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EXCHANGE COLLISIONS BETWEEN THE IONIC GROUND STATE AND THE NEUTRAL METASTABLE STATE OF ATOMS FORMED AND ALIGNED BY ELECTRON IMPACT

Tetsuo Hadeishi and Chung-Heng Liu

July 5, 1967

Berkeley, California

DISCLAIMER

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The radio-frequency paramagnetic resonance method was used to observe the exchange collisions between the Xe ionic ground state having a $^2P_{3/2}$ configuration and the neutral metastable state having a $^3P_2$ configuration. The ionic ground-state and the metastable-state atoms are both formed and aligned by unidirectional-low energy, high flux electron beam impact. The magnetic resonance of the ionic ground-state atoms was observed by monitoring changes in the transparency of the resonance radiation to the metastable state.

By unidirectional-low energy electron impact excitation of Xe atoms from the $^1S_0$ ground state to the $^3P_2$ metastable state, the magnetic sublevels $M_J = 0$ and ± 1 are more selectively excited than those with $M_J = \pm 2$. This is also experimentally verified from the paramagnetic resonance experiment of the metastable state. Similarly, certain magnetic sublevels of $Xe^+(^2P_{3/2})$ are expected to be selectively excited by the electron impact. Suppose if one would produce a high concentration of the aligned $Xe^+(^2P_{3/2})$ and $Xe(^3P_2)$ state atoms by high flux electron beam, a certain population equilibrium will be reached in a steady state. A destruction of the alignment of $Xe^+(^2P_{3/2})$ would result in a new population re-distribution of the $Xe(^3P_2)$ metastable state. Such a phenomenon is observable by monitoring

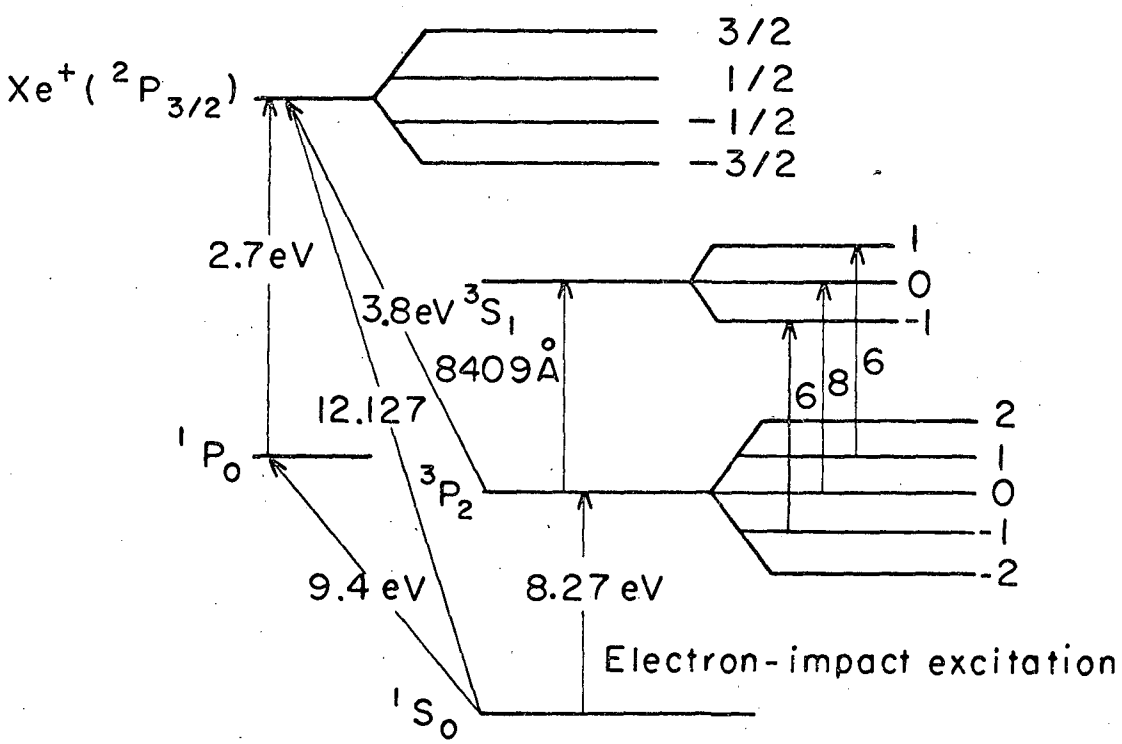
the change of transparency of linearly polarized resonance radiation due to the absorption of the light by the metastable state.

The high flux, low energy-unidirectional electron beam was obtained by means of space charge neutralized electron flow using a planar diode structure electron tube with an indirectly heated "hot" cathode operating under the Xe gas pressure of about 5×10^{-4} torr at 70 mA/cm^2 electron current density at slightly above the ionization potential of Xe. The first slide shows the relevant energy level diagram. The second slide shows the experimental arrangement.

The third slide shows an experimental result which gives the $^3P_2$ as well as $^2P_{3/2}$ magnetic resonances. The fourth slide shows the magnetic resonances of $Xe^{129}(^3P_2)$, $Xe^{131}(^3P_2)$, and even isotope $Xe^+(^2P_{3/2})$.

Recently we observed that the nucleus of Xe^{131} having $I = 3/2$ can also be aligned by metastability exchange between an initially randomly oriented nucleus in the $^1S_0$ ground state and aligned $Xe^{131}(^3P_2)$ by electron impact. The fifth slide shows the experimental result of nuclear alignment by metastability exchange collisions.

Thus by means of an extremely simple apparatus, we have found that: (1) it is possible to observe alignment of the ionic ground state and (2) it is possible to align the nucleus in the $^1S_0$ ground state. A more detailed investigation is presently in progress to study the mechanisms involved more precisely.



Relevant energy level used in Xe ($^3P_2$) resonance absorption

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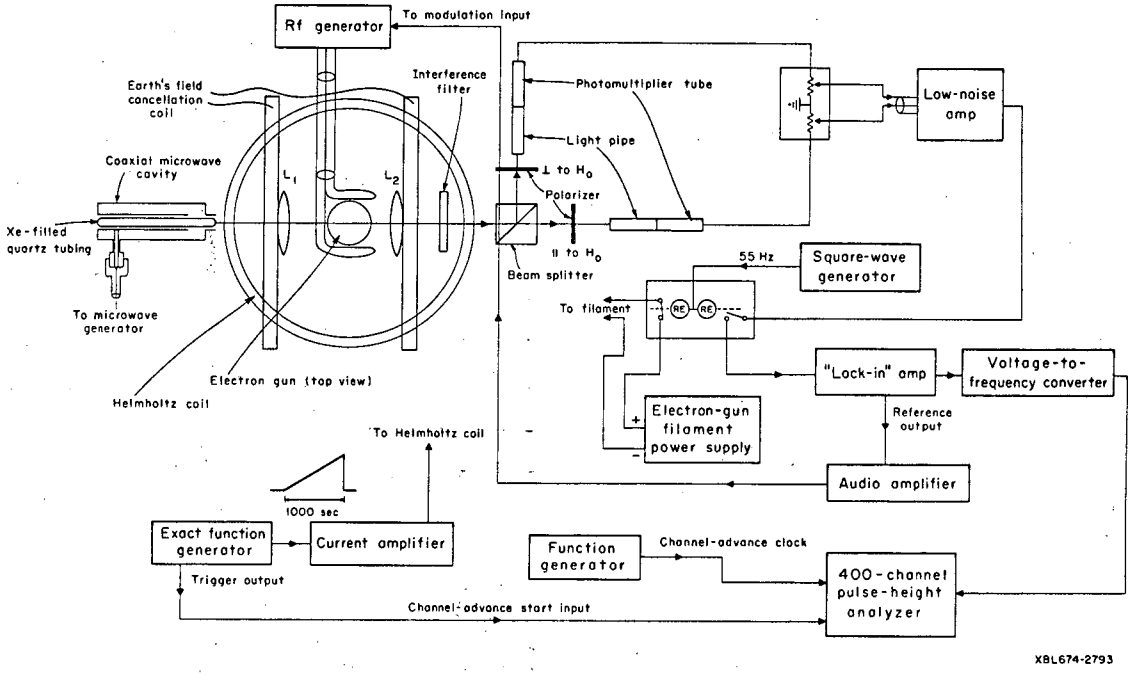
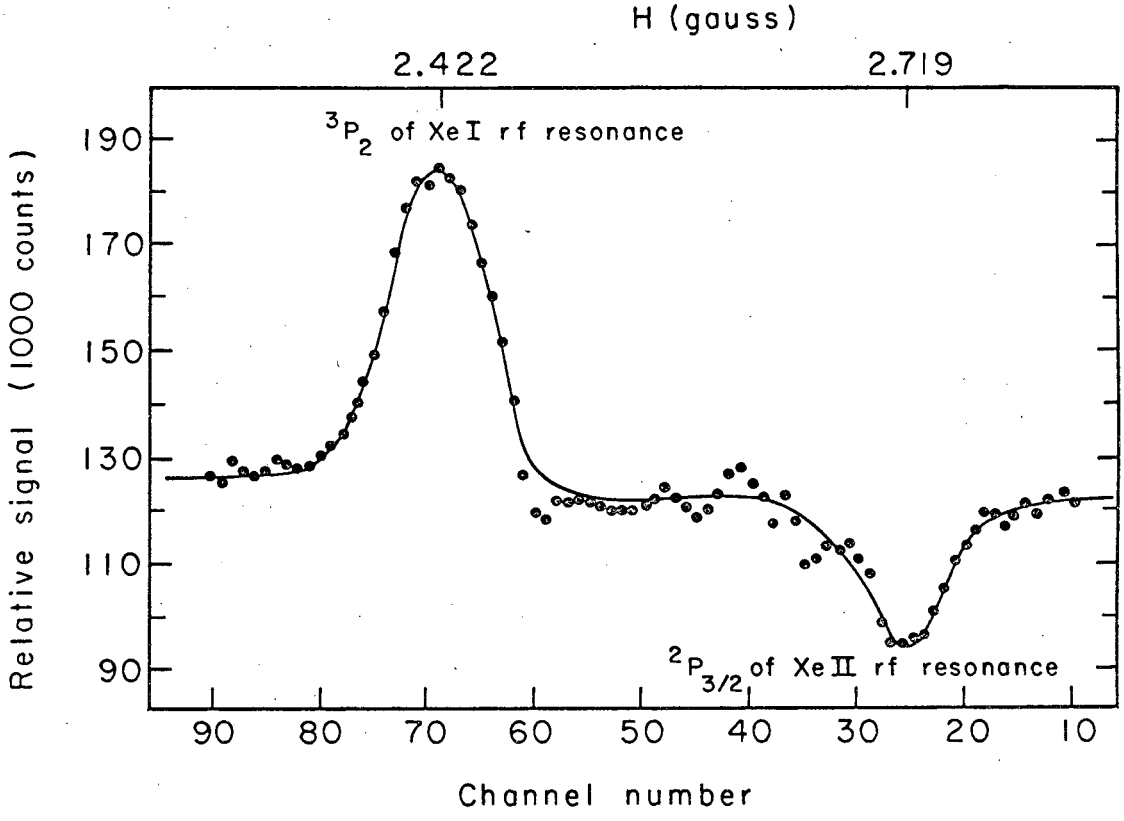
Slide 1.


Rf generator
To modulation input
Earth's field cancellation coil
Interference filter
Photomultiplier tube
Low-noise amp
Light pipe
Coaxial microwave cavity
L1
L2
⊥ to H0
Polarizer
Xe-filled quartz tubing
∥ to H0
Beam splitter
55 Hz
Square-wave generator
To filament
To microwave generator
Electron gun (top view)
Helmholtz coil
"Lock-in" amp
Voltage-to-frequency converter
Electron-gun filament power supply
Reference output
To Helmholtz coil
Audio amplifier
1000 sec
Exact function generator
Current amplifier
Function generator
Channel-advance clock
400-channel pulse-height analyzer
Trigger output
Channel-advance start input
XBL674-2793

Slide 2.



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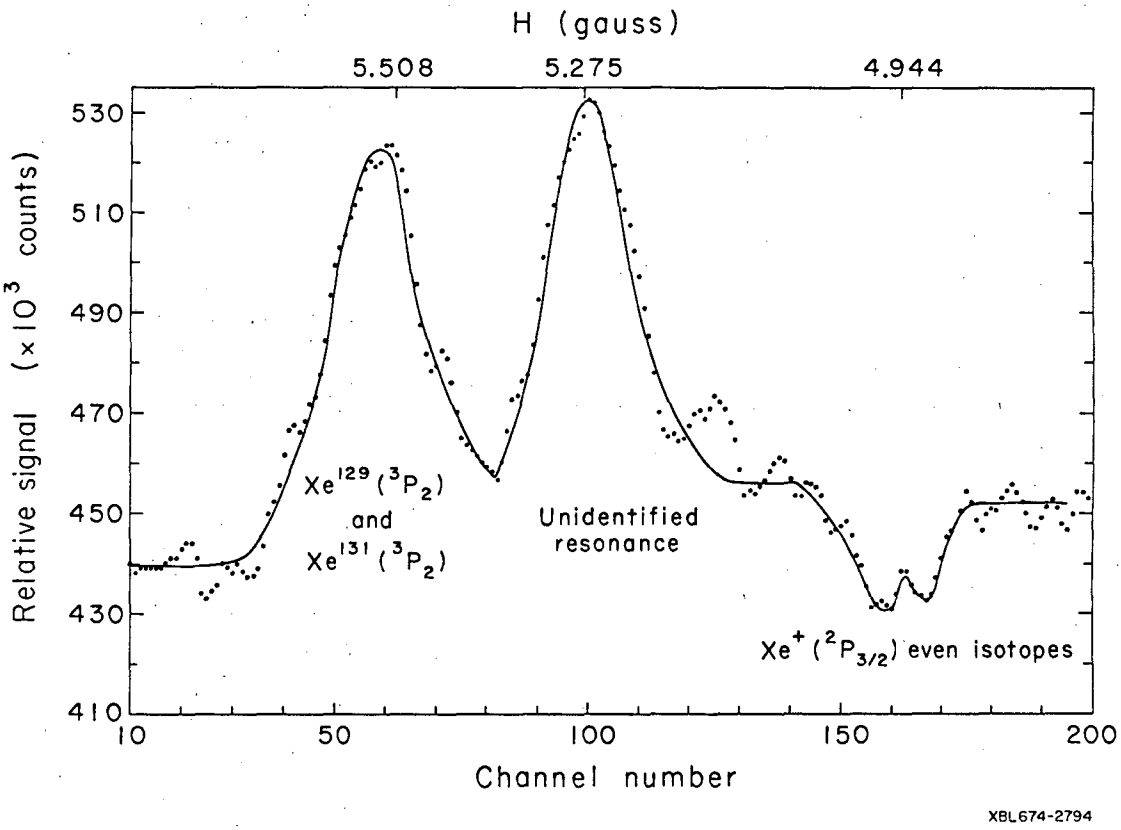
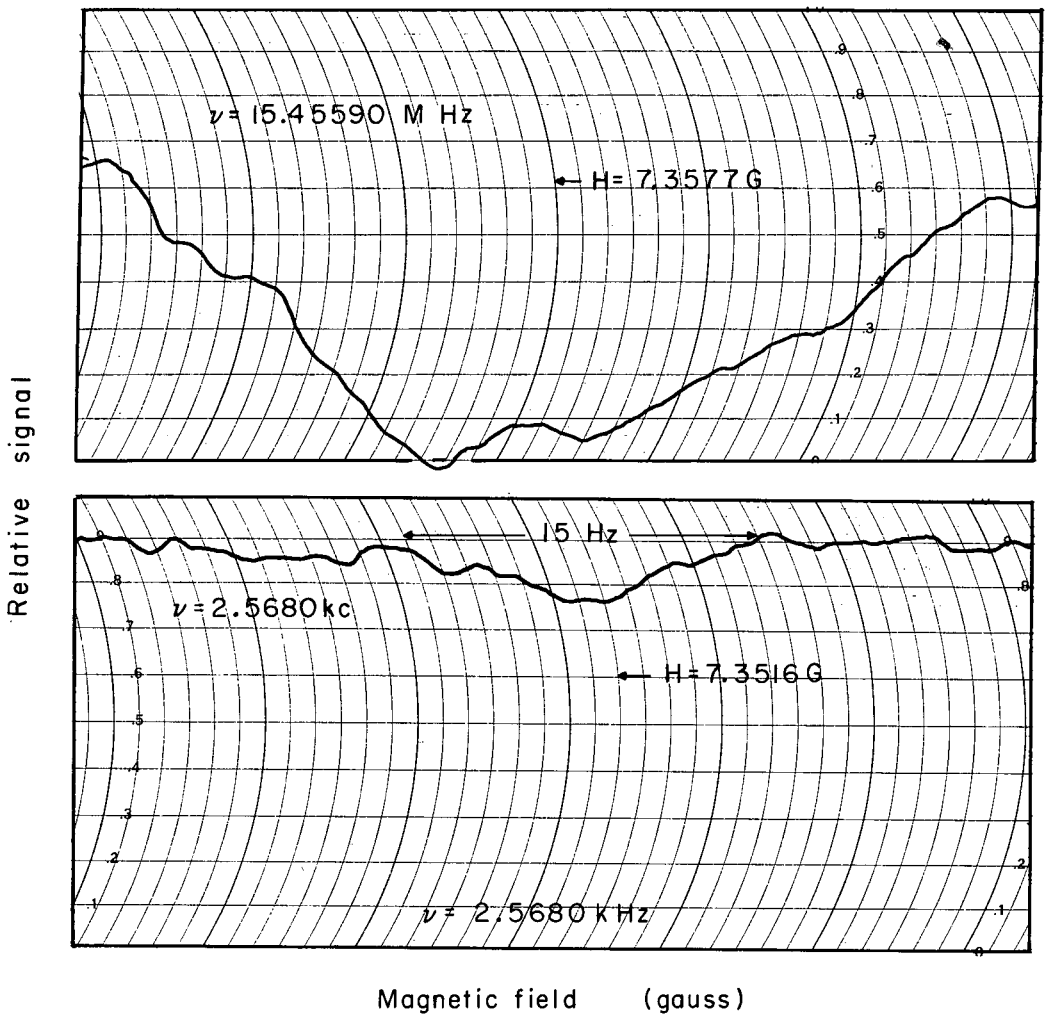
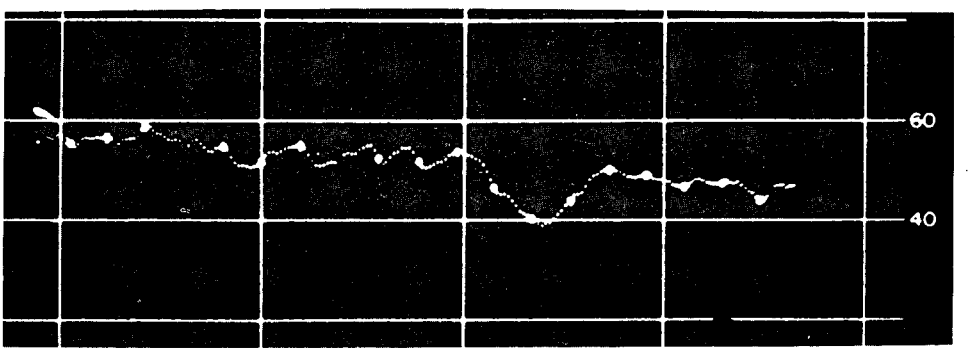
Slide 3.


H (gauss)
5.508
5.275
4.944
530
510
490
470
450
430
410
Relative signal (x10³ counts)
Xe¹²⁹ (³P₂)
and
Xe¹³¹ (³P₂)
Unidentified
resonance
Xe⁺ (²P₃/₂) even isotopes
10
50
100
150
200
Channel number
XBL674-2794

Slide 4.





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Slide 5.