Noise enhanced sensing and switching with nanoelectronic devices

SUBTLE

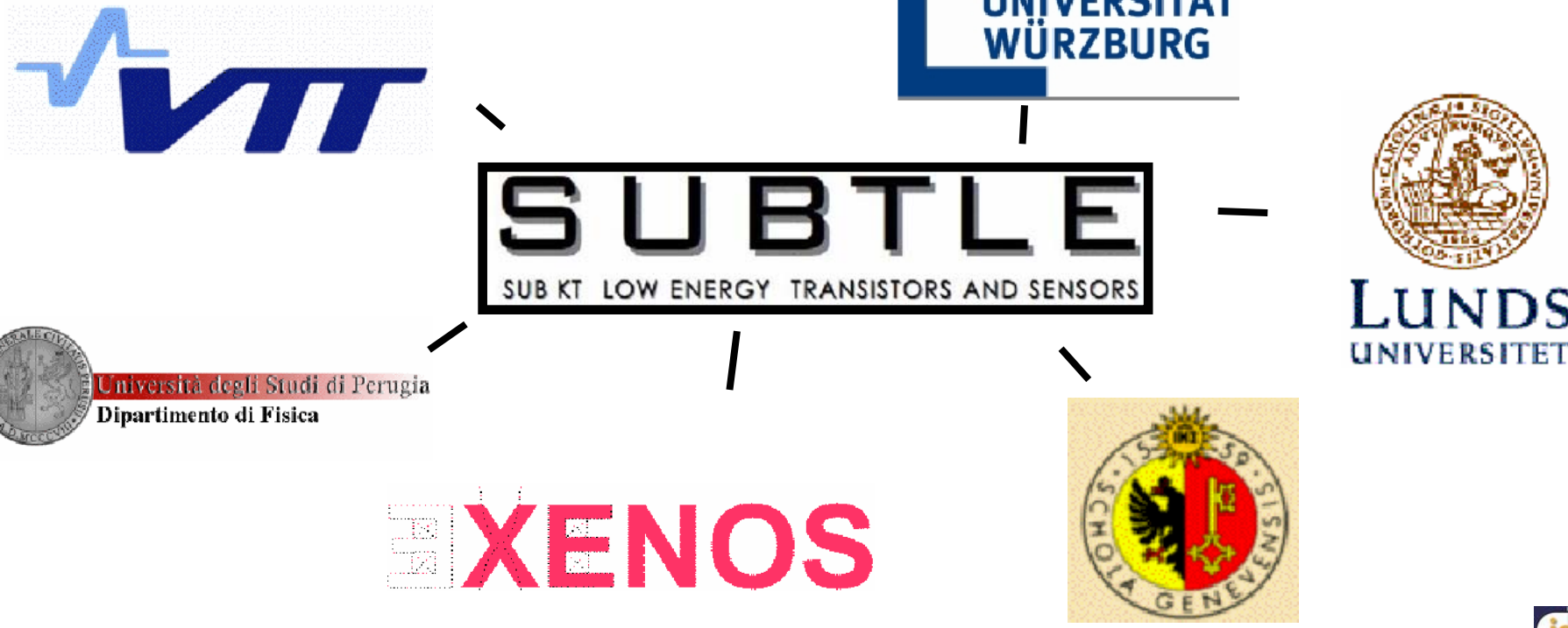
SUB KT LOW ENERGY TRANSISTORS AND SENSORS

Contract Number: IST-034236

Project duration: October 1, 2006 to September 30, 2009

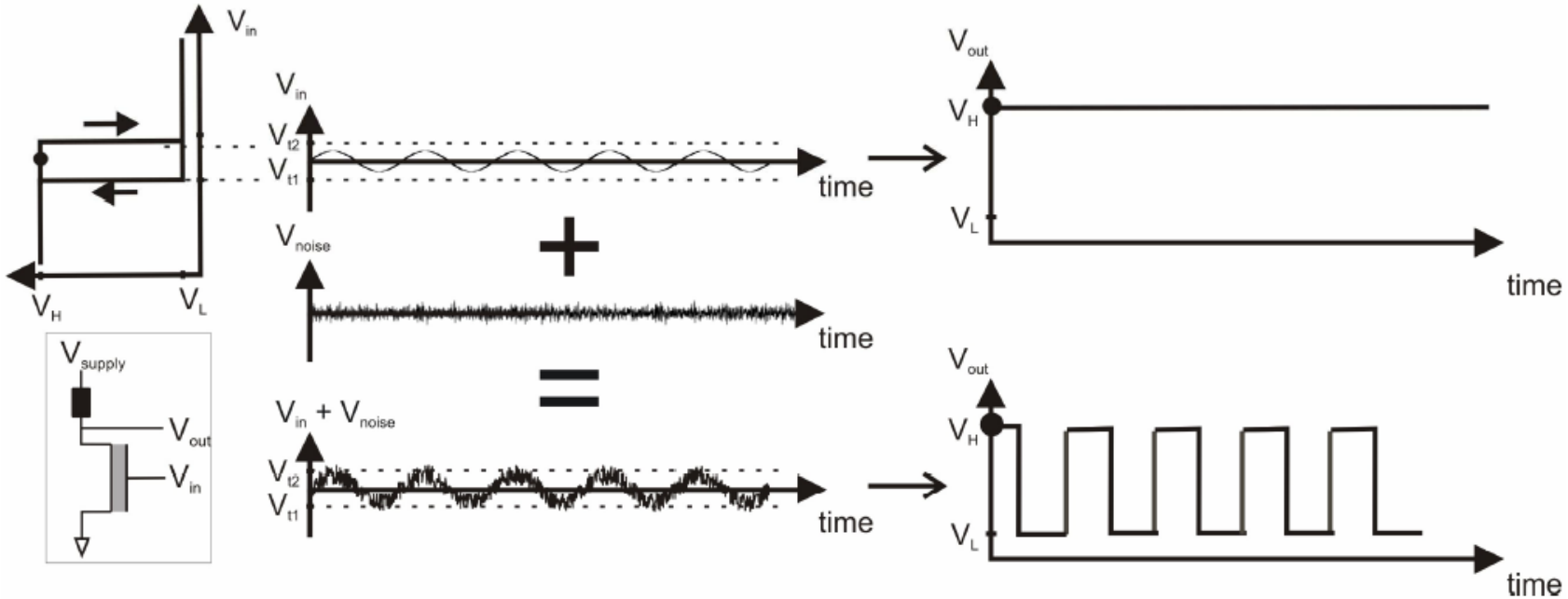
Project consortium

No	Participating Institution	Nick Name	Country
1	Bayerische Julius Maximilians Universität Würzburg	UWUERZ	Germany
2	Technical Research Centre of Finland	VTT	Finland
3	Lund University	LU	Sweden
4	University of Geneva	UNIGE	Switzerland
5	Dipartimento di Fisica Universita degli Studi Perugia	UNIPG	Italy
6	XENOS Semiconductors Technologies GmbH	XENOS	Germany



Stochastic resonance (SR)

- **Major idea:** exploitation of stochastic-resonance (SR) phenomena in nanoelectronics

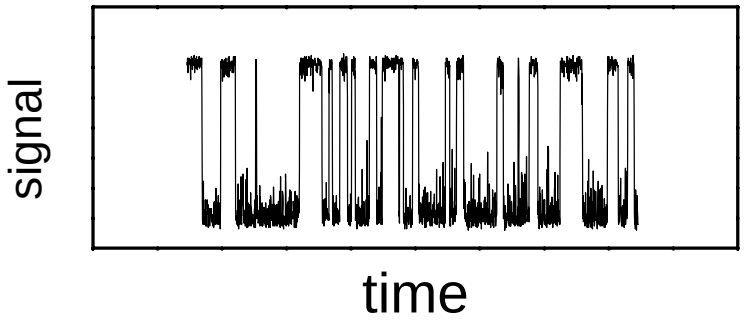


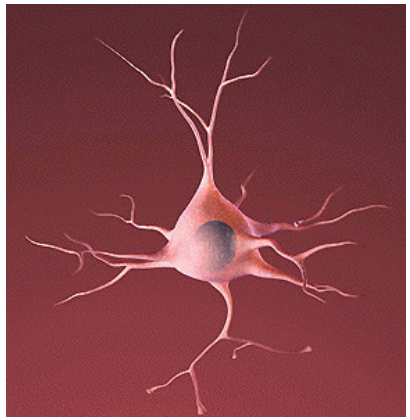
- Nanoelectronic devices with **key properties:**
  - Subthermal signal resolution
  - Noise activated switching
  - Noise enhanced signal processing

Key ideas

- Stochastic-Resonance-related phenomena due to
  - Back-action between gate and channel
  - Noise
    - External
    - Intrinsic
- Feedback between low-dimensional conductors
  - Lateral
  - Vertical
- Sensing and switching
  - Subthermal resolution
  - Asymmetry due to non linear transport: magnetic & electric
  - Artificial neuron nodes

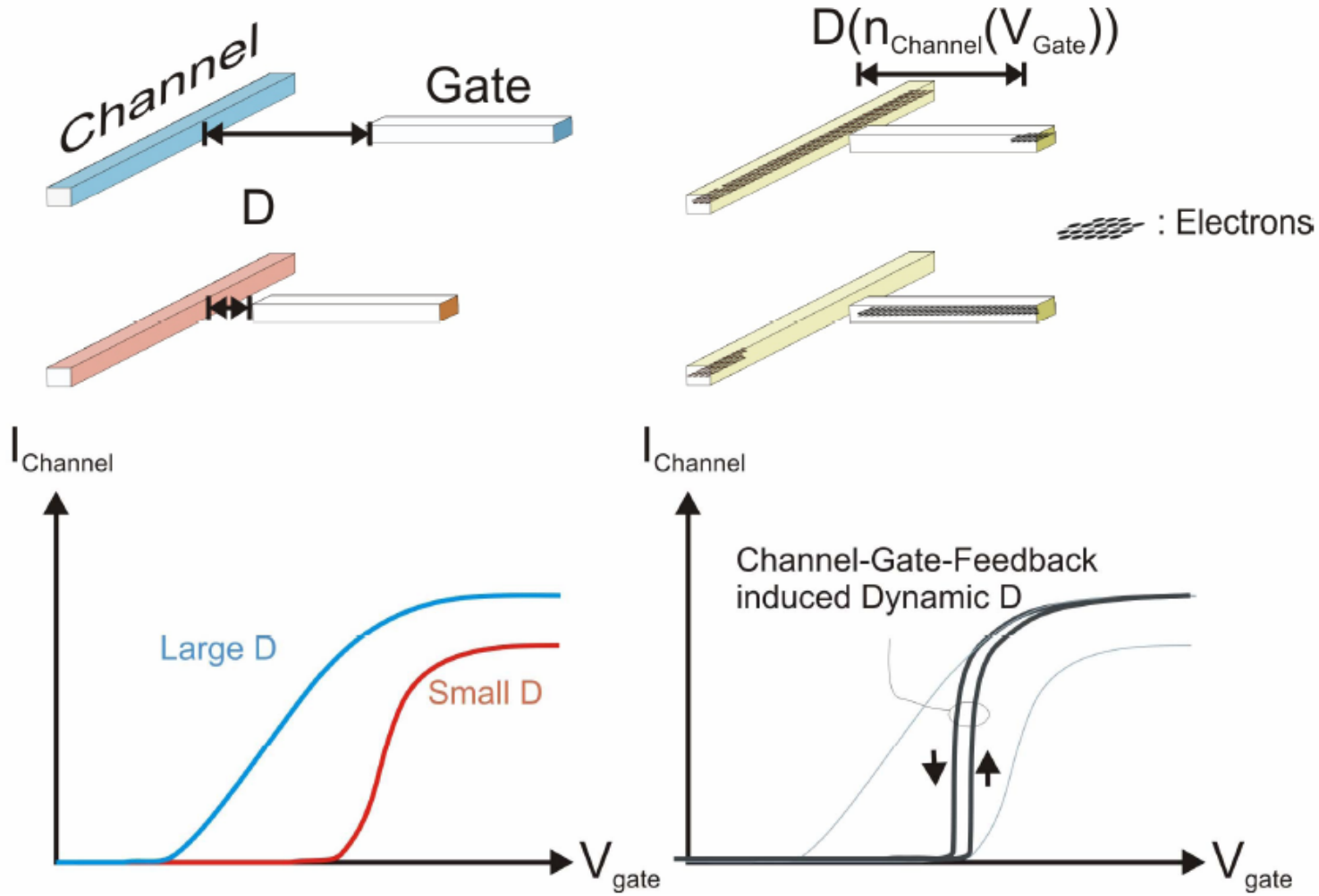
} usually one tries to avoid these features





Switching principle

- Nanoelectronic devices with nonlinear dynamic characteristics for noise enhanced functioning
  - Steep threshold, bistable switching, noise



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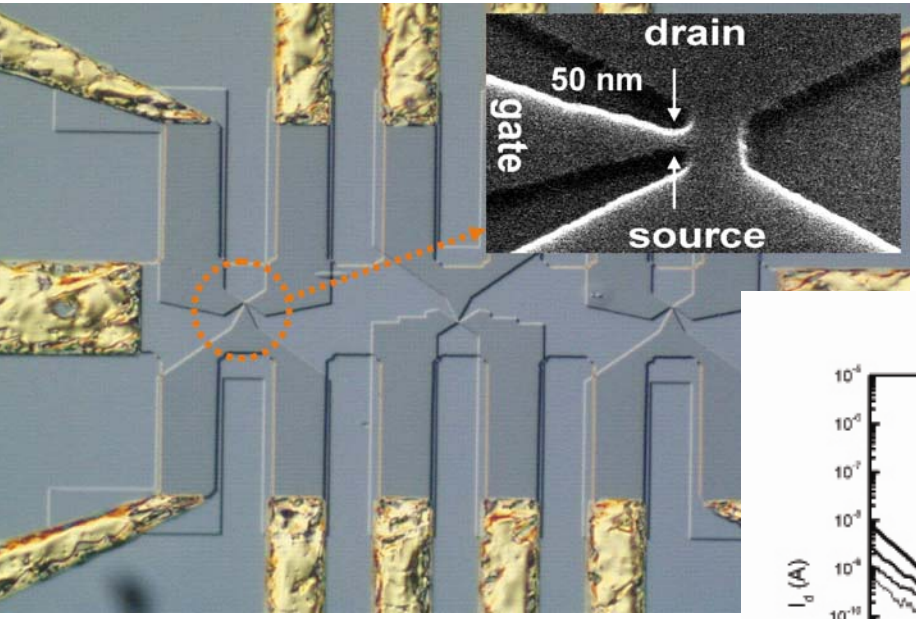
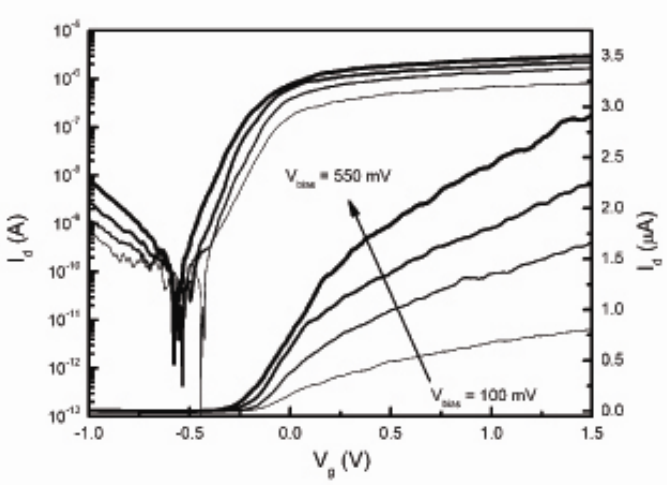
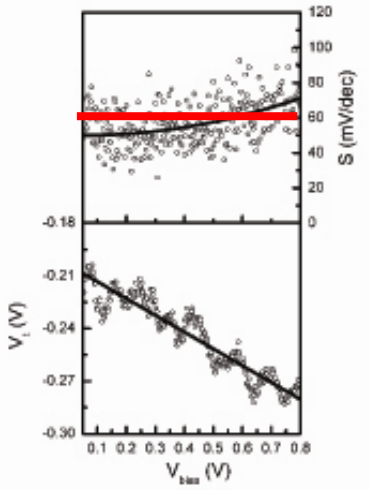
Three-terminal junction TTJ : low-dimensional gate



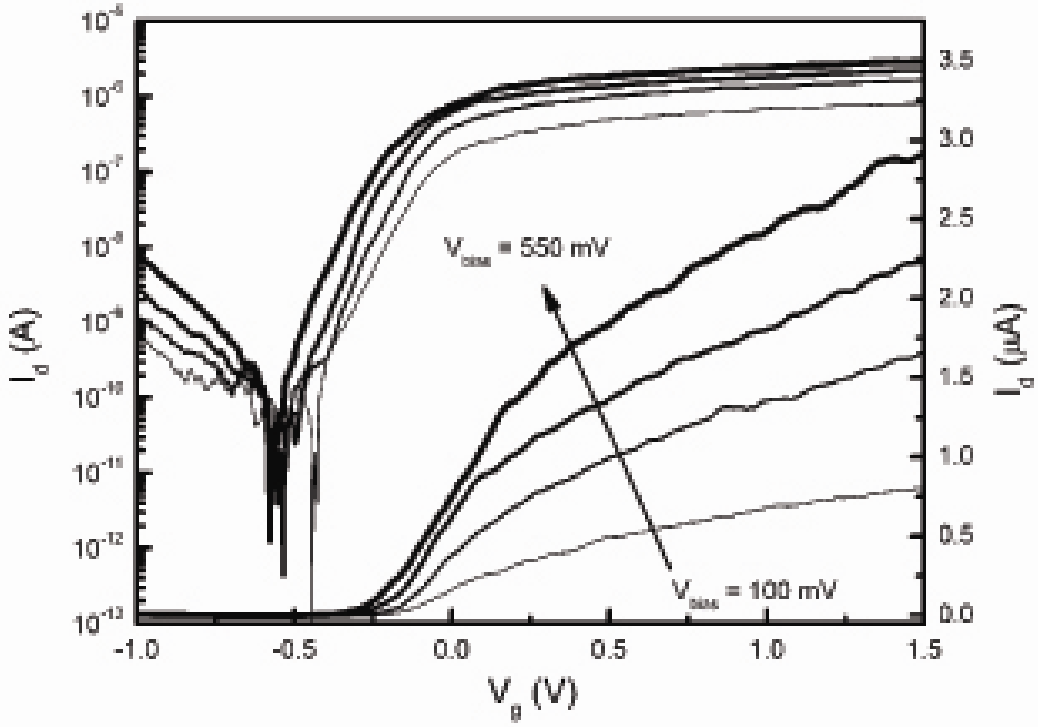




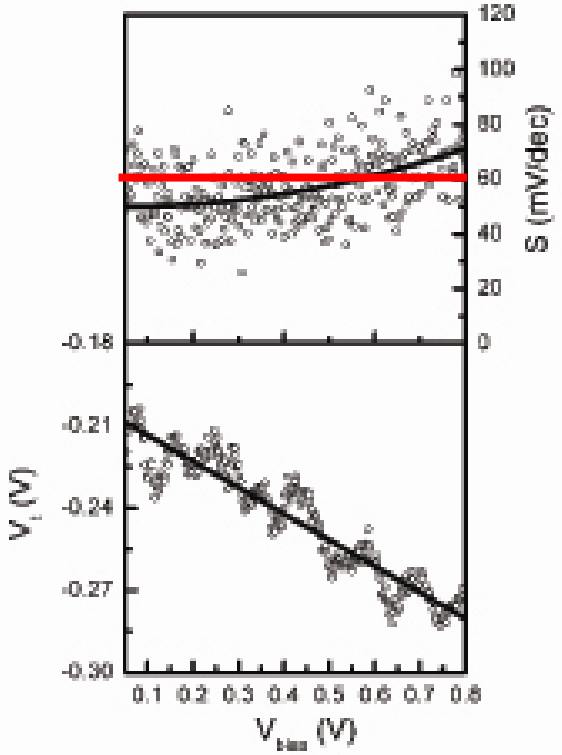
GaAs based HEMT ➔ TTJ by ebeam lithography + lift-off
Microscope image of a monolithically integrated triple TTJ device
Monolithic gate: dimension smaller than channel

Electrical measurements of monolithically integrated triple –TTJ devices

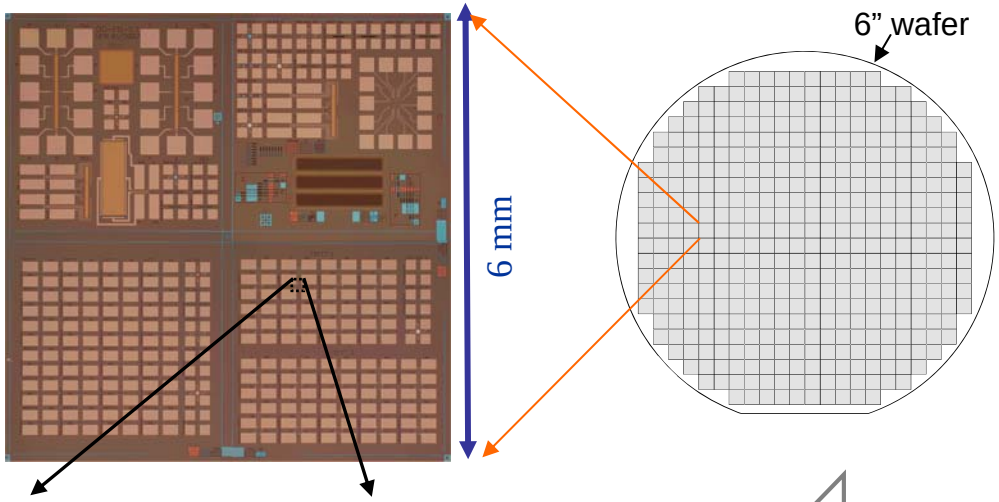
Transfer characteristics of a TTJ

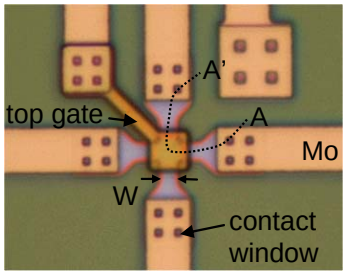


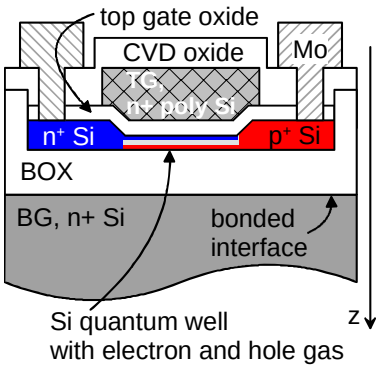
Sub-threshold swing smaller than 60mV @ RT and threshold voltage

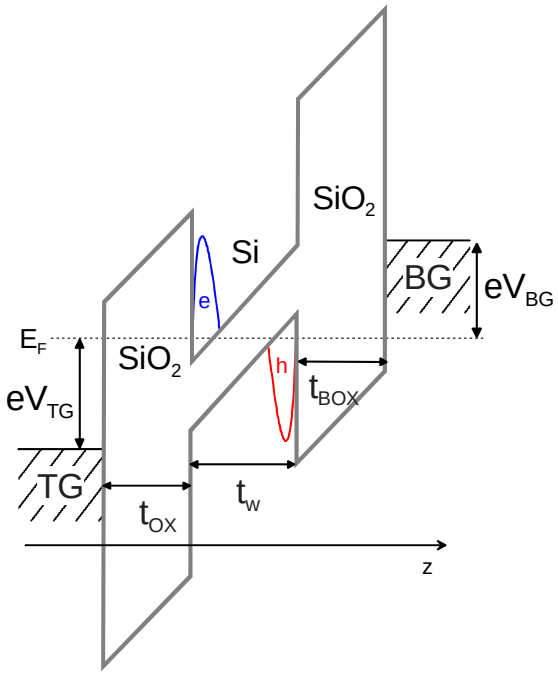


Si based bilayers with 9-layer CMOS-process

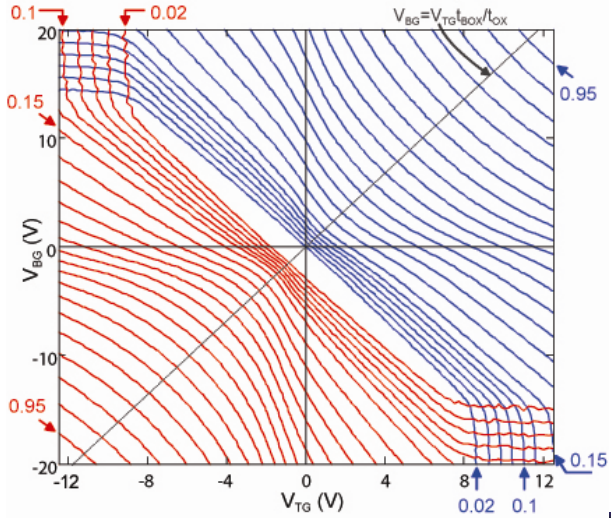




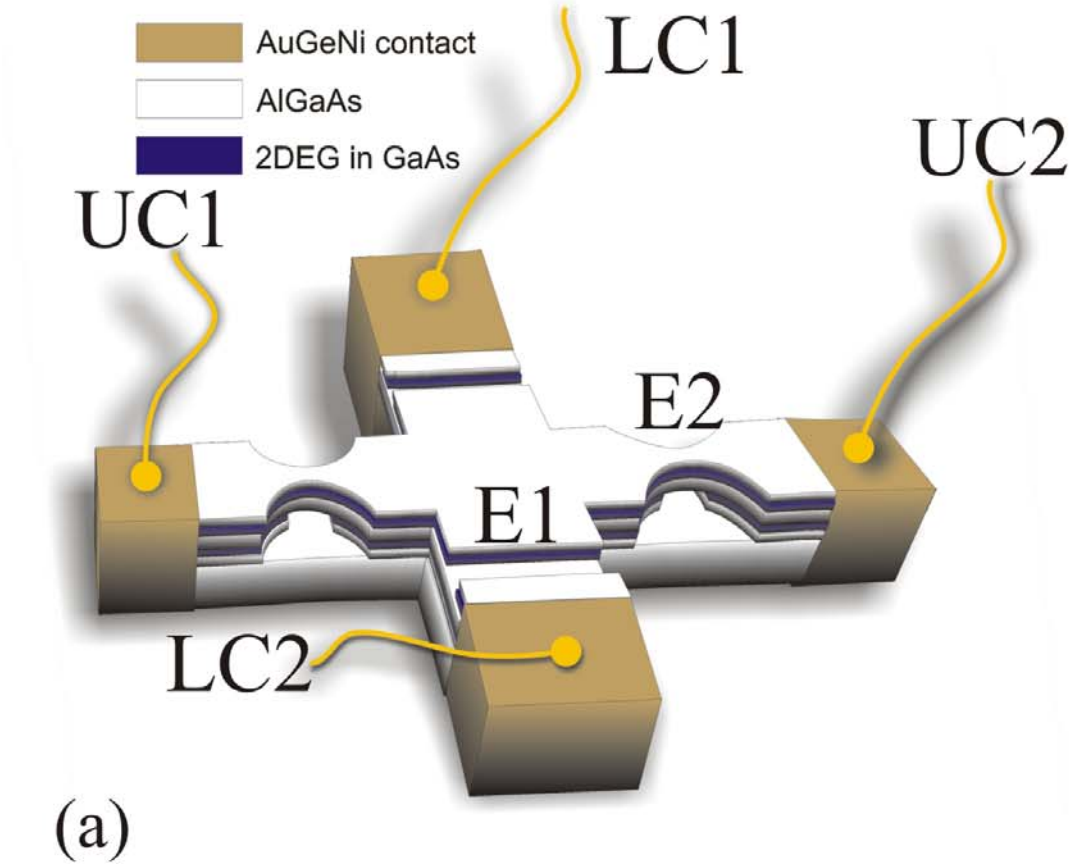


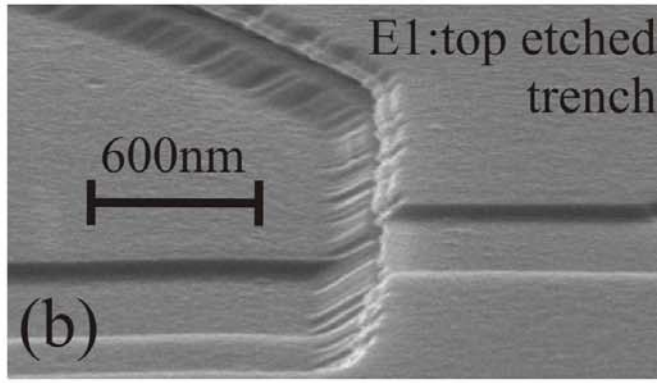


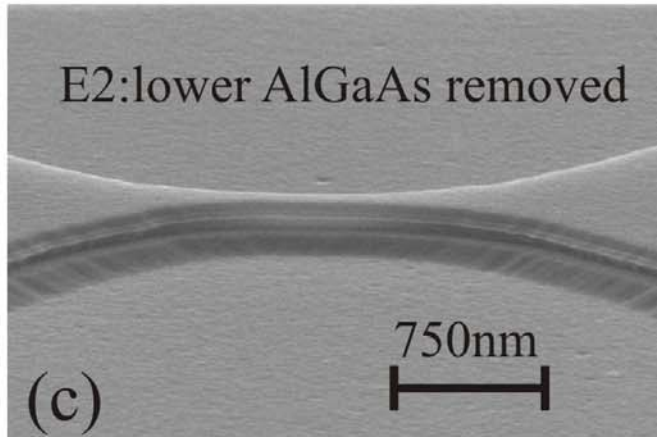
- Design and first successful fabrication of a 9–layer CMOS-based fabrication process for Si electron-hole bilayer devices and RT drag resistance



Independent contact double QW FET





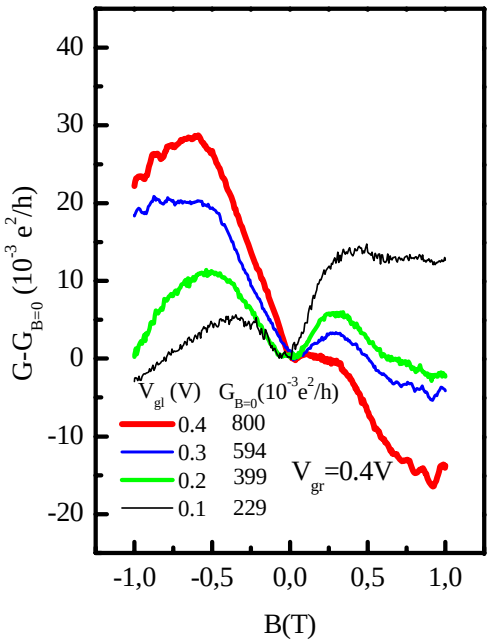


- Variation of Al content using two Al sources
- Selective etching
- FET operation with efficient gating

Nonlinear magnetic asymmetry

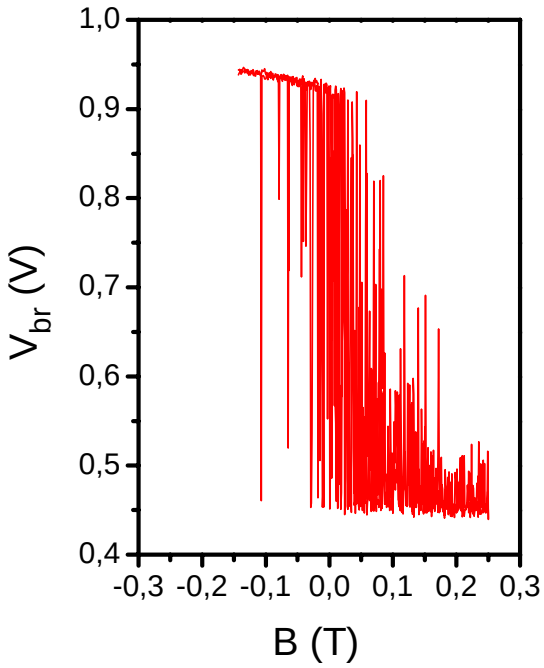
- **Key devices**
  - Electrochemical capacitance induced feedback transistors (**FBFETs**)
  - Noise activated nonlinear devices (**NADS**)
  - Noise enhanced signal processing nodes (**NENS**)

- *Asymmetry of nonlinear mesoscopic transport in a quantum wire*

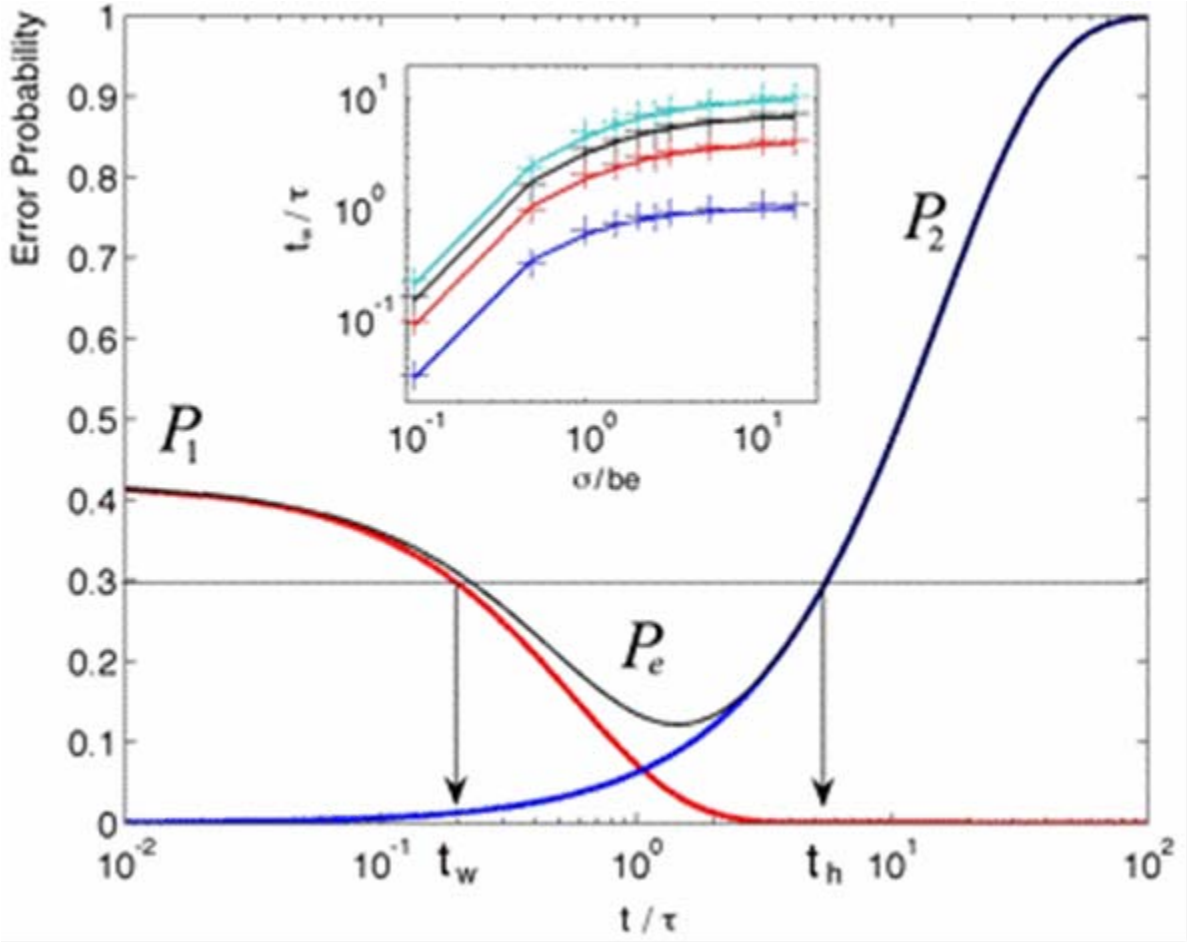


+ noise

- *Exploited in a **NAD** as magnetic field detector*

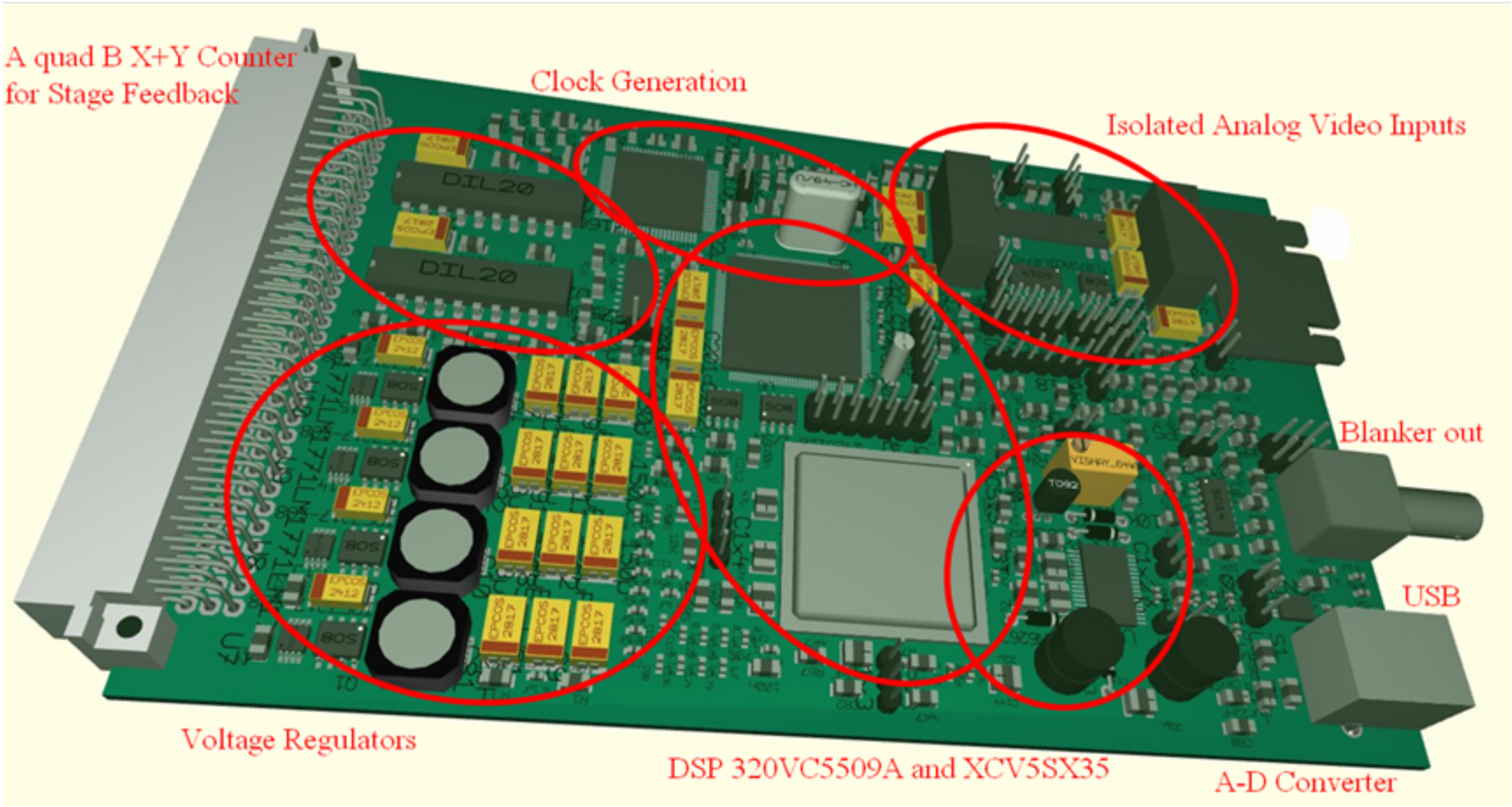


Noise limited computational speed



- The presence of the noise sets a fundamental limit to the computing speed.
- We found an optimal *idle time* interval that minimizes the error probability.

E beam pattern controller



- Architectural design of 150 MHz pattern controller

SUBTLE key results to date (1.year)

Theory

- Models were developed for description of manybody effects in electro-chemical capacitance describing the role of dephasing and thermal averaging on the charge relaxation
- First simulation results of Stochastic Resonance and residence time variations in NADs
- Modeling of noise limited computational speed

Experiment-Applications

- Observation of field-effect controlled magnetic field asymmetry in nonlinear mesoscopic transport
- Independent contacts to GaAs quantum wells (QWs) in a double QW structure separated less than 10 nm on the basis of nanofabrication techniques and selective etching
- Design and first successful fabrication of a 9–layer CMOS-based fabrication process for Si electron-hole bilayer devices
- Development of double-dot FET InGaAs/InP with HfO ALD isolation
- Three-terminal junction (TTJ) FET with subthreshold swing smaller than kTln10
- First prototype (NADS) for nanoscale magnetic field sensor

Acknowledgement