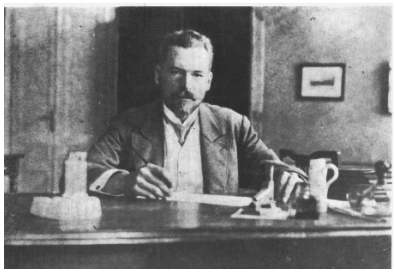

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Fundamental limitations of the step quantum heat engine

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The model of a step quantum heat engine (SQHE) is defined as a working body, given by the two-level system (TLS), acting separately (i.e. in steps) with the heat baths and the energy storage system (a battery). A single step of the engine is defined as the unitary and energy conserving operation. For the general SQHE we prove the fundamental attainable efficiency, given as a function of a cold and hot temperature, which is below the Carnot efficiency. The reason is that the engine is quasi-autonomous, i.e. there is no extra external control like fields commonly used in a non-autonomous setting, but in contrary the SQHE is realised by a unique physical process of the TLS population inversion via a strong coupling with the heat bath. For our model of the SQHE we additionally discuss the problem of the work definition for the fully quantum systems. So far one of the reasonable definition of the work (consistent with the fluctuation theorems) is given by the change in a mean energy of the battery which has additionally a translational symmetry, i.e. these changes do not depend on how much energy is currently stored in the battery. However, this symmetry impose a nonphysical property that the battery cannot have a ground state. We solve this problem showing that the battery with a ground state can be used as a proper energy storage system only if the work is defined as a change of the ergotropy instead of a mean energy.

Summary

Primary author: Dr ŁOBEJKO, Marcin (University of Gdańsk)

Co-authors: Dr MAZUREK, Paweł (University of Gdańsk); Prof. HORODECKI, Michał (University of Gdańsk)

Presenter: Dr ŁOBEJKO, Marcin (University of Gdańsk)

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