Interaction correction to conductivity of $Al_xGa_{1-x}As/GaAs$ double quantum well heterostructures near the balance

G. M. Minkov,[1,2] A. V. Germanenko,[2] O. E. Rut,[2] A. A. Sherstobitov,[1,2] A. K. Bakarov,[3] and D. V. Dmitriev[3]

[1]*Institute of Metal Physics RAS, 620990 Ekaterinburg, Russia*

[2]*Ural State University, 620000 Ekaterinburg, Russia*

[3]*Institute of Semiconductor Physics RAS, 630090 Novosibirsk, Russia*

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The electron-electron interaction quantum correction to the conductivity of the gated double well $Al_xGa_{1-x}As/GaAs$ structures is investigated experimentally. The analysis of the temperature and magnetic field dependences of the conductivity tensor allows us to obtain reliably the diffusion part of the interaction correction for the regimes when the structure is balanced (i.e., for equal electron concentrations in the wells) and when only one quantum well is occupied. The surprising result is that the interaction correction does not reveal resonant behavior: it is practically the same for both regimes.

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I. INTRODUCTION

The double quantum well (DQW) structures exhibit a number of salient features. For instance, the resistance of the structures with different mobilities in the wells strongly depends on the potential profile of the quantum wells and has a peak when the latter is symmetric.[1–3] The DQW structures are convenient systems to study a wide variety of the oscillatory phenomena originated from the peculiarities of the Landau quantization of the energy spectrum.[4–8]

The quantum corrections to the conductivity are also expected to demonstrate peculiar behavior when the population of the quantum wells and/or the interwell transition rate is varied. The interference quantum correction in DQWs has been studied in Refs. 9–13 where the specific features of the interference-induced magnetoresistance and dephasing processes have been investigated both theoretically and experimentally. An unexpected result has been obtained in Ref. 13. Analyzing the positive magnetoconductivity induced by suppression of the quantum interference by magnetic field, the authors have found that the dephasing rate in the lower quantum well is independent of whether the upper quantum well contributes to the conductivity or not. This observation is inconsistent with the results of the theory which takes into account the inelasticity of the electron-electron (e–e) interaction in the singlet channel only. Such a simplified theoretical approach would yield an increase of the dephasing time in double layer structures as compared with the single-layer case.

The correction to the conductivity due to e–e interaction[14] is investigated in DQW structures significantly less,[12,15] although it is of paramount importance in complicated systems. For instance, the effect of interaction on the conductivity has recently attracted a great deal of interest in a context of two-dimensional (2D) systems with strong e–e interaction showing a metallic-type behavior of the conductivity, $d\sigma/dT < 0$.[16–18]

Main features of the interaction correction expected in DQW structures can be revealed by considering the case of single quantum well system with two-valley energy spectrum. Such structures are relevant to the problem of an apparent metal-insulator transition in 2D silicon MOSFET systems.[16,19]

The diffusion part of the interaction correction to the conductivity, which is dominant at low temperature, $T \ll 1/\tau$, is given by[19–21]

$$\delta\sigma_{ee} = K_{ee}G_0 \ln(T\tau),$$
$$K_{ee} = 1 + \left(4n_v^2 - 1\right)\left[1 - \frac{1+\gamma_2}{\gamma_2}\ln(1+\gamma_2)\right], \quad (1)$$

where $G_0 = e^2/\pi h \simeq 1.23 \times 10^{-5}\ \Omega^{-1}$, n_v is the number of valleys, and γ_2 is the Landau's Fermi liquid amplitude expressed through the Fermi liquid constant F_0^σ: $\gamma_2 = -F_0^\sigma/(1+F_0^\sigma)$.[22] For the high conductivity, the value of F_0^σ depends on the gas parameter $r_s = \sqrt{2}/(a_B k_F)$. Here a_B is the effective Bohr radius and k_F is the Fermi quasimomentum. For small values of r_s, the Fermi liquid constant can be estimated as[17]

$$F_0^\sigma \to -\frac{1}{2\pi}\frac{r_s}{\sqrt{2-r_s^2}}\ln\left(\frac{\sqrt{2}+\sqrt{2-r_s^2}}{\sqrt{2}-\sqrt{2-r_s^2}}\right), \quad r_s^2 < 2. \quad (2)$$

The coefficient K_{ee} involves two terms coming from singlet and multiplet channels [the first and second terms in Eq. (1), respectively]. The singlet term does not depend on the interaction constant F_0^σ and the number of valleys. This term favors localization, i.e., it leads to the conductivity decrease with lowering temperature. In contrast, the multiplet term depends on both F_0^σ and n_v. The multiplet channel gives the antilocalization contribution to the conductivity for any F_0^σ given by Eq. (2). This correction is independent of the magnetic field provided the Zeeman splitting is sufficiently small, $g\mu_B B \ll T$, where g is the effective Landé g-factor. Importantly, in the two-valley case, the multiplet term contains a large factor $4n_v^2 - 1 = 15$ and hence dominates over the localizing singlet term already for not too strong interaction.

The value of K_{ee} can be experimentally determined from the temperature and magnetic-field dependences of the resistivity. Let us demonstrate how strongly K_{ee} depends on the valley degeneracy. For the 2D electron gas in GaAs quantum well (i.e., $n_v = 1$, $a_B \simeq 100$ Å) with the density $n = 5 \times 10^{11}$ cm^{-2}, we obtain from Eq. (2) that $F_0^\sigma = -0.255$ ($\gamma_2 = 0.343$) and $K_{ee} \simeq 0.6$. The positive sign of K_{ee} means that the e–e

interaction favors localization. For the hypothetical case of the two-valley electron spectrum, $n_v = 2$, with the same effective mass and electron density per one valley, the correction in the multiplet channels is larger than that in the singlet one. As a result, the coefficient K_{ee} has the opposite sign, $K_{ee} \simeq -1.3$, i.e., the correction would be antilocalizing.[23]

It is natural to think that DQW heterostructures based on the single-valley semiconductors should demonstrate behavior similar to the case of two-valley systems. The two quantum wells in DQWs play the role of artificial valleys. Importantly, DQW structures provide a possibility of controllable manipulation of this "valley" degree of freedom, which is not easy in real two-valley systems. As follows from the above discussion, this renders DQW heterostructures particularly interesting for studying interaction-induced effects on transport properties. In particular, a crucial change of the interaction contribution to the conductivity is expected to be observed in the gated DQW structures when, by changing the gate voltage, one varies the electron concentration in the two quantum wells. Specifically, one can expect huge variations of K_{ee} in the DQW structure, when crossing over from the regime when the structure is in the balance to the regime when the upper quantum well is empty.

In order to model a two-valley system with the help of a DQW, the following special conditions have to be fulfilled. At the balance, not only the electron densities in the wells should be equal to each other, $n_1 = n_2$, but the mobilities as well. Moreover, the scatterers should be common for the carriers in the different wells: each specific impurity should scatter the carriers of the lower and upper wells identically. In addition, the interwell distance d should be small, $\varkappa d < 1$, where $\varkappa$ is the inverse screening length, but the interwell transition time t_{12} should be large, $t_{12} \gg 1/T$. In reality, it is very difficult to fulfill (and especially to check the fulfillment of) all these requirements. However, because the qualitative speculation presented above predicts a very huge effect, it seems that significant change of the interaction correction in DQW structure at varying of the density should be observed easily even in structures that fall short of this ideal. To the best of our knowledge, such a renormalization of the interaction contribution to the conductivity in the singlet and multiplet channels at varying ratio of densities in the wells was never observed experimentally.

In this paper, we have tried to detect the resonant change of the interaction-induced correction to the conductivity in the GaAs DQW heterostructures. Surprisingly, we have found that the interaction correction is practically independent of whether two or one quantum well contribute to the conductivity. The situation in DQW heterostructures is thus very nontrivial. Clearly, the model of two essentially independent 2D electron gases would yield a twice larger value of K_{ee} than for a single layer. Indeed, in the limit $d \to \infty$, the two layers can be thought of as two parallel conductors which do not affect each other. Their conductivities, including the interaction-induced corrections, would just add up, when contacts are attached to both layers. The actually observed value of K_{ee} at the balance is, however, close to that found in the effectively single-layer case. This suggests that the two layers are strongly coupled by Coulomb interaction under our experimental conditions. Then, naively, it would resemble a single-layer system with two valleys, where the intervalley and intravalley interactions are equally important. In this case, the singlet contribution to K_{ee} is the same as in a single-valley system, see Eq. (2): the valley degeneracy (number of parallel conductors) is compensated by the increase of the screening (electrons from both valleys participate in the dynamical screening of Coulomb interaction). However, according to Eq. (2), the multiplet interaction in this situation is expected to change the sign of K_{ee}, contrary to experimental observations. Thus, none of the limiting cases may explain that at the balance K_{ee} has essentially the same value as in the single-layer case.

II. EXPERIMENTAL DETAILS

The results presented in this paper have been obtained for just the same samples for which the weak localization effect has been investigated in Ref. 13. The gated samples were made on the basis of the DQW heterostructures in which the two GaAs quantum wells of width 8 nm are separated by 10 nm $Al_{0.3}Ga_{0.7}As$ barrier. Two δ layers of Si have been situated in the barriers to deliver the electrons in the wells. The main doping δ layer of Si is in the center of barrier separating the wells. To compensate the electric field of the Schottky barrier, the second δ layer is located above the upper quantum well at distance of 18 nm from the well interface. Two heterostructures, 3243 and 3154, with different doping levels have been investigated. The main parameters of the samples have been determined in Ref. 13 and for two regimes considered in this paper are listed in Table I. The regime when only the lower quantum well is occupied is referred as SQW regime. Balance is the regime of the equal electron densities in the wells. The energy splitting between the symmetric and antisymmetric states (Δ_{SAS}) in this regime is about 0.1 meV,[13] that is much less than $1/\tau$ and less than the temperature under our experimental conditions.

For both heterostructures, the results obtained were mostly analogous and in what follows, we shall discuss in more detail the results obtained for the structure 3243.

III. RESULTS AND DISCUSSION

To extract the interaction contribution to the conductivity, we have used the unique property of this correction in the diffusive regime: the interaction gives contribution to the one component of the conductivity tensor, namely, to σ_{xx}, whereas $\delta\sigma_{xy} = 0$.[14] At low interwell transition rate, the components

TABLE I. Parameters of the structures investigated.

Structure	#3243		#3154	
Regime	SQW	Balance	SQW	Balance
V_g (V)	−4.1	−1.5	−3.6	−2.0
n (10^{11} cm^{-2})[a]	7.0	7.5	4.0	4.5
μ (10^3 cm^2/V s)	14.5	15	4.8	6.5
$K_{ee} \pm 0.05$, exp.	0.60	0.57	0.53	0.50
K_{ee}, theor.[b]	0.58	0.72	0.51	0.59

[a]The electron density per quantum well.
[b]Estimated from Eqs. (1) and (2) for SQW regime and according to Ref. 24 for the balance.

of the conductivity tensor in the double well structures are simply the sum of the components of each well, $\sigma_{xx,xy} = \sigma^{(1)}_{xx,xy} + \sigma^{(2)}_{xx,xy}$. Therefore, the temperature dependence of σ_{xx} at the high magnetic field, $B > B_{tr}$, which suppresses the temperature dependence of the WL correction, is determined by the interaction correction only. Here $B_{tr} = \hbar/2el^2$ is the transport magnetic field and l is the transport mean free path. The temperature dependence of σ_{xx} should be logarithmic and the slope of σ_{xx} vs $\ln T$ plot should give the value of K_{ee}.

The situation becomes more complicated at $T\tau > 0.1$, when the ballistic contribution of interaction becomes important.[17] This contribution results in the temperature-dependent correction to the mobility.[17,25] In its turn, this leads to appearance of the magnetic field dependence of $\Delta\sigma_{xx} = \sigma_{xx}(T) - \sigma_{xx}(T_0)$ and the temperature dependence of $\Delta\sigma_{xy}$:

$$\Delta\sigma_{xx}(B,T) = \sum_{i=1}^{2} \frac{1-\mu_i^2(T_0)B^2}{\left[1+\mu_i^2(T_0)B^2\right]^2} en_i\Delta\mu_i(T) + \left[K^{(1)}_{ee} + K^{(2)}_{ee}\right]G_0 \ln\left(\frac{T}{T_0}\right), \quad (3)$$

$$\Delta\sigma_{xy}(B,T) = \sum_{i=1}^{2} \frac{2\mu_i(T_0)B}{\left[1+\mu_i^2(T_0)B^2\right]^2} en_i\Delta\mu_i(T), \quad (4)$$

where summation runs over the quantum wells, $\Delta\mu_i(T) = \mu_i(T) - \mu_i(T_0)$, T_0 is some fixed temperature, $K^{(1)}_{ee}$ and $K^{(2)}_{ee}$ stand for K_{ee} in the lower and upper well, respectively. As seen from Eq. (3), the temperature dependence of σ_{xx} in this case is determined not only by $K^{(1)}_{ee}$ and $K^{(2)}_{ee}$, but by μ_1, μ_2, $\Delta\mu_1$, and $\Delta\mu_2$ also. Things will get better preferably when the mobilities in the wells are close to each other. Then, as seen from Eq. (3), the temperature dependence of σ_{xx} at $B = 1/\mu$ is determined by diffusion interaction correction only. Therefore, let us start our analysis of the data from this case.

For the structures 3243 and 3154, the balance, $n_1 = n_2$, takes place at $V_g = -1.5$ and -2 V, respectively. Detailed analysis of the gate voltage dependences of the electron densities and mobilities performed for these structures in Ref. 13 demonstrates that near the balance, the mobilities have close values. The magnetic field dependences of σ_{xx}, σ_{xy}, and $\Delta\sigma_{xx,xy} = \sigma_{xx,xy}(4.2\text{ K}) - \sigma_{xx,xy}(1.35\text{ K})$ taken for the structure 3243 at $V_g = -1.5$ V are presented in Figs. 1(a) and 1(b), respectively. One can see that $\Delta\sigma_{xx}$ decreases strongly up to $B = 1$ T whereas $\Delta\sigma_{xy}$ is not small over the whole magnetic field range. (The value of B_{tr} at this gate voltage is about 10^{-2} T. Therefore, the variation of σ_{xx} and σ_{xy} is not associated with the contribution of the weak localization correction.) Such variations of $\Delta\sigma_{xx}$ and $\Delta\sigma_{xy}$ with the changing temperature and magnetic field do not match to the diffusion interaction correction. It is not surprising because the parameter $T\tau = 0.08$–0.25 is not small within this temperature range and the ballistic part of interaction correction gives significant contribution.

As we mention just below Eq. (4), the diffusion contribution can be extracted in this situation by analyzing the $\Delta\sigma_{xx}$ vs T behavior at $B = 1/\mu$. Such the dependence plotted in Fig. 1(c) demonstrates that the temperature dependence of $\Delta\sigma_{xx}$ in this case is close to the logarithmic one and its slope gives $K_{ee} = 0.55 \pm 0.05$.

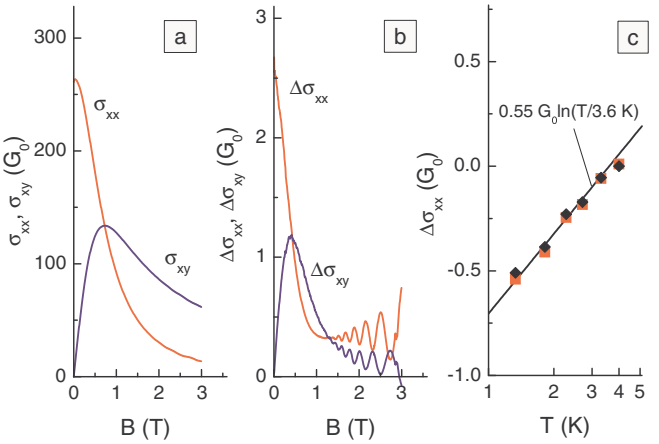

FIG. 1. (Color online) (a) The magnetic field dependences of σ_{xx} and σ_{xy} taken at $T = 1.35$ K. (b) The magnetic field dependences of $\Delta\sigma_{xx,xy} = \sigma_{xx,xy}(4.2\text{ K}) - \sigma_{xx,xy}(1.35\text{ K})$. (c) The temperature dependences of $\Delta\sigma_{xx} = \sigma_{xx}(4.2\text{ K}) - \sigma_{xx}(T)$ at $B = 1/\mu = 0.67$ T (squares) and that found from the Hall effect as described in the text (diamonds). The gate voltage is $V_g = -1.5$ V.

The diffusion part of the interaction correction has to lead to the temperature dependence of the Hall coefficient, $\Delta R_H/R_H \simeq -2\Delta\sigma_{xx}/\sigma_{xx}$, and, hence, the diffusion contribution can be independently obtained from the T dependence of the Hall coefficient. As seen from Fig. 1(c), $\Delta\sigma_{xx}$ found as $[R_H(T) - R_H(4.2\text{ K})]\sigma_{xx}(4.2\text{ K})/2R_H(4.2\text{ K})$ agrees well with the data obtained by the first method.

Finally, the diffusion contribution $\delta\sigma_{ee}$ can be obtained even over the whole magnetic field range by eliminating the ballistic part of interaction with the use of the method described in Ref. 26. Because the ballistic part of the interaction correction is reduced to the renormalization of the mobility and the diffusion part of the correction does not contribute to the off-diagonal component of the conductivity, one can obtain the μ vs T dependence from σ_{xy} provided the electron density is known, e.g., from the period Shubnikov-de Haas oscillations

$$\mu(T) = \left\{\frac{\sigma_{xy}(T)}{[en - \sigma_{xy}(T)B]B}\right\}^{1/2}. \quad (5)$$

Equation (5) allows us to find the correction $\delta\sigma_{ee}(T)$ as the difference between the experimental value of $\sigma_{xx}(T)$ and the value of $en\mu(T)/(1+\mu^2(T)B^2)$. The results of such analysis of the data are presented in Fig. 2(a) as the $\Delta\delta\sigma_{ee}$ vs $\ln T$ plot where $\Delta\delta\sigma_{ee} = \delta\sigma_{ee}(T) - \delta\sigma_{ee}(1.35\text{ K})$. It is clearly seen that the slopes of σ_{xx} vs $\ln T$ dependences are practically independent of the magnetic field and give $K_{ee} = 0.57 \pm 0.05$ in agreement with the value of K_{ee} obtained by the two previous methods.

Thus, three different methods for obtaining the diffusion interaction correction give the same results. The correction $\delta\sigma_{ee}$ is logarithmic in the temperature, and the value of the parameter K_{ee} is 0.57 ± 0.05.

Let us inspect the data for the case when only one well is occupied. For the structure 3243, it occurs at $V_g \lesssim -4$ V. There are not additional difficulties in the extraction of K_{ee}

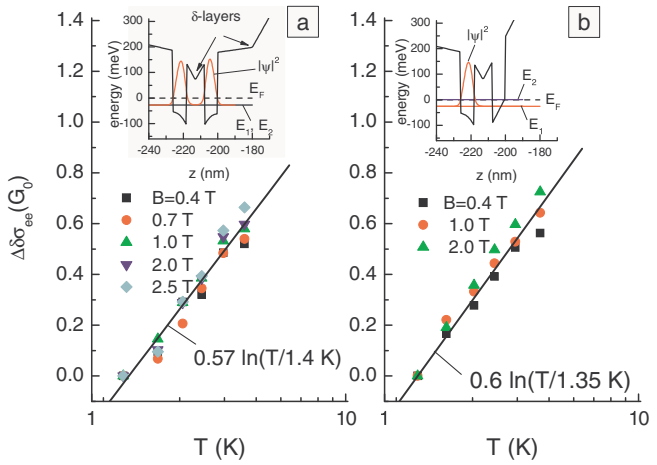

FIG. 2. (Color online) The temperature dependence of the diffusion e–e interaction correction $\Delta\delta\sigma_{ee} = \delta\sigma_{ee}(T) - \delta\sigma_{ee}(1.35\ \mathrm{K})$ for different magnetic fields near the balance, $V_g = -1.5$ V (a) and under the condition that only the lower quantum well is occupied, $V_g = -4.1$ V (b). The insets show the energy diagrams and the electron density distributions $|\psi(z)|^2$ for corresponding gate voltages. E_1 and E_2 are the energies of the subband bottoms, z is the distance from the gate electrode.

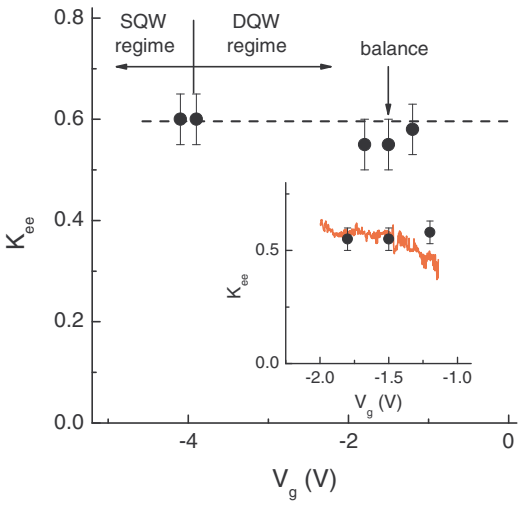

FIG. 3. (Color online) The K_{ee} values plotted against the gate voltage for two regimes, when lower quantum well is occupied and near the balance. In the inset, the line is the K_{ee} vs V_g dependence obtained by sweeping the gate voltage at different temperatures.

for this case. All three methods give also the same results. As an example, we have plotted in Fig. 2(b) the temperature dependence of $\Delta\delta\sigma_{ee}$ taken at different magnetic fields at $V_g = -4.1$ V. At this value of the gate voltage, the electron density and mobility are close to those for each well at the balance. One can see that the temperature dependences of $\Delta\delta\sigma_{ee}$ taken at different B for this case are close to each other also. The slope of the $\Delta\delta\sigma_{ee}$ vs $\ln T$ dependence gives $K_{ee} = 0.60 \pm 0.05$ that corresponds to $F_0^\sigma = -0.225$. This value is in a good agreement with the theoretical estimate, Eq. (2), $F_0^\sigma = -0.237$.

Surprisingly, the value of K_{ee} in the balance practically coincides with that for the regime in which only one quantum well is occupied.[27] Such coincidence seems strange. It does not agree with the qualitative picture considered in Sec. I.

It is possible that the structure 3243 at $V_g = -1.5$ V is close to the balance but not exactly in it. Let us analyze the data at the gate voltages in the vicinity of -1.5 V. In this situation, the mobilities in the wells are distinguished and strictly speaking the method used for $V_g = -1.5$ V is not applicable. However, one can easily assure that by using the total electron density $n_1 + n_2$ and the average mobility $\mu^* = \sigma^*/e(n_1 + n_2)$ (where $\sigma^* = 1/\rho_{xx}$ at $B = 1/\mu^*$) in the data processing one obtains the value of K_{ee} very close to its average value. The values of K_{ee} obtained by this way for $V_g = -1.2$ and -1.8 V are close to that in the balance as shown in Fig. 3.

The resonant change of K_{ee} occurs quite possible within a very narrow range of V_g and we could overlook it measuring K_{ee} at fixed V_g. To check such an occasion, we have measured ρ_{xx} and ρ_{xy} at fixed magnetic field $B = 1/\mu_b$, where μ_b stands for the mobility in the balance, and different temperatures sweeping the gate voltage. The dependence of K_{ee} vs V_g was found as the slope of the σ_{xx} vs $\ln T$ plot. As seen from the inset in Fig. 3, the coefficient K_{ee} changes monotonically[28] and exhibits no resonant feature within the sweeping V_g range. Analogous results were obtained for the structure 3154.

Thus, all the results presented above demonstrate that the noticeable resonant change of K_{ee} to say nothing of change of its sign is not observed in the structures investigated.

One possible reason of the absence of the K_{ee} resonance can be the fact that the scatterers are not common enough in spite of our efforts to design special structures and despite proximity of the mobilities in the wells. The unavoidable variation in the scatterer positions with respect to the center of the barrier results in the fact that the specific impurity scatters the carriers from the lower and upper wells differently. Besides, the interwell distance is not sufficiently small in our case. The parameter $\varkappa d$ is equal to 3.6, so the interaction between the electrons in the different wells is noticeably weaker than that between electrons within the one well.

On the other hand, the interaction correction for the structure with the sufficiently large interwell distance, $d \gg 1/\varkappa$, should be equal to the sum of the correction in wells. The value of K_{ee} for the case when one well is occupied is 0.60 ± 0.05 for structure 3243 (see Table I). So, at $V_g = -1.5$ V, when both wells are occupied and each of them has approximately the same density, the value of K_{ee} would be expected as large as $\simeq 1.2$. In fact, the observed value of K_{ee} is twice less. We conceive that this paradox can be resolved by taking into account the screening of the e–e interaction between the carriers in the one well by the carriers of the other one, which was not taken into account in qualitative consideration above. This screening reduces the e–e interaction strength and, consequently, diminishes the interaction contribution to the conductivity.

It is clear that for the adequate understanding of the role of e–e interaction in the DQW structures, a theory, which properly takes into account the interaction in the singlet and multiplet channels and specifics of the screening for different interwell distances, is necessary. Such theoretical consideration is presented in the following paper.[24] The authors analyze both the interaction and weak localization corrections to the

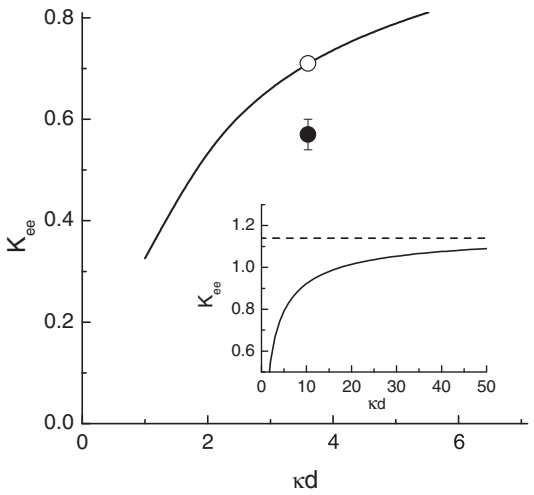

FIG. 4. (Color online) The K_{ee} value at the balance plotted as a function of $\varkappa d$. The solid line is calculated according to Ref. 24 with $n = 7.5 \times 10^{11}$ cm^{-2}. The solid circle is obtained experimentally, the open circle marks the theoretical value of K_{ee} for the structure 3243. The inset shows the calculated K_{ee} vs $\varkappa d$ dependence in wider κd range (solid line). The dashed line is the K_{ee} value in the limiting case of two independent wells.

conductivity of the double layer structures in framework of the random phase approximation. The interaction effect is considered for the case of the identical layers. Unexpected result is that the multiplet contribution even in the case of common scatterers does not win the singlet contribution for $\varkappa d > 1$ and, consequently, does not result in the change of the K_{ee} sign, as we have naively reasoned in Sec. I.

Let us compare the theoretical results[24] with the experimental data. For both structures 3243 and 3154, the experimental and theoretical values of K_{ee} for SQW regime and for the balance are presented in Table I. The calculations have been performed with the electron densities listed in the table, $\varkappa = 2 \times 10^6$ cm^{-1}, and $d = 1.8 \times 10^{-6}$ cm. Because no fitting parameters have been used, agreement between the theory and experiment can be considered as reasonably good.

Figure 4 illustrates the sensitivity of K_{ee} to the interwell distance. The theoretical and experimental values of K_{ee} corresponding to the sample 3243 are marked by open and solid circles, respectively. As seen K_{ee} diminishes with decreasing distance between the wells. However, being always positive it does not even approach the value $K_{ee} \sim -1$ expected in the beginning of the paper for the equal contributions of 15 multiplet channels in the DQW heterostructures with the small interwell distance. The other limiting case of independent contributions to K_{ee} from each well is achieved at very large distance, $\varkappa d > 30$ (see inset in Fig. 4). This is clear indication of the great importance of specific feature of screening of electron-electron interaction in the double layer systems.

IV. CONCLUSION

We have studied the electron-electron interaction correction to the conductivity of 2D electron gas in the gated double quantum well $Al_xGa_{1-x}As$/GaAs heterostructures. Using three different methods, we have obtained the diffusion part of the interaction correction under the conditions when one and two quantum wells are occupied. It has been found that the interaction correction, contrary to naive expectations, is practically independent of whether two or one quantum well contribute to the conductivity. This observation is consistent with the results of the paper by Burmistrov *et al.*,[24] in which the theory for the dephasing and electron-electron interaction in the DQW structures is developed.

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[27]Notice that the electron density in the SQW regime is slightly less than the density per one well in the balance. As seen from Table I, the difference is about 10% for both samples. Therewith, as it follows from Eqs. (1) and (2), the increase in 10% in the electron density in SQW regime results in 3% increase in K_{ee} value that is beyond our experimental accuracy.
[28]The monotonic run of experimental plot in inset in Fig. 3 results from the fact that the measurements were performed at fixed magnetic field corresponding to $1/\mu_b$, whereas the mobilities at V_g above and below the balance gate voltage are somewhat different.