Preface

Have you heard of quantum teleportation, quantum cryptography, or quantum computation? These seem science fiction, but are truly most-advanced scientific topics that are growing involving physics, information science, and mathematics. This area, called quantum information science, is information science based on "quantum theory," which is a fundamental theory of physics in the microscopic world.

This area has the potential to produce fascinating technology for teleportation, unconditionally secure cryptography, and ultrahigh-speed computer. Unfortunately, although this is an emerging area, non-experts, especially undergraduate students, have no sufficient opportunities to glance at this topic.

Considering this circumstance, professors in quantum information science have brought out this textbook, which explains the fundamentals of quantum information science. This book requires only first-year calculus, first-year linear algebra, and elementary probability theory as background knowledge, and does not require any knowledge of quantum theory and information science so that undergraduate students can read this textbook independently. Before the publication of the original Japanese version, confronted with the problem that there is no undergraduate course for quantum information science in Japan, the authors organized Winter School of Quantum Information Science in the seminar house in Tohoku University in Japan in 2009, 2010, and 2011. The authors published the following original Japanese version based on the lecture materials and the participants' responses in the above winter school.

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Precise description of quantum information science requires various background knowledge of the related fields. Fortunately, since the five authors of this book are from different backgrounds, this requirement is satisfied. After finishing the first manuscript, the authors adjusted the relation between chapters. Finally, Hayashi coordinated the whole organization.

The organization of this book and the responsible persons for the respective chapters are given as follows. First, in Chap. 1, Hayashi introduces an overview of quantum information science and describes the details of this textbook as its coordinator. Please read Sect. 1.5 "Organization of this book" before reading the contents of this book. Next, in Chap. 2, using vectors and matrices, Kimura explains the simplified formulation of quantum theory as an expert on foundation of quantum theory so that a beginner can easily understand it. In Chap. 3, Kawachi describes the foundations of quantum computation and quantum circuit as an expert of quantum computation. In Chap. 4, Kawachi treats quantum algorithms, which are algorithms for quantum computer. For example, Shor's algorithm is treated as a quantum algorithm that solves factorization problem by using quantum computer. In Chap. 5, Kimura explains the advanced structure of quantum theory, which is necessary to learn quantum information science. In Chap. 6, Ogawa introduces various information quantities for quantum system as an expert on quantum information theory. In Chap. 7, Ishizaka treats quantum entanglement as an expert on quantum entanglement and statistical physics. In Chap. 8, Ogawa explains quantum channel coding. In Chap. 9, Hayashi treats quantum error correcting code and quantum cryptography as an expert on quantum information theory and quantum cryptography. This book is organized so that Chaps. 2–4 can be read with elementary calculus for matrices and inner products of complex vectors. The latter chapters require advanced knowledge for linear algebra, which are summarized in Appendix A by Kimura, Hayashi, and Ogawa.

Since this book covers various fields in quantum information, it can be used as a text for a lecture course or a seminar. Especially, since it contains many exercises with solutions in Appendix B, it also can be used for an exercise course. Further, it also treats a recent development in quantum information science. Hence, the reader can investigate more advanced topics by using the references after finishing this book. The authors hope that readers develop interest in quantum information science.

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