Defense Technical Information Center Compilation Part Notice

ADP012846

TITLE: Spectral Response of Quantum Hall Effect Far Infrared Detector

DISTRIBUTION: Approved for public release, distribution unlimited
Availability: Hard copy only.

This paper is part of the following report:

TITLE: Nanostructures: Physics and Technology International Symposium [6th] held in St. Petersburg, Russia on June 22-26, 1998 Proceedings

To order the complete compilation report, use: ADA406591

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP012712 thru ADP012852

Ioffe Institute
6th Int. Symp. "Nanostructures: Physics and Technology"
St Petersburg, Russia, June 22–26, 1998.

Spectral response of quantum Hall effect far infrared detector

V. I. Gavrilenko‡, I. V. Erofeeva‡, N. G. Kalugin‡, *A. L. Korotkov*‡,
M. D. Moldavskaya‡, Y. Kawano† and S. Komiyama†
‡ Institute for Physics of Microstructures RAS, Nizhny Novgorod
† Graduate School of Arts and Sciences, University of Tokyo,Japan

Abstract. Cyclotron resonance photoconductivity of 2D electrons in GaAs/AlGaAs heterostructure in millimeter and submillimeter wavelength range in strong magnetic fields was investigated. Quantum Hall effect device was demonstrated as sensitive magnetically tunable narrow band (2–5 cm^{-1}) far infrared detector.

Introduction

The magnetic field dependence of far infrared photoresponse of two-dimensional (2D) electrons has been the subject of several investigations [1-5]. In high magnetic fields the gap in the density of delocalized states occurs and quantum Hall effect (QHE) is observed. When the Fermi level ε_F lies in localized states between two adjacent Landau levels the longitudinal resistance R_{xx} vanishes and the Hall resistance R_H is quantized to a multiple of h/e^2. Hence one can expect that the finite R_{xx} emerges when electrons and holes are photoexcited in delocalized states near the level center above and below ε_F. This suggests that QHE device may serve as excellent cyclotron resonance (CR) detector in far infrared (FIR) range. In the work [5] high sensitive QHE FIR detector based on 2D electron gas in GaAs/AlGaAs heterostructures was realized. The photoresponse was studied using tunable by the magnetic field n-InSb emitter as a radiation source with rather broad emission line (about $20\,\mathrm{cm}^{-1}$). In the present work the high resolution study of the photoresponse in wavelength range $100\,\mu$m to 2 mm was carried out.

1 Experimental

The sample under study was fabricated from high mobility ($\mu_{4.2\mathrm{K}} \approx 8 \cdot 10^5\,\mathrm{cm}^2/\mathrm{V}\cdot\mathrm{s}$) GaAs/AlGaAs heterostructure. The sample was a long Hall bar with a width $W =$ 50 mm and a length $L = 170$ mm patterned in zig-zag shape and fitted into an area $4 \times 4\,\mathrm{mm}^2$ [5]. The sample was biased by dc current of $4\,\mu$A. In 2 mm wavelength range the response was studied as a function of the magnetic field using backward wave tube as a source of monochromatic radiation. At higher frequencies up to $100\,\mathrm{cm}^{-1}$ the spectra of the photoresponse were investigated using BOMEM DA3.36 Fourier-transform spectrometer. All measurements were made at $T = 4.2\,\mathrm{K}$.

2 Results and discussion

The dc measurements of the resistance R_{xx} in magnetic fields are shown in Fig. 1. 2D electron concentration obtained from the period (in $1/B$ scale) of Shubnikov-de Haas oscillations is $\mathrm{n_s} = 2.8 \cdot 10^{11}\,\mathrm{cm}^{-2}$. The observed minimums of R_{xx} as a function of magnetic field correspond to the filling factors $\nu = hn_s/eB = 2$ (at $B = 5.6\,\mathrm{T}$), 4, 6, 8

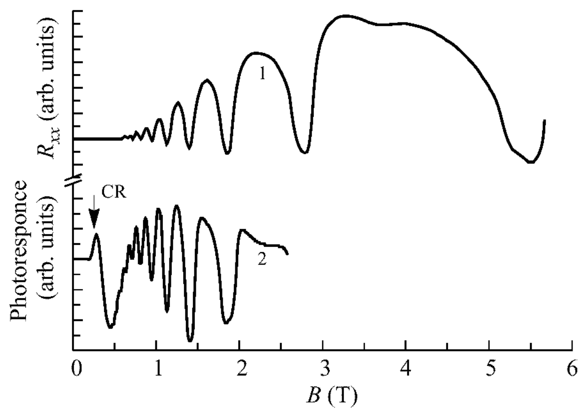

Fig 1. Longitudinal resistance R_{xx} (curve 1) and photoresponse signal at $\lambda = 2.3$ mm (curve 2) of the sample versus magnetic field; $T = 4.2$ K.

etc. Fig. 1 presents also the magnetic field dependence of the sample photoresponse at $\lambda = 2.3$ mm. As it seen the CR signal (indicated by the arrow) is accompanied by distinct oscillations. The period of the photoresponse oscillations as well as the positions of maximums and minimums coincide with those for the Shubnikov–de Haas oscillations. The signal mechanism is tentatively considered as bolometric: the absorption results in heating of the electrons (ΔT_e) and in the change in the electron mobility, the magnitude of the signal being proportional to $(\partial R_{xx}/\partial T) \cdot \Delta T_e$. It is seen that oscillations of the photoresponse are stretched rather far from the CR line and suppressed at $B \approx 3$ T that indicates the finite density of delocalized states between Landau levels [4]. The results of the detailed investigations of the photoresponse in the submillimeter wavelength range using backward wave tubes will also be presented in the report.

Fig. 2 represents the photoconductivity spectra of the sample in constant magnetic fields near integer filling factors $\nu = 8, 6, 4, 2$. The spectra were measured either "to the left" or "to the right" of R_{xx} minimums. Sharp CR peaks with line width of few cm^{-1} were observed in the spectra. CR line positions (from both Fig. 1 and Fig. 2) versus the magnetic field are plotted in Fig. 3a. The dependence is linear with the slope corresponding to the GaAs electron mass value $m = 0.068m_0$. The peak sensitivity was earlier shown to increase with the electron mobility and in this sample was estimated at $\nu = 2$ as 10^6 to 10^7 V/W [5]. The CR linewidth values (measured at 1/2 of the peak signal in Fig. 2) versus the magnetic field are shown in Fig. 3b. It is clearly seen that the linewidth undergoes rapid leaps near the integer values of the filling factors $\nu = 4$ and $\nu = 6$ that seems to result from the reduced screening due to density-of-states gaps [6]. At the filling factors $\nu \approx 2$ ($B = 5.5$ T) the linewidth increases 2 times that corresponds to the observed peculiarities of the linewidth oscillations in the transmission experiments [6].

Thus the QHE device was demonstrated as sensitive magnetically tunable narrow band FIR detector. The first results on the spectroscopic study of the FIR emission of hot carriers in MQW heterostructures obtained with QHE detector will be discussed in the report.

The research described in the publication was made possible in part Grants No. 7.8 from Russian Scientific Program "Physics of Quantum and Wave Phenomena/Funda-

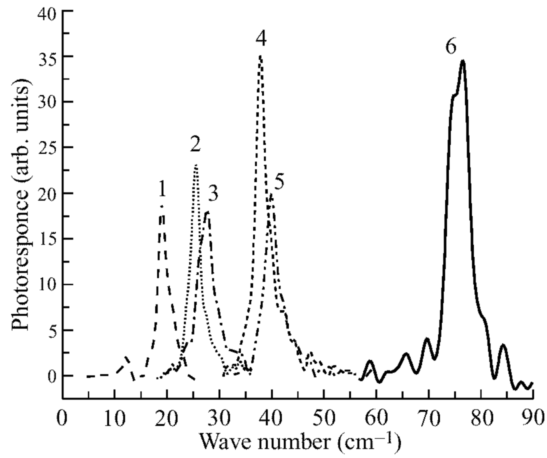

Fig 2. Spectra of the CR photoconductivity of the sample in constant magnetic fields near integer filling factor $\nu = 8$ ($B = 1.4$ T, curve 1); $\nu = 6$ ($B = 1.8$ T, curve 2 and $B = 1.9$ T, curve 3); $\nu = 4$ ($B = 2.8$ T, curve 4 and $B = 2.9$ T, curve 5); $\nu = 2$ ($B = 5.5$ T, curve 6); $T = 4.2$ K.

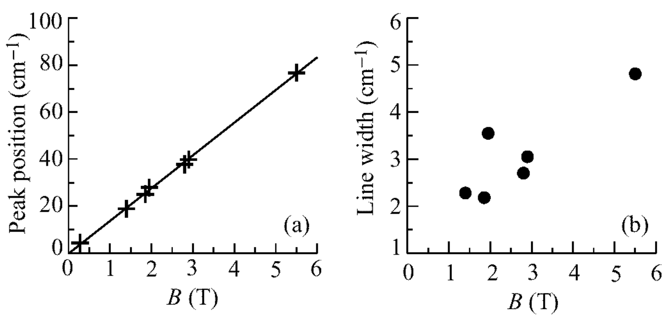

Fig 3. (a) the CR line positions from Fig. 1 and Fig. 2 versus magnetic field; (b) the CR linewidths (FWHM) from Fig. 2 versus magnetic field.

mental Spectroscopy”, No. 97-2-14 from INCAS, #96-1023 from Russian Scientific Program “Physics of Solid State Nanostructures”, No. 4.5 from Russian Scientific Program “Physics of Microwaves” and No. 97-02-16311 from RFBR.

References

[1] D. Stein, G. Ebert, K. von Klitzing and G. Weimann. *Surf. Sci.* **142** 406 (1984).

[2] M. J. Chou, D. C. Tsui and Y. Cho.*Proc. 18th Int. Conf. on Physics of Semiconductors (World Scientific, Singapure, 1987)* 437.

[3] G. L. J. A. Rikken, P. Wyder, K. Ploog, et al. *Surf. Sci.* **196** 303 (1988).

[4] N. A. Varvanin, V. N. Gubankov, I. N. Kotel'nikov et al. *FTP* **24** 635 (1990).

[5] S. Komiayma, Y. Kawano and Y. Hisanaga. *Proc. 21st Int. Cohf. on Infrared and Millimeter Waves, Berlin, 1996)* Bt2.

[6] W. Sedenbusch, E. Gornik and G. Weimann. *Phys. Rev. B* **36** 9155 (1987).