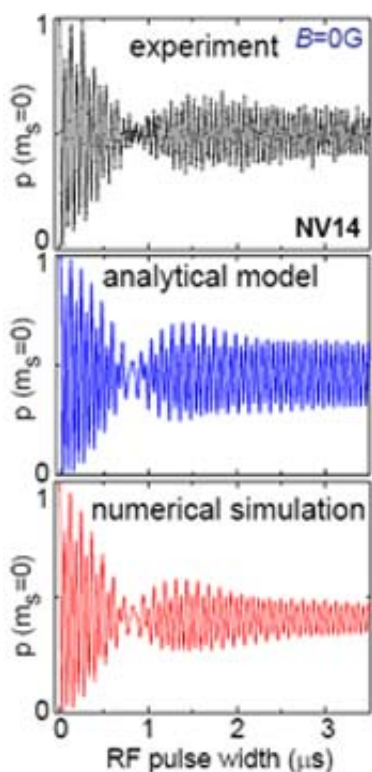


Physicists Bring Quantum Computing Closer to Reality

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These images depicting coherently driven spin oscillations of a nitrogen-vacancy (N-V) center show the excellent level of agreement achieved between experiment, analytical theory and computer simulation in the research on the fundamental physics of a single quantum spin by Ames Laboratory, the University of California, Santa Barbara, and Microsoft Station Q.

Researchers at the U. S. Department of Energy's Ames Laboratory, the University of California, Santa Barbara, and Microsoft Station Q have

made significant advancements in understanding a fundamental problem of quantum mechanics – one that is blocking efforts to develop practical quantum computers with processing speeds far superior to conventional computers. Their respective theoretical and experimental studies investigate how microscopic objects lose their quantum-mechanical properties through interactions with the environment.

The results of the researchers' investigations were announced at the American Physical Society meeting held March 10-14 in New Orleans and also reported in *Science Express*, the advance online publication of the journal *Science*.

“Quantum-mechanical particles can interact with their environments: visible light, or photons; molecules of the air; crystal vibrations; and many other things,” said Viatcheslav Dobrovitski, an Ames Laboratory theoretical physicist. “All these uncontrollable interactions randomly ‘kick’ the system, destroying quantum phases, or the ability of particles to preserve coherence between different quantum states.”

Quantum coherence is essential to developing quantum computers in which information would be stored and processed on quantum mechanical states of quantum bits, called qubits. So the self-destructive nature of quantum-mechanical states interacting with the environment is a huge problem.

To find out more about how quantum coherence breaks down and to study the dynamics of this decoherence process, the Ames Lab, UCSB and Microsoft Station Q team studied certain spin systems, called nitrogen-vacancy, N-V, impurity centers, in diamond. (Spin is the intrinsic angular momentum of an elementary particle, such as an electron.) N-V impurity centers in diamond are interesting because of the ability to control and manipulate the quantum state of a single center, allowing scientists to study the loss of coherence at a single-particle

scale.

The Ames Lab, UCSB and Microsoft Station Q researchers were able to manipulate the N-V centers interacting with an environment of nitrogen spins in a piece of diamond. Amazingly, the physicists were able to tune and adjust the environmental interference extremely well, accessing surprisingly different regimes of decoherence in a single system. The scientists showed that the degree of interaction between the qubit and the interfering environment could be regulated by applying a moderate magnetic field. By using analytical theory and advanced computer simulations, they gained a clear qualitative picture of the decoherence process in different regimes, and also provided an excellent quantitative description of the quantum spin dynamics. The experiments were performed at room temperature rather than the extremely low temperatures often required for most atomic scale investigations.

Dobrovitski noted that quantum coherence of N-V centers in diamond is being studied by leading scientific groups worldwide. “The combined efforts of these groups could help in opening the way to developing a series of interacting qubits – steps to a quantum computer – where each N-V center would act as a qubit,” he said.

“In addition to quantum computers, quantum coherence plays an important role for future less exotic, but not less spectacular, applications,” said Dobrovitski. “For instance, quantum spins can be employed to develop coherent spintronic devices, which would work much faster than traditional microelectronic elements and dissipate much less energy. Quantum coherence between many spins can be employed to perform measurements with ultrahigh precision for metrology applications or to drastically increase the sensitivity of modern nuclear magnetic resonance, NMR, or electron spin resonance, ESR, experiments.

“However, in order to implement these appealing proposals, a very good understanding of quantum coherence and its destruction by the environment is needed,” Dobrovitski emphasized. In particular, from the application point of view, it is important to understand the loss of coherence of quantum systems in solid-state environments, which form the basis of modern technology.”

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Source: Ames Laboratory

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