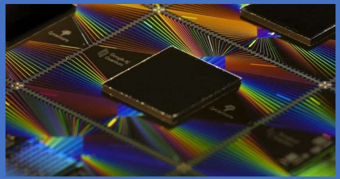

QUANTUM COMPUTATION USING DIAMOND N-V CENTRES

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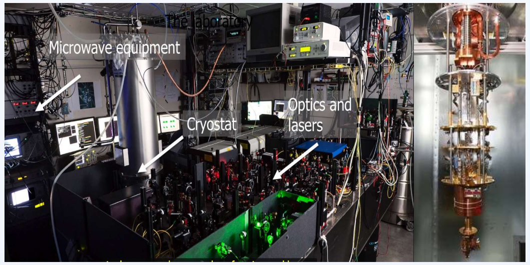
INTRODUCTION

- A quantum computer uses the quantum phenomena of subatomic particles to compute complex mathematical problems
- Nitrogen-vacancy (NV) centers in diamond have recently emerged as a unique platform for fundamental studies in QIP (Quantum Information Processing) and Nanoscale Sensing.
- These vacancies provide robust, room-temperature operation of solid-state qubits.



WHY QUANTUM COMPUTERS

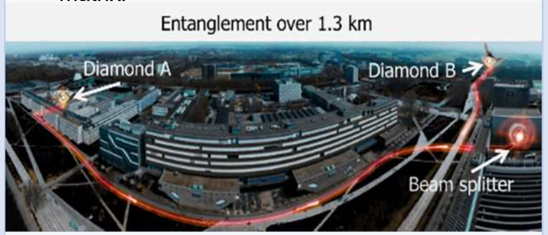
- Quantum computation can offer much more than cramming more and more bits into silicon and multiplying the speed of microprocessors.
- It can support an entirely new kind of computation with qualitatively new algorithms based on quantum principles!
- On the atomic scale matter obeys the rules of quantum mechanics, which are quite different from the classical rules that determine the properties of conventional logic gates.

QUBITS

- Classical computing bits have two possible states **either zero or one**
- A qubit (short for "quantum bit") is a unit of quantum information—the quantum analogue to a classical bit
- Special Properties:
  - **Superposition**
  - **Entanglement**

QUANTUM LOGIC GATES

- A quantum logic gate is a basic quantum circuit operating on a small number of qubits
- Unlike many classical logic gates, quantum logic gates are reversible
- The number of qubits in the input and output of the gate must be equal; a gate which acts on **n** qubits is represented by a $2^n \times 2^n$ unitary matrix.



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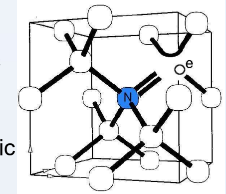
GOOD QUBITS

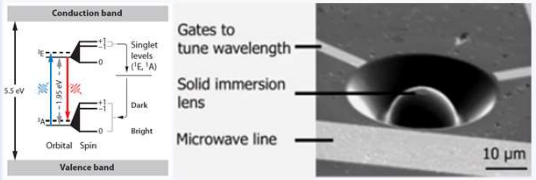
- As summarized by David DiVincenzo, following are the properties of a good Qubit:
  - **Having a method of initialization**
  - **Having a universal set of quantum gates**
  - **Long coherence time relative to the gate operation time**
  - **Qubit specific state readout**

DIAMOND N-V CENTRES



- Negatively charged N-V centres are paramagnetic point defects.
- Six electrons occupy this defects localized electronic states
- Due to confinement of electronic states within 5.5eV bandgap of diamond, N-V centres regarded as "trapped atoms".
- Role of the diamond is to confine the electronic state and hold it in fixed position.
- Moreover, the diamond lattice provide good primary protection against the decohering influence of the solid-state environment

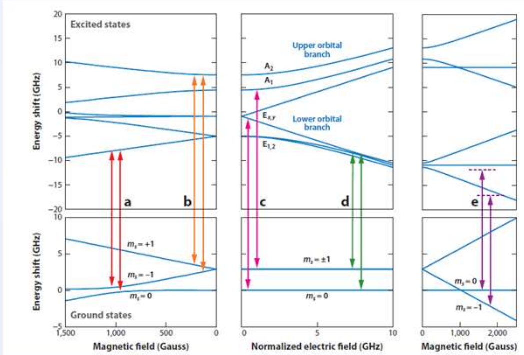
MAGNETIC RESONANCE OF N-V SPIN



- Magnetic control of single NV centre spin is implemented by applying AC magnetic field (Rabi driving field) with carrier frequency close to frequency of relevant spin transition.
- Continuous driving and pulsed fields in magnetic resonance are applied to spin ensembles positioned as shown above.
- Spectral measurements are performed using one or more fixed frequency driving fields while the static external field is varied

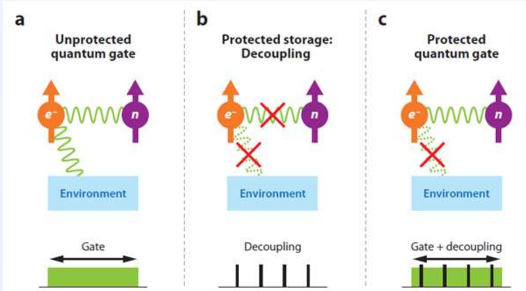
RESONANT OPTICAL CONTROL

- Allows for selective driving of a particular transition between levels, in contrast to non-resonant excitation through the phonon sidebands that drives transitions at once.
- Conveniently excited by visible light sources.
- Optical transitions can be used to obtain single-spin control, high spatial resolution, reduced sample heating (compared to microwaves) and to interface the N-V center with a photonic network.



COUPLING WITH NUCLEAR SPINS

- Nuclei of the ^{13}C isotope is present in diamond with an abundance of 1.07%
- Some can also be present close to the N-V center; strongly coupled to the electronic spin
- Resonance frequency of the N-V electron spin becomes dependent on the state of the proximal ^{13}C nuclear spins and the resonance lines of the proximal ^{13}C spins become dependent on the state of the N-V spin.
- Drawback: probabilistic appearance of C-13 isotopes near NV Center which largely decrease as we use isotopically purified samples (to increase coherence time).
- Better approach is to use always present nuclear spin of neighboring N atom as qubit.
- In contrast to C, spin of N nucleus is always present. Its properties are fixed by the NV geometry and can be measured with high precession.



QUANTUM NETWORKS

- Challenge for large scale QIP with NV centres is connecting many qubits together to form large scale entangled states.
- In principle, we can create such networks using photons and resonant optical control.