

Fast tunable coupler could lead to better quantum computing models

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(PhysOrg.com) -- One of the subjects of immense interest to scientists (and non-scientists as well) is the development of quantum computers. However, there are many challenges associated with quantum computing. One of the difficulties to achieving practical quantum computing is related to the way the quantum bits (qubits) that make up a quantum computer are connected together.

“The easiest way to couple superconducting [qubits](#) is via fixed coupling, where the coupling strength does not change,” Bialczak says. “Many experiments done with superconducting qubits so far have been with fixed coupling, but there are lots of problems with fixed coupling architectures because they are difficult to scale up to many qubits.”

Bialczak worked with a team at UC Santa Barbara to look for a way around the problems caused by fixed coupling. They developed a novel tunable coupler design that has the potential to be scalable, possibly improving current quantum computer designs. The team’s work can be found in the *Physical Review Letters* article “Fast Tunable Coupler for Superconducting Qubits.”

With fixed coupling, Bialczak explains, it is easy to couple the qubits so that they can exchange information, but keeping the qubits from interacting with each other is difficult and causes errors in single-qubit operations and measurement. On top of that, problems with fixed coupling multiply as you add more qubits. “As you increase the number of qubits,” Bialczak says, “it gets increasingly difficult to isolate an

individual qubit from the others. It's like having a room full of people and wanting to isolate each person from the conversation of the other people. You won't be able to do so because there are so many people...each person will hear one or more of the other persons' [conversations].”

In order to overcome these issues, the team at UC Santa Barbara developed a method of fast tunable coupling. “With tunable coupling, you can directly turn off the interaction between qubits,” Bialczak says, “The coupler can also arbitrarily tune the coupling strength on nanosecond timescales allowing for fast qubit interaction times while minimizing errors in single-qubit operations and measurement.”

For realistic quantum operations, a practical tunable coupler is needed. Such a coupler would need to be tuned quickly, on the order of nanoseconds. Additionally, large on/off ratios are required, as well as scalability so that many qubits can be coupled. “Previous demonstrations of tunable coupling were able to show one or more of the above in a given device, but were unable to combine all the criteria in one device, making them of limited use in realistic [quantum computing](#) experiments,” Bialczak points out. The UCSB team hopes that their new tunable coupler will satisfy all these criteria.

In order to create the tunable coupler circuit, two superconducting qubits are coupled using a fixed negative mutual inductance. This mutual inductance is shunted with a current-biased Josephson junction. The junction acts as a tunable positive inductance and can therefore cancel out the fixed coupling due to the mutual inductance.

“Our coupler also has the added feature of being modular and being able to couple elements over large spatial distances. We can also couple them to other devices and possibly even to qubits from other architectures,” Bialczak says.

Right now, the coupler is being used to develop a new measurement scheme that doesn't destroy prepared quantum states. "This is commonly called a quantum non-demolition measurement scheme," Bialczak says.

Bialczak has great hopes for the applications of this coupler. "We feel this is a general modular superconducting circuit element that can have many applications, even outside of quantum computation."

More information: R. Bialczak, et. al., "Fast Tunable Coupler for Superconducting Qubits," *Physical Review Letters* (2011). Available online: link.aps.org/doi/10.1103/PhysRevLett.106.060501

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