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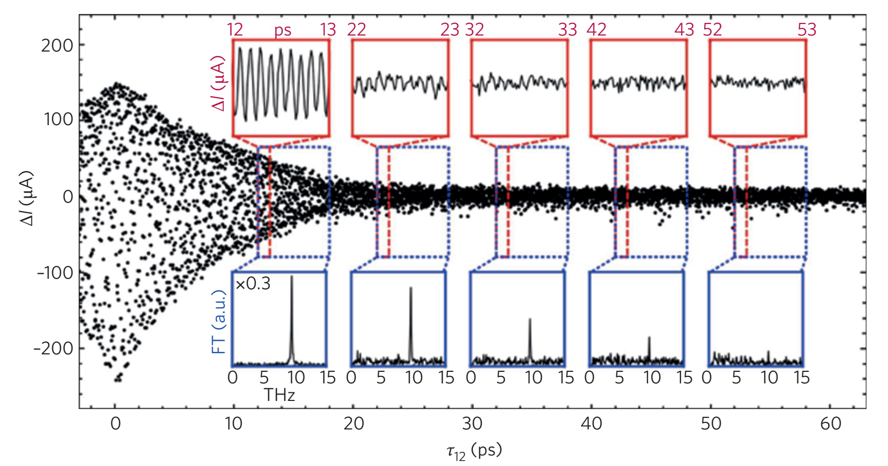
QUANTUM COMPUTING

Silicon qubits

One of the main challenges of quantum technologies is merging quantum physics and electronic systems within the same Si-based platform. In this respect, the long-sought realization of a quantum computer has shifted the quest for a suitable qubit platform from electrons, atoms and quantum dots to silicon impurities. Now, Ben Murdin and collaborators from universities in the UK, the Netherlands and Switzerland demonstrate full control of the creation and destruction of wave packets in silicon (*Nature Commun.* **6,** 6549; 2015). In this case, phosphorus impurities trapped in the silicon layer (Si:P) were used as qubits, representing a model two-level system as they transition between the 1*s* and 2*p* orbital states.



Quantum mechanics allows for the superposition of states between the two orbitals, and the researchers read out the states using both electrical and all-optical schemes. First, they used a free-electron laser, tunable in the THz range, to resonantly excite the 1*s*–2*p* transition with ultrashort pulses (about 6 ps). They used Ramsey interferometry, a well-established technique used in atomic clocks and in the International System definition of the second, to probe the interaction of the two-level system with the optical field. The pulses were split into two, and the time delay of the second pulse with respect to the first was varied. As the researchers detected the photoconductivity ΔI of the sample with respect to the delay between the two pulses (τ_{12}), they observed electrically the so-called Ramsey fringes of interference (pictured). The red insets show interference even at 60 ps, but it is more pronounced in the Fourier transformed signals, shown in the blue insets. The fringes provided evidence of the manipulation of the quantum state; indeed, the first pulse prepared the coherent superposition and the second re-mixed the states, thus allowing the researchers to probe a phase shift.

Second, the researchers developed an all-optical echo scheme, which, compared with the electrical detection scheme, requires an additional third pulse, to not only confirm their results but also to extract useful time constants for the system. Importantly, the results from the two schemes were consistent, which allowed the researchers to measure the relaxation time T_1 and the homogeneous and inhomogeneous decoherence times T_2 and T_2^*, respectively, using a single set-up.

The combination of ultrafast switching times with a silicon platform constitutes a crucial step towards a realistic implementation of the much-wanted quantum computer. A natural next step would be the implementation of such fast dynamics for quantum logic gates on-chip, for use in computing applications that demand speeds currently unachievable with classic computers.

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