ANR PNANO **MICONANO**

REVUE de PROJET du 22 Octobre 2008

ANR-05-NANO-059-01

Transport dans des structures nanoscopiques controle par micro-onde

MICROWAVE CONTROL of TRANSPORT NANOSCOPIC STRUCTURES

GHMFL

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cea

leti

PRESENTATION

- ***---Dima L.SHEPELYANSKY***
- **Nouveaux aspects theoriques**
- **Etudes des effets d' interactions des particules dans le transport ratchet**
- ***---Jean-Claude PORTAL***
- **Resultats experimentaux et scientifiques du consortium MICONANO(Etat en Octobre 2008)**
-
- **Un effet universel :Premiere version electronique de l' effet ratchet**
- **Photovoltage ratchet avec inversion du signe de la polarite dans des heterostructures AlGaAs/GaAs**
- **Photovoltage ratchet dans des heterostructures d' un materiau industriel Si/SiGe**
- **Avancement de l' ensemble du projet et des travaux du consortium des 4 partenaires**
- **Diffusion des resultats :Publications ,conferences internationales ,theses, distinctions , prix scientifique international AIXTRON, ANR PNANO highlight .**
- **Premiere version electronique d' une cellule de photovoltage ratchet cree sous l' effet d' irradiation de micro-onde:Realisation**
- **Pilotage du consortium et interactions entre les 4 partenaires et avec des collaborations externes**
- **Difficultes financieres et prolongation du projet jusqu' au 30 avril 2009**
- **Perspectives du developpement des etudes et des applications industrielles prochaines**
- **Conclusion**

Microwave Control of Transport in Nanoscopic Structures (MICONANO)

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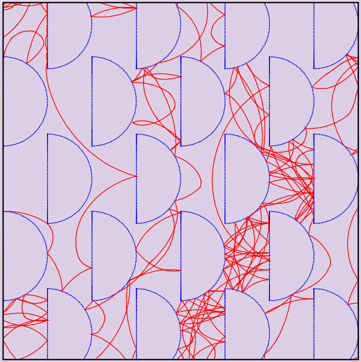
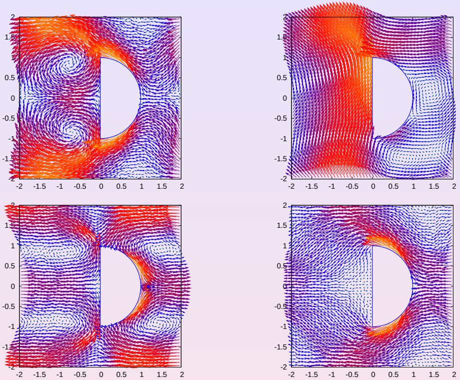
with A.D.Chepelianskii (ENS-Orsay), M.V.Entin, L.I.Magarill (Novosibirsk), A.S.Pikovsky (Potsdam)

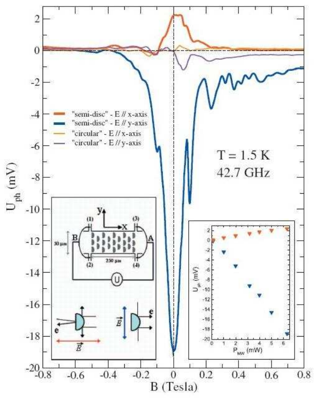


A.D.Chepelianskii *et al.* EPJB **56**, 323 (2007)

- Ratchet transport:
  kinetic theory and numerical simulations
- Ratchet for interacting particles
- Experiments: Zero-resistance states
- Synchronization
- Coulomb interactions,
  rotating Wigner crystal
- Other systems

Ratchets in asymmetric nanostructures

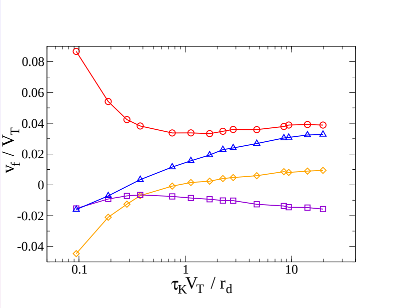




A most rapid ratchet in the world:
$(v_{rx}, v_{ry}) \approx 0.1 v_F (r_d f / E_F)^2 (-cos(2\theta), \sin(2\theta))$, $v_r \sim 10^5 cm/s$.
Grenoble experiment: S.Sassine et al. Phys. Rev. B **78**, 045431 (2008)
Theory of deterministic ratchets:
A.D.Chepelianskii, M.V.Entin, L.Magarill, DS, Eur. Phys. J. B **56**, 323 (2007)

Kinetic theory and effects of interactions

Dependence of the ratchet velocity v_f on the Kapral interaction scattering time τ_K in the semi-disk model, numerical data are shown by symbols: $v_{f,y}/v_T$ (red circles) and $v_{f,x}/v_T$ (yellow diamonds) for $\theta = \pi/4$; $v_{f,x}/v_T$ (violet squares) for $\theta = 0$; $v_{f,x}/v_T$ (blue triangles) for $\theta = \pi/2$; curves are drown to adapt an eye.



Kinetic theory:

$$v_{fx}/v_T = -B(Fv_T\bar{\tau}_c/T)^2 a_{xxx}[\cos^2\theta/(a_x^3(1+\omega^2\tau_x^2)) - \sin^2\theta/(a_x a_y^2(1+\omega^2\tau_y^2))]$$

$$v_{fy}/v_T = -B(Fv_T\bar{\tau}_c/T)^2 a_{xyy}\sin(2\theta)(1+\omega^2\tau_x\tau_y)/(a_x a_y^2(1+\omega^2\tau_x^2)(1+\omega^2\tau_y^2)) \quad ,$$

where $B = CT^2\bar{\tau}_c/2v_T^3$ and $C = \int_0^\infty d\varepsilon (f^{(0)\prime})^2 (v^3/\tau_c)'/\int_0^\infty d\varepsilon\varepsilon (f^{(0)\prime})^2$, $1/\bar{\tau}_c = \int_0^\infty d\varepsilon (f^{(0)\prime})^2 (\varepsilon/\tau_c(\varepsilon))/\int_0^\infty d\varepsilon\varepsilon (f^{(0)\prime})^2$, prime marks the derivative over energy ϵ and we note $\tau_i = \bar{\tau}_c/a_i$. The calculations give for the cuts model $\tau_c = \bar{\tau}_c$, $a_{xxx} = 1/6\pi$, $a_{xyy} = -1/3\pi$, $a_x = 3/2 + 4/\pi^2$, $a_y = 1/2$, $C = 2\sqrt{\pi}/(2m\tau_c\sqrt{2mT})$, $\tau_c = const$ and for the semi-disks model $a_{xxx} = -a_{xyy} = 1/12$, $a_x = 2/3 + 8/3\pi$, $a_y = 2/3$, $C = 2/(m\bar{\tau}_c\sqrt{mT})$, $\bar{\tau}_c \propto T^{-1/2}$.

Ratchets of interacting particles:

A.D.Chepelianskii, M.V.Entin, L.Magarill, DS, arXiv:0808.2970 (PRE to appear)

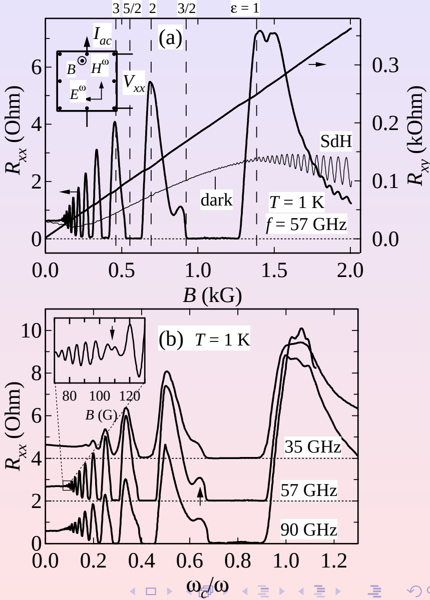
Experiments on Zero-Resistance States (ZRS)

- High mobility 2DEG in a microwave field

  *M.A.Zudov, R.R.Du, J.A.Simmons, J.I.Reno PRB **64**, 201311 (2001)

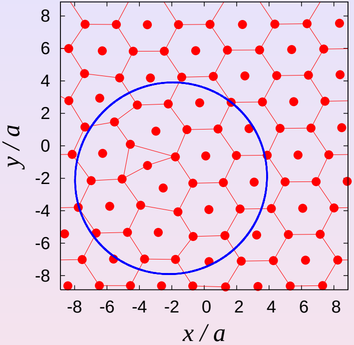
  *R.G.Mani, J.H.Smet, K. von Klitzing, V.Narayanamurti, W.B.Johnson, V.Umansky Nature **420**, 646 (2002)

  *M.A.Zudov, R.R.Du, I.N.Pfeiffer, K.W.West PRL **90**, 046807 (2003) (Fig. image)



Synchronization and Rotating Wigner Crystal

Instant image of the rotating Wigner crystal formed by $N = 100$ electrons (points) in a periodic cell with $L = \sqrt{N/\rho} \approx 17.72a$, $\omega t = 480$ $\omega_B = \omega$, $fa/E_F = 0.02$ and $N_B = 34.7$ (bottom curve in one of previous Fig.); the circle shows an orbit of one electron for $240 \leq \omega t \leq 480$; lines are drawn to adapt an eye showing a hexagonal crystal with a defect.

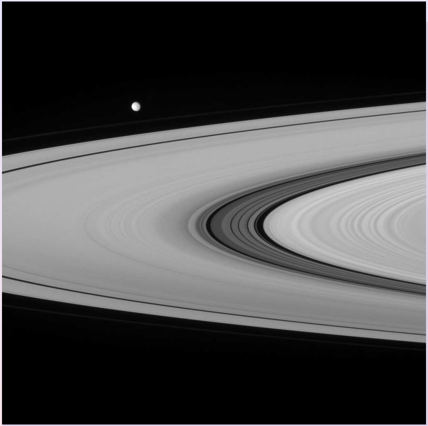


Synchronization domain of ZRS phase:

$$|\omega_B - \omega| \leq 0.8f/mv_F \ , \quad (1)$$

For experiment conditions the relative size of ZRS plateau is $\Delta\omega/\omega \approx 2\nu/\omega \approx fv_F/\omega E_F$ and with $E_F \sim 100K^o$, $v_F \sim 3 \times 10^7 cm/s$ and $\omega/2\pi = 35GHz$ this gives $\Delta\omega/\omega \approx 0.1$ if the field strength acting on an electron is $f/e \approx 5V/cm$. The coherent rotation of electrons in the crystal creates a rotating current in 2D plane which in its turn generates a magnetic field $B_W \sim \mu_0 e v_F \rho \sim 1G$ parallel to 2DEG and rotating in the plane with a frequency close to ω.

Synchrony Conjecture for Saturn Rigns



Mimas and the Great Division
(NASA Cassini Mission
image of Sept 7, 2007;
http://photojournal.jpl.nasa.gov/
catalog/PIA09750)

A generic mechanism of
SYNCHRONIZATION INDUCED SELF-ASSEMBLY is proposed