Preface

The title of this book is short and one cannot resist thinking of Milan Kundera's observation that one quality we have lost is slowness. At times when books were not so numerous and readers were patient, one might have preferred to speak about quantum mechanics of particles confined to regions of tubular form, in particular, relations between their spectral and scattering properties and the geometry of confinement, *et cetera*. But habits are different nowadays, hence *quantum waveguides*, even if the guided objects are not exactly waves, and not a small part of what we are going to discuss concerns states in which the particles do not move. However, although the term we have coined may not be fully fitting, it has the advantage of linking the subject of the book to related problems in areas of classical physics such as acoustics and electromagnetism.

Guided quantum dynamics, as discussed in this book, attracted attention in the second half of the 1980s. The motivation came from two sources. On the one hand, new developments in solid-state physics called for a theoretical analysis of such effects, and on the other hand, from the mathematical point of view these questions opened new and unexplored areas in spectral geometry. The older one of the authors had been lucky to participate in those studies from the beginning, the younger one joined this effort a decade later. The subject proved to be rich and looking back at those years we see many interesting results obtained by numerous people; we feel that the time may be right to summarize the understanding achieved as well as to identify new challenges.

The questions we address in the book are physical, or at least they come from physics, and the instruments we use are mathematical. This means, in particular, that the claims are made with full rigor, the proofs being either given completely or sketched to a degree allowing the reader to fill in the details. Some of these exercises are delegated to problems accompanying each chapter. The level of those vary, some boil down to simple if tedious computations or extensions of the results derived in the main text, while others represent more complicated questions which may constitute the contents of a research paper.

Since mathematics is a tool we employ, not the goal, our theorems are formulated with a reasonable degree of generality, however, we do not strive for the

weakest possible assumptions and a mathematically minded reader will find a lot of room for improvements. Technically speaking, our arguments come mostly from applied functionals analysis, but we also need results from differential geometry, probability, and other areas. We decided not to burden the book with appendices summarizing this material; we assume the reader is acquainted with the basic concepts and we provide references whenever we find it necessary.

Most problems discussed in the book involve various simple geometric considerations, and consequently, it would be easy to accompany the text with numerous drawings. We resist this temptation, believing the reader will profit from working these things out while going through the text. Old textbooks used to come with a parenthetical encouragement—(Draw a picture!)—but we are sure he or she would know when such a visual support is needed. In addition, many original papers we cite, including some of our own, are full of illustrations.

Dealing with problems of different kinds, we also have to think about the notation. We try to be consistent but not pedantic. For instance, we use vector notation at places where it is convenient due to a frequent use of components but drop the arrows elsewhere. Similarly, tensor notation is employed only when needed to work with objects like curved surfaces, layers, or networks, etc.

Since our goal is to provide a summary of the research activities of numerous people over a quarter of a century, we had to augment the exposition with a reasonable representative, if not exhaustive, bibliography which will allow the reader to understand the history and pursue the further development of each topic discussed here. We strived to keep it up to date during the writing, being aware, of course, that the field is full of life and new interesting papers will surely keep appearing after the book is published.

Working on quantum waveguide problems over the years we benefited from the opinions of many colleagues whom we want to thank for the pleasure of fruitful discussions and common work. They were numerous and we have to do it in part anonymously, mentioning only some names. In the first place our thanks go to Petr Šeba and the late Pierre Duclos who understood importance of quantum waveguides and made weighty contributions to the field at its early stages. We are also grateful to our other coauthors, especially to F. Bentosela, D. Borisov, T. Cheon, T. Ekholm, M. Fraas, R. Frank, E. Harrell, T. Ichinose, A. Joye, S. Kondej, D. Krejčiřík, J. Lipovský, M. Loss, K. Němcová (Ožanová), O. Post, G. Raikov, P. Šťovíček, M. Tater, O. Turek, S. Vugalter, T. Weidl, K. Yoshitomi, as well as to J. Avron, C. Cacciapuoti, J.-M. Combes, E.B. Davies, G.F. Dell'Antonio, P. Freitas, F. Gesztesy, A. Laptev, E. Lieb, H. Neidhardt, K. Pankrashkin, A. Sadreev, E. Soccorsi, V. Zagrebnov, and many, many others. Last but not least, we are deeply obliged to our wives and our families for their understanding and support which made the writing of this book possible.

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