NOISE-INDUCED CURRENT OSCILLATIONS IN SUPERLATTICES: FROM STATIONARY TO MOVING DOMAINS

E. Schöll [1], J. Hizanidis [1], A. Balanov [1], A. Amann [2]

[1]Institut für Theoretische Physik, Technische Universität Berlin

[2]Tyndall National Institute, Lee Maltings, Cork, Ireland

Model Equations

Continuity equation:

$$e\frac{dn_m}{dt} = J_{m-1\to m} + D\xi_m(t) - J_{m\to m+1} + D\xi_{m+1}(t)$$

Poisson equation:

$$\epsilon_r\epsilon_0(F_m - F_{m-1}) = e(n_m - N_D)$$

Global constraint:

$$U = -\sum_{m=0}^{N} F_m d$$

Ohmic boundary conditions:

$$J_{0\to 1} = \sigma F_0, \quad J_{N\to N+1} = \sigma F_N \frac{n_N}{N_D}$$

Gaussian white noise

$$\langle \xi_m(t)\rangle = 0$$

$$\langle \xi_m(t)\xi_{m'}(t')\rangle = \delta(t-t')\delta_{mm'}$$

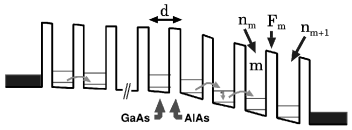
Current dependent noise intensity [4]

$$D(J) = \left(\frac{eJ}{A}\right)^{1/2}$$ SHOT NOISE

cross section

Schematic Diagram

Sequential tunneling model [1,2]



$J_{m\to m+1}$ current density

n_m electron density

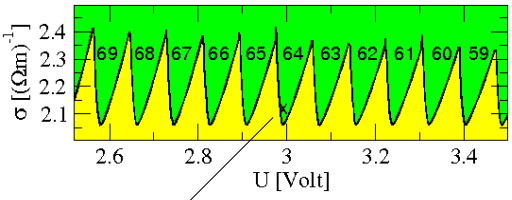
F_m electric field

σ contact conductivity

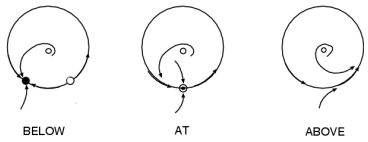
N_D doping density

$m = 1,\ldots,100$

From stationary to moving domains $D = 0$



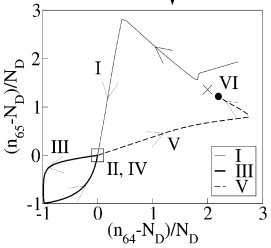
SCHEMATIC DIAGRAM OF SNIPER

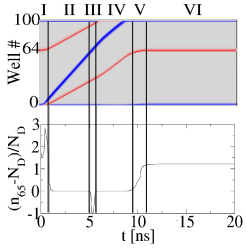


stable and unstable fixed point collide giving birth to a limit cycle

transition governed by GLOBAL BIFURCATION:
saddle-node bifurcation on a limit cycle (SNIPER)

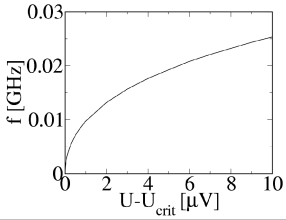
PHASE PORTRAIT





SPACE-TIME PLOT

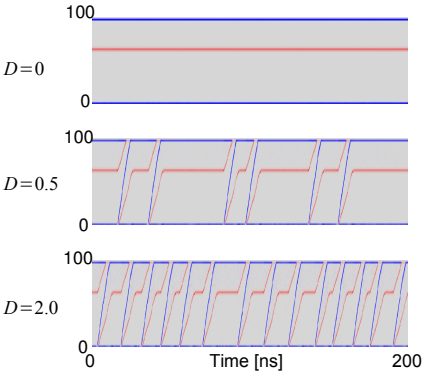
SQUARE-ROOT SCALING LAW



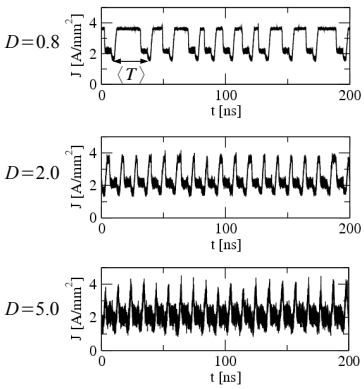
Noise-induced current oscillations $D \neq 0$

System prepared below SNIPER. Noise switched on. $[D] = As^{1/2}/m^2$

FRONT MOTION



CURRENT OSCILLATIONS

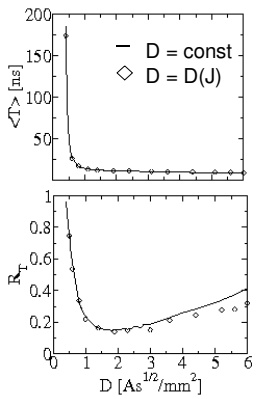


measure for coherence

$$R_T = \frac{\sqrt{\langle T\rangle^2 - (\langle T\rangle)^2}}{\langle T\rangle}$$

normalized fluctuations of interspike interval

COHERENCE RESONANCE



mean interspike interval <T> controlled by noise intensity

optimal regularity at finite noise strength

depletion front accumulation front neutral well

Conclusions

- Saddle-node bifurcation on a limit cycle responsible for transition from stationary to moving domains in semiconductor superlattices
- Gaussian white noise induces front motion and associated current oscillations
- Maximum coherence of oscillations at optimal noise intensity: coherence resonance
- Sensitivity to noise and distance from bifurcation point: possible application of superlattice as fast noise sensor

References

[1] A. Wacker, Phys. Rep. **357**, 1 (2002)

[2] E. Schöll, *Nonlinear spatio-temporal dynamics and chaos in semicobductor*s, Cambridge University Press, 2001

[3] A. Amann, and E. Schöll, J. Stat. Phys. **119**, 1069 (2005)

[4] Y. M. Blanter and M. Büttiker, Phys. Rep. **336**, 1 (2000)

[5] J. Hizanidis, A. G. Balanov, A. Amann and E. Schöll, Phys. Rev. Lett. **96**, 244104 (2006)