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C4Or1A-04: Space-oriented adiabatic demagnetization refrigerator adapted for quantum applications

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Adiabatic demagnetization refrigeration (ADR) is an efficient and reliable cooling technology well used for temperatures below 1 K. It is particularly well suited for space applications, thanks to the absence of fluid refrigerant and of moving parts and to a competitive Carnot efficiency. A multi-ADR cooler, that is the last stage of a cryogenic chain, is proposed for the LiteBIRD and Athena space missions. This technology can also be used to meet the increasing cryogenic needs of quantum technologies and to prevent the potential future crisis in 3He supply. In this context, our laboratory is involved in two national projects for quantum applications, in which ADR is a candidate for beeing an alternative to helium based dilution refrigerator.
In particular, the Cryonext project aims to build an ADR stage for the 20 mK –100 mK temperature range, the stage providing up to 10 µW at 100 mK.
We report here on the developpement process of such a stage. The setup is based on the space environment expertise of the laboratory which is tranfered to build a prototype for cooling ground quantum applications. One of the aim is to focus on the application requiring small cooling power at low cooling temperature. This would be well suited for initial qbit characterizations or for operations in remote environments. Hence, a focus will be put on the reliability, portability and compactness of the ADR stages. As for the design of the stage, a numeric tool was created for optimising ADR stage dimensions. The code is based on thermodynamic equations and a strong experimental data base (magnetic properties of materials, ultra low temperature magnetic hysteresis curves, thermal conductances and heat losses). For this project, it is used to optimize the dimensions of the paramagnetic material, coil and magnetic shield and to predict the efficiency of the overal ADR device. Finally, the targetted temperature range requires dedicated temperature sensors and readout electronics. A part of Cryonext aims to design a ADR technology to be industrialized.

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