Development of Cryogenic Technologies for Quantum Computers and Science

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(a) New type of attenuator for microwave cables

We are developing an innovative attenuator which can potentially reduce a density of thermal photons coming through microwave coaxial cables down very close to that at the base temperature of dilution refrigerator (DR) (10 mK). It makes use of a quantum liquid which has a good thermal contact with metallic parts and conduction even at mK. This device may dramatically increase dephasing time of superconducting qubits much longer than a millisecond.

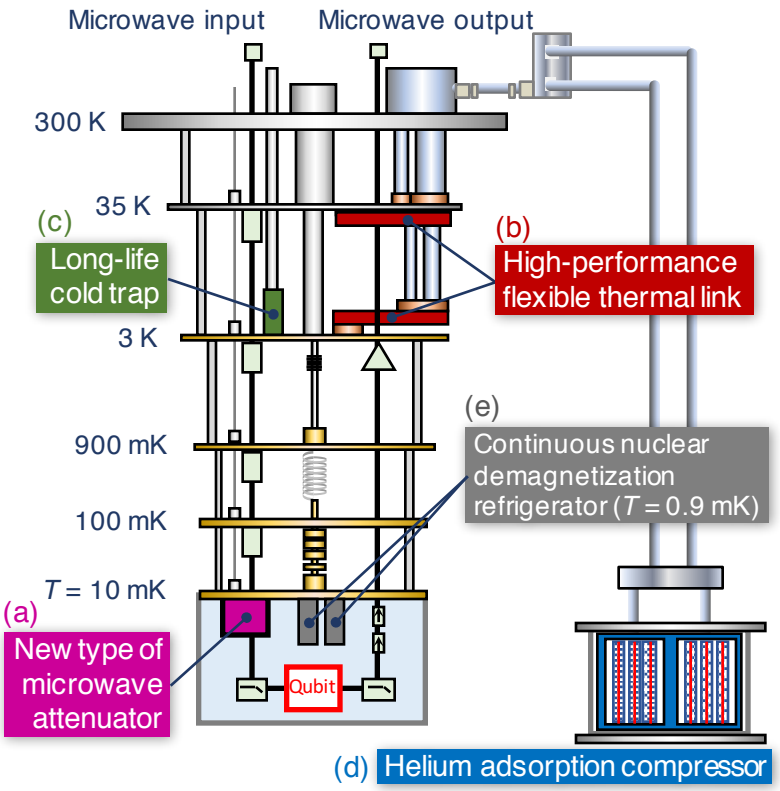

Fig. Dilution refrigerator for studies of quantum science. (a)–(d) Key ingredients of our developments.

(b) High-performance flexible thermal link

Compared to conventional copper straps, the material which we are proposing to use in this thermal link has a factor of three higher thermal conductivity at $T = 4$ K and much higher flexibility. This should reduce mechanical vibrations from pulse tube refrigerator (PT) transmitting into lower temperature stages more effectively.

(c) Long-life cold trap

Practical superconducting quantum computers are expected to work stably for a long period over years. Such a long term operation of DR is sometimes terminated by unexpected blocking of helium-3 condensing line by contaminations. To overcome this problem, we are proposing a cold trap consisting of two identical traps in parallel, where one of them is alternately used after baking without stopping DR operation.

(d) Helium adsorption compressor

New adsorbent, which can adsorb helium gas even at 50–80 K, is now under development. Once it becomes available, it can be used in maintenance-free adsorption-type helium compressors for PT or other refrigerators with lower running costs than current mechanical compressors. Such an advanced adsorbent should also be quite useful for hydrogen storage with much wider applications.

(e) Continuous nuclear demagnetization refrigerator

In near future, the frontier of quantum science and technology may be shifting down from current 10 mK to below 1 mK, i.e., the micro-K regime. We are developing a unique compact nuclear demagnetization refrigerator based on $PrNi_5$ which can maintain the sample temperature at 900 micro-K continuously.