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Interplay of spins, charges and photons in low-dimensional systems

Habilitation

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To the memory of my father,

and with gratitude to my academic friends

General Introduction

This *Habilitationsschrift* is based on 20 selected papers published/submitted after I joined the University of Hamburg on September 2, 1999, which include 2 invited ones, 16 others published in Physical Review Letters, Europhysics Letters, Physical Review B, Applied Physics Letters, and 2 preprints. Three papers on spintronics are based on experiments performed before I joined the Universität Hamburg. Writing the work provides me a chance to look back over my past five and a half year's academic life in Hamburg, where I have enjoyed and appreciated the hospitality of my colleagues in the Institut für Angewandte Physik of Universität Hamburg.

The Habilitationsschrift begins with this general introduction followed by a list of papers on three seemingly different topics: spintronics, photoconductivity, and the bilayer two-dimensional electron system. The work covers three different materials, namely semiconductors, ferromagnetic metals, and their hybrid samples. They are experimentally investigated by three different techniques: magneto- and spin-dependent transport, far-infrared transmission spectroscopy, as well as microwave and infrared photoconductivity spectroscopy. Cross thinking of different systems *vs* various techniques has been a convenient source of developing new ideas for performing experiments. At the heart of the topics which I have been absorbed over the years is the interplay between spins, charges, and photons in low-dimensional electron systems.

The Habilitationsschrift is organized in five chapters:

spin-orbit coupling,
spin-charge conversion in transport,
spin-charge mixing in spectroscopy,
electron-electron interaction,
electron-phonon interaction.

We start with a chapter on spin-orbit coupling, followed by a chapter studying spin injection in transport experiments. The three other chapters investigate the interplay and coupling between spin-, charge-, and lattice-

dynamics. An introduction has been written for each chapter, to give a brief historical context of the subject, to explain how our work fits into the general evolution of the research field, and to point out connections between different chapters. Writing the Habilitationsschrift provides me a distant but consistent view to the papers selected. Some critical thoughts are given in the brief outlook at the end of each chapter. The Habilitationsschrift ends with a chapter of general outlook describing briefly a blueprint and a vision of the future. With my collaborators, we are on the way in those directions.

In the legend of the ancient Chinese intellectual society, friendships are said to be established by exchanging papers （以文会友）. My past five years of academic life in Hamburg started with a hard time by losing my father, — my first mentor, who ignited my interests in science with books hardly available in a time when life itself was hard to make. It comes up with the endless joy that many of my mentors, colleagues and students became my friends during these years. A French philosopher once said *"all the past are future in preparation"*, I realized that the main experimental techniques I set up in Hamburg together with my young collaborators, namely, microwave and infrared photoconductivity on low-dimensional electron systems, which inherently combines the transport with spectroscopy, is mainly based on the knowledge I learnt from my mentors, namely, photo-thermal-ionization spectroscopy from Professor Shuechu Shen, far-infrared transmission spectroscopy from Professor Edwin Batke and Professor Detlef Heitmann, spin- and magneto-transport from Professor Junsaku Nitta, Professor Hideaki Takayanagi and Professor Gottfried Landwehr. Equally fortunate for me is that I have the privilege to collaborate with many talented colleagues and young students in China, Japan, and especially in Germany.

In this sense, I dedicate my Habilitationsschrift to my father and to my academic friends. I was thinking whether I should also dedicate it to my two lovely sons David and Peter, both born in Hamburg. However, it becomes clear that they are now more interested in their own toys than in mein, and it is a big question whether any paper printed here would remain worth reading after they grow up. It is a great challenge to write a paper which I would feel confident that David and Peter would proudly read decades later, — perhaps I should take this as the best motivation for my research in future.

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