A Brief introduction to Quantum Computing from the Perspective of Ladder Logic

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Abstract

Quantum computing, for several years the media and public perception of the subject has treated it akin to magic, using it as a catchall for any science fiction plot device deemed necessary. Because of this, otherwise capable individuals may tend to stray away from the subject purely due to its perceived difficulty, many assuming they would need doctorates to even begin to comprehend the complexities of quantum computing. Indeed, quantum physics is very complex, having many important real-world ramifications. With that said, quantum computing is merely a small part of quantum physics, and much like the computing most people use daily, operates by a well-defined set of rules. By utilizing a subset of these rules, specifically tools such as quantum ladder logic, quantum assembly (QASM), and visual aids such as Bloch spheres, much of the initial barrier to entry can be circumvented. While this approach isn't perfect, and will require more serious individuals to pursue much of the background math and physics on their own. It is my hope that students, specifically those with a background in electronic circuits and/or programming will find the contents of this paper able to greatly reduce the amount of time and effort needed in order to start learning how to program a quantum computer and thus prepare themselves for a future where such technology is prevalent.
Keywords: Quantum, Computing, Ladder, Logic, QASM, Introduction

1 Introduction 5 lines to max 1/2 page

Explain the context of the experiment here. Why is condensed matter physics interesting or important? Optional things you could talk about (but don't have to – this is up to you): transistors, computers, Quantum computers, fundamental knowledge (e.g. the resistance quantum).

Briefly explain what methods you will use in the experiment, and what values you will extract from the data.

For this section and all following sections: If you refer to an equation, previous result or theory that is not regarded as common knowledge, then cite the source (article or book) where you found this. For example, you can cite the Nano 3 Lecture notes [1].

2 Background Concepts

This section is not meant to be an exhaustive list, but, in my personal experience, learning about the background concepts below will greatly assist a person's ability to better understand quantum computing. The following sections will provide a brief explanation of the concepts.

2.1 Balanced Ternary

insert balanced ternary section here along with comparison table.

3 Theory 2-3 pages

3.1 Two-dimensional Electron Gas

Here, explain the concept of a 2-DEG in GaAs/AlGaAs. What is a 2-DEG and why does it arise?

3.2 Hall Effect

Explain the classical Hall effect in your own words. What do I measure at $B = 0$? And what happens if $B > 0$? Which effect gives rise to the voltage drop in the vertical direction?

3.3 Quantum Hall Effect

Explain the IQHE in your own words. What does the density of states look like in a 2-DEG when $B = 0$? What are Landau levels and how do they arise? What are edge states? What does the electron transport look like when you change the magnetic field? What do you expect to measure?

4 Experiment 1-2 pages

4.1 Fabrication

Explain a step-by-step recipe for fabrication here. How long did you etch and why? What is an Ohmic contact?

4.2 Experimental set-up

Explain the experimental set-up here. Use a schematic picture (make it yourself in photoshop, paint, ...) to show how the components are connected. Briefly explain how a lock-in amplifier works.

5 Results and interpretation 2-3 pages

Show a graph of the longitudinal resistivity (ρ_{xx}) and Hall resistivity (ρ_{xy}) versus magnetic field, extracted from the raw data shown in figure **??**. You will have the link to the data in your absalon messages, if not e-mail Guen (guen@nbi.dk). Explain how you calculated these values, and refer to the theory.

5.1 Classical regime

Calculate the sheet electron density n_s and electron mobility μ from the data in the low-field regime, and refer to the theory in section 3. Explain how you retrieved the values from the data (did you use a linear fit?). Round values off to 1 or 2 significant digits: 8.1643 $= 8.2$. Also, 5e-6 is easier to read than 0.000005.

!OBS: This part is optional (only if you have time left). Calculate the uncertainty as follows:
$u(f(x,y,z)) = \sqrt{(\frac{\delta f}{\delta x}u(x))^2 + (\frac{\delta f}{\delta y}u(y))^2 + (\frac{\delta f}{\delta z}u(z))^2}$, where f is the calculated value (n_s or μ), x, y, z are the variables taken from the measurement and $u(x)$ is the uncertainty in x (and so on).

5.2 Quantum regime

Calculate n_s for the high-field regime. Show a graph of the longitudinal conductivity (ρ_{xx}) and Hall conductivity(ρ_{xy}) **in units of the resistance quantum** ($\frac{h}{e^2}$), depicting the integer filling factors for each plateau. Show a graph of the plateau number versus its corresponding value of $1/B$. From this you can determine the slope, which you use to calculate the electron density. Again, calculate the uncertainty for your obtained values.

6 Discussion 1/2-1 page

Discuss your results. Compare the two values of n_s that you've found in the previous section. Compare your results with literature and comment on the difference. If you didn't know the value of the resistance quantum, would you be able to deduce it from your measurements? If yes/no, why?

Item	Quantity
Widgets	42
Gadgets	13

Table 1: An example table.

7 Some LaTeX tips

7.1 How to Include Figures

First you have to upload the image file (JPEG, PNG or PDF) from your computer to writeLaTeX using the upload link the project menu. Then use the includegraphics command to include it in your document. Use the figure environment and the caption command to add a number and a caption to your figure. See the code for Figure 1 in this section for an example.

7.2 How to Make Tables

Use the table and tabular commands for basic tables — see Table 1, for example.

7.3 How to Write Mathematics

LaTeX is great at typesetting mathematics. Let $X_1, X_2, \ldots, X_n$ be a sequence of independent and identically distributed random variables with $\text{E}[X_i] = \mu$ and $\text{Var}[X_i] = \sigma^2 < \infty$, and let

$$S_n = \frac{X_1 + X_2 + \cdots + X_n}{n} = \frac{1}{n} \sum_{i}^{n} X_i \tag{1}$$

denote their mean. Then as n approaches infinity, the random variables $\sqrt{n}(S_n - \mu)$ converge in distribution to a normal $\mathcal{N}(0, \sigma^2)$.

The equation 1 is very nice.

7.4 How to Make Sections and Subsections

Use section and subsection commands to organize your document. LaTeX handles all the formatting and numbering automatically. Use ref and label commands for cross-references.

7.5 How to Make Lists

You can make lists with automatic numbering . . .

1. Like this,
2. and like this.

. . . or bullet points . . .

- Like this,
- and like this.

. . . or with words and descriptions . . .

Word Definition

Concept Explanation

Idea Text

We hope you find writeLaTeX useful, and please let us know if you have any feedback using the help menu above.

References

[1] K. Grove-Rasmussen og Jesper Nygård, *Kvantefænomener i Nanosystemer*. Niels Bohr Institute & Nano-Science Center, Københavns Universitet