Spin Polarization of Electrons in Lateral Periodic Potential
Around Filling Factor $\nu=3$

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Abstract
We have investigated the spin polarization of electrons in a Be-$\|$-doped single heterojunction modulated by a field-induced lateral potential by a circularly polarized magneto-photoluminescence spectroscopy. We observe minimum in the polarization of the lowest state at the filling factor $\nu=3$ at a bias voltage $V_B=0$ V. The minimum becomes less pronounced with increase in the lateral periodic potential, which is related with unstabilization of the Skyrmion excitation.

Introduction
A circular polarization dependent photoluminescence (PL) spectroscopy is a powerful tool for direct detection of the spin polarization of electrons in the two-dimensional electron systems (2DES). This method has been successfully applied for the investigations of the Skyrmionic excitations at $\nu=1$ [1]. In constrast to the case of $\nu=1$ [2], there have been arguments for the observation of the Skyrmion excitation at odd integer $\nu\geq3$ [3]. Kerridge et al. interpreted the depolarization of the lowest state of the 2DES to be due to the formation of Skyrmions [4]. In this paper, we report the dependence of this depolarization on the magnitude of a lateral periodic potential.

Results and discussions
The lateral periodic potential is tuned by applying a bias voltage $(V_B)$ between a back gate and a surface gate of square mesh of a period of 250-400 nm prepared by the electron beam lithography on a Be-$\|$-doped single heterojunction [5]. A Be-$\|$-doped layer is located 25 nm from the heterointerface with a nominal doping density of $2\times10^{10}$ cm$^{-2}$. The electron density was estimated to be $3.6\times10^{11}$ cm$^{-2}$ from an optical Shubnikov-de Haas measurement without applying $V_B$. PL spectra were obtained by illuminating the samples at 800 nm at the excitation power density of about 10 mW/cm$^2$ at 1.8 K. The results are shown for the $\|$ excitation. No significant difference is observed between the excitation polarizations.

The magnetic field dependencies of the degree of circular polarization of the PL from the four lowest Landau-levels (LL$N$, $N=0, 1, 2, 3$) at $V_B=0$ V in the low magnetic field regime are shown in Fig. 1. The polarization of the PL from the partly occupied Landau-levels shows maxima at odd filling factors ($\nu=5, 7$) due to the enhancement of the spin splitting in agreement with the literature [1].

Figure 2 shows the magnetic field dependencies of the degree of circular polarization of the PL from the lowest state at $V_B=0$ V, -0.3 V, -0.5 V. The minimum at around $\nu=3$ for LL0 was ascribed to be due to the Skyrmion formation [5]. No polarization maximum is observed in Fig. 2 at $\nu=3$ in the partly occupied second Landau-level at $V_B=0$ V, probably due to the saturation of the degree of the polarization. The position of the minimum at $\nu=3.17$ (4.7 T) in the lowest state is not shifted between $V_B=0$ V and -0.3 V indicating that the local electron density at the lateral position mainly contributing to the PL is not decreased by the negative bias voltage. This minimum disappears at $V_B=-0.5$ V, which can be interpreted that the Skyrmion stability depends on the magnitude of the lateral confinement potential. Measurements are also performed for samples with a surface gate structure of
square mesh of a period of 250 nm, and qualitatively similar but stronger $V_B$ dependencies are observed. Lateral potential modulation energy is estimated to be about 0.5 meV at $V_B = -0.5$ V [5]. The application of the lateral potential is considered to change the exchange energy and hence the spin configuration of the electrons. The abrupt change of the magnetic field dependencies between $V_B = -0.3$ and -0.5 V may support the picture of the Skyrmion formation at $n = 3$.

In summary, the spin polarization of electrons in a field-induced lateral potential is investigated by a circularly polarized magneto-photoluminescence spectroscopy. The observed minimum in the polarization at $n = 3$ becomes less pronounced with increase in the magnitude of the lateral periodic potential, which is related to unstabilization of the Skyrmion excitation.

References

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Fig. 1 Magnetic field dependent polarization of the PL from LL0 (closed circles), LL1 (closed boxes), LL2 (open triangles), and LL3 (open boxes) at $V_B = 0$ V in the low magnetic field regime.

Fig. 2 Magnetic field dependent polarization of the PL from the lowest state at $V_B = (i) 0$ V (closed circles), (ii) -0.3 V (open triangles), (iii) -0.5 V (closed boxes), and from (iv) LL1 at $V_B = 0$ V (open circles) .