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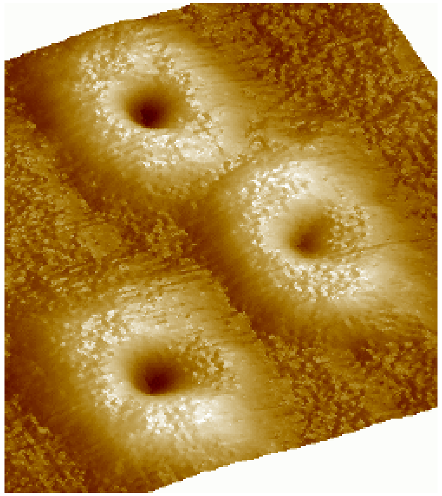
Title and Authors

2 March 2000

The Smallest Rings of Electricity

In most quantum systems, an electron in the ground state has no preferred direction, as in the spherical "1s" orbital of an electron in a hydrogen atom. But adding a magnetic field can change that. An electron confined to a wire ring in a magnetic field zips around at high speed in only one direction, even in its lowest energy state. This effect has now been verified in the 6 March *PRL*, using the smallest rings ever to support measurable currents. Only 50 nm across, the rings act like pure quantum systems of one or two confined electrons, allowing researchers to study the behavior of electrons in a new and controlled way. They may also lead to digital data storage devices in the future.



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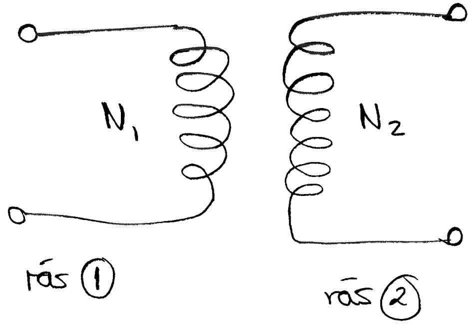
Round and round she goes. These 50-nm-diameter rings can each host a single circulating electron in a pure quantum state, easily controlled by magnetic fields and voltages on nearby plates. They allow studies of electrons under idealized conditions that were not previously available.

Quantum dots are microscopic, carefully tailored regions of a semiconductor surface in which researchers have learned to precisely control the number of electrons and observe a range of quantum effects. Some hope to use them to store bits in future quantum computers. One way to make many dots at once is to spray two atomic layers of InAs on a GaAs surface. Surface tension forces the InAs into beads, like water droplets on a well-waxed car, forming as many as 10^{11} so-called self-assembled quantum dots. Axel Lorke and his colleagues at the Ludwig Maximilians University in Munich and collaborators at the University of California in Santa Barbara (UCSB) managed to make rings from such structures by capping the dots with a 1-nm-thick layer of GaAs and waiting a minute, as surface tension and other

30. Kafli, span

Víxlspan, sjálfspan



Breyting á I_1 breytir segulflæðinu Φ_{12} um spólu 2 $\rightarrow$ $\mathcal{E}_2$ myndast sem vinnur á móti breytingunni

$\Updownarrow$

Víxlspan

spanaður straumur um rás 2

2

Breyting á I_1 breytir segulflæðinu Φ_{11} um spólu 1.

$$\Downarrow$$

veldur $\mathcal{E}_1$ í rás 1

$$\downarrow$$

spanaður straumur I_1
vinnur á móti breytingunni á I_1

$$\Updownarrow$$

sjálfspan

Almennt gilti í kafla 29 að breyting á flæði um spólu með N vafningum olli íspennu

$$\mathcal{E} = -\frac{d(N\Phi)}{dt}$$

í spólunni

3

Athugum kerfið hér

Viljum kanna hvað gerist í spólu 1 þegar I_1 og I_2 breytast

$$\mathcal{E}_1 = -\frac{d(N_1\Phi_1)}{dt}$$

$$\Phi_1 = \Phi_{11} + \Phi_{12}$$

flæði um spólu 1 vegna I_1

flæðinu spólu 1 vegna I_2

$$\rightarrow \mathcal{E}_1 = -N_1\frac{d}{dt}\left(\Phi_{11} + \Phi_{12}\right)$$

Athugum sitthvorn liðinn

sjálfspan

Φ_{11} verður til vegna I_1

$$N_1 \Phi_{11} = L_1 I_1$$

sjálfspanstuðull spólu 1
háður lögun hennar eingöngu

Víxlspan

Φ_{12} verður til vegna I_2

$$N_1 \Phi_{12} = M I_2$$

Víxlspanstuðull

$$\mathcal{E}_1 = \mathcal{E}_{11} + \mathcal{E}_{12} = -L_1 \frac{dI_1}{dt} - M \frac{dI_2}{dt}$$

Allar rásir hafa sjálfspan
og sjálfspanstuðul, misstóran

Einingin fyrir spanstuðlana er

$$1\,H = 1\,Wb/A$$

Henry

L er eiginleiki spólu, eins og C
er eiginleiki þéttis.

Dæmi

Löng spóla með lengd l og
þvermál A

Segulsviðið innan langrar spólu

$$B = \mu_0 n I \,, \qquad n = \frac{N}{\ell}$$

þéttleiki vafninga

$$\Phi = (\Phi_{11}) = BA = \mu_0 n I A$$

↑ í hverjum vafningi

en $\quad N\Phi = LI$

$$\to \quad L = \frac{N\Phi}{I} = \mu_0 \frac{N^2}{\ell^2} A \ell$$

$$\boxed{L = \mu_0 n^2 \underbrace{A\ell}_{\text{spólu}}}$$

eiginleikar

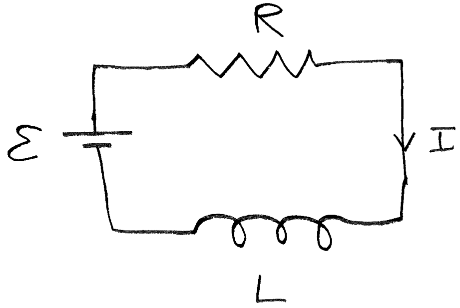
tómarúms

spólu

LR-rás

Kveikt á

Klukkan $t = 0$



$\frac{dI}{dt} > 0 \quad$ Straumur eykst

↓

spólan vinnur á móti því

Kirchhoff → $\boxed{\mathcal{E} - IR - L\frac{dI}{dt} = 0}$

Ummyndum diffurjöfnuna:

$$y = \frac{\mathcal{E}}{R} - I$$

$$\to \quad \frac{dy}{dt} = -\frac{dI}{dt}$$

$$\frac{\mathcal{E}}{R} - I - \frac{L}{R}\frac{dI}{dt} = 0$$

$$\rightarrow \frac{L}{R}\frac{dy}{dt} = -y$$

$$\rightarrow \frac{dy}{dt} = -\frac{R}{L}y$$

umröðum

$$\frac{dy}{y} = -\frac{R}{L}dt$$

$$I(0) = 0 \rightarrow y(0) = \frac{\mathcal{E}}{R}$$

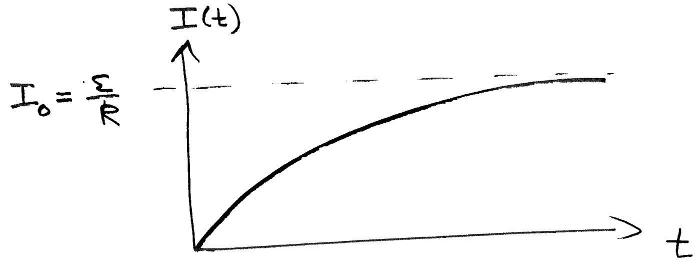
$$\int_{y(0)}^{y(t)} \frac{dy'}{y'} = -\frac{R}{L}\int_0^t dt'$$

$$\ln\left(\frac{y(t)}{y(0)}\right) = -\frac{R}{L}t$$

$$\rightarrow y(t) = y(0)\exp\left(-\frac{Rt}{L}\right)$$

$$\rightarrow \frac{\mathcal{E}}{R} - I(t) = \frac{\mathcal{E}}{R}\exp\left(-\frac{Rt}{L}\right)$$

$$\rightarrow I(t) = \frac{\mathcal{E}}{R}\left\{1 - \exp\left(-\frac{Rt}{L}\right)\right\}$$



náttúrulegur tímafasti

$$\tau \equiv \frac{L}{R}$$

(svipað og fyrir þetta, $\tau = \frac{1}{RC}$)

Slökkt klukkan $t = 0$

$$I(0) = \frac{\mathcal{E}}{R} \quad \text{(samfella)}$$

$$\frac{dI}{dt} < 0$$

spólan reynir að viðhalda ispennu rafhlöðu

$$-IR - L\frac{dI}{dt} = 0$$

$$\rightarrow \quad \frac{dI}{I} = -\frac{R}{L}\,dt$$

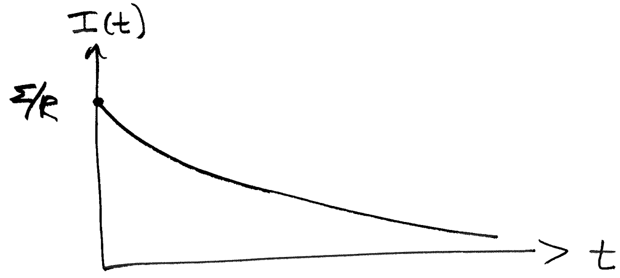
$$\int_{I(0)}^{I(t)} \frac{dI'}{I'} = -\frac{R}{L}\int_0^t dt$$

$$\rightarrow \ln\left(\frac{I(t)}{I(0)}\right) = -\frac{R}{L}\,t$$

eða

$$I(t) = I(0)\exp\left(-\frac{Rt}{L}\right)$$

$$= \frac{\mathcal{E}}{R}\exp\left(-\frac{Rt}{L}\right)$$



veldisvísis dofnun