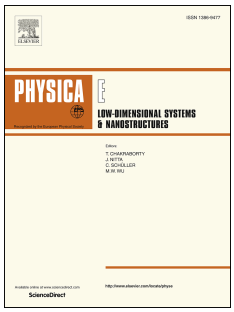
Accepted Manuscript



Tunneling of heat: Beyond linear response regime

Kamil Walczak, David Saroka

PII: S1386-9477(17)30773-7

DOI: 10.1016/j.physe.2017.10.007

Reference: PHYSE 12934

To appear in: *Physica E: Low-dimensional Systems and Nanostructures*

Received Date: 31 May 2017

Revised Date: 27 July 2017

Accepted Date: 10 October 2017

Please cite this article as: K. Walczak, D. Saroka, Tunneling of heat: Beyond linear response regime, *Physica E: Low-dimensional Systems and Nanostructures* (2017), doi: 10.1016/j.physe.2017.10.007.

Tunneling of Heat: Beyond Linear Response Regime

Kamil Walczak[1] and David Saroka[1,2]

[1] *Department of Chemistry and Physical Sciences, Pace University*
1 Pace Plaza, New York, NY 10038, USA

[2] *Department of Physics and Astronomy, California State University*
1250 Bellflower Boulevard, Long Beach, CA 90840, USA

(Submitted: May 29, 2017; Corrected: July 26, 2017)

We examine nanoscale processes of heat (energy) transfer as carried by electrons tunneling via potential barriers and molecular interconnects between two heat reservoirs (thermal baths). For that purpose, we use Landauer-type formulas to calculate thermal conductance and quadratic correction to heat flux flowing via quantum systems. As an input, we implement analytical expressions for transmission functions related to simple potential barriers and atomic bridges. Our results are discussed with respect to energy of tunneling electrons, temperature, the presence of resonant states, and specific parameters characterizing potential barriers as well as heat carriers. The simplicity of semi-analytical models developed by us allows to fit experimental data and extract crucial information about the values of model parameters. Further investigations are expected for more realistic transmission functions, while time-dependent aspects of nanoscale heat transfer may be addressed by using the concept of wave packets scattered on potential barriers and point-like defects within regular (periodic) nanostructures.

PACS numbers: 05.60.Gg, 05.70.Ln, 72.70.+m, 73.63.–b

I. INTRODUCTION

Quantum biology is a brand new research field in which quantum dynamics at molecular level determine the behavior of biological systems at macroscale [1,2]. In a trivial sense, life is of quantum origin as an emergent phenomenon from the molecular realm, although all the specifics are not yet entirely clear. Obviously, the cellular function depends on the shapes of molecules and their chemical affinities, but those properties require quantum physics to be fully explained. However, quantum effects may also play a crucial role in the proper functioning of complex biosystems. Among them are: coherent nature of matter waves, quantum tunneling, entanglement and superposition of quantum states, intrinsic quantum magnets (spins), quantum interference, environmental post-selection and the watchdog effect (reduction of quantum states during the measurement process). Needless to mention that many biological and/or chemical processes, which involve energy conversion, are of quantum nature. Among them are [3]: light absorption and emission, quantum tunneling phenomena during photosynthesis, cellular respiration, DNA mutations and repairs, formation of electronic excited states, and energy transfer via excitons [4].