Qubit Research and Atomic Orbitals

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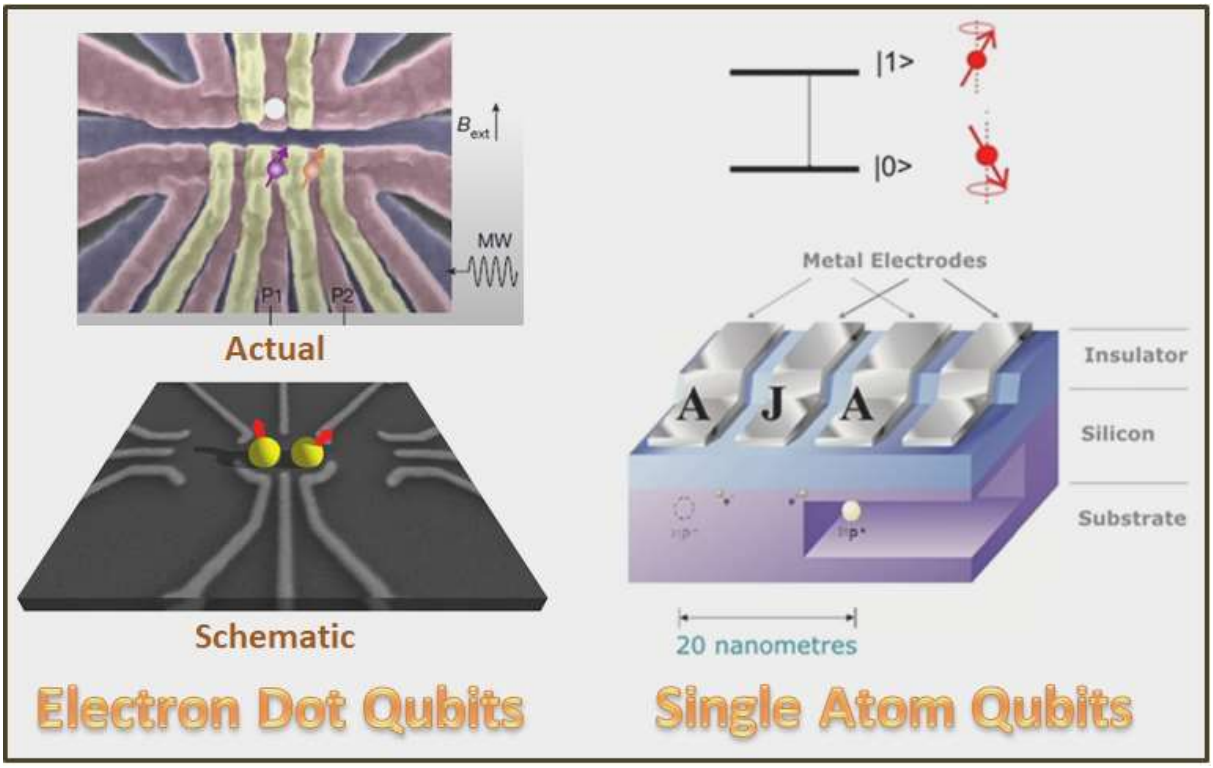
Abstract

Paralleling recent advances in the areas of nanoscience, large-scale integrated circuit development and quantum computing, are technologies that allow the manipulation and control of individual atoms and electrons. With the promise of increased miniaturisation, faster parallel computing and register-per-bit-pair capabilities purported by quantum computing, currently multiple technologies are being developed to represent ***quantum bits*** *(****qubits****) by the* ***quantum spin*** *of atoms and electrons and the chiral spin of photons. These technologies and the associated research are also providing new insights that may change our understanding of the sub-atomic world and electron orbitals in particular.*

One area of qubit research is based upon the use electron spin qubits based upon quantum dots, wherein the spin energy of electrons is reduced to below the Fermi level so that they are trapped within a well within a host substrate. The spin direction of electrons is manipulated electromagnetically, with a '0' being the lower state energy level of a down-spin electron and a '1' by the higher energy state of an up-spin electron.

Rather than being either in a distinct 0 or 1 state, the combination of nuclear precession and spin-change dynamics means that a qubit reflect components of both states at the same time, with its various states plotting as points anywhere on a Bloch sphere. Although the range of states of quantum dot qubits conforms statistically to the quantum mechanics wave equations, the electrons being manipulated have physical size, mass and momentum, much of which does not fit well with the point-form electron definition used to satisfy the wave equations.



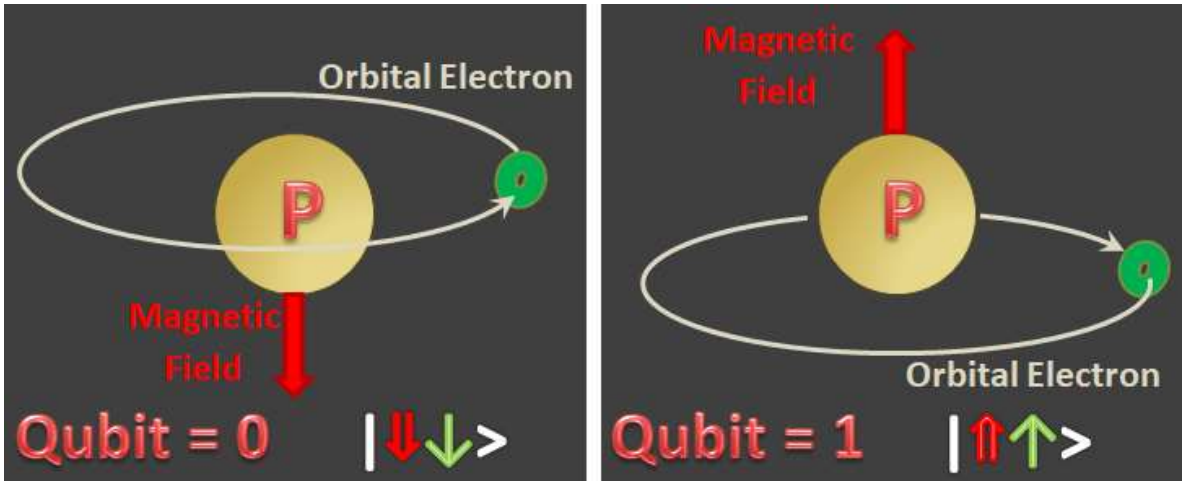
Intel is quite well advanced in the quantum dot approach, having announced a 49 qubit processor test board in 2018 and is currently researching mass production possibilities for their technologies. Things are progressing quite rapidly.

Another qubit technology involves the placement of individual phosphorus atoms within an ultra-pure silicon substrate. For this approach, University of New South Wales (UNSW) researchers represent a qubit as a single **phosphorus anion**. They use nuclear magnetic resonance (**NMR**) techniques to selectively change and detect the nuclear spin of the atom to represent a binary 0 or 1, with the orbital ionic electrons being manipulated to **entangle** a pair of qubits. The 2018 UNSW video lecture by M Simmons titled 'The Einstein Lecture: The Quantum Computing Revolution' describes how phosphorus anions are injected and manipulated, and the 2022 high fidelity qubits video by A Morello provides more detail regarding the development of a qubit logic gate. The ability of the UNSW team to set up and manipulate the orbit of an electron around a phosphorus atom suggests that, at close to absolute zero, the only electron orbitals present are **ionic electron orbitals**.

According to the **'spdf' model**, a phosphorus atom has 15 orbital electrons: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ with the outer 3 electrons having a common spin direction; or according to the Bohr model it has [2, 8, 5] electrons in the [K, L, M] shells. The single phosphorus atoms used are phosphorus anions (P^-) but, rather than pairing with one of the $3p^3$ electrons or joining the other five M-orbital electrons, the extra ionic electron apparently ignores the other orbital electrons to take up its own conduction band orbital that can readily be manipulated and controlled via microwave bursts of the appropriate frequency.

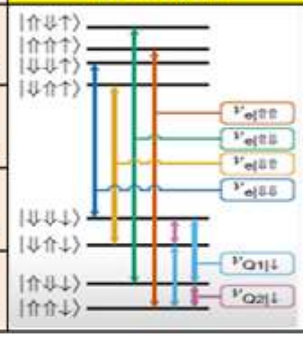
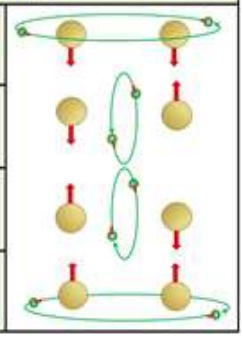
The UNSW single-atom qubit research indicates that the lower 15 'spdf' and/or Bohr electron orbitals appear unaffected by all the energy regimes to which they subjected: for instance, they do not emit or re-emit EMF during qubit experimentation. For the conventional Science atomic model, this research presents the problem as to why and how the underlying orbital electrons are unaffected by the robust manipulation of both the ionic electron and the nucleus. The lack of a 'sign of life' from the lower orbital shells in these detailed studies raises the distinct possibility that the 15 orbital electrons, in fact, do not exist. This represents an even bigger problem for conventional Science.

Taking a different tack, the STEM Development group (SDG) contends that the only orbital electrons within atoms are **ionic electrons**. STEM considers that ionic electrons, which are functionally similar to conduction band electrons, are held in **planar orbitals** by electromagnetic fields generated by the outer full neutron or proton layers of an atom's nucleus. SDG's suggested structure for a phosphorus-31 atom is a nucleus consisting of six full octagonal nucleon layers plus an embedded helium form (see page 80 in the 'Ionisation and Redox' chapter of SDG's Atomic Structure paper). The nucleon layers consist of three double proton/neutron layers plus a partial layer consisting of two neutrons and one proton. Although a neutral phosphorus atom contains no orbital electrons, in its **ionic form**, it is considered that, the outer full neutron layer generates an electric field that holds an ionic electron within an anti-clockwise circular orbit above the nucleus (when viewed from above), as represented schematically in the graphic below left.



At temperatures near to absolute zero (0^{O} kelvin), as used for the UNSW qubit project, the P-31 nucleus within the silicon substrate would appear to behave in a similar manner to an ionic gas or solution with an ability to respond to externally applied nuclear magnetic resonance (NMR) electromagnetic fields. When a P-31 nucleus is inverted from a spin-down to a spin-up condition, the nucleus and its associated magnetic field are reversed carrying the orbiting ionic electron with it, so reversing its electron spin and orbital travel direction (so as to become clockwise when viewed from above, as shown as the graphic above right). The electron spin can also be independently reversed by using microwaves of the appropriate frequency, as indicated by the dashed single arrows (⇡ and ⇣) in the table below.

Referring to the notation in the table below, the atom's default condition of '0' is represented as |⇓↓>, and its inverted orientation '1' condition is |⇑↑>, with the independently inverted electron spin versions indicated as |⇓⇡> and |⇑⇣> respectively. The measured energy levels ($\mathbf{V_e}$ ranges) in the table below indicate the overlapping energy ranges associated with each possible configuration. As for quantum dots, both the P-31 nucleus and its ionic electron can each be both part in the '0' and '1' state at the same time, as required to qualify as a qubit. UNSW testing indicates that the nuclear qubits have an a higher **coherence time** (up to 1 sec read/process time) than quantum dot qubits, and over **99.9% fidelity** (i.e. reliability of the qubit set-value corresponding to its subsequent measured-value).

Number		Notation			Measured Energy Levels (V_e Ranges)	Entangled Qubits	
Value	Binary	Electron ↓	Electron ↑	V_e Range			
0	0 0	|⇓↓⇓↓> (|⇓⇓↓>)	|⇓⇡⇓⇡> (|⇓⇓⇡>)	V_e⇓⇓ |⇓⇓↓> to |⇓⇓⇡>		Q1 O Q2 Loop	
1	0 1	|⇓↓⇑↓> (|⇓⇑↓>)	|⇓⇡⇑⇡> (|⇓⇑⇡>)	V_e⇑⇓ |⇑⇓↓> to |⇑⇓⇡>		Q1 2 Q2 Cross Over	
2	1 0	|⇑↓⇓↓> (|⇑⇓↓>)	|⇑⇡⇓⇡> (|⇑⇓⇡>)	V_e⇑⇓ |⇑⇓↓> to |⇑⇓⇡>		Q1 2 Q2 Cross Over	
3	1 1	|⇑↓⇑↓> (|⇑⇑↓>)	|⇑⇡⇑⇡> (|⇑⇑⇡>)	V_e⇑⇑ |⇑⇑↓> to |⇑⇑⇡>		Q1 O Q2 Loop	

Note: *The '**Notation**' and the '**Measured Energy Levels**' columns above are from published UNSW resources. However, the '**Entangled Qubit**' orbital patterns have not been endorsed by the UNSW research team.*

In a conventional computer, calculations are made by the CPU which loads data in various groups of 8-bit bytes into registers that are operated upon by an ALU (Arithmetic Logic Unit) under program logic control. To maximise their parallel computing capability, quantum computers require ALUs to operate at the bit-pair level. This means that pairs of entangled qubits need to be able to be defined and manipulated together by a range of programmable quantum logic operators, with most of the initial research effort having been directed to that end.

The UNSW project uses P-31 anion pairs set 20nm apart and at the same depth within a silicon substrate to represent qubit pairs: such physical pairing is referred to as qubit **superposition**. To be able to lock the set-values in each qubit pair for the time needed to carry out logic operations on them, they need to be **entangled**. Amazingly, **entanglement** is achieved by causing the ionic electron orbitals to be shared by both nuclei, which somewhat resembles **covalent bonding**. The SDG graphical interpretation and representation of this process is shown rightmost in the **'entangled Qubit'** column of the table above, with the shared orbitals being oval-shaped above/below the nuclei for '00' and '11' settings; and circular and located between them for '01' and '10' settings. And once the two atoms are entangled, they can apparently be moved about as a separate entity without a loss of fidelity.

High energy plasma research related continues to report a range of unusual quantum phenomena, with high energy collider studies yielding a range of strange particles that the Standard Model protagonists claim underpin the structure of atoms. However, neither Quantum Mechanics nor Standard Model research has led to a comprehensive model of the atom beyond that of the Bohr and 'spdf' orbital models that are now more than 90 years old.

At temperatures close to absolute zero, low energy nanoparticle-related qubit research uses powerful state-of-art devices such as high-resolution electron tunnelling microscopes, which are capable of mapping the outer surface crystalline silicon/hydrogen surface topology atom-by-atom, and atomic tweezer related technologies, to manipulate individual atoms and electrons. As well as contributing to the possible development of more powerful computers, such hands-on experimental qubit research and development work is also providing new insight into the sub-atomic world.

Over the past 10 years (within a single decade), as well as paving a pathway to the next generation of computing capabilities, low energy nanoparticle oriented research is proving to be significantly more productive in terms of our understanding of the atom and its associated fundamental particles than all the extensive and incredibly expensive high energy research areas combined. However, rather than being supportive of conventional Science's orbital nuclear model involving multiple electron orbital shells or 'spdf' orbitals that fully enwrap the nucleus, evolving low energy sub-atomic qubit research would seem to be more supportive of the planar orbital above and/or below the nucleus. As well as potentially changing the future landscape of computing, qubit research and development may very well end up having an even bigger impact on the future landscape of atomic Physics.