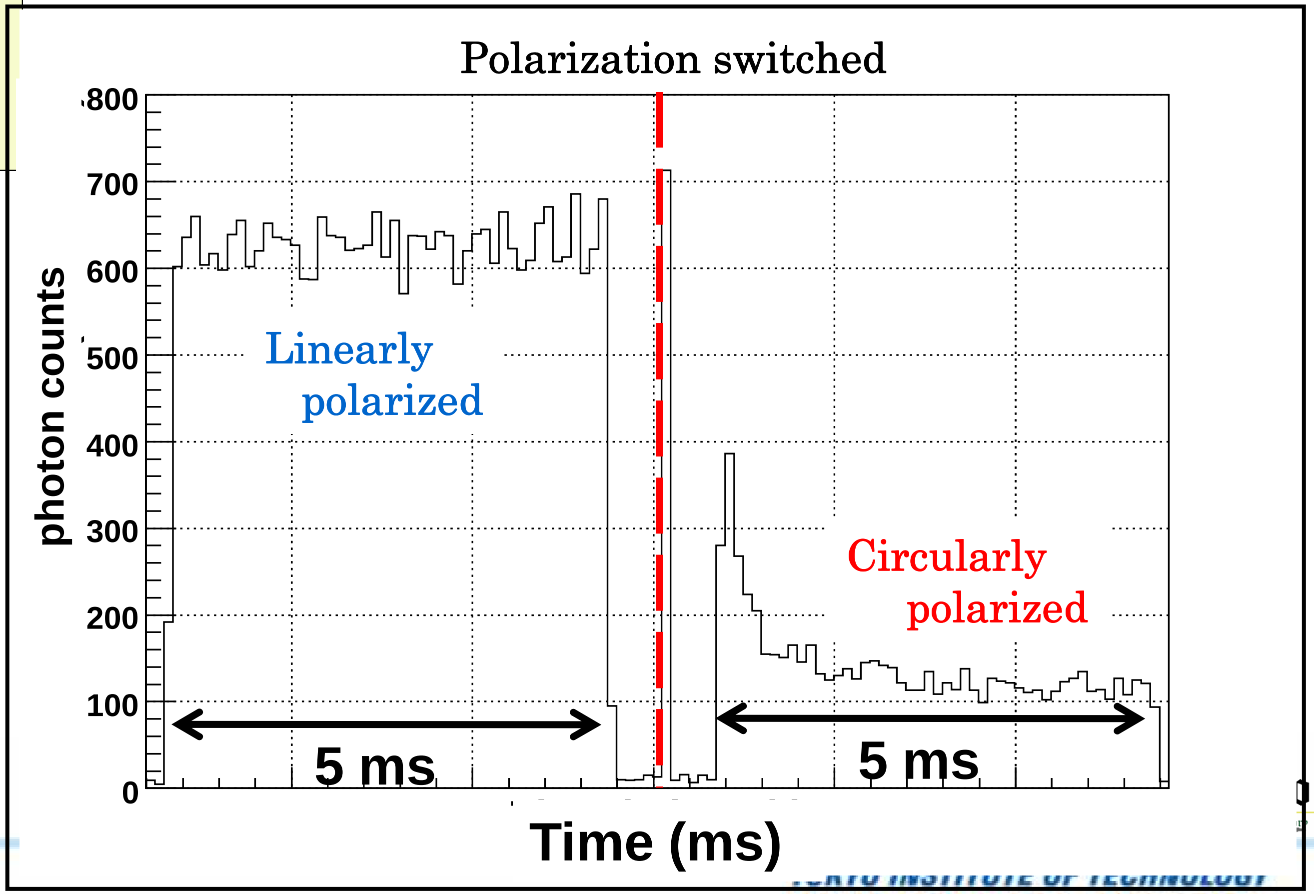
Produce the polarization in stable Rb, Cs in He II

Polarization : ~90 %(Cs)
~50 %(Rb)

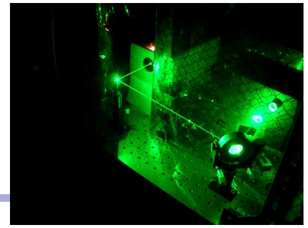


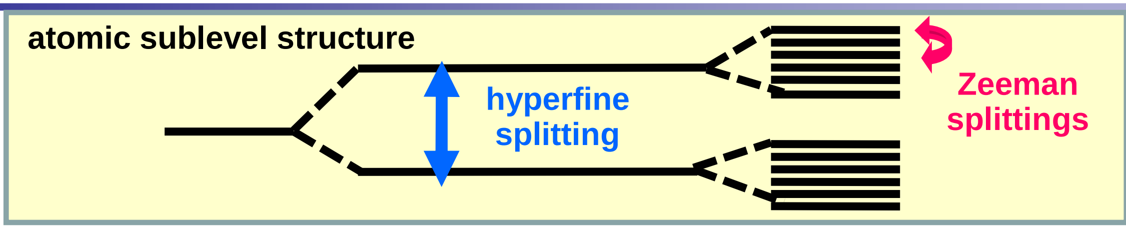
Polarization: increased

LIF intensity: decreased

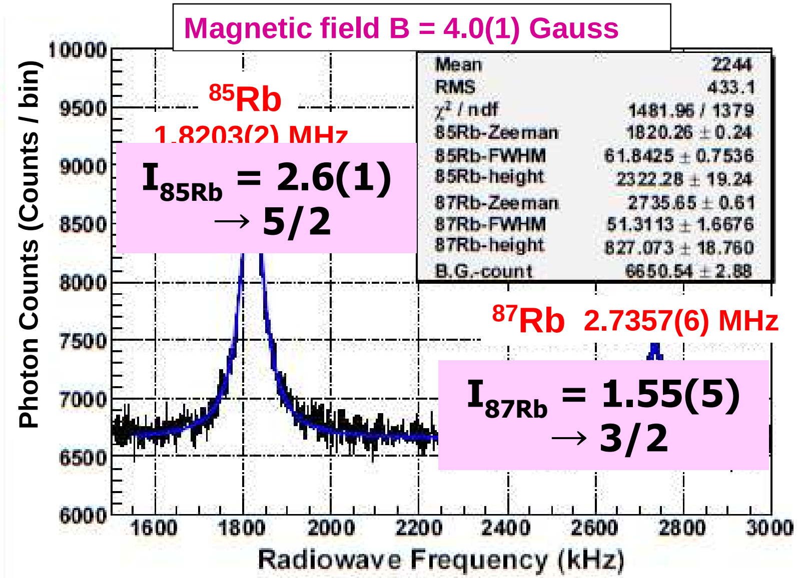


Nuclear spin & moment determination





Zeeman resonance of Rb isotopes



I_{85Rb} = 2.6(1) → 5/2

I_{87Rb} = 1.55(5) → 3/2

$$\Delta \nu_{Zmn} = g_F m_B B / h = \frac{2.8(\mathrm{MHz}) \times B(\mathrm{Gauss})}{(2I+1)}$$

Nuclear spin

Hyperfine resonance of ^{85}Rb

Hyperfine interaction
Hyperfine anomaly (Bohr-Weisskopf effect)
) Both different from free space

Pressure effect of He II

indicates interesting phenomena of atoms in He II

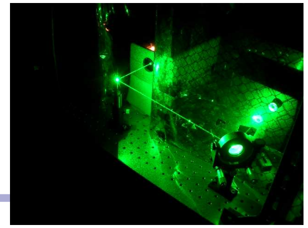
⇩

	μ_I^{85Rb} (μ_N)
This work (from A_{HeII})	1.357 83 (7) μ_N
previous (from A_{vacuum})	1.358 071(1) μ_N
literature value (NMR)	1.353 351 5 μ_N

T. Furukawa, Doctoral thesis, Osaka Univ. (2007)

T. Furukawa, *et.al.*, Hyp. Int. **196** 190 (2010)

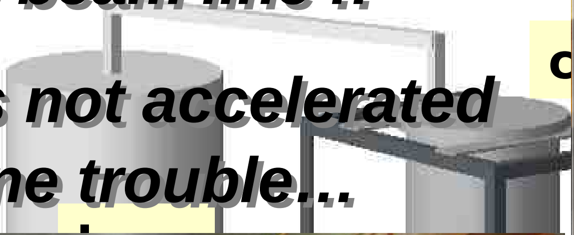
On-line test with Rb beam

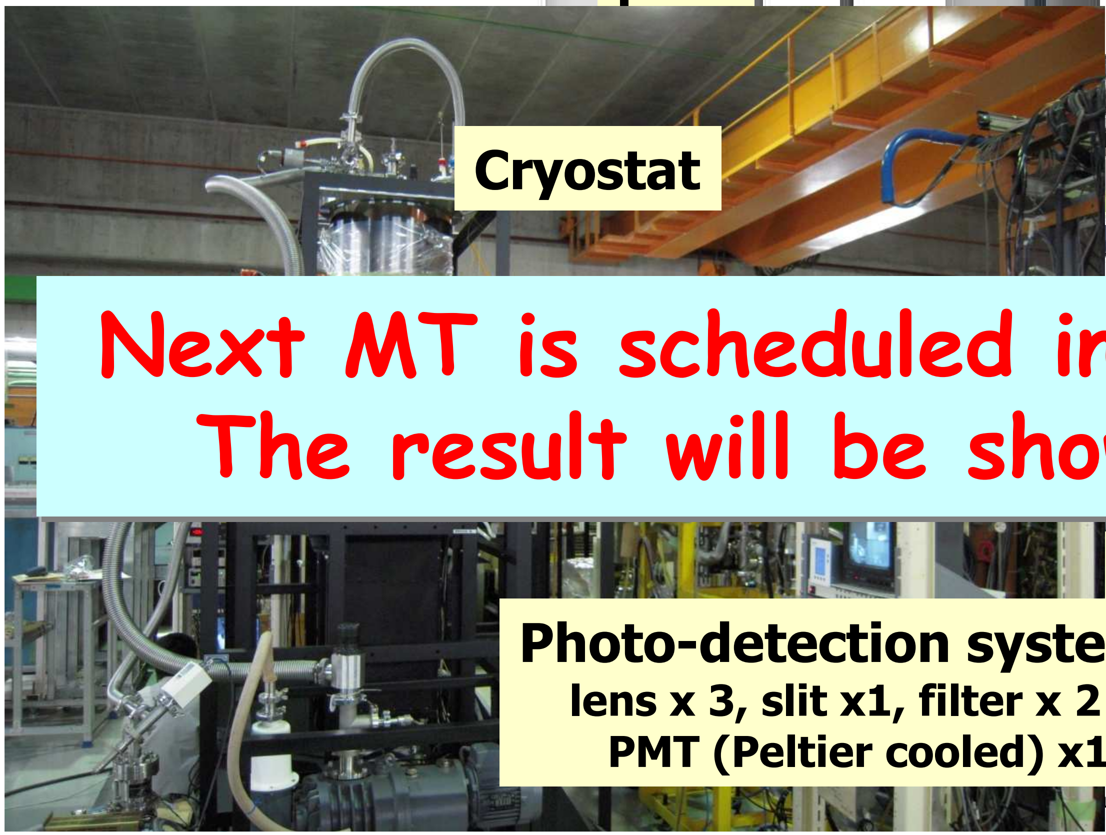


Remaining uncertainty ： photo-detection efficiency
→ confirmed with on-line experiment

All the devices were mounted on RIKEN RIPS beam line !!

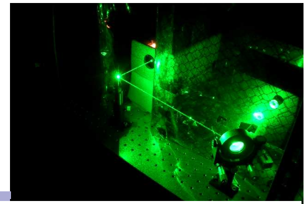
But Rb beam has not accelerated due to machine trouble…





Next MT is scheduled in this September.
The result will be shown next time …

Laser spectroscopy of Ag and Au



T. Furukawa, K.Fujikake *et al.*, to be published…

Apply to noble metal Ag and Au atoms

Broadened absorption spectra in He II.

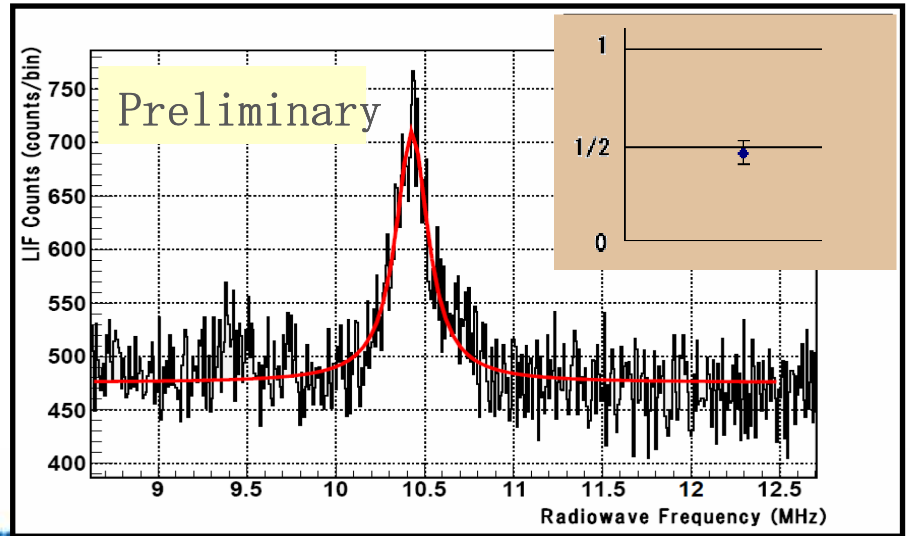
→ feasible to optically pumping various atomic species

(less limitation of laser wavelength)

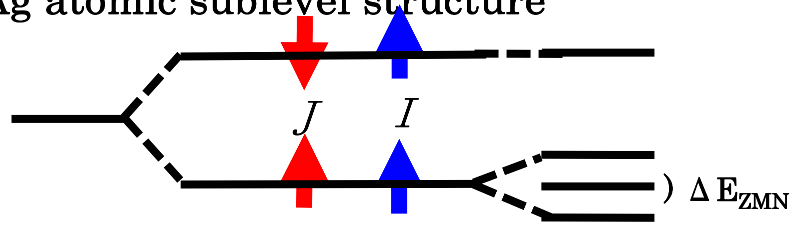
polarization： ～８０％(Ag), ～６０％(Au)

incomplete polarization is due to imperfect circular polarization of laser

Zeeman splitting of stable ^{107,109}Ag isotopes (both I=1/2)



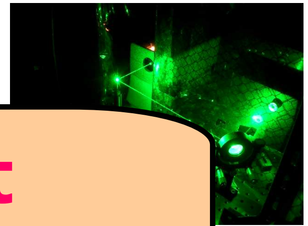
Ag atomic sublevel structure



Nuclear spin I=1/2 can be deduced clearly.

今後の予定

Feasible elements i



Next attempt

Optical pumping of In and Tl

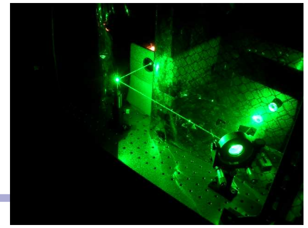
feasible

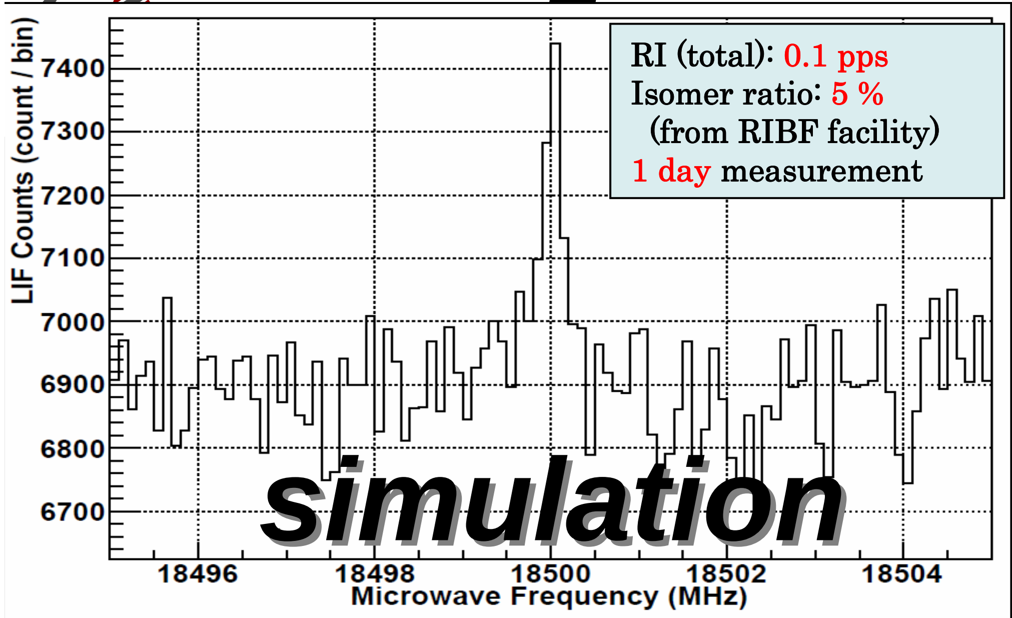
succeeded

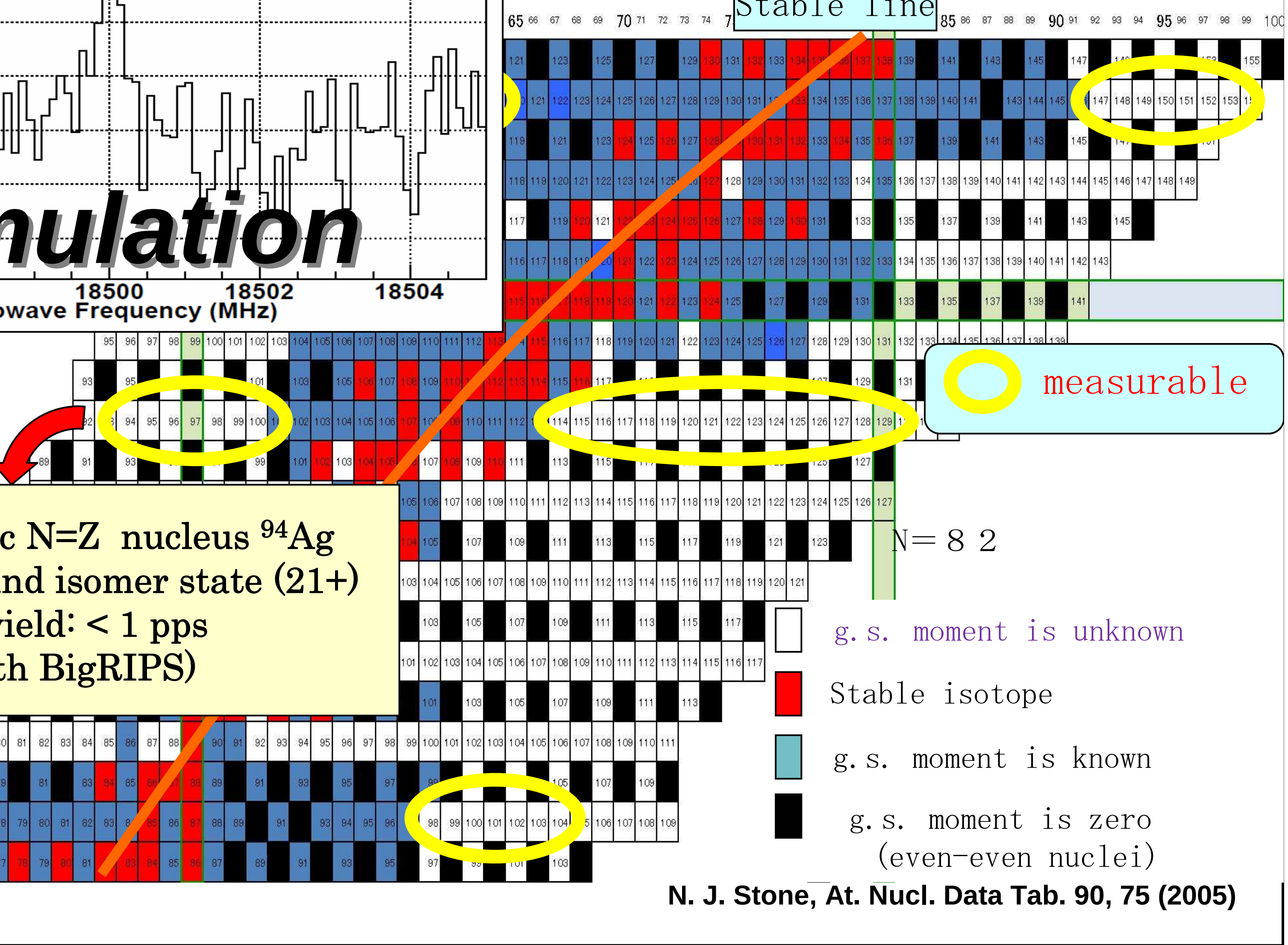
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	[L]	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	[A]	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	112	113	114	115	116	117	118

[L]	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
[A]	Ac	Th	Pa	U	Np	Pu	Am	C	Bk	Cf	Es	Fm	Md	No	Lr

spect







1[st] goal :exotic N=Z nucleus ^{94}Ag

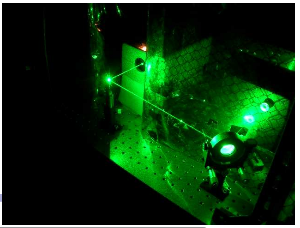
I, μ of g.s. and isomer state (21+)

expected yield: < 1 pps

(with BigRIPS)

N. J. Stone, At. Nucl. Data Tab. 90, 75 (2005)

Conclusion



"OROCHI" Project

Optical Radioisotope-atom Observation in Condensed Helium as Ion-catcher

- We developed the new laser spectroscopy metthod "OROCHI" for determining nuclear spins and moments of exotic RI far from stability by using superfluid helium (He II) as a stopper of RI beam and host matrix of laser spectroscopy.

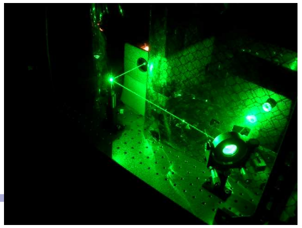
- Atomic spectra in He II (largely blue-shifted and broadened) enable us to measure for the extremely low yield RI whose yield is less than 1 pps. It is also useful to optical pumping of various atomic species.

- In our off-line development using stable Rb and Cs isotopes, we have successfully demonstrated the determination of nuclear spins and moments from the measured Zeeman and hyperfine splitting respectively. We have also demonstrated the optical pumping and double resonance of stable Ag and Au isotopes in recently.

- Preparation of setups for online experiment is almost finished.

We hope This OROCHI will open the door to measure nuclear spins and moments of exotic nuclei, particularly proton drip-line, N=Z nucleus ^{94}Ag

OROCHI - Collaborator



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Osaka Univ. :

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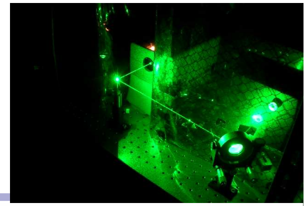
  by the Ministry of Education, Culture, Sports, Science, and Technology, Japan.

- Program for Global Center of Excellence
- "Nano-science and Quantum Physics"
- in Tokyo Institute of Technology

Last word…



- We feel OROCHI can be useful not only for nuclear laser spectroscopy, but also β-NMR, decay spectroscopy, and so on.

- In 1980's, some groups reported that the low energy atomic or molecular beams can be introduced into He II with electric field.

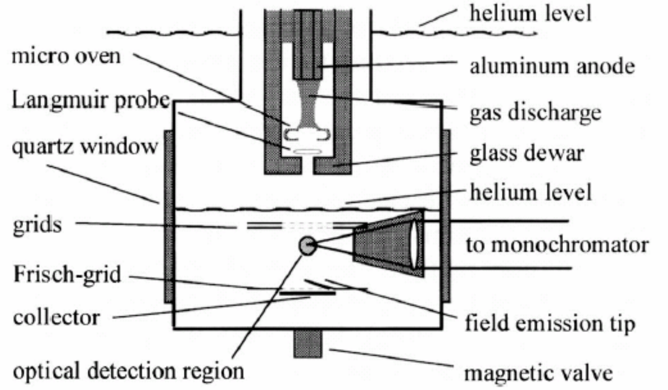


Fig. 7. Implantation of impurity ions into superfluid helium by an ion beam. The probe material is placed in small ovens shielded by a glass dewar.[89]

B. Tabbert et al., JLTP 109 516 (1997)

If you have some interests or ideas to use OROCHI for DESIR, please contact us, and collaborate with us if you prefer !

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Thank you for your attention.

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