

# Lawrence Berkeley National Laboratory

## Recent Work

### Title

OBSERVATION OF RESONANCE EFFECT IN MODULATED FLUORESCENT LIGHT FROM COHERENTLY EXCITED  $42S_{1/2}$  AND  $42P_{1/2}$  LEVELS IN  $4\text{He}^+$

### Permalink

<https://escholarship.org/uc/item/3ds9q40k>

### Author

Hadeishi, Tetsuo.

### Publication Date

1969-04-01

Published in Phys. Rev. Letters 22, 815 (1969)

UCRL-18880  
Preprint

*ey. 2*

RECEIVED  
LAWRENCE  
RADIATION LABORATORY

JUN 23 1969

LIBRARY AND  
DOCUMENTS SECTION

OBSERVATION OF RESONANCE EFFECT IN MODULATED  
FLUORESCENT LIGHT FROM COHERENTLY EXCITED  
 $4^2S_{1/2}$  AND  $4^2P_{1/2}$  LEVELS IN  $^4\text{He}^+$

Tetsuo Hadeishi

April 1, 1969

AEC Contract No. W-7405-eng-48

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy  
which may be borrowed for two weeks.  
For a personal retention copy, call  
Tech. Info. Division, Ext. 5545*

LAWRENCE RADIATION LABORATORY  
UNIVERSITY of CALIFORNIA BERKELEY

UCRL-18880

*ey. 2*

## **DISCLAIMER**

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

OBSERVATION OF RESONANCE EFFECT IN MODULATED FLUORESCENT LIGHT  
FROM COHERENTLY EXCITED  $4\ 2S_{3/2}$  and  $4\ 2P_{1/2}$  LEVELS IN  $4\text{He}^+$ .\*

Tetsuo Hadeishi<sup>†</sup>.

Department of Physics, University of Arizona, Tucson, Arizona 85721

Abstract

We have observed a resonance phenomenon in the fluorescent light from  $4\text{He}^+$  at a frequency corresponding to the interval between the non-degenerate Zeeman components  $\beta$  and  $f$  of the  $4\ 2S_{3/2}$  and  $4\ 2P_{1/2}$  states excited by an electron beam modulated at the corresponding frequency (uhf-microwave). The observations can be interpreted as "quantum beats". An observation which we recently described in this way is better considered as a time-dependent level-crossing effect.

We recently reported<sup>1</sup> our observation of S-P level crossings by means of detection of variation of the amplitude of modulation of resonance fluorescence as the level-crossing points are swept through by changing the magnetic field. Unfortunately, the words "quantum beats" used in the title was not an appropriate description of the phenomena we reported. The physical basis of the S-P level crossing experiment is related to the differential damping of the excited states in such a way that the amplitude of modulation of the fluorescent light reflects the amount of mixing of the state. More detailed explanation

of the mechanism behind the experiment will be reported by Dr. G. W. Series. Recently, it was pointed out by Eck and Huff<sup>2</sup> that Hadeishi's earlier observation<sup>1</sup> of a modulated signal in the region of level-crossing would contain a component originating from the modulation of a D.C. signal. A similar D.C. signal was also observed by L. L. Hatfield and R. H. Hughes.<sup>3</sup>

In this letter, we shall present experimental observations which represent the real quantum-beats phenomena which can be considered as due to the interference of electromagnetic fields in the spontaneous decay of  ${}^4\text{He}^+$  from coherently excited, non-degenerate, states  $4\ 2S_{1/2}$  and  $4\ 2P_{1/2}$  mixed by a static electric field (the levels  $\beta$  and  $f$  of Fig. 2). The states are excited from the ground state of neutral helium atoms by a modulated electron beam. The main interest at the present state of the work is in demonstrating a phenomenon and the experiment in its present form is not a precision measurement. Under these conditions it is predicted (Refs. 1 and 4) that the intensity of the fluorescent light will be given by

$$I(t) \propto B_2 \cos ft + C_2 \sin ft$$

$$\text{where } B_2 = \frac{\frac{\Gamma}{2}}{\left(\frac{\Gamma}{2}\right)^2 + \nu^2}, \quad C_2 = \frac{\nu}{\left(\frac{\Gamma}{2}\right)^2 + \nu^2}, \quad \nu = |q - f|, \text{ the off}$$

resonance variable,  $f$  is the circular frequency of modulation of the electron beam, and  $q$  is the Stark-perturbed interval between the levels  $\beta$  and  $f$ .

The experimental observation of  $I(t)$  was made by rectification of the photo-current using a superheterodyne technique. Under such detection methods, the signal one expects to observe is given by

$$I(t) = B_2 \cos ft + C_2 \sin ft = \left( B_2^2 + C_2^2 \right)^{1/2} \cos (ft + \phi)$$

and what one measures is the amplitude of oscillation given by

$$\left\{ B_2^2 + C_2^2 \right\}^{1/2} = \left\{ \left[ \frac{\frac{\Gamma}{2}}{\left(\frac{\Gamma}{2}\right)^2 + \nu^2} \right]^2 + \left[ \frac{\nu}{\left(\frac{\Gamma}{2}\right)^2 + \nu^2} \right]^2 \right\}^{1/2}$$

$$= \left[ \frac{1}{\left(\frac{\Gamma}{2}\right)^2 + \nu^2} \right]^{1/2}, \text{ the square root of a Lorentzian.}$$

Figure 1 shows an experimental arrangement similar to that used in Ref. 1, with the exception of high frequency modulation of the electron beam at uhf to microwave frequency instead of rf frequency ranging from 3 to 60 MHz and modified detection system to detect these high-frequency light beats. In the modulation frequency up to 500 MHz, an inexpensive photomultiplier tube 1P21 operated at the maximum allowable voltage was quite satisfactory. In the microwave frequency region (1 to 2 kHz) we used a RCA C40045C photomultiplier tube.

Figure 2 shows the relevant energy levels showing the region of the observation of light beats along with a typical experimental result of amplitude variation of high frequency modulated resonance fluorescence (light beats) in uhf region when the Stark effect perturbation

$$\frac{|\langle 4^2S_{1/2}, m = -1/2 | \frac{E \cdot p}{h} | 4^2P_{1/2}, m = -1/2 \rangle|}{h} > \frac{\delta}{4} .$$

The calculated

energy separation between the level  $\beta$  and  $f$  corresponding to 416 MHz is about 2.34 kG, using the Lamb shift order of Lea, Leventhal, and Lamb.<sup>5</sup> The light beat, when the electron beam is modulated at 416.47 MHz, occurred at the magnetic field slightly less than 2.34 kG as is shown in Fig. 2. This is due to the repulsion of the energy levels by the Stark effect. Similar phenomena were observed at the higher modulation frequencies up to 1.7 MHz at the appropriate higher magnetic field values.

We believe that the observations of light beats at high frequency and that of the level-crossing effect we observed in Ref. 1, complete the confirmation of Series' proposal of 1964.<sup>4</sup> At present, we are working on reproduction of the phenomena we reported using the University of Arizona Van de Graaff generator. We expect to observe the variation in the beat frequency first observed by Bashkin<sup>6</sup> as we vary the magnetic field.

I would like to thank Dr. G. W. Series for numerous helps in clarifying interpretation of this experiment and that of the level-crossing experiment we reported previously.

References

- \* Work done at Lawrence Radiation Laboratory, Berkeley, California, and supported by the United States Atomic Energy Commission.
- † On leave of absence from Lawrence Radiation Laboratory, Berkeley, California.
- <sup>1</sup> T. Hadeishi, Phys. Rev. Letters 21, 957 (1968).
- <sup>2</sup> T. G. Eck and R. J. Huff, Phys. Rev. Letters 22, 319 (1969).
- <sup>3</sup> L. L. Hatfield and R. H. Hughes, Phys. Rev. 156, 102 (1967).
- <sup>4</sup> G. W. Series, Phys. Rev. 136, A684 (1964).
- <sup>5</sup> K. R. Lea, M. Leventhal, W. E. Lamb, Jr., Phys. Rev. Letters 16, 163 (1966).
- <sup>6</sup> S. Bashkin, W. S. Bickel, D. Fink, and R. K. Wangsness, Phys. Rev. 162, 12 (1965).



Fig. 1. Experimental arrangement. Interference filter with  $\lambda = 4685\text{\AA}$  was used to detect  $n = 4 \rightarrow n = 3$  transitions.

Fig. 2. a) Relevant energy level diagram. The dashed line shows the Stark-shifted energy level when

$$\frac{|\langle 4^2S_{1/2} m = -1/2 | \frac{E \cdot p}{\hbar} | 4^2P_{1/2} m = -1/2 \rangle|}{\hbar} > \frac{\delta}{4}, \text{ when } E_{\text{ext}}$$

is parallel to the magnetic field, where  $\delta$  is the difference of damping constant between S and P levels. The arrow indicates the pair of levels that gives the maximum amplitude of light beats shown in (b).

b) A typical experimental observation of the variation of light oscillation (light beats) as a function of the externally applied magnetic field when the electron beam is modulated at 416.47 MHz.

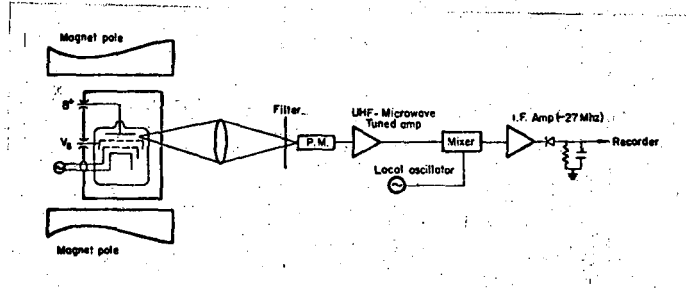


Figure 1

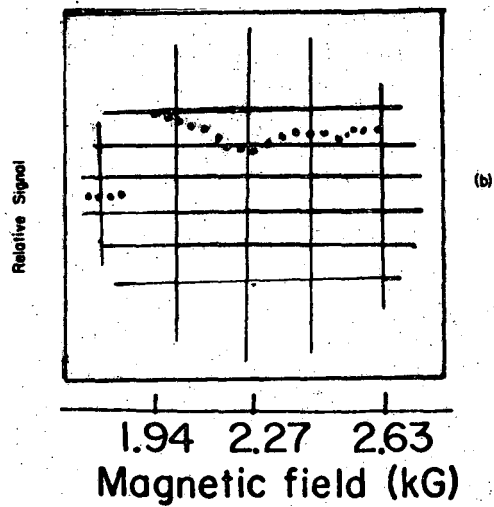
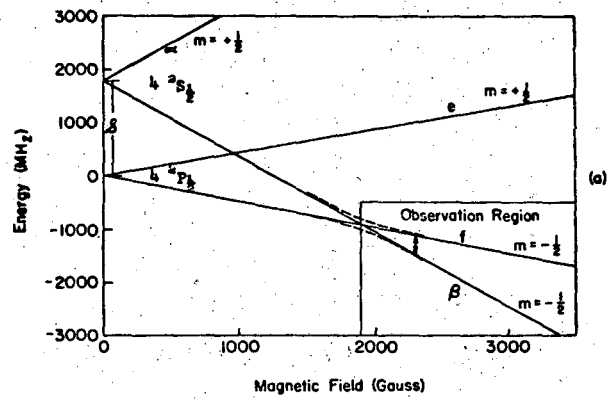


Figure 2

LEGAL NOTICE

*This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:*

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or*
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.*

*As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.*

TECHNICAL INFORMATION DIVISION  
LAWRENCE RADIATION LABORATORY  
UNIVERSITY OF CALIFORNIA  
BERKELEY, CALIFORNIA 94720