In-Situ Calibration of the Relaxation Calorimeter for SCM1

Y. H. Kim, Y. Takano (UF, Physics); H. Tsujii (Kanazawa Univ., Physics)

Introduction

A relaxation calorimeter has been in use at the DC Field Facility of the NHMFL in Tallahassee since 2001 [1], in the dilution refrigerator for the 20-tesla superconducting magnet SCM 1. More than 100 thermal cycles between room temperature and 20 mK in the last eight years have finally taken their toll this year, damaging a thermal weak link between the sample platform and the thermal reservoir. This damage and subsequent repair of the calorimeter have made recalibration of the calorimeter necessary.

Principle

Calibration of a relaxation calorimeter normally consists of determination of the thermal conductance of the weak link as a function of temperature and magnetic field. In the present case, however, we have been forced to also calibrate the resistance thermometer simultaneously, since the thermometer has been affected by the calorimeter repair. This is done by measuring the thermal relaxation times of the calorimeter with two standard materials whose heat capacities are known and have different temperature dependences.

At a given temperature and magnetic field, let the heat capacities of two standard materials be $C_1$ and $C_2$, and the thermal relaxation times of the calorimeter with them $\tau_1$ and $\tau_2$. Then

$$\frac{C_1}{C_2} = \frac{\tau_1 - \tau_0}{\tau_2 - \tau_0}, \tag{1}$$

where $\tau_0$ is the calorimeter relaxation time without a sample. If the two heat capacities $C_1$ and $C_2$ have different temperature dependences, then the ratio $C_1/C_2$ will be a function of temperature, allowing the temperature to be determined via Eq. 1. Subsequently, the conductance $\kappa$ of the weak link will be given by $\kappa = C(\tau - \tau_0)$, where $C$ and $\tau$ are those of either material 1 or 2.

We use platinum and silver as the standard materials for two reasons: (1) platinum has a relatively small phonon specific heat in comparison with silver, making the ratio of the total specific heats of the two metals $C_{Pt}/C_{Ag}$ to vary with temperature $T$ for $T > 1$ K; (2) the nuclear specific heat of platinum contributes to $\tau_{Pt}$ because of the short spin-lattice relaxation time $T_1$ of $^{195}$Pt, whereas no such contribution exists in silver because of the very long $T_1$ of $^{107}$Ag and $^{109}$Ag, causing detected $C_{Pt}/C_{Ag}$ to be strongly temperature dependent at $T < 1$ K. The figure shows the ratio $C_{Pt}/C_{Ag}$ (for equal molar amounts) at various magnetic fields, excluding the undetectable nuclear specific heat of silver. Here $C_{Pt}$ has been taken from Refs. [2], to which calculated nuclear specific heat has been added, and $C_{Ag}$ comes from Ref. [3].

As the figure shows, the method does not work in zero field at temperatures below about 0.9 K, where the ratio $C_{Pt}/C_{Ag}$ becomes nearly constant. We use aluminum instead of platinum in this temperature region, where the metal is a superconductor whose heat capacity differs vastly from that of silver, a normal metal.

Acknowledgements

We thank J. S. Kim for repairing the calorimeter. This work was supported in part by a Grant-in-Aid from the JSPS.

References