10-3 TUNABLE MONOCHROMATIC FAR INFRARED SOURCE USING HOT ELECTRON TRANSITIONS BETWEEN LANDAU LEVELS IN n-InSb

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We report the first observation of tunable monochromatic far infrared radiation from n-type InSb at liquid helium temperature under crossed electric and magnetic fields, due to transitions of hot electrons btween Landau levels. This tunable emission offers the possibility of a useful application as a high power tunable light source for far infrared spectroscopy.

The specimens used in the present experiment were high purity single crystal of n-type InSb contaning the free carrier concentration of $2x10^{13}$-$2x10^{14}/cm^3$ at 77 K. Magnetic fields up to 20 KOe in strength were applied by a superconducting solenoid transverse to the sample current. The pulsed electric field of 0 - 20 V/cm with the duty ratio of $6x10^{-3}$ was applied. The radiation emitted from the specimen was detected by a narrow band Ge/Sb photoconductive detector,[1)] which has a maximum spectral response at a photon energy of 9.8 meV with a band width of $\Delta\lambda/\lambda \simeq 0.15$.

The intensity of observed far infrared radiation is shown in Fig.1 as a function of the magnetic field. For peaks 1α, 1β, 2, and 3 from the high magnetic field side are seen. The peaks 1, 2, and 3 satisfy the condition

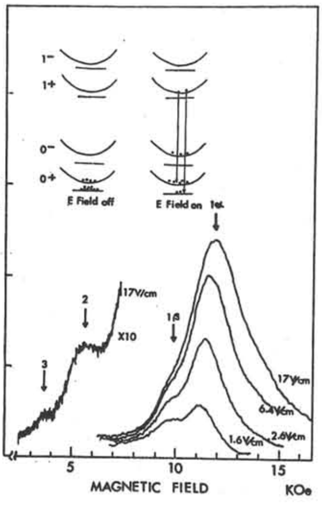
$$n\hbar\omega_c = 9.8 \text{ meV}, \qquad n = 1, 2, 3$$

where ω_c=eH/mc is the cyclotron frequency, with the effective mass $m=0.013\ m_o$. These peaks are identified to be the hot electron transition between Landau levels, i.e. $(1^+\to 0^+)$, $(2^+\to 0^+)$, and $(3^+\to 0^+)$, respectively. The subsidial peak 1β is the result of radiative capture of electrons from the 1^+ Landau level directly into the impurity ground state. The intensity of the 1α peak rapidly increases and then tends to saturate, while the 1β peak becomes masked with the 1α peak with increasing electric field.

The maximum power of the observed 1α radiation is estimated to be 10^{-1}Watt, however, high power of $\gtrsim 1$ μWatt can be expected using larger specimen. The width of the peaks in Fig.1 were determined mostly by the band width of the Ge/Sb detector. Assuming the band width of the emission line $(1^+\to 0^+)$ and absorption line $(0^+\to 1^+)$ are nearly equal, the band width of far infrared radiation of 1α was estimated as $\Delta\lambda/\lambda \sim 10^{-2}$ at λ = 119 μm from the cyclotron resonance absorption in the pulsed electric field.[2)]

Such a narrow band width tunable emitter provides a new type of far infrared spectrometer which is schematically shown in Fig.2. This type of spectrometer is expected to reduce the scanning time of the spectrometer comparing the conventional grating spectrometer. Wavelength range of the proposed spectrometer may be limited between 50μm and 300μm due to reststrahlen band and broadening of Landau levels for the short and long wavelength limits, respectively. The resolution is estimated typically to be 1 cm^{-1} at the wave number of 100 cm^{-1}.

1) Y. Oka, K. Nagasaka, and S. Narita, Japan. J. Appl. Phys. 7, 611(1968).
2) K. L. I. Kobayashi and E. Otsuka, Solid State Comm. 11, 85(1972).



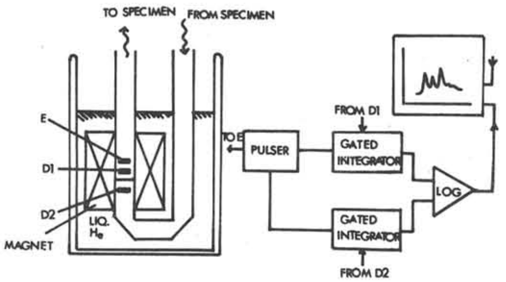


Fig. 2

← Fig. 1

Fig. 1 Intensity of the far infrared emission at different electric field strengths. The recorder trace in the lower magnetic field side is in enlareged scale to show structures clearly. The insertion shows schematically the electron distribution with and without electric field.

Fig. 2 Schematic diagram of the proposed far infrared spectrometer. E is the tunable far infrared source. D1 and D2 are n-InSb tunable cyclotron resonance detectors, which are always in resonance with the emitter E. Taking logarithm of the ratio of the output signals of D1 and D2, absorption coefficient of specimen can be obtained.