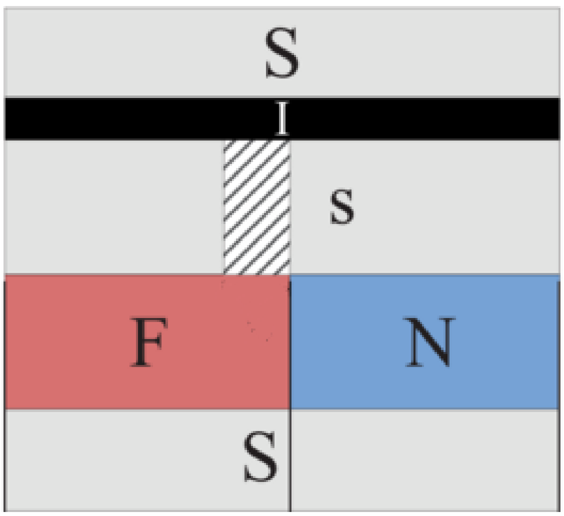
Scientists develop a control system for rapid superconducting memory cells

March 16 2016



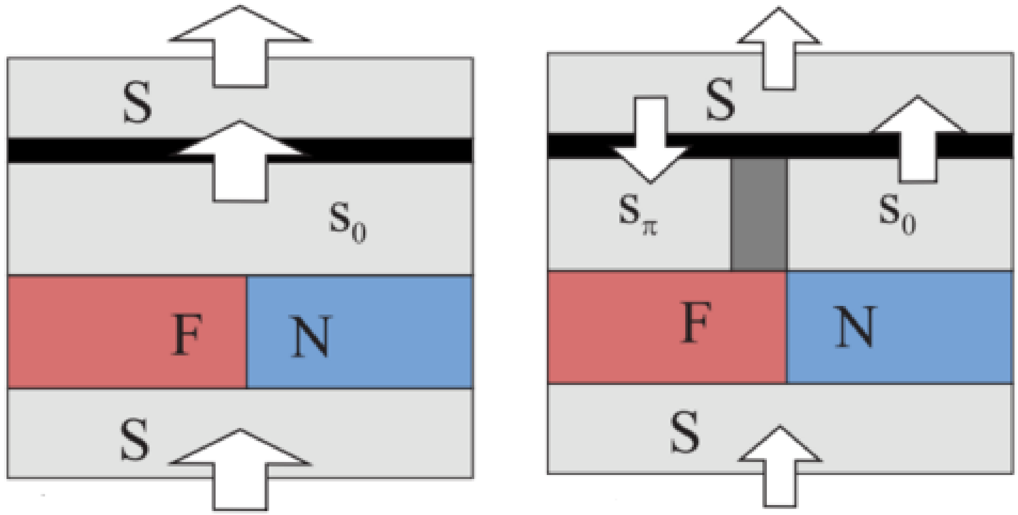
S – superconductor, I – insulating tunnel barrier, F – ferromagnet, N – normal metal, shaded area – potential barrier arising in the superconducting zone. Credit: Moscow Institute of Physics and Technology

A group of scientists from Moscow Institute of Physics and Technology and from the Moscow State University has developed a fundamentally new type of memory cell based on superconductors – this type of memory works hundreds of times faster than the memory devices commonly used today, according to an article published in the journal *Applied Physics Letters*.

"With the operational function that we have proposed in these memory cells, there will be no need for time-consuming magnetization and demagnetization processes. This means that read and write operations will take only a few hundred picoseconds, depending on the materials and the geometry of the particular system, while conventional methods take hundreds or thousands of times longer than this," said the study author Alexander Golubov, the head of MIPT's Laboratory of Quantum Topological Phenomena in Superconducting Systems.

Golubov and his colleagues have proposed creating basic memory cells based on quantum effects in superconductor "sandwiches." Superconductors were predicted in the 1960s by the British physicist Brian Josephson. The electrons in these "sandwiches," called "Josephson junctions," are able to tunnel from one layer of a superconductor to another, passing through the dielectric like balls passing through a perforated wall.

Today, Josephson junctions are used both in quantum devices and conventional devices. For example, superconducting qubits are used to build the D-wave quantum system, which is capable of finding the minima of complex functions using the quantum annealing algorithm. There are also ultra-fast analogue-to-digital converters, devices to detect consecutive events, and other systems that do not require fast access to large amounts of memory. There have also been attempts to use the Josephson Effect to create ordinary processors. An experimental processor of this type was created in Japan in the late 1980s. In 2014, the research agency IAPRA resumed its attempts to create a prototype of a superconducting computer.



Superconducting currents when reading various states of the memory cell. The greater current the larger arrow. Credit: Moscow Institute of Physics and Technology

Josephson junctions with ferromagnets used as the middle of the "sandwich" are currently of greatest practical interest. In memory elements that are based on ferromagnets, information is encoded in the direction of the magnetic field vector in the ferromagnet. However, there are two fundamental flaws with this process: first, the "packaging" of the memory elements has a very low density—additional chains need to be added to provide extra charge for the cells when reading or writing data. And second, the magnetization vector cannot be changed quickly, which limits the writing speed.

The researchers proposed encoding the data in Josephson cells in the value of the superconducting current. By studying the superconductor-normal metal/ferromagnet-superconductor-insulator-superconductor junctions, the scientists discovered that in certain longitudinal and transverse dimensions, the layers of the system may have two energy minima, meaning they are in one of two different states. These two minima can be used to record data—zeros and ones.

In order to switch the system from "zero" to "one" and back again, the scientists have suggested using injection currents flowing through one of the layers of the superconductor. They propose to read the status using the current that flows through the whole structure. These operations can be performed hundreds of times faster than measuring the magnetization or magnetization reversal of a ferromagnet.

"In addition, our method requires only one ferromagnetic layer, which means that it can be adapted to so-called single flux quantum logic circuits, and this means that there will be no need to create an entirely new architecture for a processor. A computer based on single flux quantum logic can have a clock speed of hundreds of gigahertz, and its power consumption will be dozens of times lower," said Golubov.

More information: S. V. Bakurskiy et al. Superconducting phase domains for memory applications, *Applied Physics Letters* (2016). DOI: 10.1063/1.4940440

Provided by Moscow Institute of Physics and Technology