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Impossibility of the persistent-current in a superconductor

Gokaran Shukla

School of Physics, Trinity College, Dublin 2, Ireland

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Presence of *"persistent"*, *"directional-current"* in a superconducting states is a direct *"threat"* to the 2^{nd} law of thermodynamics. In this paper we will show that there will never be a *directional, (either clockwise, or anti-clockwise)* *"persistent-current"* for *"infinite-time"* in any superconductor (or in any material at any pressure or temperature), otherwise 2^{nd} law of thermodynamics will break down! We will show that the presence of very small, *non-zero*, finite, electrical resistance below the critical temperature and critical magnetic field in a superconductor is the clear *"signature"* of finite life-time of circulating-current, and thus, direct experimental *"validation"* of 2^{nd} law of thermodynamics at quantum-mechanical level.

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I. INTRODUCTION

Materials can be classified into insulators, semiconductors, conductors and superconductors based on their electrical response to the applied voltage. First time superconductivity has been discovered by Heike Kamerlingh Onnes in 1911, when he was working with solid mercury wire at 4.2K[12]. He found that resistivity of solid mercy wire drops $\sim 10^{-5}$ ohm at 4.2K[12]. For this discovery, he was awarded Nobel prize in physics in 1913[12]. After that, a number of attempt has been made to realize superconductivity at room temperature. There is general belief in scientific community that, *"once the material reaches into superconducting states, then no further power is required to maintain the electrical current in superconducting material"*. And, thus, one can use superconducting material electrical property and can run in principle any electrical circuit which made from superconducting material without any electrical cost persistently. Many research group[3] claims that continuation of persist current in experiments breaks essence of the 2^{nd} law of thermodynamics. They claim that 2^{nd} law of thermodynamics require serious modification at-least at quantum mechanical level. In this paper we will resolve this controversy and will show that the 2^{nd} law of thermodynamics still valid in superconducting materials at quantum mechanical level.

II. SUPERCONDUCTING $YBa_2Cu_3O_{7-\delta}$, I-V DATA[4]

Superconducting material transform into a superconducting states at a very precise temperature known as critical temperature, and below very precise magnetic field known as critical magnetic field. There are three type of superconductor namely: type-I, type-II, and type-1.5, depending upon whether material reject/allows the magnetic lines to pass through it or not, or whether there is any static/moving, attractive/repelling magnetic vortices's[25] under the presence of external magnetic field. We will not cover this topic in great details, because, our purpose is not to write another review article on superconductor, but, our main purpose in this paper is to analyze the persistent current which present in superconducting states, and whether this persistent current violates the 2^{nd} law of thermodynamics or not. We will use

$YBa_2Cu_3O_{7-\delta}$ superconductor as our test case, without losing any generality. One can use another superconductor for analysis, but, conclusion will remain the *"same"*. If one see (see in Figure 11) $YBa_2Cu_3O_{7-\delta}$ film resistance versus temperature curve at zero external magnetic field, then one notice that there is transition in resistance from 20 ohm to nearly 0 ohm between 92-90K. Key point here is that $YBa_2Cu_3O_{7-\delta}$ film behaves like normal material above 92K, while turns into superconducting states below the 90K with effectively zero resistance. Why we are saying *"effectively- zero-resistance"*, because if one plot the same resistance versus temperature curve on logarithmic plot, then one notice that resistance is not *"exactly"* zero below the 90K. There is *"non-zero"*, finite resistance at any temperature, even at 0-K. The origin of this resistance is due to pure quantum mechanical effect (for more detail, read[6]). It has nothing to do phonon scattering with electrons. However, phonon does contribute in finite resistivity or finite conductivity at any non-zero temperature. The net resistance at any temperature will be the sum of resistance arises due to quantum mechanical effect, resistance due to phonon scattering, and other impurity scattering contributions. The net resistance will never be zero at any temperature or pressure. Only net resistance value can be minimized, but this value will never become *"absolute-zero"*. If one see $YBa_2Cu_3O_{7-\delta}$ film $\mathrm{I-V}$ curve (see in Figure 2), then, one notice that there is finite voltage drop at any current value, below the transition temperature (90K). Finite *"potential-drop"* (see in Figure 2) below the transition temperature at any applied current suggest that there is *"finite-resistance"* during superconducting-state in $YBa_2Cu_3O_{7-\delta}$ films. This resistance is the sum of quantum mechanical resistance plus the resistance arises due to temperature (phonon contribution). Value of this resistance can be minimized but this net value will *"never"* become *" absolute-zero"*. The reason that net resistance will never become absolute-zero at any temperature (even at 0K), because resistance arises due to

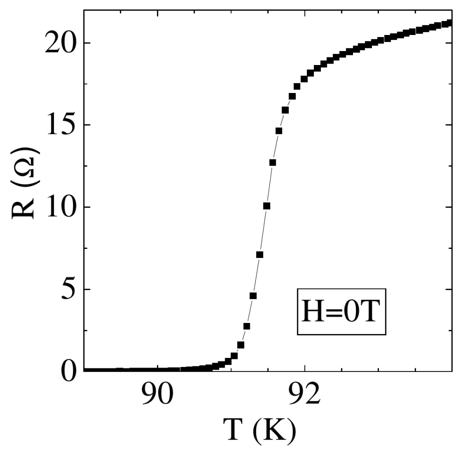

FIG. 1: Resistive transition under zero magnetic field for $YBa_2Cu_3O_{7-\delta}$ film[4].

quantum mechanical effect will always contribute. This quantum part of resistance is immortal at any temperature (for more detail about it, read[6]). Presence of very small, non-zero, finite resistance during superconducting states will guarantee that no current in superconducting material will survive infinite time. This current will *never* become *"immortal"* in the presence of very small, finite, non-zero resistance. Thus we are concluding that circulating current in superconducting states will *"vanish"* in finite time. Finite time may be one second, one minute, one hour, one day, one year, 100 year, or 10,000 year. 10,000 year is also a finite time. If current persistent long, then there is a great chance and greater certainty that some electronic device can be made based on the superconducting material, which can be used to improve living standard. Existence of very small, non-zero, finite-resistance at any temperature (even at 0-K) below the transition temperature will *"guarantee"* that superconducting-current will *"die"* its own natural death in a finite time, and thus, 2^{nd} law of thermodynamics will *"win"* this battle with full certainty.

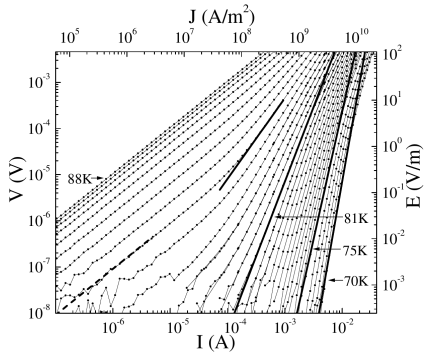

FIG. 2: I-V curves for $YBa_2Cu_3O_{7-\delta}$ film , at constant temperature on log-log plot[4].

III. CONCLUSION

In this paper we have tried to resolve the conflicting issue between 2^{nd} law of thermodynamics and persistent current during superconducting states in superconductor. We have shown that the presence of very small, finite, non-zero, electrical resistance below the critical temperature and critical magnetic field is the clear evidence of finite life-time of circulating current in superconductor. Since, according to laws of thermodynamics, every directional process in nature is irreversible (degree of irreversibility vary from process to process, but no directional process is 0% irreversible, or 100% reversible) and has finite lifetime, therefore, circulating current will not persistent continuously infinite time in a superconductor. We have shown that the presence of very-small, non-zero, finite resistance in superconducting states is the direct evidence of validation of the 2^{nd} law of thermodynamics at quantum mechanical level.

We hope that this paper will clear the controversy surrounding the 2^{nd} law of thermodynamics at quantum mechanical level, and will stimulate the scientific community to go in a new direction with certain responsibility towards some very fundamental laws of nature, such as 2^{nd} law of thermodynamics.

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