


A nano -trampoline to probe quantum behavior

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In recent years the scientific community has shown growing interest in quantum phase transitions in which a system transits between two thermodynamic states at absolute zero temperature, as a result of manipulating a physical parameter such as magnetic field, pressure or chemical composition instead of temperature. In these transitions, the change is driven not by the thermal energy provided to the system by heating, but rather by quantum fluctuations.

The theoretical prediction of quantum criticality was provided a few decades ago, but how to measure this experimentally has remained a mystery. Through this Chairs of excellence project, we have for the first time provided the answer [1].

In normal phase transitions there is a unique measurable quantity which is used to detect a critical point: this is the specific heat which measures the amount of heat energy that should be supplied to a system in order to raise its temperature by one degree. The specific heat rises near the critical point and its measurement provides information on the fluctuations.

Measuring specific heat of a system close to a quantum critical point poses a much greater challenge. Firstly, the measurements must be carried out at low temperatures. Secondly, the systems under study are nano-thin layers which require extremely sensitive measurements. The team overcame these obstacles by developing a unique experimental design based on a thin membrane suspended in air by very narrow bridges, thereby forming a «nano-trampoline» (Fig. 1). This setup enabled specific heat measurements of the thin films through a quantum phase transition from a superconducting state to an electrically insulating state, close to absolute zero temperature.

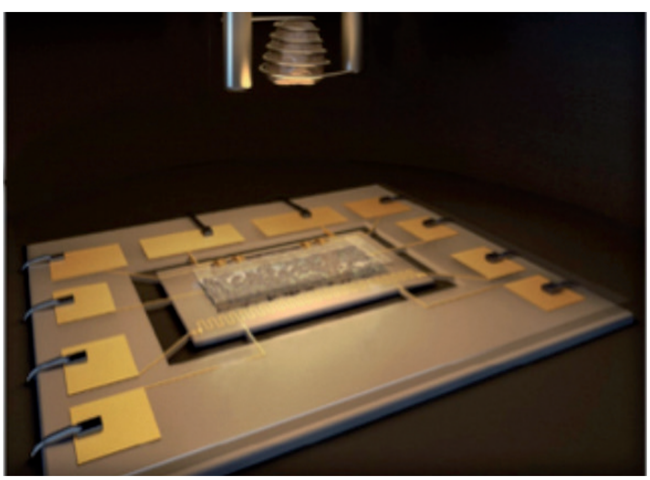

Fig. 1: view of the experimental setup.

This is the first of its kind. The results demonstrate that just as in the case of a thermal phase transition, the specific heat increases in the vicinity of a quantum critical [1] point, and can be used as a probe for quantum criticality. This work is expected to be a milestone in the understanding of physical processes that govern the behavior of ultrathin systems at ultralow temperatures.

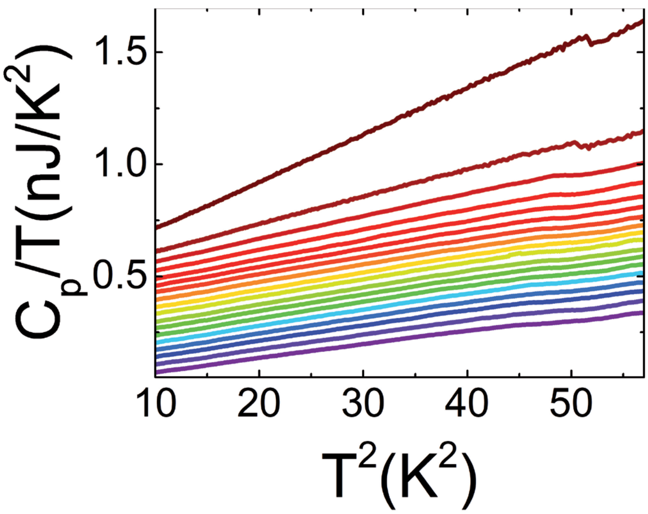

Fig. 2: Specific heat versus T obtained on thin layers of Pb with different thickness values from 8.9 to 29 nm.

OUTCOMES

[1] Quantum criticality at the superconductor-insulator transition revealed by specific heat measurements, Nature Commun. 8, 14464 (2017).

[2] Specific heat measurement set-up for quench condensed thin superconducting films, Rev. Sci. Instrum. 85, 053903 (2014).

Conferences: Oral presentation, Conference on Applied and Nano Superconductivity, Germany, july 2016.

PhD: S. Poran (2013-2017); Y. Stein (2017-2020).

Leverage: Bourse Chateaubriand, one year PhD visit