DIRECT OBSERVATION OF QUANTUM BEATS DUE TO COHERENT EXCITATION OF NONDEGENERATE EXCITED STATES BY PULSED ELECTRON IMPACT*

Tetsuo Hadeishi and William A. Nierenberg†

Lawrence Radiation Laboratory, University of California, Berkeley, California

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We have observed a modulation of exponential decay of resonance luminescence arising from the interference of coherently excited nondegenerate states $m_J=+1$ and -1 of $7\,^3P_1$ of Cd excited by a sharply pulsed electron impact. The excitation by a sharply pulsed electron impact whose pulse width is much shorter than the lifetimes of the excited states enabled us to observe directly the consequence of atomic fluorescence decay. Similar results were observed by Aleksandrov by means of a modulated electron-beam excitation rather than a single pulsed excitation.[1] Also, the coherent excitation of nondegenerate states by optical excitation was recently observed by various authors.[2-4] We believe that this is the first time that the modulation of the exponential decay of the resonance luminescence was observed directly by pulsed-electron-impact excitation.

Breit has shown a possibility of coherent excitation of nondegenerate sublevels if the exciting resonance radiation is pulsed in time much shorter than the decay time of the excited states,[5] since under this condition the exciting light has a very broad range of spectral frequencies. Similar excitation is possible by a pulsed electron impact since the electron, with its energy corresponding to the energy of the threshold of excitation, can excite the atom in a time of the order of 10^{-16} sec, if we assume an electron speed of 10^8 cm/sec and an atomic diameter of about 10^{-8} cm.

In the case of Cd whose ground state is $7\,^1S_0$ and whose excited state is $7\,^3P_1$, the $m_J=+1$ and -1 states of $7\,^3P_1$ can be coherently excited when the direction of the propagation of the exciting electron is perpendicular to the externally applied magnetic field at the excitation energy slightly above the threshold of excitation. Under such excitation the probability of photon emission is described by a damped-oscillator-type function[1,5,6] $e^{-t/\tau}\{A+B[\cos(\Omega t+\varphi)]\}$, where A, B, and φ are time-independent constants, τ is the lifetime of the excited state, and $\Omega=|E_2-E_1|/\hbar$, with E_2 and E_1 being the energy of the $m_J=+1$ and -1 states of $^3P_1$, respectively.

A Pierce-type electron gun using an impregnated dispenser-type cathode was constructed. With the energy near the threshold of excitation the electron current was quite low, resulting in a very low photon flux. Therefore, the photon counting technique was employed. The well-distilled Cd metal was sealed into the envelope of the electron gun, which is enclosed in an oven with a quartz window. The electron gun was operated at an oven temperature of about 200°C. A solution of 14 g of nickel sulfate and 10 g of cobalt sulfate in 100 cc of water with a Corning glass filter type 7-54 was used to filter the $\lambda3261$ resonance luminescence corresponding to the transition $7\,^3P_1$ to $7\,^1S_0$. This filter combination had a bandpass width of 200 Å centered at 3200 Å and was quite effective in blocking off the light radiating from the cathode.

The electron pulse, whose pulse width is about 5 nsec, was obtained by pulsing the grid of the electron gun.

The $\lambda3261$ photons were detected through filters and a Glan-Thompson quartz polarizer by an RCA type 1P28 photomultiplier tube. To observe the quantum-beats phenomena, we used a multichannel delayed-coincidence analyzer to measure the arrival time of photons following the pulse applied to the grid of the electron gun.[7] The electron gun was pulsed at the

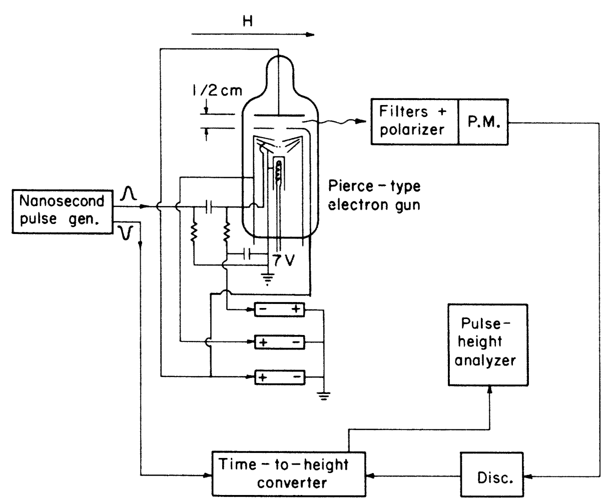

FIG. 1. Schematic diagram of the apparatus.

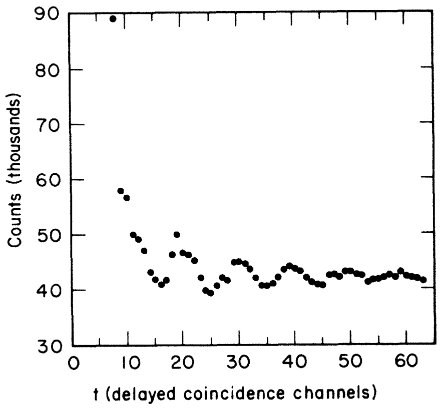

FIG. 2. Quantum beats at 0.88 G.

rate of 10 kc/sec. The count rate was very low, so that the probability of two photons arriving during the duty cycle of the time-to-height converter was negligible. The schematic of the apparatus is shown in Fig. 1.

Figure 2 shows the effect of quantum beats at 0.88 G. The data-accumulation time, because of the low count rate, was 10 h. The period of oscillation corresponded to 270 nsec, resulting in $g_J = 1.5$. The lifetime measured from the exponential decay is 2.2×10^{-6} sec. Similar results were also observed in the $4\,^3P_1$ state of Zn for the transition between $4\,^3P_1$ and $4\,^1S_0$ at 3076 Å, but with a much weaker signal owing to the lower vapor pressure of Zn. It seems that some interesting application of this type of detection method may be realized in the near future.

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†Present address: Scripps Institution of Oceanography, San Diego, California.

[1]E. B. Aleksandrov, Opt. i Spektroskopiya 16, 377 (1964) [translation: Opt. Spectry. (USSR) 16, 209 (1964)].

[2]E. B. Aleksandrov, Opt. i Spektroskopiya 14, 436 (1963) [translation: Opt. Spectry. (USSR) 14, 233 (1963)].

[3]A. Corney and G. W. Series, Proc. Phys. Soc. (London) 83, 207, 213 (1964).

[4]J. N. Dodd, R. D. Kaul, and D. M. Warrington, Proc. Phys. Soc. (London) 84, 176 (1964).

[5]G. Breit, Rev. Mod. Phys. 5, 91 (1933).

[6]P. A. Franken, Phys. Rev. 121, 508 (1961).

[7]W. R. Bennett, Jr., in Advances in Quantum Electronics, edited by J. Singer (Columbia University Press, New York, 1961).

MOTION OF SUSPENDED PARTICLES IN TURBULENT SUPERFLOW OF LIQUID HELIUM II

David Y. Chung and P. R. Critchlow

Department of Physics, University of British Columbia, Vancouver 8, British Columbia, Canada
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We report here some observations on the motion of suspended particles in pure superflow. Solid hydrogen is less dense than liquid helium, whereas solid deuterium is more dense. By mixing hydrogen and deuterium gases together at room temperature in the correct proportions, solid particles with a density very close to that of liquid helium may be obtained.[1]

The superfluid wind tunnel is very similar to the one used by Koehler and Pellam.[2] The essential features are shown schematically in Fig. 1. Except for the superleaks F_1 and F_2 and the Kovar seals K_1 and K_2, the apparatus is constructed entirely of glass. A cloud of H_2-D_2 particles is introduced into the main experimental region S by allowing a predetermined quantity of hydrogen and deuterium mixture to enter the tube G. The heater H' allows some control of the particle size. A horizontal flow of pure superfluid is achieved using the heater H and the superleaks, which are constructed of tightly packed cerium-oxide powder. This double superleak configuration prevents the back flow of normal fluid through S by providing a thermal ground through the metal sections. Superfluid velocities are determined by measuring the rate of filling of a 2-cc beaker B. Small corrections to this velocity are made to allow for evaporation and film flow. A fountain pump P enables the beaker to be emptied