Technische Universität Berlin
Institut für Theoretische Physik
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www.itp.tu-berlin.de/stat-i-ss07.html

# 1. Übung/Projekt zur Statistischen Physik I, computational methods

**Transport in NEMS (nanoelastomechanical systems)**

We consider a two-level quantum dot coupled to a single cavity boson mode (photon or phonon),

$$H_{\rm Rabi} \equiv \frac{\varepsilon}{2}\left(|1\rangle\langle 1| - |2\rangle\langle 2|\right) + g(a+a^\dagger)\left(|1\rangle\langle 2| + |2\rangle\langle 1|\right) + \Omega a^\dagger a. \tag{1}$$

**Exercise**

- Consider the case $g = 0$ (no coupling between electrons and bosons) and derive the Master equation for transport through the two dot levels by coupling to a left ($L$) and a right ($R$) electron reservoir with chemical potentials $\mu_L = \infty$ and $\mu_R = -\infty$. Introduce tunnel rates $\Gamma_{L/R}$ for the two dot levels as in the Lectures.
- Solve the Master equation analytically in the stationary state, i.e. for times $t \to \infty$. Calculate the occupation of the two levels.
- Solve the Master equation in the stationary state numerically, using MATHEMATICA.
- Solve the Master equation in the stationary state numerically, using Fortran or C++ combined with a suitable LAPACK routine.

**Project I**

Derive the Master equation for the case $g > 0$ in the number state basis and start to write a Fortran or C++ code for its solution.
To follow in this project during this semester as we proceed with the material in the Lectures:

- Stationary electronic current as a function of the coupling strength $g$.
- How the boson mode can be 'controlled' electronically. Wigner function (phase-space) representations.
- Electronic and bosonic quantum noise as a tool to learn more about this coupled electron-boson system.

More detailed instructions will be given on subsequent sheets.

**Other Projects to Follow**

- One further NEMS project (dot-resonator system), full counting statistics (quantum noise and transport) - this will probably start in one or two weeks.
- One project on the NRG (numerical renormalisation group). This will start in two or three weeks.

**NOTE:**

Exercises should be done by all participant. Projects are for those who wish to get a 'Schein', or for those who wish to apply the material in the Lecture Notes to some interesting problems. These projects are related to some recent research in our group.

**Bitte Rückseite beachten!⟶**

- **Internetseite der Veranstaltung:** http://www.itp.tu-berlin.de/stat-i-ss07.html
- **Vorlesung:** Mittwoch 12:15 - 14:00 Uhr im PN 201 und Donnerstag 14:15 - 16:00 Uhr im PN 731
- **Tutorium:** Dienstag 8:30 - 10:00 Uhr im PN 731
- **Scheinkriterien:** Erfolgreiche Teilnahme an den Übungen und erfolgreiche Durchführung eines Projektes
- **Sprechstunden:**
  - Prof. Dr. Tobias Brandes: Montags, 13:00 - 14:00 Uhr
  - Philipp Zedler: Mittwoch, 11:00 - 12:00 Uhr
- **Literatur:**
  - Vorlesungsskript (web-page)
  - H. Carmichael, An Open System Approach to Quantum Optics
  - D. F. Walls and G.J. Milburn, Quantum Optics
  - U. Weiss, Quantum Dissipative Systems
  - H. Haug and A. P. Jauho, Quantum Kinetics in Transport and Optics of Semiconductors
  - F. Haake, Quantum Signatures of Chaos
  - A. J. Leggett, S. Chakravarty, A. T. Dorsey, M. P. A. Fisher, A. Garg and W. Zwerger, Rev. Mod. Phys. **59**, 1 (1987)
  - Literatur zur NRG wird später angegeben.