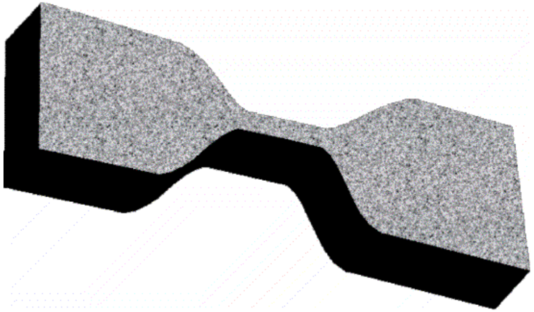


Information Society

Nano-Tera

IST Project 2001-32517

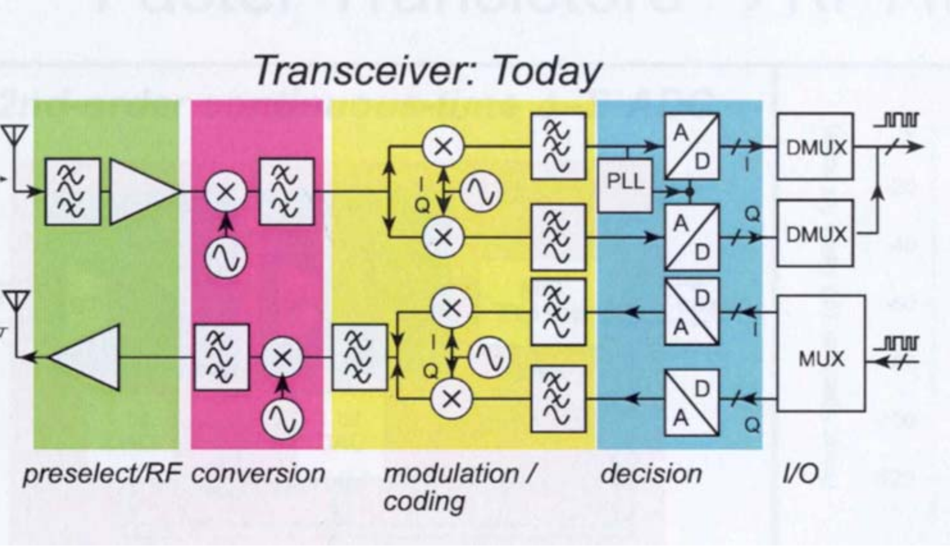
Project funded by the Future and Emerging Technologies arm of the
IST Programme. - Nanotechnology Information Devices

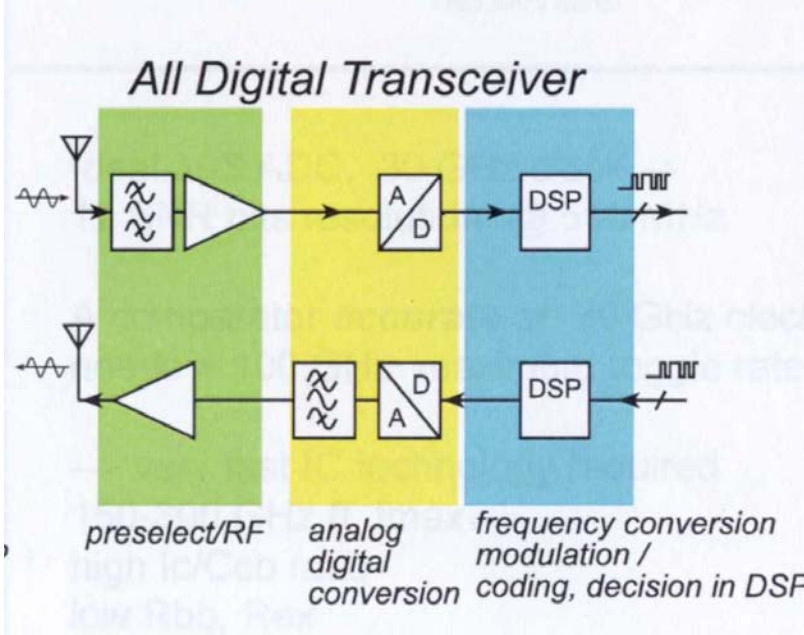
Partners

- Institute of Electronics, Microelectronics and Nanotechnology (Lille France)
- University of Salamanca (Spain)
- Université catholique de Louvain (Belgium)

MOTIVATIONS

- Needs for ultra high speed devices





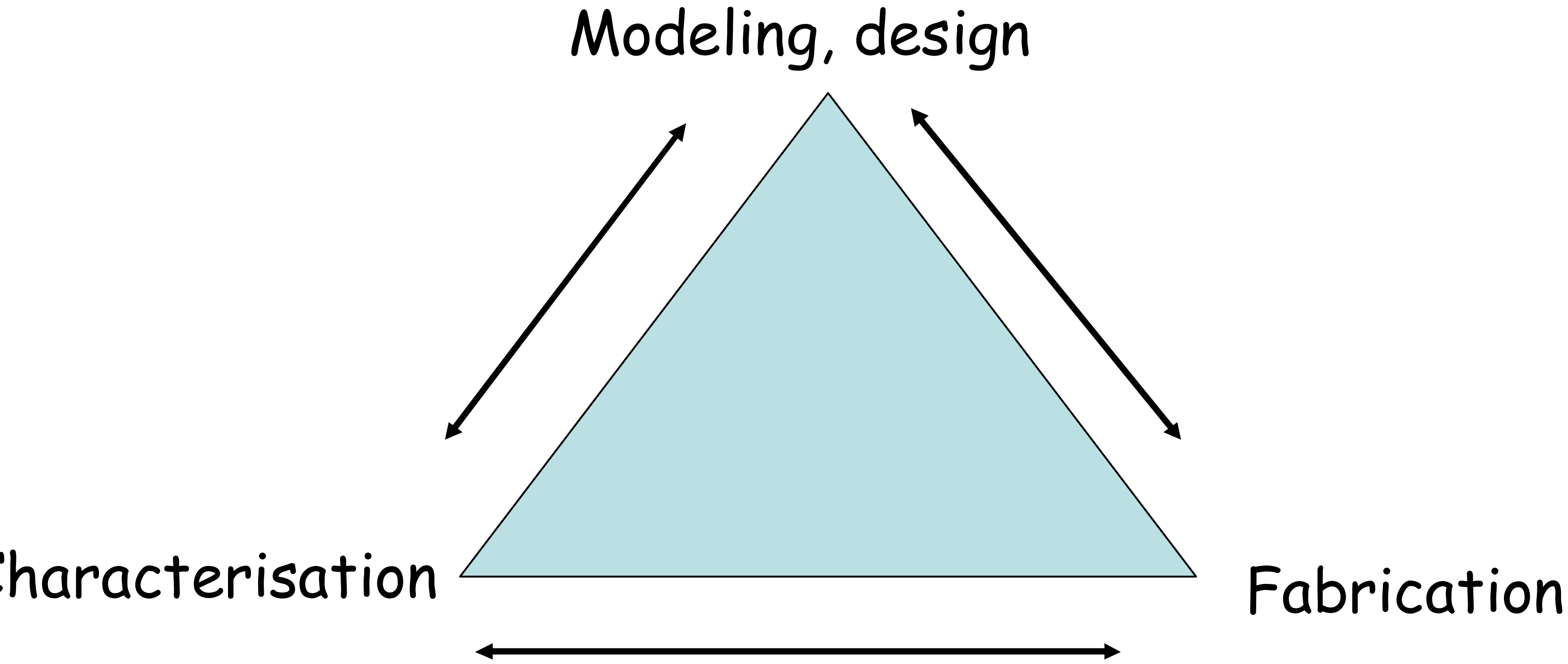
MOTIVATIONS

- Normally for semiconductor devices, Fmax ~ 1/L
- For small L, ballistic or quasi ballistic transport (Without scatterings) occur.
- Ballistic transport will provide the highest frequency of operation.
- Classical transport. No quantum transport. No phase coherence (room temperature).

NANOTERA OBJECTIVES

- Design, fabrication and characterisation of ballistic devices for room temperature operation in the millimetre wave range.
  - passive T or Y branch junctions
  - active (with gate control) ballistic devices for MUX/DEMUX or inverter applications

NANOTERA WORKPROGRAM

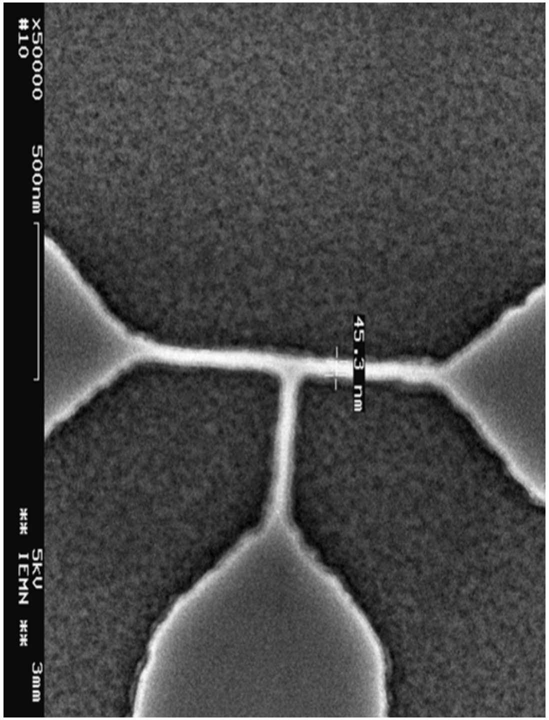


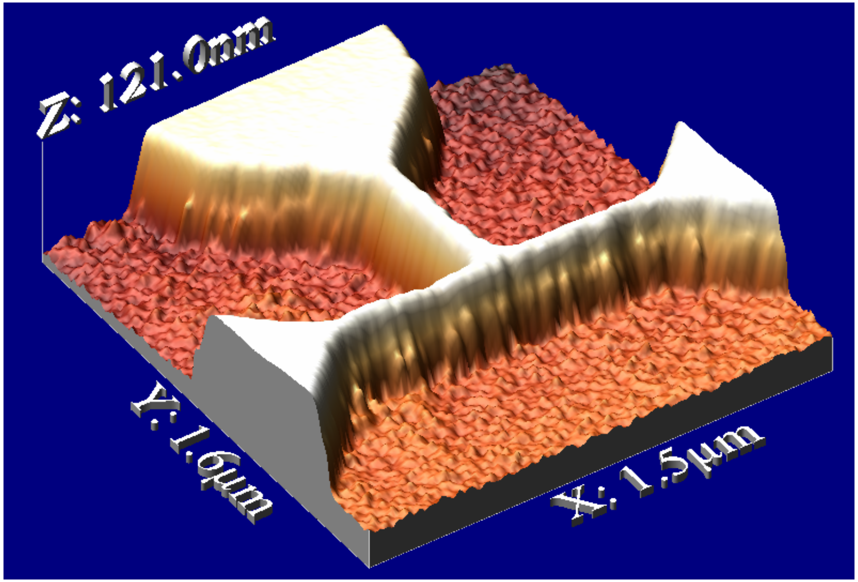
Modeling, design

Characterisation

Fabrication

Ballistic TBJs





Material system

Cap layer InGaAs $6\ 10^{18}/cm^3$ 100Å

Schottky barrier LM InAlAs nid 150Å

Delta doping plane Si

Spacer LM InAlAs nid

Channel $In_{0.7}Ga_{0.3}As$ nid 150 Å

Buffer InAlAs nid 4000 Å

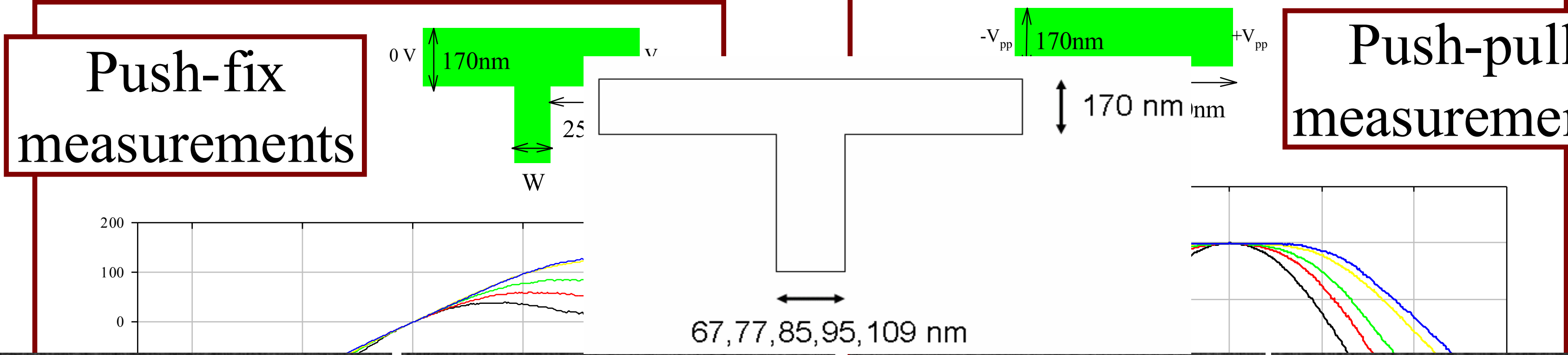
InP SI substrate

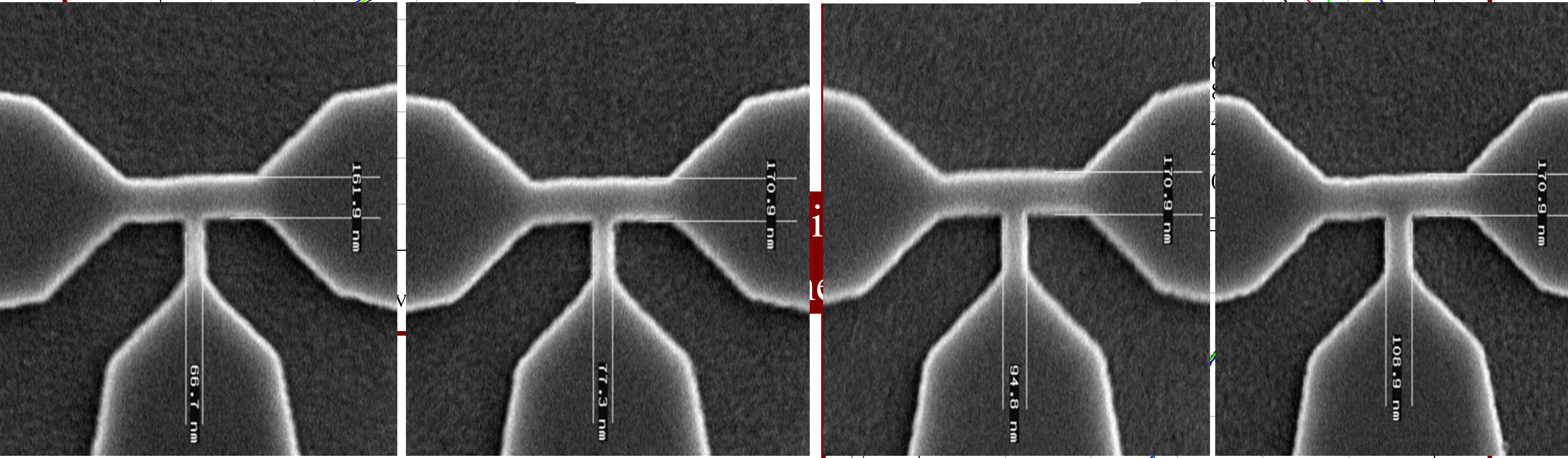
Lp ~ 200 nm

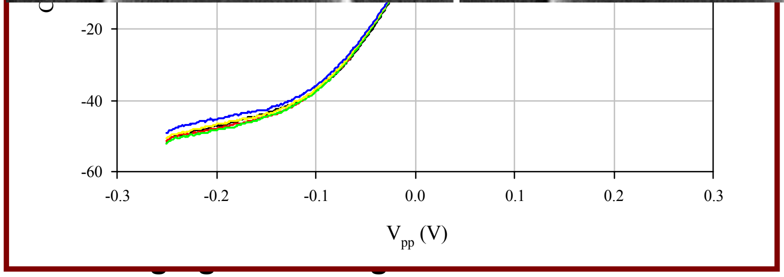
Spacer Thickness	Number	Hall 300K		Hall 77K	
		n_H $\times 10^{12}$ /cm²	μ_H cm²/Vs	n_H $\times 10^{12}$ /cm²	μ_H cm²/Vs
50	x6	5.26	10150	4.36	38680
100	x2	2.65	14000	2.6	74000
200	x2	1.82	14800	1.76	92000

Push-fix measurements

Push-pull measurements

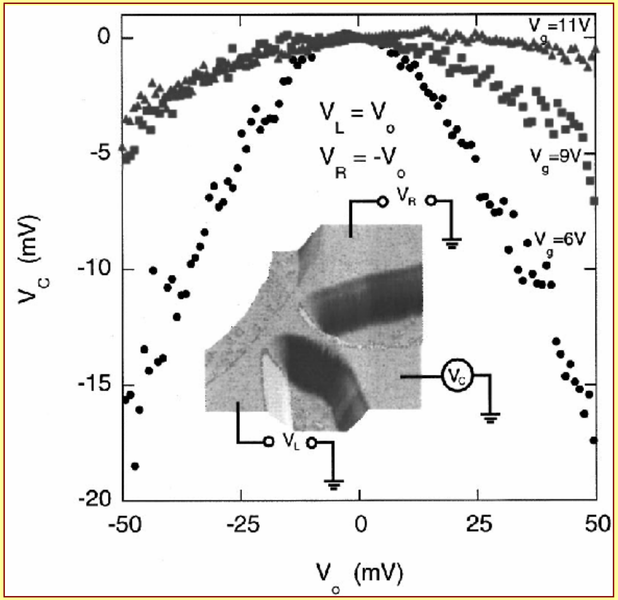






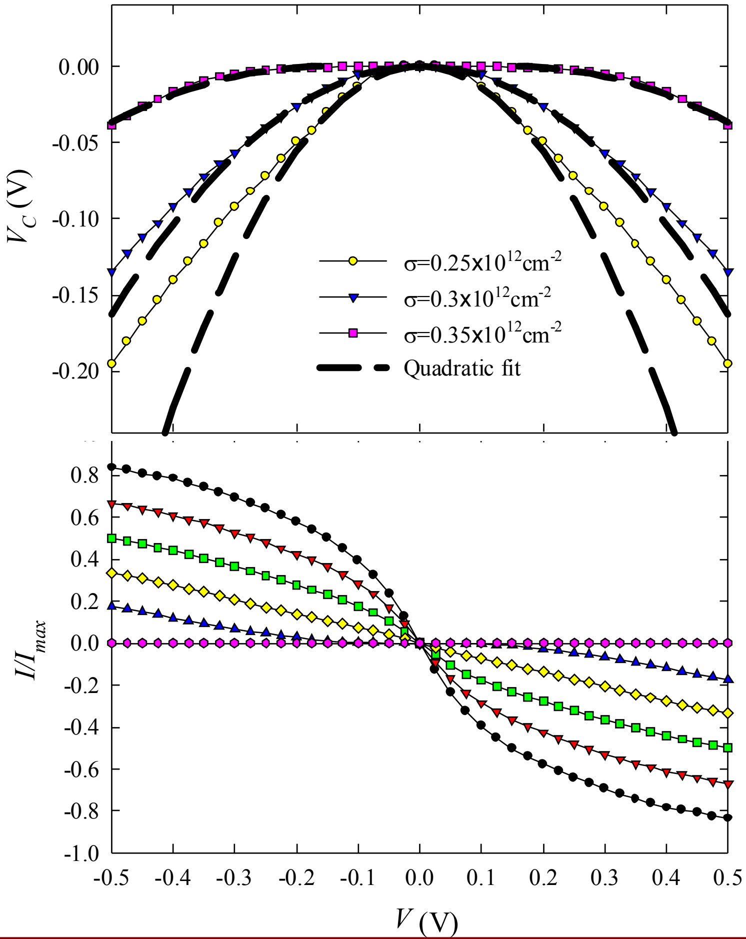
Modelling-simulation

Experimental



Shorubalko *et al.*, *Appl. Phys Lett.*, 2001

Monte Carlo



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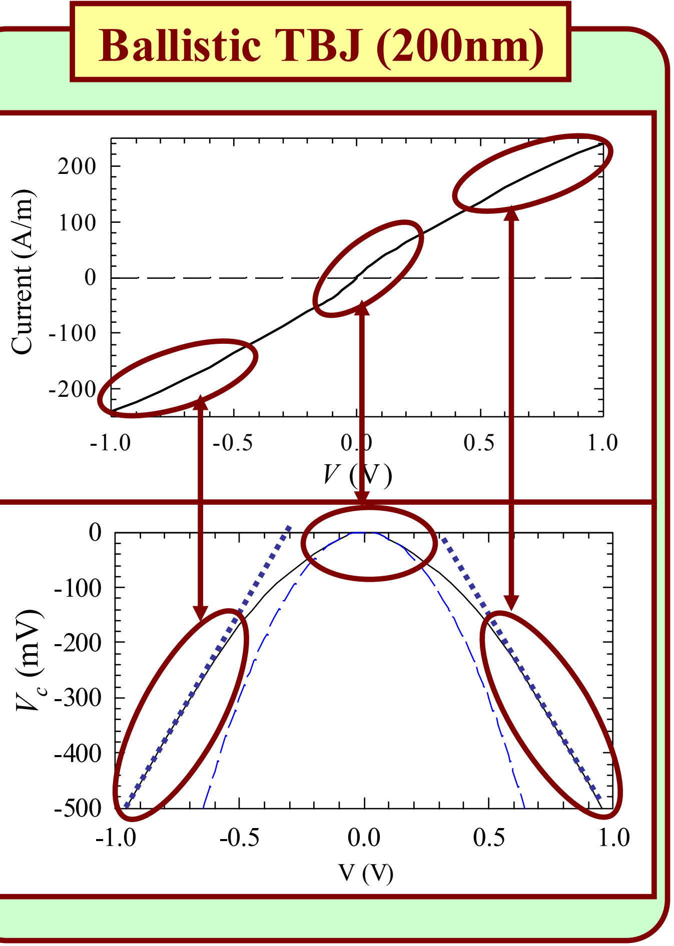
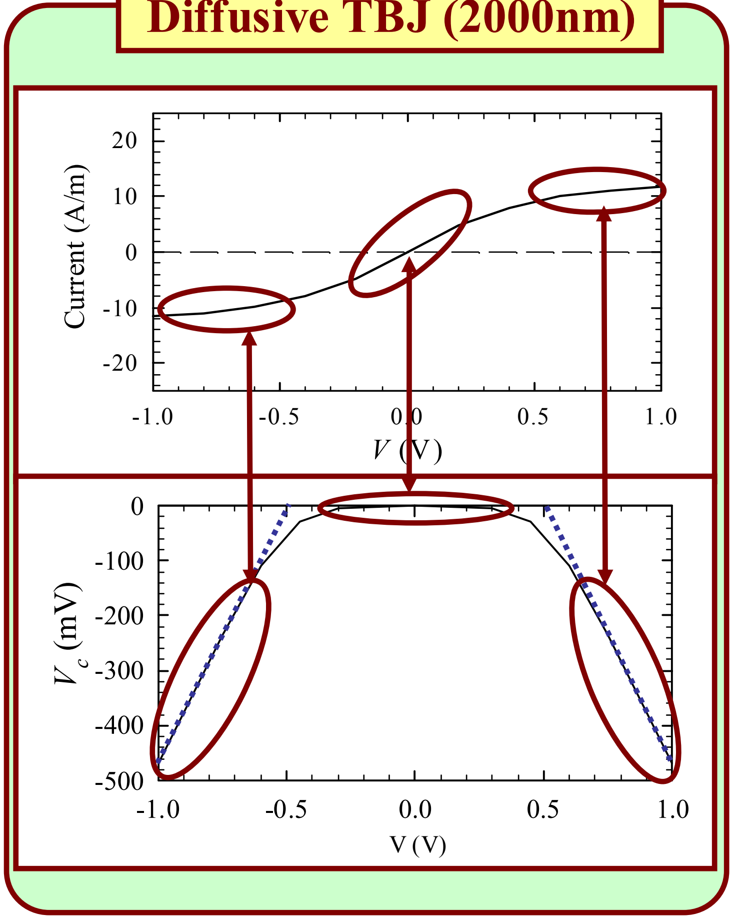

Ballistic TBJ (200nm)

Parabolic V_c(V)


Diffusive TBJ (2000nm)

V_c=0.0 V

High Bias

Intervalley transfe

Saturation of *I*-*V*

Linear V_c(V)

Low Bias

Linear *I*-*V*

Ballistic/diffusive regimes can be distinguished by measuring V_c

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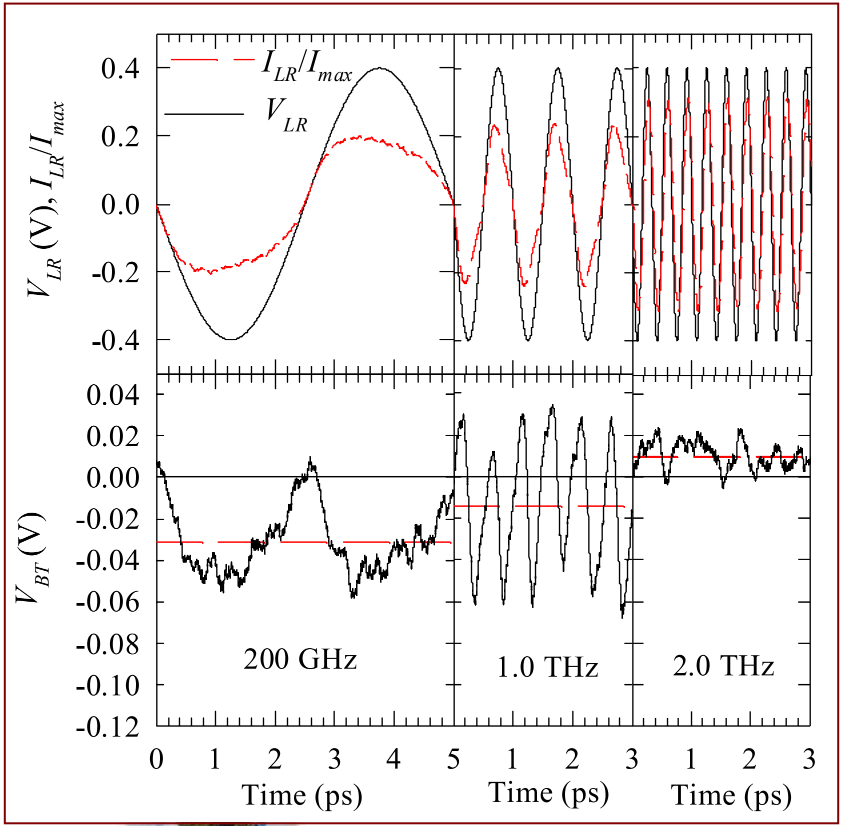
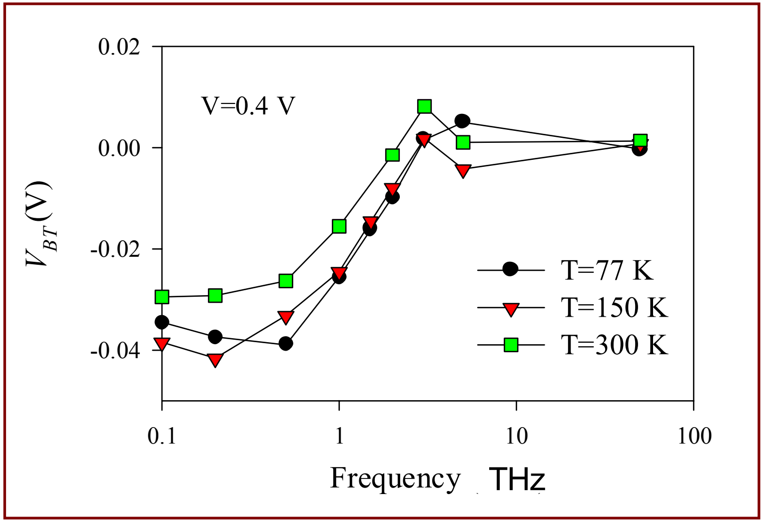
Frequency Response

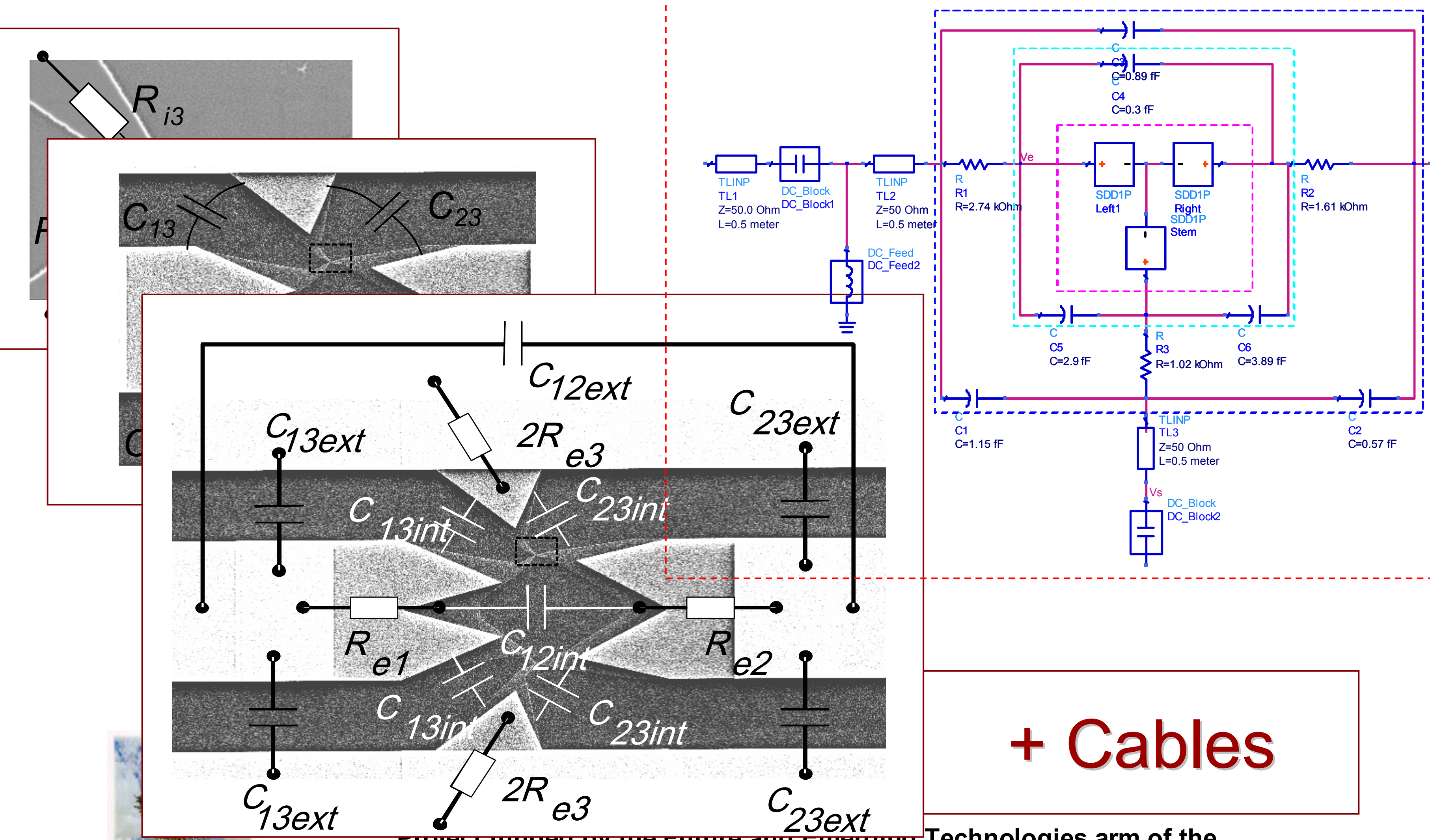
300 K



Amplitude of V_{BT} vs. Frequency



Electrical modelling



+ Cables

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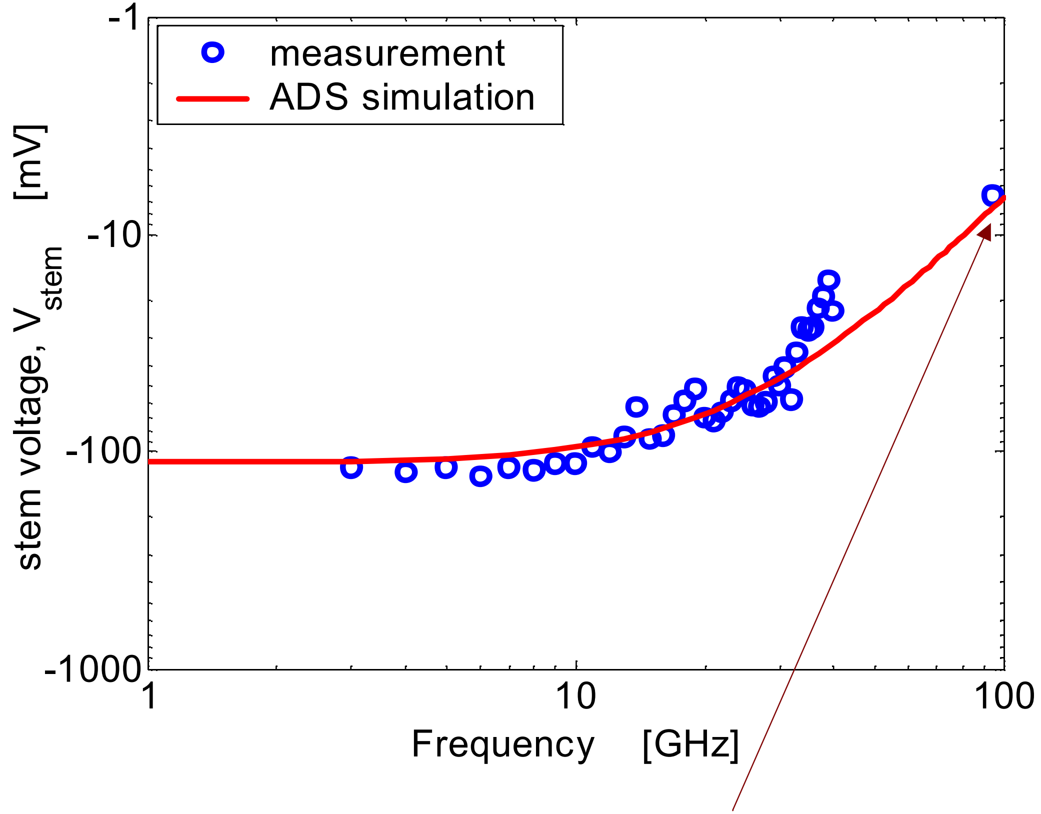
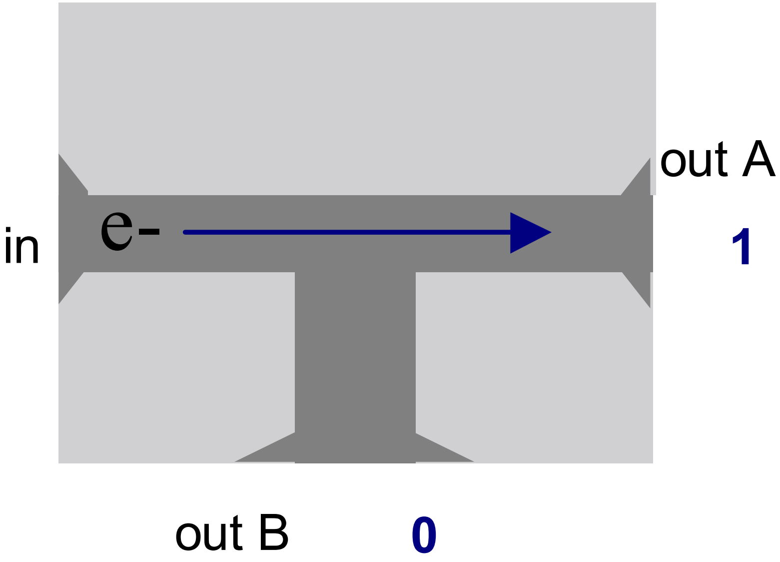
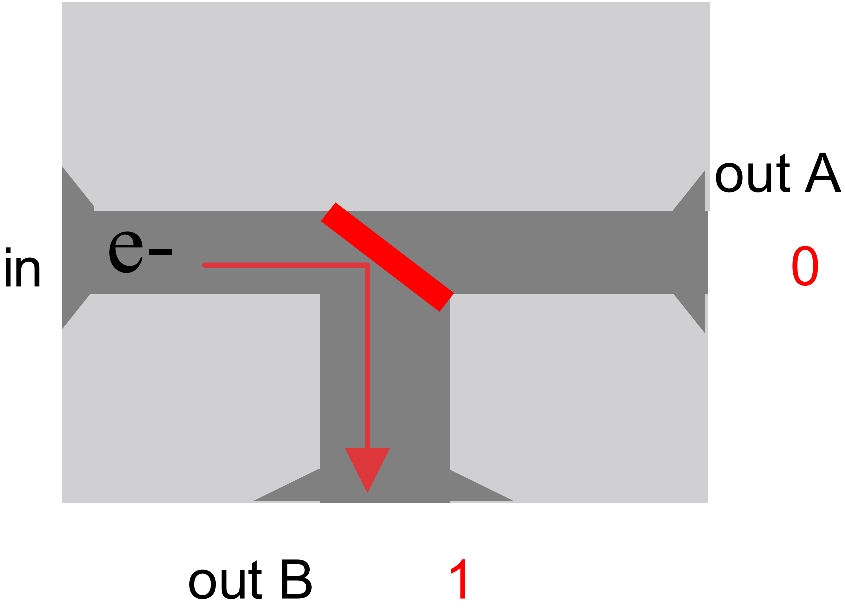
Frequency behaviour of a ballistic detector



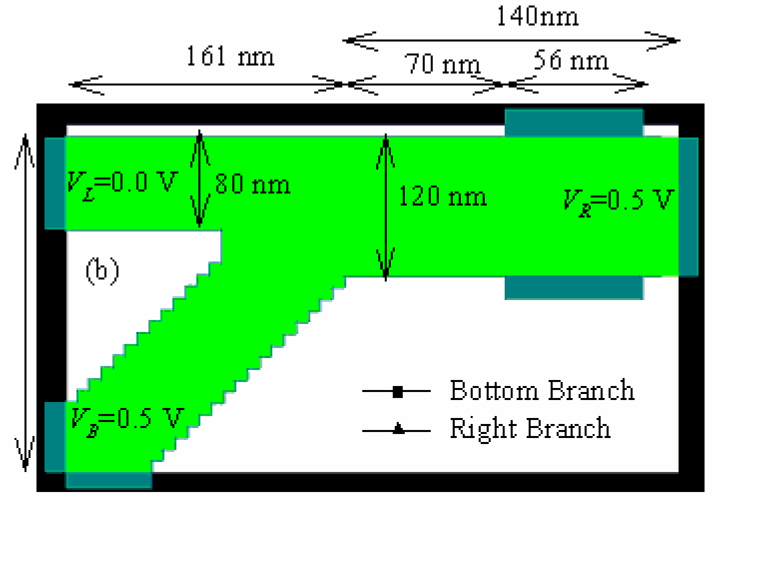
Device still working at 100 GHz (and higher)

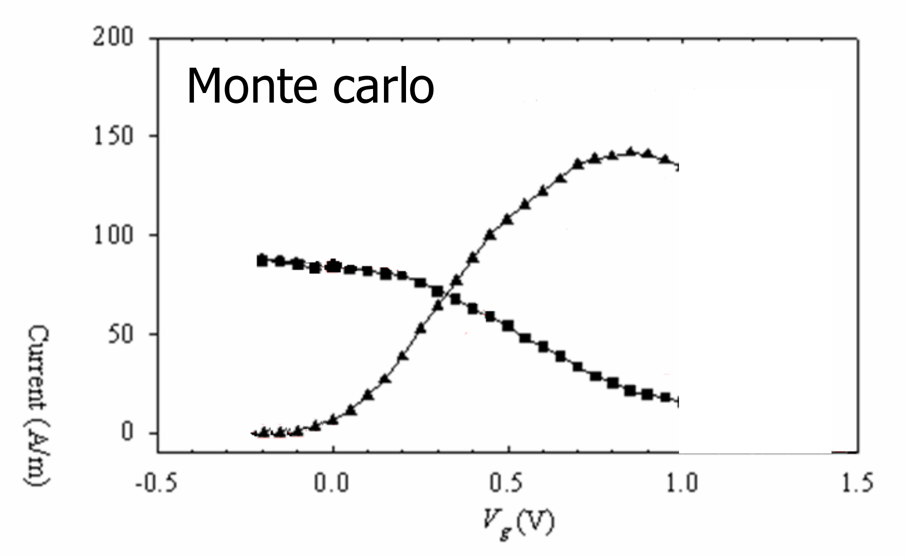
Active ballistic devices





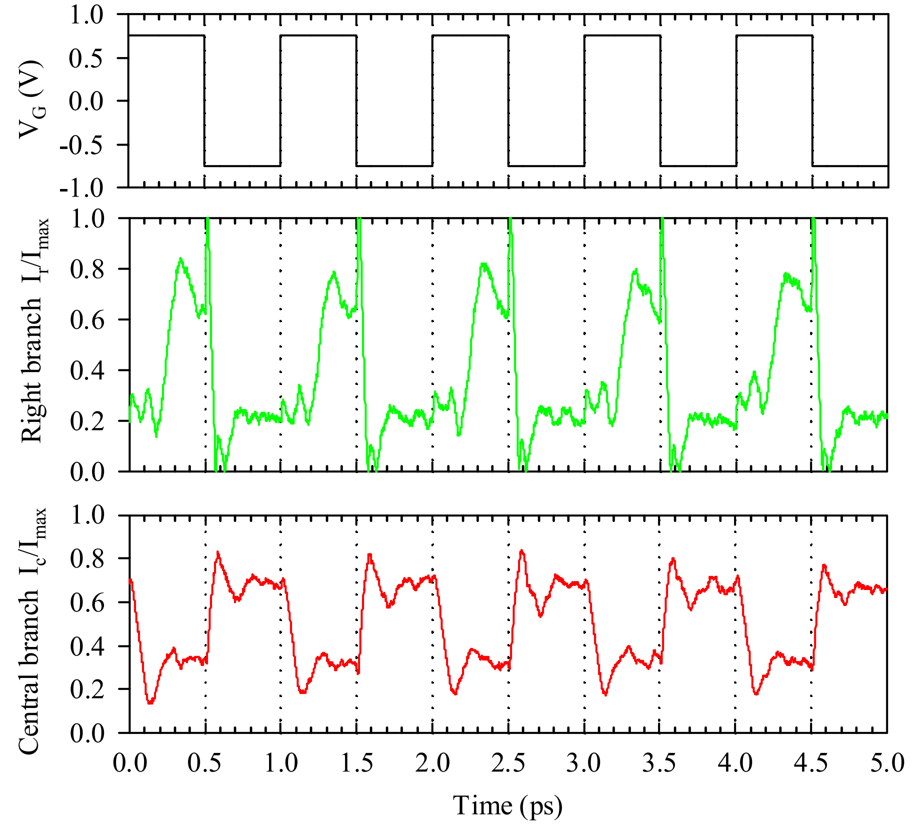
MUX/DEMUX Optimization

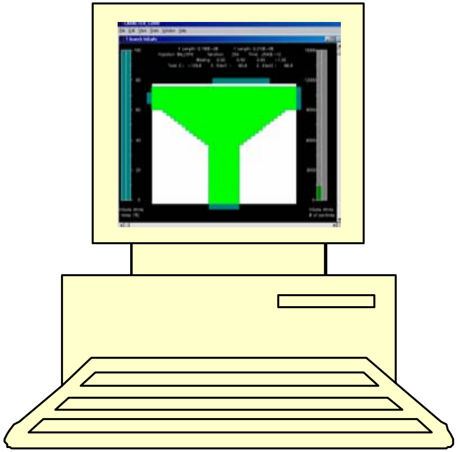




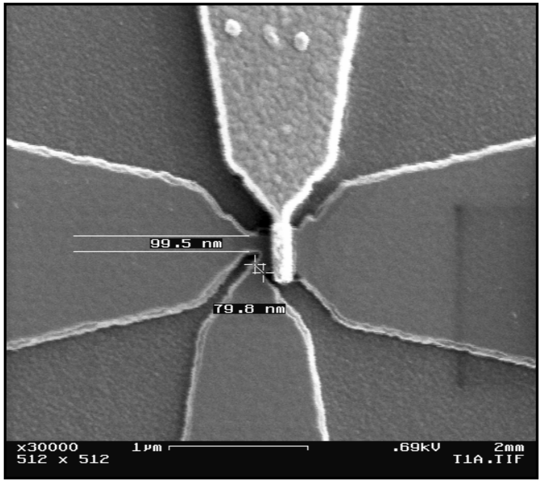
Dynamic Behaviour

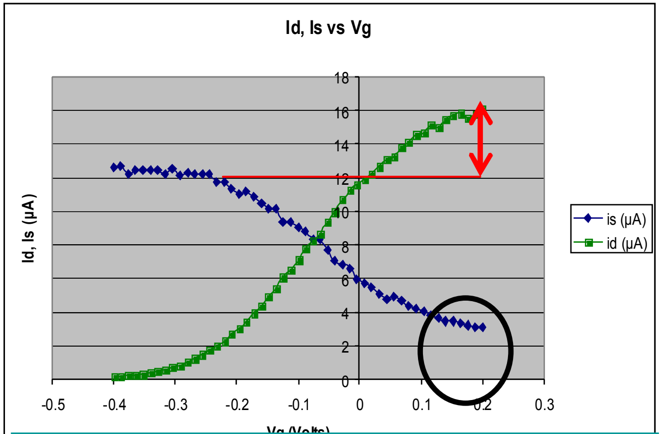
1 THz Operation



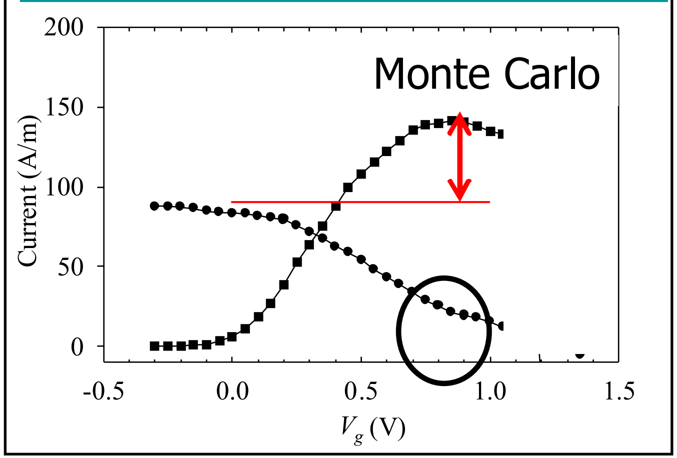


Experimental results





VERY GOOD AGREEMENT



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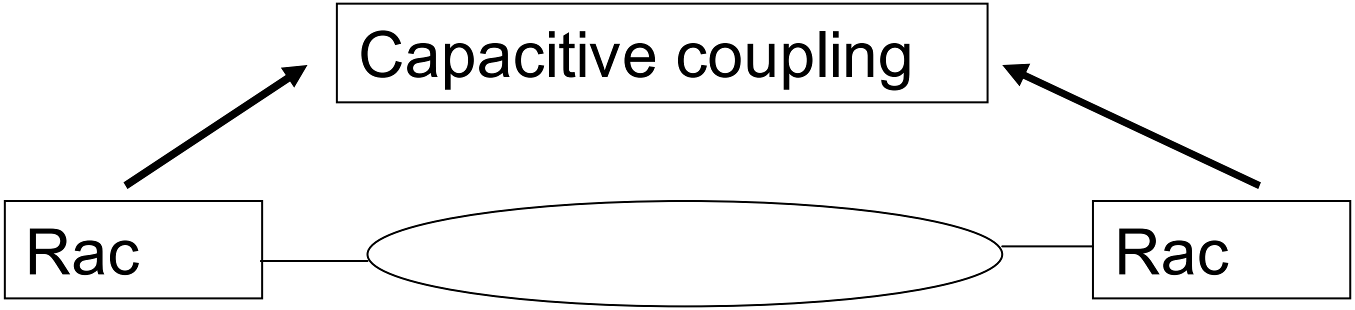
Conclusion

- In depth analysis on the ballistic transport at RT in TBJ and related devices
- Very high intrinsic cut off frequency but limitations by the parasitics (Racces, Cpad……)
- Functionality of a TBJ based detector demonstrated at 100 GHz and RT.
- Active (gated) TBJ fabricated and tested. Good agreement with MC simulation. MUX/DEMUX behaviour demonstrated

Conclusion

- Dynamic behaviour of nanodevices entirely determined by parasitics.



Capacitive coupling

Rac

Rac