NPL National Physical Laboratory | QMI Quantum Metrology Institute

Quantum Technologies
CCEM Workshop
March 23rd, 2017

JT Janssen

The first quantum revolution

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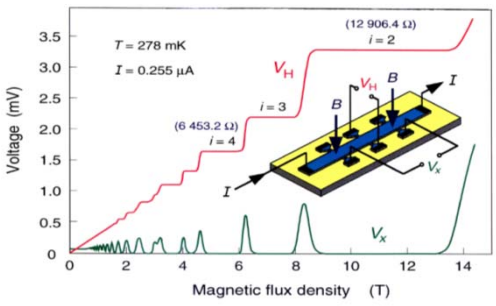
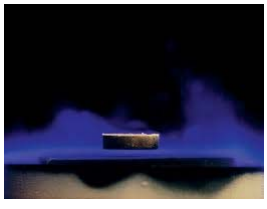
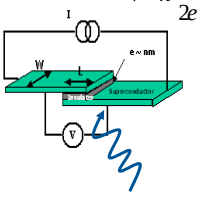




$$V = n \cdot \frac{h}{2e} \cdot f$$



The second quantum revolution

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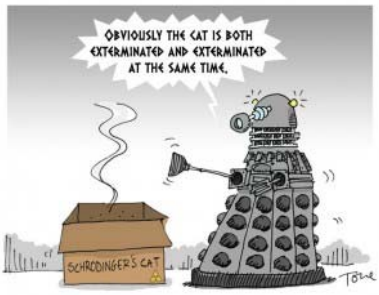

Superposition

Entanglement

The second quantum revolution

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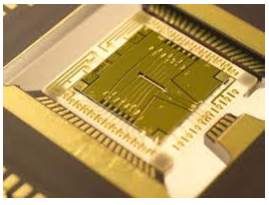


Innovate UK Technology Strategy Board

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

The UK quantum technologies programme

- A 5 year programme with a 10 year vision.
- Delivering new devices and new businesses from world leading UK research
- Industry, academia and public bodies working together to create opportunities for UK wealth creation.

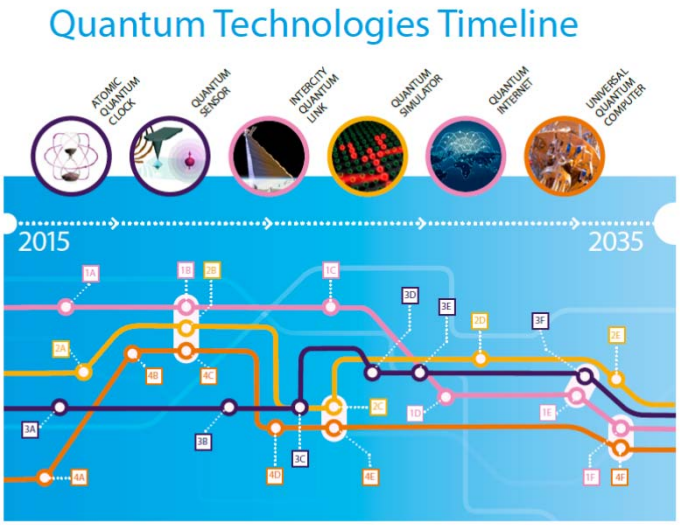
Autumn statement 2013

£270M

UK Government investment in quantum technologies research

Department for Business Innovation & Skills · EPSRC Pioneering research and skills · Innovate UK Technology Strategy Board · Knowledge Transfer Network · [dstl] · NPL National Physical Laboratory · CESG

EU Quantum Flagship: **€1 billion**



http://qurope.eu/system/files/u7/93056_Quantum%20Manifesto_WEB.pdf

QMI Focus

- Link to UK national programme to develop and **commercialise** quantum technologies
- Establish and share key facilities for the **test and validation** of quantum technologies
- Develop the technical basis for future standards for quantum technologies
- Develop UK **skills** and expertise in quantum technologies
- Develop new technologies, **instrumentation** and products
- Develop the **quantum SI** (2018 -)

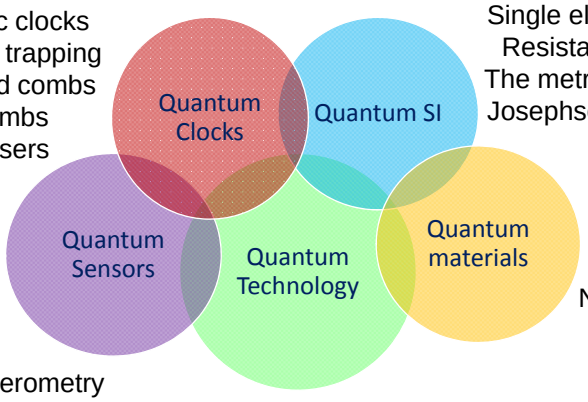
Advanced Quantum Metrology Lab.

Will open in 2018

NPL Quantum Metrology Institute

Microwave & optical atomic clocks
Small atomic clocks
Ion and atom trapping
Femtosecond combs
Micro-combs
Stable lasers

Second, amp, metre
Quantum current std.
Single electron pumping
Resistance standards
The metrological triangle
Josephson voltage stds.

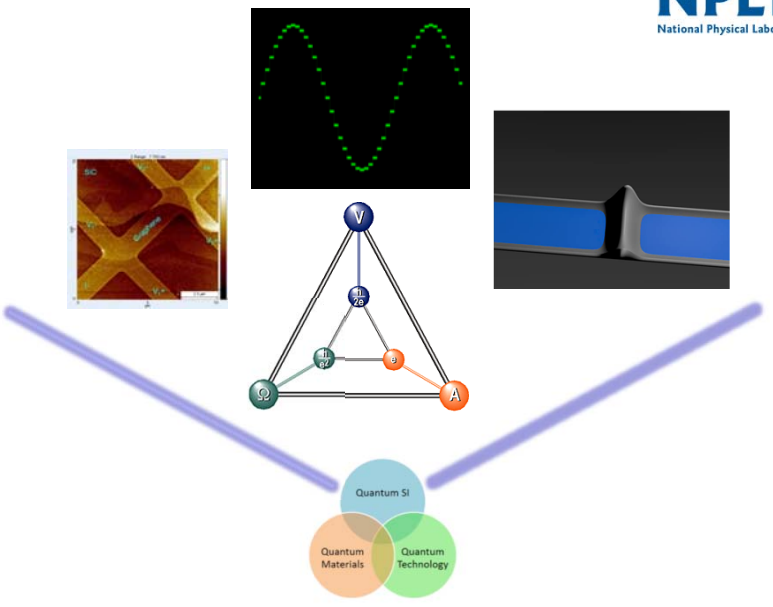


Graphene
SiNb nanowire
Nanomagnetism

Atom interferometry
Atomic magnetometry
NanoSQUIDS
NEMS

Semiconductor Microtraps
Quantum Communications
Superconducting qubits

Quantum SI



Creating current standards based on Coherent Quantum Phase Slip (CQPS)

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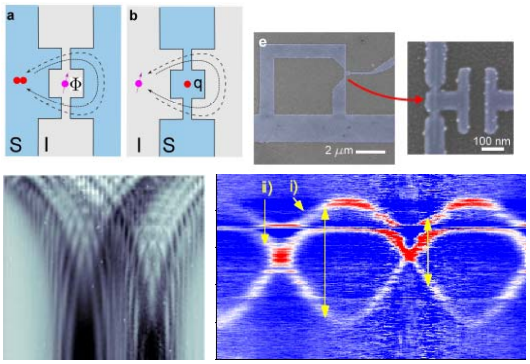
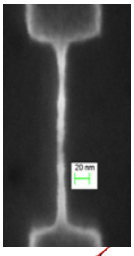
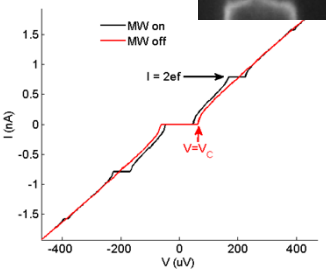
New device: CQUID







De Graaf et al., Nature Nanotechnology (in review)
Peltonen et al., Phys. Rev. B 94, 180508 (2016)

Quantum Materials

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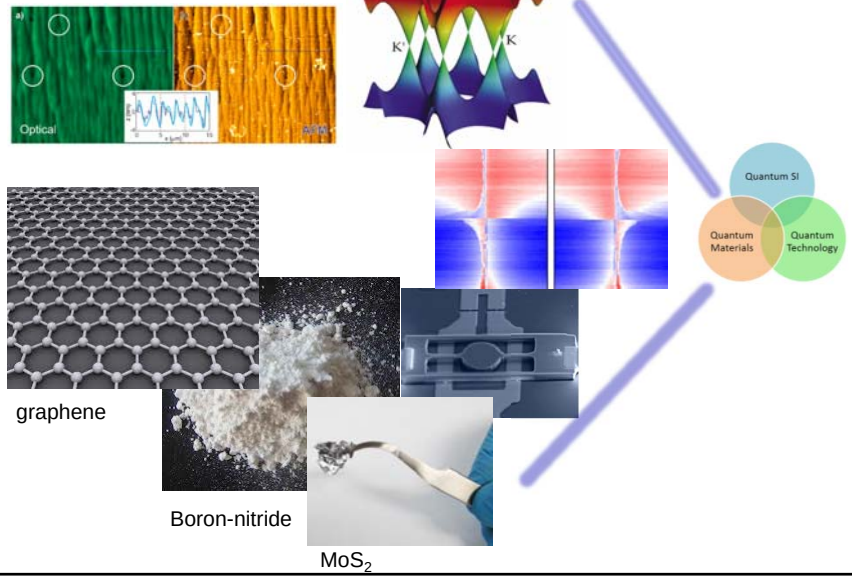
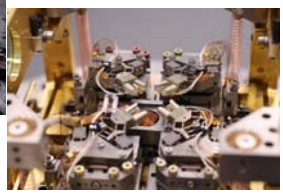


Characterisation techniques for 2D materials

Omicron LT nanoprobe

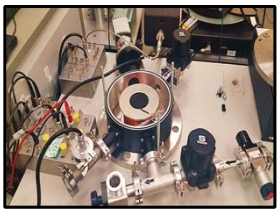
T= 5 – 300 K, B = 25 mT

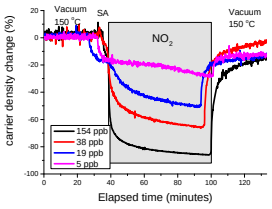


Nanoscale s-SNOM & AFM-IR

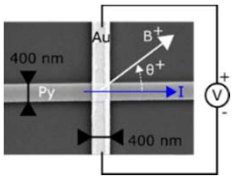
Confocal Raman microscope

Instrumentation: environmental system





Non-contact (in-line) characterisation technique



Magnetic nanosensors for bio-medical applications

Quantum Technology

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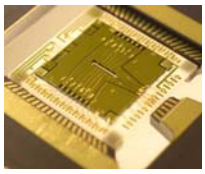

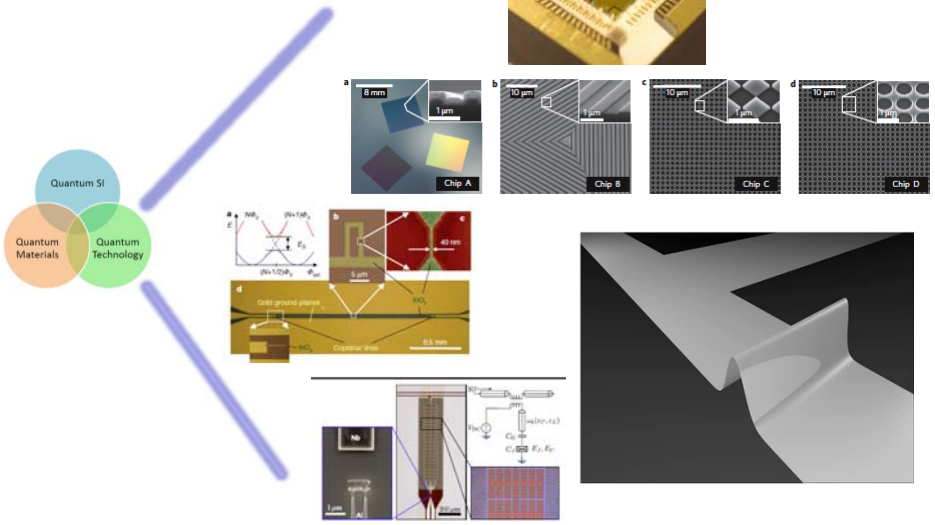

Electron Spin Resonance: Study implanted rare-earth ions for solid-state qubit applications

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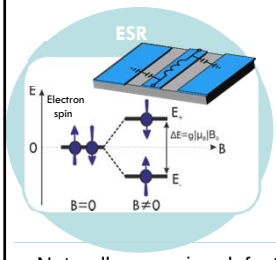
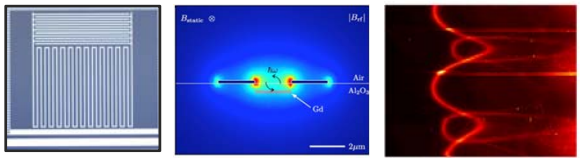
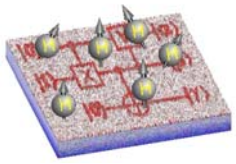
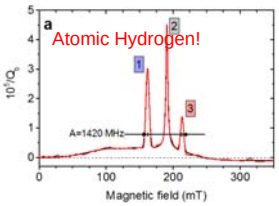


Artificially introduced ions



Naturally occurring defects (sources of noise, decoherence)





Defect-ESR: Impact on quantum technologies, medical imaging, surface analysis, catalysis, geological prospecting, …

Towards single spin ESR, quantum memories & transducers

De Graaf et al., Phys. Rev. Lett. (2017)
Wisby et al., Phys. Rev. Appl. (2016)
Wisby et al., Appl. Phys. Lett. (2014)

Microwave microscopy: Demonstrate sensitivity to 2-level systems presence at single photon energies

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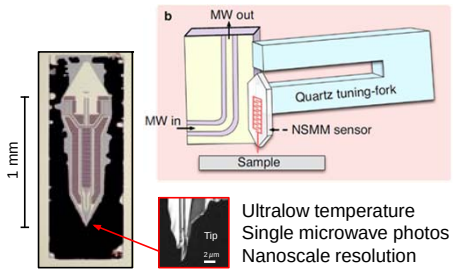
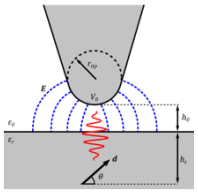
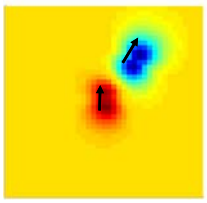
Quantum limited Near-field scanning microwave microscopy



Ultralow temperature
Single microwave photos
Nanoscale resolution





Goal: Quantum imaging of individual two-level systems (qubits, defects, …)

De Graaf et al., Scientific Reports (2015)
De Graaf et al., Rev. Sci. Instrum. (2013)

Correlation noise measurements

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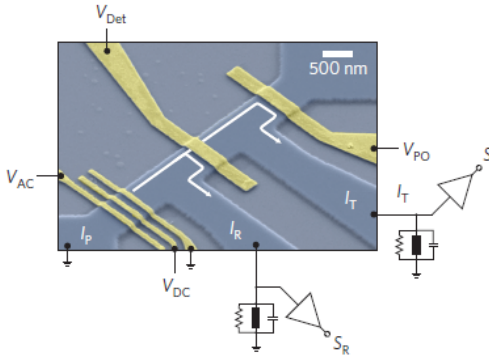
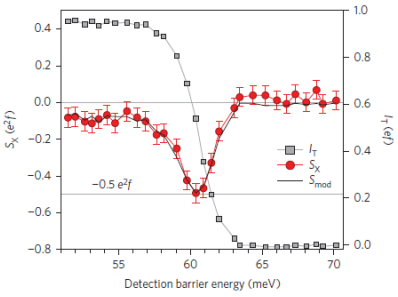
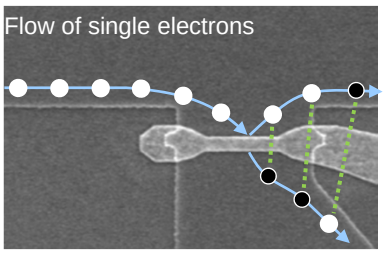
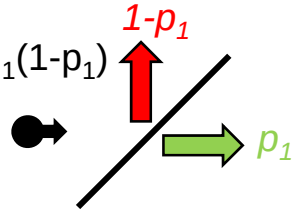


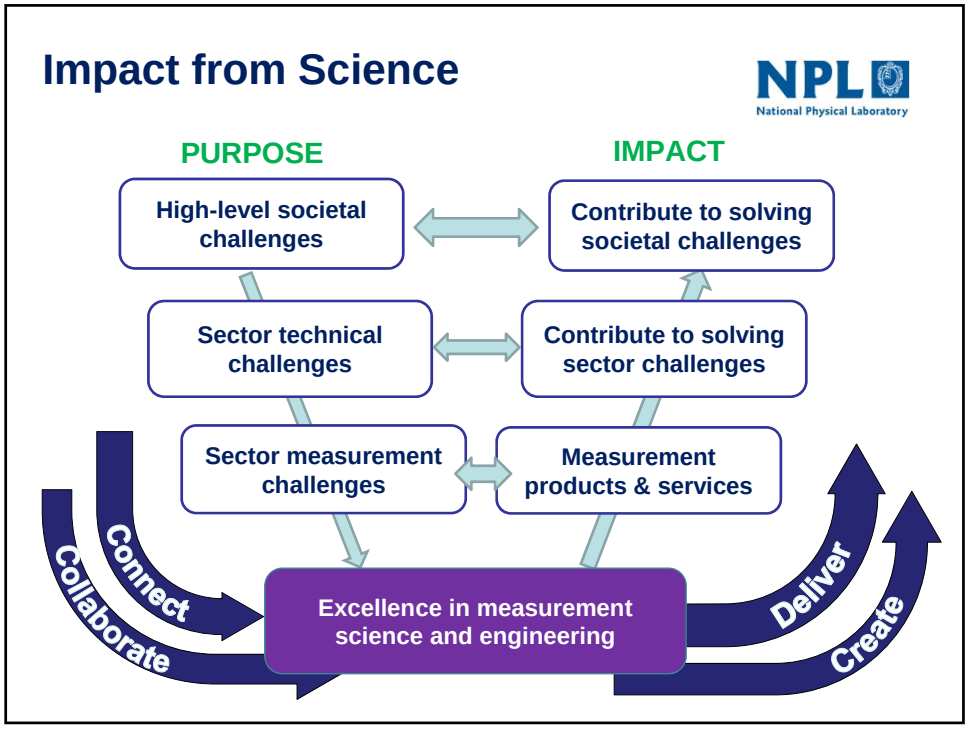


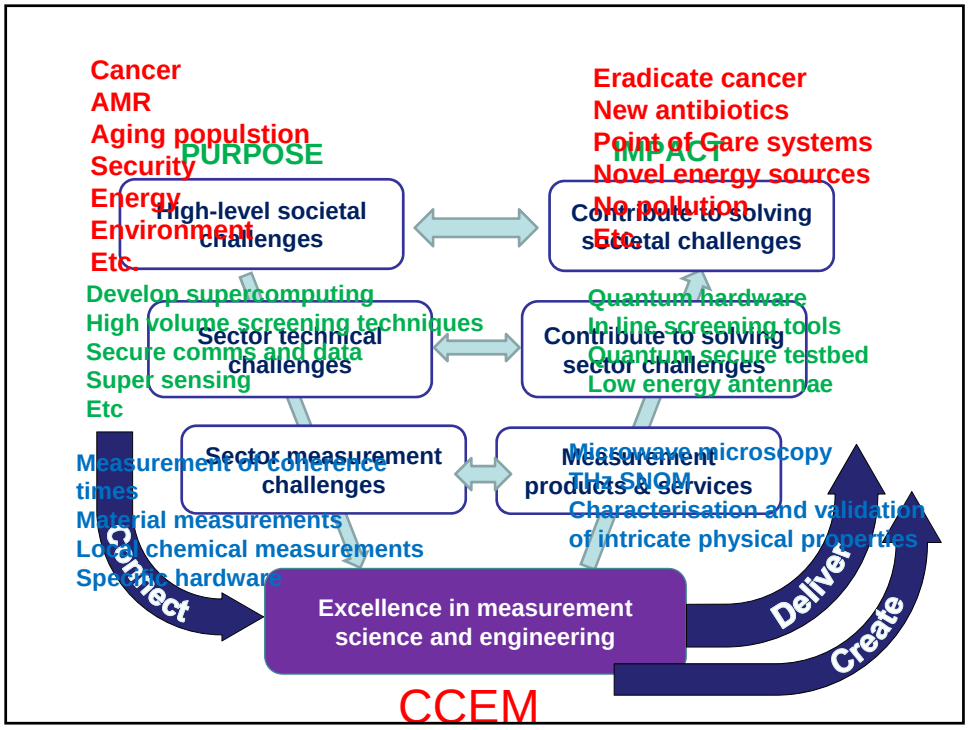


$I_T = p_1 ef$

$S_x = -2e^2 f\, p_1(1-p_1)$




Impact from Science
NPL
National Physical Laboratory
PURPOSE
IMPACT
High-level societal challenges
Contribute to solving societal challenges
Sector technical challenges
Contribute to solving sector challenges
Sector measurement challenges
Measurement products & services
Connect
Collaborate
Excellence in measurement science and engineering
Deliver
Create


Cancer
AMR
Aging populstion
Security
Energy
Environment
Etc.
PURPOSE
IMPACT
Eradicate cancer
New antibiotics
Point of Care systems
Novel energy sources
No pollution
Etc
High-level societal challenges
Contribute to solving societal challenges
Develop supercomputing
High volume screening techniques
Secure comms and data
Super sensing
Etc
Sector technical challenges
Contribute to solving sector challenges
Quantum hardware
In-line screening tools
Quantum secure testbed
Low energy antennae
Sector measurement challenges
Measurement products & services
Measurement of coherence times
Material measurements
Local chemical measurements
Specific hardware
Microwave microscopy
THz SNOM
Characterisation and validation of intricate physical properties
Connect
Excellence in measurement science and engineering
Deliver
Create
CCEM