

論文 / 著書情報
Article / Book Information

題目(和文)	量子情報処理に向けた表面弾性波駆動単一電子輸送
Title(English)	Surface Acoustic Wave-Driven Single-Electron Transport for Quantum Information Processing
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

論文要旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	電気電子 電気電子	系 コース	申請学位 (専攻分野)： Academic Degree Requested	博士 (工学) Doctor of Engineering
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

This paper, titled "Surface Acoustic Wave-Driven Single-Electron Transport for Quantum Information Processing," consists of six chapters.

Chapter 1, "Introduction," states that to realize quantum information processing devices, numerous milestones must be achieved, including the realization of large-scale integrated high-fidelity qubits, and the optimization of their manipulation and readout. In particular, it discusses the need for methods to coherently transport quantum information over long distances, highlighting surface acoustic wave (SAW)-driven single-electron transport as a promising technology. The chapter outlines the research background, identifies the challenges that the technology has faced, and explains the objectives of the series of studies conducted in this paper, as well as its structure.

Chapter 2, "Optimization of surface acoustic wave generation method," summarizes two experiments on SAW generation and optimization that are essential to the experiments in later chapters. These include the material dependence of the characteristics of interdigital transducers (IDTs) used to generate and detect SAWs, and the development of a technique to generate single SAW pulses. The chapter also explains the technical background of SAWs, the design and fabrication of IDTs, and the measurement methods.

Chapter 3, "In-flight distribution of an electron within a surface acoustic wave," describes experiments that used pulse techniques to obtain distribution information of a single electron carried by a SAW, enabling the transport of single electrons at the specifically chosen bottom of a SAW. The chapter reports the first demonstration of identified transport of electrons between quantum dots 20 μm apart using SAWs, with an electron-confinement fidelity of $97\pm 2\%$ within a specific bottom of SAW when using the SAW amplitude of 24 meV. This achievement enabled the previously impossible synchronous transport of multiple single electrons, and led to an experiment in which single electrons were transported synchronously from two quantum dots and collided within a coupled quantum wire, resulting in the observation of antibunching due to Coulomb interactions.

Chapter 4, "On-demand single-electron source using surface acoustic wave pulses," states that by combining the developed single SAW pulses with quantum wires, a simple method for generating single electrons without quantum dots has been realized. The chapter explains that the operation of an on-demand single-electron source was demonstrated by observing single electrons generated in quantum wires by continuous SAW pulses as quantized currents. This single-electron source can generate single electrons on a nanosecond scale with any desired delay and does not require the time-consuming operations to prepare an electron in a quantum dot, wiring, and the high-frequency operation needed for timing synchronization, making it an excellent single-electron source in terms of future scalability.

Chapter 5, "Suppression of electromagnetic wave by differential excitation for surface acoustic wave generation," addresses the problem of electromagnetic wave crosstalk revealed in single SAW pulse experiments. It proposes and demonstrates an IDT differential excitation method that can reduce unwanted electromagnetic waves generated when producing SAWs. Using this method, electromagnetic wave generation was suppressed by over 90% while maintaining the intensity of the generated SAWs. While conventional methods relied on spatial separation using the difference in velocity between electromagnetic waves and SAWs to mitigate the effects of electromagnetic wave crosstalk, this new method reduces the generation of electromagnetic waves themselves, easing the operational constraints of IDTs and providing solutions for expanding the system.

Chapter 6, "Conclusion and perspectives," summarizes the conclusions and future perspectives of the paper. It explains that the achievements of this paper enhance the stability and precision of this method, expand its degrees of freedom, and contribute to the transport experiments of multiple single electrons. It also describes the direct importance of these results for the realization of quantum computers using flying electron qubits and suggests their application in long-distance quantum information transport, a requirement for the realization of quantum computers with semiconductor spin qubits.

In summary, this paper resolves fundamental issues previously encountered with SAW-driven single-electron transport technology, obtaining essential results and techniques necessary for advancing this technology and conducting research that opens up new fields. The findings presented are pivotal for laying the foundation for the future realization of quantum information processing devices using SAWs.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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