Gate-Voltage Controlled Aharonov-Bohm Oscillations In InAs-Inserted InGaAs/InAlAs Based Rings

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We present an experimental study of Aharonov-Bohm (AB) conductance oscillations in two-dimensional mesoscopic rings fabricated using an InGaAs-based heterostructure, in which Rashba spin-orbit (SO) interaction is particularly strong[1]. It has been theoretically predicted[2] that Rashba SO interaction may affect the frequency spectrum of the AB oscillations. Recently, different experimental observations[3,4,5] have been attributed to this effect. Here, we focus on the measured Fourier spectrum of the AB oscillations and we find that sample specific effects can result in features similar to those induced by SO interaction. We show that these sample specific effects can be suppressed down to a level where SO effect may become visible by using an appropriate averaging procedure.

Figure 1 shows one of the rings used in our investigations. A gate electrode permits to change the properties of the ring, e.g. its electron density and the strength of the spin-orbit interaction[1]. The magnetoresistance of the ring measured at three different values of the gate voltage is shown in Figure 3. AB oscillations are clearly visible in all cases. The observed magnetoresistance trace, as well as the envelope function of the AB oscillations, strongly depends on the applied gate voltage in a random way. This is typical for sample specific phenomena. As a function of gate voltage, the shape of the Fourier spectrum of the AB oscillations exhibits similar behavior. This demonstrates that also the shape of the Fourier spectrum is determined by sample specific effects.

In certain cases, depending on the applied gate voltage, the Fourier spectrum of the AB oscillations can show a pronounced splitting. The splitting may be incorrectly attributed to a spin effect on the AB oscillations. The same holds true for directly observed beatings in the AB oscillation amplitude as a function of magnetic field. However, the random appearance and disappearance of these features for different values of gate voltage indicates that these are not SO induced spin effects.

To further analyse the role of sample specific effects we have investigated the behavior of the *averaged Fourier spectrum* of the magnetoresistance and compared it to the Fourier spectrum of the average magnetoresistance. Averages are calculated over measurements performed at different gate voltages. We find that sample specific features are largely suppressed in the averaged Fourier spectrum as compared to the Fourier spectrum of an individual magnetoresistance trace and to that of the averaged magnetoresistance (see Figure 4). This indicates that the study of the averaged Fourier spectrum may allow the observation of effects induced by SO in AB oscillations.

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References:

[1]J. Nitta, T. Akazaki, H. Takayanagi and E. Enoki, Phys. Rev. Lett. **78,** 1335 (1997)
[2]A.G. Aronov and Y.B. Lyanda-Geller, Phys. Rev. Lett. **70**, 343 (1993)
[3]M.J. Yang, C.H. Yang, K.A. Cheng and Y.B. Lyanda-Geller, cond-mat/0208260 (2002)
[4]A.F. Morpurgo *et al.*, Phys. Rev. Lett **80**, 1050 (1998)
[5]J.B. Yau, E.P. de Poortere and M. Shayegan, Phys. Rev. Lett. **88**, 146801 (2002)

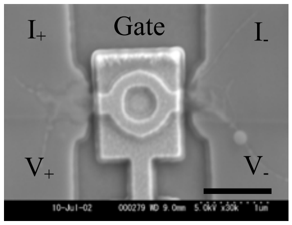

Figure 1: SEM picture of a sample used in our investigations. The black bar is 1μm.

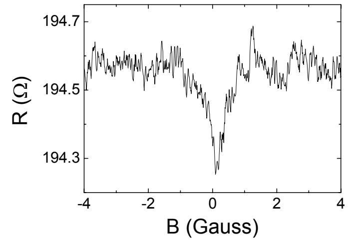

Figure 2: Low field magnetoresistance measured on a Hall bar made on the same heterostructure used to fabricate the rings. The minimum at zero field is due to weak anti-localization caused by Rashba SO interaction.

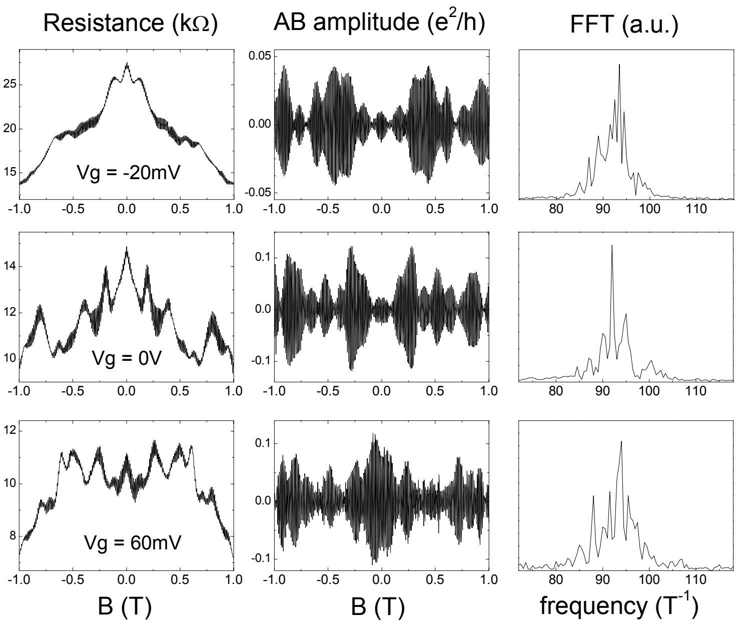

Figure 3: Gate-voltage dependence of the magnetoresistance (column 1), and its Fourier spectrum (column 3). The envelope functions of the AB oscillations are obtained by low frequency filtering of the R(B) curves, and are shown in column 2. We find that these three quantities depend strongly on the gate voltage, in a random way.

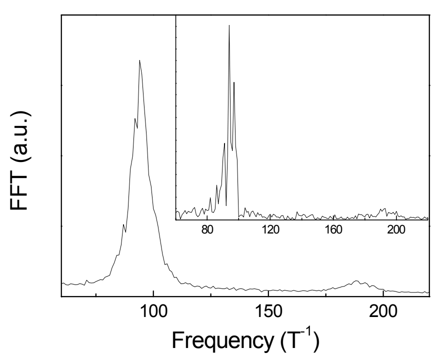

Figure 4: Average of 34 FFT's taken at different gate voltage. In this averaged FFT sample specific structure on the h/e peak is suppressed. In contrast, the inset shows the Fourier spectrum of the averaged magnetoresistance, in which sample specific features are still present, as expected.