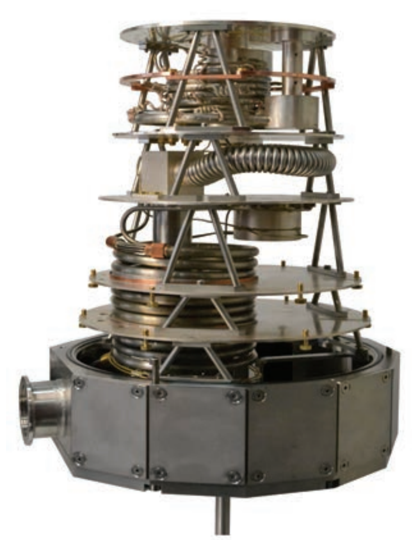
Table-top dilution cryostat: Sionludi

A series of table-top dilution cryostats has been realized at the Néel Institute. These cryostats, which are highly appreciated by our experimentalists, make it possible to reach temperatures of about 30 mK in only 3 hours. The currently available cooling power is about 200 µW at 100 mK and the minimum temperature is about 15 mK.

Dilution cryostats achieve very low temperatures by diluting liquid He^3 in liquid He^4. The mixing process is endothermic, thus extracting heat from the surroundings. This allows cooling of experimental samples or devices to very low temperatures. Our new, improved dilution cryostats (see Figure) were developed by the cryogenic, experimental, and mechanical engineering teams of the Néel Institute, inspired by the design of the "upside-down" dilution refrigerator called ''Sionludi'', which was invented by A. Benoit in 1990. 20 years of user-experience allowed us to improve the performance as follows:

- two times faster cooling
- 4 times higher cooling power
- 4 times lower temperatures
- reduced liquid He consumption (less than 8 litres/day).



New generation of the Sionludi table-top dilution cryostat, with its thermal shields and outer vacuum container removed. The compact, inverted design allows the cryostat to be mounted on a bench top. The sample space is located on top of the upper plate, making it easily accessible.

These improvements were achieved by optimizing the injection and pumping lines, mixing chamber, cold mass, and by an improved geometry. We also rearranged the elements in the system in order to maximize the space available for each cooling stage.

Our dilution cryostats are composed of a vacuum chamber containing a succession of six cryogenic stages whose temperatures progress down from 80 K to 15 mK. In order to increase the efficiency, each stage - consisting of a plate and a thermal shield - is situated inside the following stage, going from very low to higher temperatures, analogous to a Russian doll.

The outer two stages, at 80 and 20 K, are cooled by means of a counter-flow heat exchanger, in which we find the He^3/He^4 injection lines and the He^4 pumping line. The third stage at 4 K is permanently cooled from a liquid He^4 storage vessel located directly under the cryostat. This stage can also be used to cool heavy experimental parts close to the sample, such as superconducting field coils.

The fourth stage at 0.8 K is thermalized to the so-called "still". The still continuously extracts the He^3 from the mixture, thus allowing a steady-state operation. The fifth stage at 50 mK can absorb a heat load of about 1 mW. The last stage is the mixing-chamber stage with a base temperature of about 15 mK. These last three stages represent the heart of the dilution refrigerator where only the He^3/He^4 mixture circulates. They contain a Joule-Thomson heat exchanger, which replaces the "1-K-box" of a classical dilution system. It also contains the condensation impedance, the still, a counter-flow heat exchanger, several discrete heat exchangers, and the mixing chamber.

This device has received an increasing interest for users because of the following principal advantages:

Greatly improved accessibility of the cold volume: Contrary to traditional dilution refrigerators, the coldest part of the cryostat is easily accessible. This cold volume is situated at the top of the apparatus, separated from the 300 K vacuum chamber only by 3 to 5 thermal shields. This is an unquestionable advantage for rapid sample-changing and for direct optical or mechanical access.

Compactness and rigidity: The mechanical structure of the Sionludi design makes it compact and rigid, which allows us to achieve a high level of stability. For example, it can be used for cooling STMs (Scanning Tunneling Microscopes) and AFMs (Atomic Force Microscopes) and generally for all experiments that require a low level of vibration.

Considerably improved performance: The time needed to reach the target temperature is a prime factor for experimentalists. This device - designed with fast and slow injection lines, associated with the compactness of these lines - makes it possible to reach low temperatures in only 3 hours. Moreover, a fast circulation of the He^3 allows us to reach a high cooling power of 200 µW. Finally, without being completely optimized, the volume of He^3 needed for the He^3/He^4 mixture remains relatively low (7 litres of gaseous He^3).

A new version of this dilution cryostat is under construction. It will integrate a top-loading system, which will allow the transfer of samples between an ultra-high vacuum chamber and the precooled table-top dilution cryostat.

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