Standing Waves of Magnetic Edge States in Mesoscopic Magnetic Rings

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There has recently been much interest in the realisation of microscopic magnetic potentials and the channelling of electrons along magnetic edge states (MES) [1, 2]. The latter drift perpendicular to the magnetic gradients in a periodic oscillatory motion that we demonstrate for the first time here. We have measured the wavelength of MES by forcing them to follow a closed path at the edge of a magnetic puddle. This places an additional boundary condition that quantises the angle at which MES cross the magnetic edge and hence form discrete ring modes.

We defined the magnetic puddles by fabricating single ferromagnetic (Dysprosium, Co/Pt) disks at the surface of a high-mobility two-dimensional electron gas. The diameter of the disks ranged between 2 and $4\mu m$. Here we report on the magnetoresistance and bend resistance measured at liquid helium temperature and at various electron concentrations. At $|B|<0.6T$, the magnetoresistance of a $2\mu m$ dot shows a series of *oscillations periodic in B* whose amplitude remains remarkably constant down to $B=0$, as shown in figure 1. The inset to figure 1 plots the index of oscillation minima, λ, against B for two values of electron concentration. At $n_s=11.1\times10^{11}cm^{-2}$, the period of these oscillations ($\sim 25mT$) is 38 times larger than the expected period of Aharonov-Bohm oscillations ($0.66mT$). Similar B-periodic oscillations were also observed in the measurement of the bend resistance of Dy antidots while completely absent in regions of the same sample that have uniform Dy coverage. We therefore postulate that these oscillations arise when the MES period, $\lambda_s=\alpha(n_s).2R_c$, matches the dot/antidot perimeter: $\lambda.\lambda_s=2\pi R_d$ where $\alpha(n_s)$ is a fitting parameter, R_d is the dot radius and $\lambda=1,2,3...$ is the oscillation index. Fitting the slope of the inset using equation 1 gives $\alpha=0.46$ for $n_s=10.41\times10^{11}cm^{-2}$.

$$\frac{\Delta\lambda}{\Delta B} = \frac{\pi e R_d}{\alpha\hbar\sqrt{2\pi n_s}} \qquad [1]$$

We have measured, for the first time, the period of snake orbits and find, in the case mentioned above with $n_s=10.41x10^{11}cm^{-2}$, $\lambda_s=0.93R_c$. The results presented here draw a parallel with the Bohr-Sommerfeld model quantisation, whereby a finite number of wavelengths fit within the perimeter.

[1] A. Nogaret *et al*., *Phys. Rev. Lett*. **84**, 2231 (2000)
[2] S. Keppeler *et al*., *Phys. Rev. Lett*. **88**, 046401 (2002); J. E. Müller, *Phys. Rev. Lett*. **68**, 385 (1992); J. Reijnier *et al*., *J. Phys. Cond. Matt*. **12**, 9771 (2000)

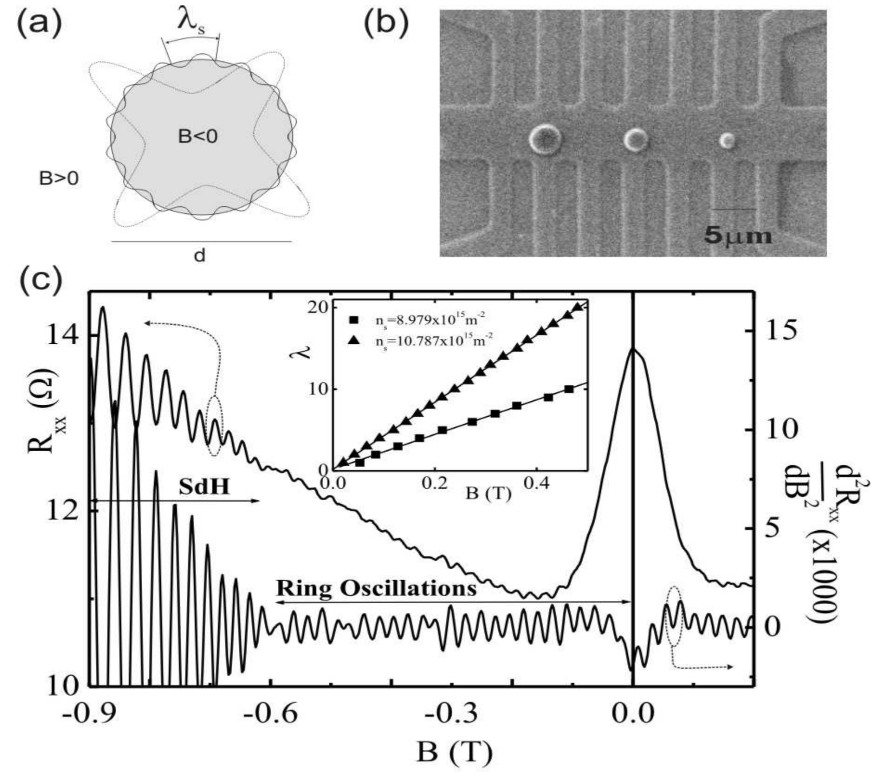

Figure 1: (a) Theoretical snake modes around dysprosium disks (b) when an integer number of snake wavelengths, λ_s, fits within the circumference. (c) Resistance measured across a dot with a diameter *2μm* plotted against *B* along with the second derivative of resistance. Oscillations periodic in *B* are consistent with the release of successive snake modes from the disk as *B* increases. The inset shows oscillation minima against *B* for two values of electron density