1 Introduction

What makes a metal to be a conductor, gold look like gold or a magnet magnetic? A lot of such questions could be asked and they all could be answered with the same phrase: 'It is the electronic structure close to or at the Fermi level'.

Judging the importance of electronic states in a solid, it is obvious that the core levels are strongly bound and maintain their atomic character. In contrast, the valence states will overlap with those of other atoms and thus form bonding and antibonding bands. Thereby, the states at the Fermi level are crucial, since the latter is the energetic boundary between occupied and unoccupied states. Here, the electrons can easily interact with other quasiparticle excitations, e.g., collective displacements of the lattice [*Hengsberger et al.*, 1999] or spin waves in the case of ferromagnetic systems [*Schäfer et al.*, 2004].

Furthermore, since physical systems try to minimize their total energy, a configuration is adapted, which represents the lowest energy. In other words, the geometric structure is determined by the valence states which contribute to the binding. The electronic structure right at the Fermi level can also influence macroscopic quantities which lead to a lowering in energy and therefore to some surprising phenomena. For example, for some epitaxially grown films certain "magic"thicknesses are preferred [*Zhang et al.*, 1998, *Luh et al.*, 2001]. This is attributed to film-related states, the so-called quantum-well states (QWS). For a thickness where the QWS lies only slightly below the Fermi energy, the total energy is unfavorable compared to a thickness where the QWS is strongly bound. The QWS also account for the exchange coupling between two ferromagnetic films across a paramagnetic spacer layer. Exchange coupling is made responsible for the so-called giant magneto resistance [*Baibich et al.*, 2005, *Binasch et al.*, 1989], which has revolutionized the magnetic storage technology.

Another aspect, in the focus of today's physics research, is the influence of the electronic structure on electron dynamics. For metals the main interaction mechanism which accounts for energy dissipation of excited electrons is electron-electron scattering [*Echenique et al.*, 2000]. Here the scattering partners of an excited electron, which are defined by the occupied electronic structure, are of vital importance as well as the unoccupied final states. Furthermore, many-body effects like screening have to be considered, which themselves are determined by the electronic structure right at the Fermi level. For ferromagnetic systems the lifetime of minority electrons is shorter than the lifetime of majority elec-

trons. Somewhat simplified, this is explained by a larger number of empty minority states serving as decay channels in inelastic electron-electron scattering. [*Aeschlimann et al.*, 1997].

Another phenomenon of current interest, which might be explained by details of the electronic structure is ultrafast demagnetization of ferromagnets upon laser excitation [*Beaurepaire et al.*, 1996]. Recently, it was claimed that a spin mixing of the electronic states at the Fermi level accounts for this effect [*Koopmans et al.*, 2005]. Direct experimental verifications are nevertheless missing. This spin mixing at the Fermi level is also of interest for new electronic devices which include the electron spin as additional bit. This area, known as "spintronics", searches for materials which could support the spin polarization of an electronic current for a sufficiently long time. A spin mixing of the states at the Fermi level, however, leads to a fast depolarization [*Fabian and Sarma*, 1998].

It is obvious that there is a great interest in the valence-band structure, not only with respect to the binding energy but also with respect to the symmetry and spin polarization. The most powerful experimental technique in terms of band mapping is photoelectron spectroscopy with synchrotron radiation. However, spin-resolved band mapping suffers from low statistics and the spin-polarized inelastic background in direct photoemission. In this work another spectroscopic tool has been employed: Two-photon-photoemission spectroscopy. This two-step photoexcitation process is normally used in a pump-probe scheme to study unoccupied surface states, which are in this work image-potential states. As will be shown below, 2PPE also reveals a lot about the initial occupied states in the vicinity of the Fermi level.

Image-potential states have themselves undergone an interesting development. Although their existence is likely not of relevance for any macroscopic physical property they were successfully used as a model system to study the dynamics of excited electrons with respect to the influence of adsorbates, defects and overlayers [*Reuß et al.*, 1999, *Boger et al.*, 2004, *Rohleder et al.*, 2005]. The binding energy of image-potential states has also been used as a sensor for the local work function on overlayer systems [*Fischer et al.*, 1993a] or as a sensor for the corrugation of the electronic potential generated by a periodic arrangement of steps [*Roth et al.*, 2002]. In this work we will show that the exchange splitting of image-potential states on ferromagnets can be used as a sensor for the magnetization.

The thesis is structured as follows: After introducing in Chapter 2 the basics about 2PPE of image-potential states, and of the systems investigated, the experimental set-up is described in Chapter 3. The results are split in two parts: In Chapter 4 the influence of the initial states on the 2PPE spectrum is discussed with the focus on spin polarization and dichroism. In Chapter 5 the spin-dependent binding energies of the image-potential states are presented, and the possibility to employ the exchange splitting as a sensor for the magnetization is demonstrated.