論文 / 著書情報
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著者(和文)	髙木一旗
Author(English)	Itsuki Takagi
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種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	材料 系 材料 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 理学 ）
学生氏名： Student's Name	高木 一旗	審査員主査： Chief Examiner	中村 一隆

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis is entitled "Ultrafast dynamics of quantum decoherence in an electron-phonon composite system", and is written in English and consists of six chapters.

Chapter 1 "Introduction" outlines the background and presents the objectives of the research. Quantum coherence is a unique property of quantum mechanics that enables the superposition of quantum states and plays a pivotal role in advancing quantum technologies, notably quantum computers. Quantum coherence has been extensively studied in various fields, including atomic, molecular, biological, and solid-state materials. In solids, quantum coherence rapidly disappears due to interactions with the enormous quantum degrees of freedom. In particular, band-to-band electronic coherence is a remarkably rapid phenomenon, occurring within attoseconds to few-femtoseconds, leading to a limited understanding of the decoherence times and mechanisms. In this thesis, I focus on the ultrafast dynamics of quantum decoherence in an electron-phonon composite system of GaAs as a test sample, and aim to reveal electronic decoherence times and decoherence phenomena.

Chapter 2 "Theory for coherent control of longitudinal optical phonons in GaAs using polarized optical pulses with relative phase locking", introduces a theoretical model that addresses the polarization effects of relative phase locked double-pulse excitation in an electron-phonon composite system. By incorporating Raman tensors representing crystal symmetry into the electron-phonon interaction, the influence of pulse polarization on the system is discussed. The constructed theoretical model elucidates how the relative polarization of the double optical pulses and the electronic decoherence time affect the observed quantum interference shapes.

Chapter 3 "Ultrafast quantum path interferometry to determine the electronic decoherence time in n-GaAs", discusses the quantitative evaluation of the electronic decoherence time in GaAs. It is found that when the relative polarization angle of the double pulses is $\pi/4$, the interference shape depends significantly on the electronic decoherence time, and the shape change is very easy to visualize. The relation between the quantum interference shapes and the decoherence is experimentally evaluated in terms of the relative polarization angle of the double pulse. By varying the degree of decoherence with the environmental temperature, we observe a variation of quantum interference shape that is consistent with theoretical predictions. Furthermore, we introduce a quantitative evaluation method for the electronic decoherence time and determine it to be 27.8 fs at 10 K, 23.0 fs at 90 K, and 12.9 fs at 290 K. In addition, the decoherence phenomenon is caused by electron scattering between photoexcited electrons and the environment within the conduction band, and electron-electron scattering is found to be a major factor in

this phenomenon.

Chapter 4 "Influence of initial phonon states on the generation of coherent optical phonons" focuses on the theoretical evaluation of coherent phonon generation under arbitrary initial conditions. The chapter defines the phonon distribution at thermal equilibrium as the initial state and investigates coherent phonon generation at finite temperatures. The results indicate that the influence of initial states on coherent phonon intensity and quantum interference shapes is minimal due to the weak electron-phonon coupling in solid materials. It is suggested that a second-order perturbation calculation with a zero phonon initial state is sufficient to theoretically evaluate quantum interference.

Chapter 5 "Coherent phonon generation with open quantum theory; optical intensity dependence" discusses the theoretical evaluation of influence of the excitation intensity in coherent phonon generation and quantum path interference. Using a theoretical model based on the band picture, the time evolution of the system is evaluated by the quantum master equation with dissipators in an open quantum system. The saturation phenomenon of the coherent phonon generation efficiency in the Raman quantum path clearly appeared at relatively weak optical pulse intensities compared to that in the optical absorption process. This is consistent with the experimental results obtained with single-pulse and double-pulse excitation. Furthermore, the electronic decoherence observed in the experiment is expressed by assuming the dissipative operators occurring in the electronic excited states. It is consistent with the electronic decoherence factors identified in Chapter 3.

Chapter 6 "Conclusion" presents the overall conclusions of this thesis: the experimental and theoretical studies in GaAs as a test material evaluate the dependence of quantum coherence and quantum path interference in electron-phonon composite systems, revealing the electronic decoherence times and decoherence factors in the femtosecond ultrafast regime. In addition, a discussion of scattering phenomena other than electron-electron scattering as a decoherence factor is described.