Quantum Labs, 2023 / Period I

Course overview

Lecturers: Ilkka Tittonen, Laure Mercier de Lépinay

Assistants: Aashish Sah, Aarne Keränen, Suman Kundu, Vladimir Kornienko

06.09.2023

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General info

- **Period I (06.09.-27.10.2022)**
- **4 different experiments**
- **Groups of 4 students**
- **3 Steps for each experiment: Labwork, report, oral presentation**
- **Time slots for Labwork can be booked in MyCourses/Scheduling, 3h/experiment**
- **2-3 presentations/experiments**
    - Not all students will do a presentation
- **Pass/Fail system:**

Teachers will grade work and students will pass if the grade is above a threshold (no pressure, just do the work seriously)

Scheduling

The experiments can only be done during the following dates:

- **Experiment 1: 08.09 - 22.09.2023**
- **Experiment 2: 08.09 - 02.10.2023**
- **Experiment 3: 17.09 - 22.10.2023**
- **Experiment 4: 13.09 - 11.10.2023**

Book 1 slot/experiment/group at least 1 week before the slot time

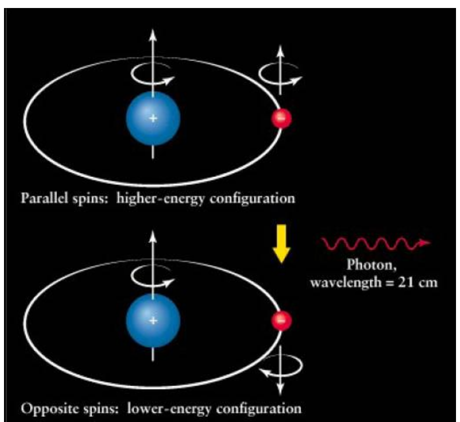
The report on each experiment should be given 1 week after experiment is done

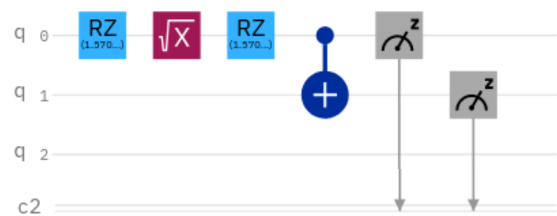
Presentations will be done in 2 slots: (please come to both)

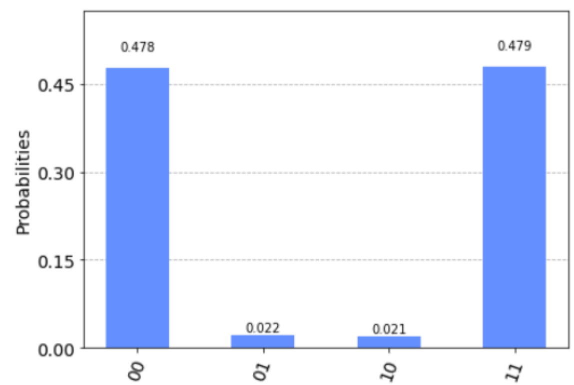
- 25.10.2023 10:15-12:00 Otakaari 1, room U119 Deloitte
- 27.10.2023 10:15-12:00 Otakaari 1, room A123 A1

Experiment 1: Quantum Measurement with Qiskit

- Responsible TA: Aashish Sah
- Measuring the energy levels of the hydrogen ground state using IBM simulator and quantum computer





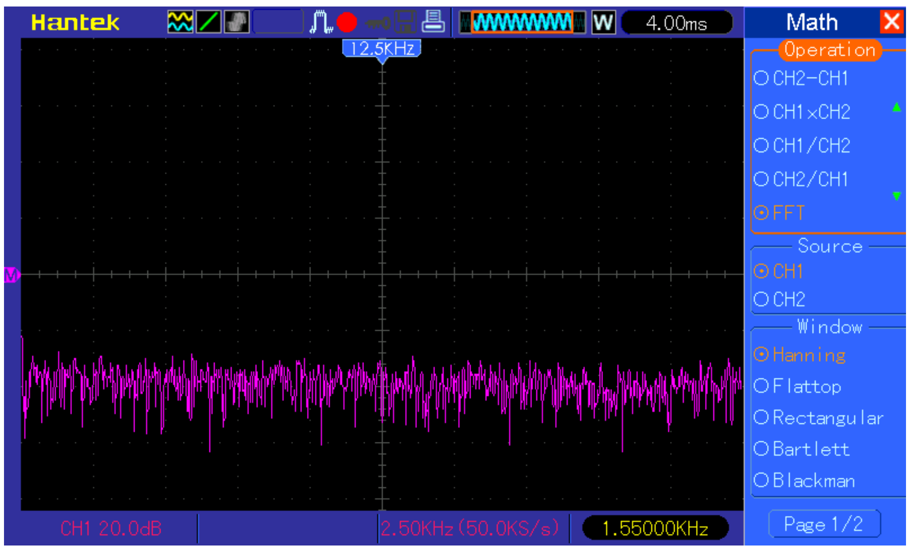


Key concepts

- Hyperfine splitting
- Single Qubit Gates
- Multiple Qubits and Entangled States
- Mitigating Noise on Real Quantum Computer

Experiment 2: Temperature-dependent noise measurement

- Responsible TA: Suman Kundu
- Noise spectrum measurement of a resistor using a spectrum analyzer
- Measurements at RT and in liquid nitrogen

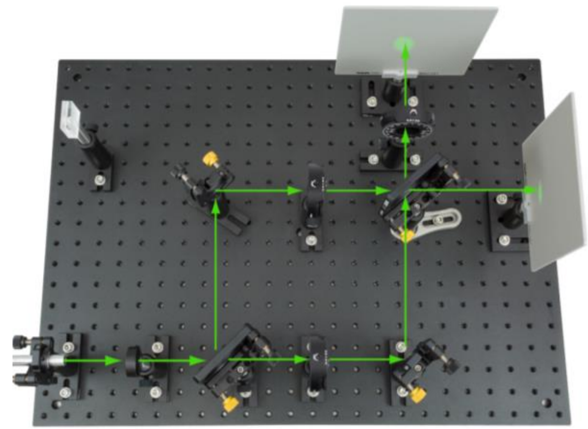


Key concepts

- Noise spectrum
- Johnson-Nyquist noise
- RF analysis: averaging, RMS
- Boltzmann constant

Experiment 3: Dual path interference

- Responsible TA: Vladimir Kornienko

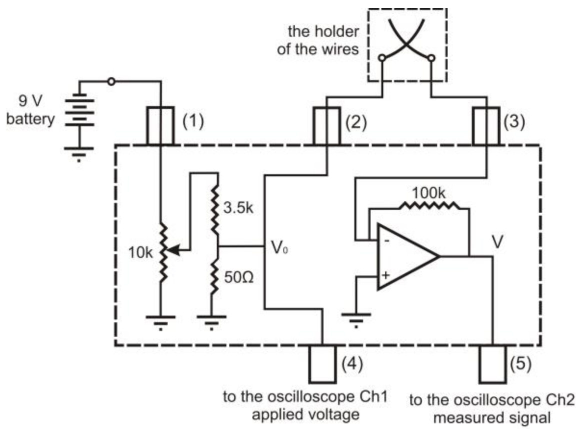


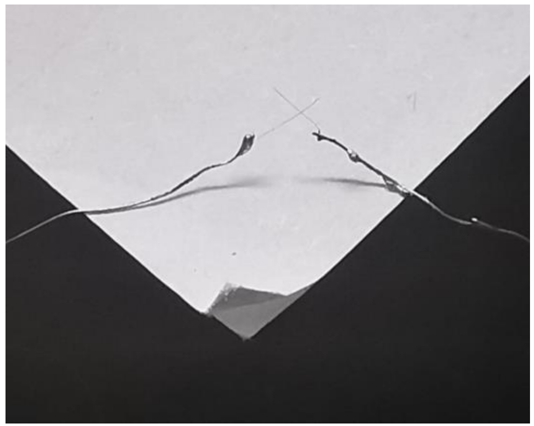
$$i\hbar \frac{\partial}{\partial t}|\Psi(t)\rangle = \hat{H}|\Psi(t)\rangle$$

Key concepts
- Wave-particle duality
- Superposition
- Interference

Experiment 4: Conduction quantization

- Responsible TA: Aarne Keränen
- Creation of gold nanowire
- Observing quantisation of conductance in gold nanowire





Key concepts

- Schrödinger equation
- Particle in square well
- Quantization of conductance

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Labwork

- Each group has 4 persons and does 4 experiments
- Each member of the group is the main responsible for 1 of the reports (on 1 of the 4 experiments)
- but **ALL group** members should be involved **in each experiment during labwork**
- 1 person's job ≠ 1 experiment
- 1 person's job = 4 experiments + writing (most of) one report + checking/giving feedback on all reports of the group
- Do not assign roles in advance in case one person is sick one day
- **Communicate between yourselves**
- Experiments are done in Micronova: don't be late

Reports

- Each group member writes a report on a single experiment (4 reports in total per group, covering all 4 experiments)
- Group members **choose among themselves** which member writes which report
- Length 4–5 pages
- **Deadline: 2 weeks after experiment:**

please remember your deadline!

Teachers are not supposed to go hunting for reports!

- After feedback from TA, if the report was done seriously, you can improve your grade (see after) by 1-2 points by making corrections
- Templates and instructions on MyCourses

Report content

Focus the report on **your work**, rather than on theory

- No need to reexplain everything (for this course at least)
- Present briefly what you did/the way you did it
- Present results **with care** (see end of this presentation)
- Discuss results
  - can you draw some conclusion from the result?
  - Is the result lower, higher, different than expected, why (do you think)?
  - Is the uncertainty particularly low or high, why?
  - Is there a systematic error, what is it, what could you do to cancel it?
  - What can be done better and how would it improve the experiment?
  - What other related experiment could you do?...

Do not copy-paste anything from any source (even Wikipedia).

Try to rephrase (sometimes difficult). At least do not <u>ever</u> write something you do not understand.

Presentations

- Point of presentations:
  - Training to present scientific results
  - Training to attend scientific presentations
  - Discuss similar/different results/methods between groups

- 2-3 presentations/experiment (No time for all groups to present all experiments)
- TAs will decide which group will present which experiment
- Each group will decide together which member within the group will present
  - ➢ You can decide that 2 members of the group present together
- Talk 8 min, questions 2 min
- All students should come to all presentations (2x 2h slots in total)

Uncertainty and error

Uncertainty characterizes the estimated possible deviation between the measured and actual values. Two different types of uncertainty:

Type A (or statistical uncertainty): Uncertainty in this category is evaluated using statistical tools such as **mean** and **standard deviation**. Experiments are repeated several times under similar conditions and the outcomes are recorded.

Statistical analysis is performed on the recorded data to quantify the Type A uncertainty in the measurement.

Type B: Uncertainty of this category is based on previous measurement data, manufacturer's specification, instrument calibration, etc.

Presenting measurement results

- A measurement result should have a **unit** (in most cases)
- Use **consistent** units throughout the report (avoid conversions back and forth between radians and degrees)
- Use "**reasonable**" units:
  - **SI** if possible (m, s, A, kg, K, … Newton, Joule, etc).
  - Numbers should be **readable by humans** (1300000 Hz -> 1.3 MHz)
  - Alternatively: 1.3×10^6 Hz
  - Present the **uncertainty** at least on important results: 10.4 ± 0.2 V
- **Round** numbers as necessary:

  134.567354 ± 1.2 V ✖

  134.6 ± 1.2 V ☺

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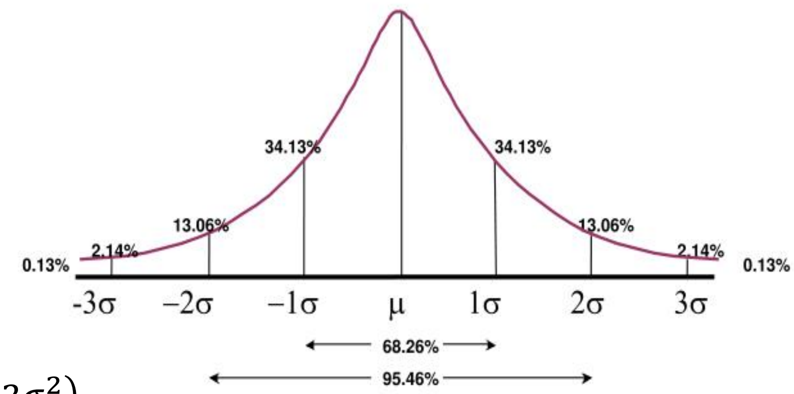
Uncertainty estimation



- When measuring a variable, always consider measurement uncertainty
- Gauss distribution $G(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)/(2\sigma^2)}$
- Standard deviation , 68% confidence interval
- Repeated measurement (N times)
  - Standard Error

Error propagation

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Presenting graphs

- **label both axes in a clear way:**
  - "Voltage" might be confusing if there are 2 relevant voltages in your experiment that this graph could represent. Use:
    - "Excitation voltage (V)" OR
    - "V_a (V)" if you have defined V_a elsewhere
  - Do not count on the text to replace the labels on the axes:
    - "The graph above represents the current as a function of the voltage"
    - "As can be seen on the graph above, the voltage is a linear function of the magnetic field"

    You *can* write such sentences if you like but the axes of the graph still need to be labeled.

- **Include the units in the axis label whenever relevant, e.g.:**
  - ❖ "Excitation voltage (V)" or "V_a (V)" if you have defined V_a elsewhere
  - ❖ "Number of occurrences" (no need for a unit, unit is "1")

Feedback