12.25-13.20 Session 8 – Molecular Electronics/Quantum Computers Computing Towards 2020

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Molecular Electronics/Quantum Computers

What was said?
What conclusions can be drawn?

Timescales

- We will never know what will be tomorrow
- We can do some clever guesses from existing promising directions (linear extrapolations)
- There will always be new favorite babies (HTS&LTS RSFQ, SET, coherent – non-coherent, MEMRISTORS, graphene, …)
- The winning technologies may not be the logic choice, but emerging from economical feed-back (window of opportunity), i.e., the parameter space is more complicated than the pure scientific and technological

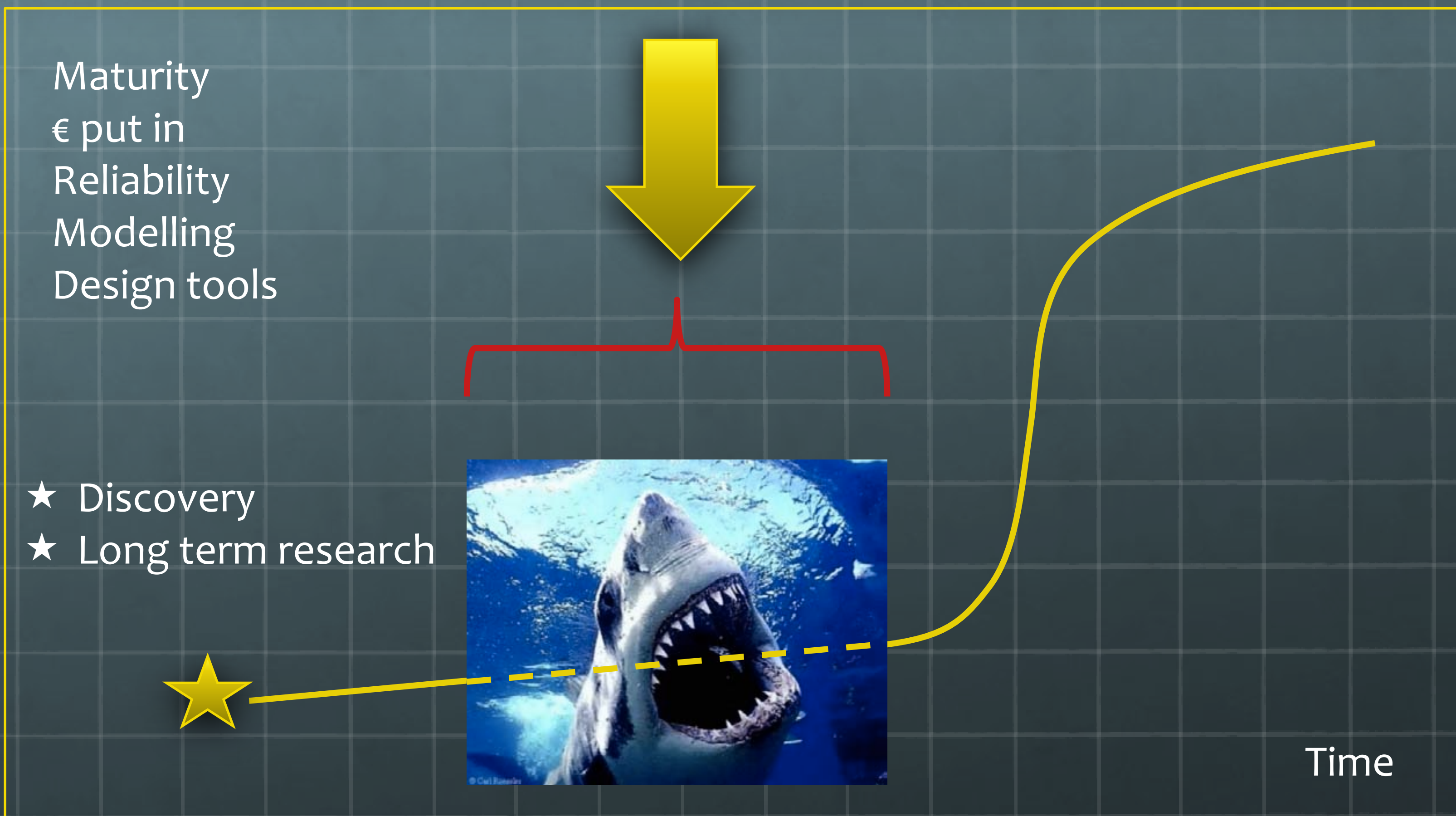
Factors

- Processor entangled vs. incoherent and classically well behaved
- Processor speed versus the chip area for synchronous clock – when do we loose the phase?
- Cooling per unit area
- Cooling for dissipation or for functionality (energy cost per switching)
- Consumer market vs. supercomputers & servers

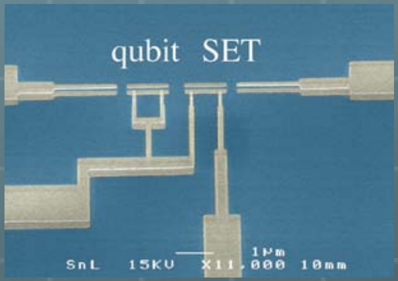
HPC applications within 10 years?

- Carbon nanotube (CNT) and/or graphene electronics ☺
- Memristors, Oxide electronics ☺
- Quantum coherent electronics ☺
- Molecular Electronics (ME) ☹
- Synaptic ME/oxide networks ☹ ☺
- Neural/brain networks *in silico* ☺

Technology valley of death or dark water



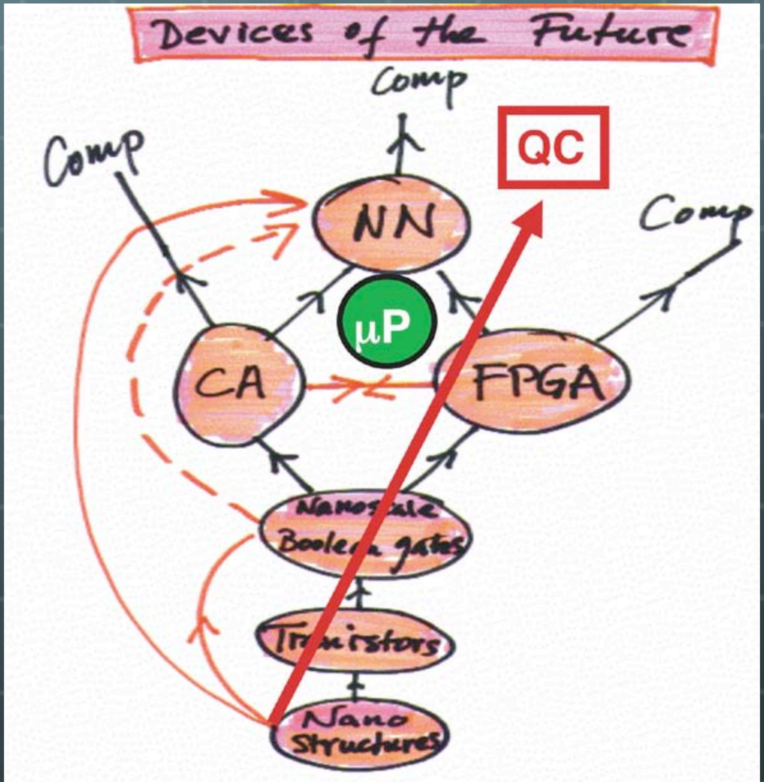
Coherent vs incoherent



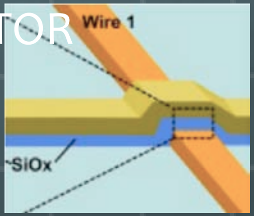
QIP

Quantum *coherent*

(1) Ion traps
(2) Atom traps
(3) Photonic circuits
(4) Spins in molecules
(5) Spins in solids
(6) Josephson junctions



Oxide or Si
MEMRISTOR



Molecular CIP

Quantum *incoherent*

(1) Single-molecule devices
(2) Multi-mol SAM devices
(3) Memristors, crossbars
(4) Neuromorphic networks

Misc notes

- Leaving the exponential computing scales
- Molecular switches
- Hybrid systems
- What computing problems should be solved
- Problems of scaling up, error codes, coherence times
- How many qubits needed for simulations? 20 – 30!
- Costs - "Best qubit"?
- How to build systems?
- SWOT analysis

Discussion

- Nanoelectronics @ Glasgow
- Quantum computing
  - Quantum communications
    - Technology demonstrated and maturing
    - Full demonstrator systems in test
    - Clear application and (niche) market
  - Quantum information processing:
    - What is the “killer application and market driver?
    - (quantum simulator, database searching, encryption factoring)
    - How many qubits are needed for each application?
    - How scalable are the competing technologies?
    - What is the cost?

Quantum Computing

- Difficult to say – evolution…
- Main questions:
  - Error corrections…
- How many qubits needed for simulations? 20 – 30!
- Scalability? Fighting decoherence!
- Costs - "Best qubit"?
- How to build systems?

Quantum Computing

- DiVincenzo guidelines but need comparison with other technologies
- Number of qubits
- Performance (scale of problems that can be solved?)
- Cost
- Total system power (i.e. cryogenics, control lasers, etc…)
- Market size for applications (business case to develop?)

Molecular Computing

- What applications?
  - Memory, logic – cheap, dense or high speed?
  - Any functions that conventional electronics cannot do
- What architechtures
  - “conventional CMOS”, fault tolerant, memory (non-volatile)
  - Neural network or other bio-inspired architectures
- Interconnects
- Etc, etc

Benchmarks Molecular Computing

- Do we need different benchmarks for each potential application?
- Performance
- Power
- Manufacturability
- Costs
- Functions