Absolute Raman Efficiencies as a tool to investigate HTc Cuprates

P. Knoll, M. Mayer, W. Brenig *, and Ch. Waidacher †

Inst. f. Exp.physik, Univ. Graz, Universitätsplatz 5, A-8010 Graz, Austria
*Inst. f. Theor. Physik, Univ. Köln, Zülpicher Str. 77, W-50937 Köln, Germany
†Inst. f. Theor. Physik, Univ. Graz, Universitätsplatz 5, A-8010 Graz, Austria

Absolute Raman efficiencies of phononic, electronic and spin excitations have been determined for doped and undoped HTc-cuprates. Anomalous temperature dependence of the Raman efficiency of the phononic 500 cm⁻¹ mode is explained as a change of the apical oxygen position. The normal state efficiency of the 'electronic' background in YBa₂Cu₃O₆.₉ has been obtained for various scattering geometries for Raman shifts up to 8000 cm⁻¹. The 2-magnon contribution to the magnetic Raman signal of the undoped and lightly doped cuprates has been measured quantitatively and compared with recent calculations based on the 3-band-Hubbard model. Possible contributions of magnetic Raman scattering to the electronic B₁₉ background of the superconducting samples are discussed.

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1. INTRODUCTION

Raman scattering has given a lot of detailed information on physics and chemistry of the HTc-cuprates. In most investigations line position and line width of the observed Raman peaks have been measured in detail. The line intensities themselves, however, have almost not been examined, although they can provide a lot of additional information. The line position indicates the energy of quasi-particle excitations of the sample and the line width corresponds to inhomogeneity and lifetime of these excitations. Line intensities, on the other hand, are determined by the interaction mechanism of the photons with the quasi-particles via the Raman vertex. Because of the large energy difference between photons and quasi-particles the Raman vertex requires no direct coupling of photons with quasi-particles but an indirect coupling via other states. Therefore, Raman line intensities sensitively

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probe the interactions of the observed quasi-particles with other excitations. This additional information obtained from the intensities can become rather important in some special cases. First, the intensities are important for the identification of states which are distributed over a large energy scale producing a more or less broad Raman signal. This is the case for the so called electronic background of the HTc cuprates which shows the superconducting gap upon cooling below the transition temperature. As there is no structure in the normal state the only possibility to characterize the states involved is the intensity itself. Second, the intensities are important in order to identify the Raman vertex yielding information about the electronic structure. The magnetic Raman scattering in the insulating cuprates deals with this second possibility and may focus sensitively on the interplay between spin and charge degrees of freedom.

Instead of using intensities we define the Raman efficiency $S$ as the differential cross section $d\sigma/d\Omega$ scaled to the scattering volume $V_s$. $S$ (units are cm$^{-1}$ sr$^{-1}$) is determined from the experiment by integrating over the spectral density $dS/d\omega$ (units are sr$^{-1}$).

$$S = \frac{d\sigma}{d\Omega V_s} = \int \frac{dS}{d\omega} d\omega$$

In order to obtain Raman efficiencies in absolute numbers some special experimental requirements have to be satisfied. The spectral sensitivity of the whole equipment has to be calibrated using a standard lamp and the absolute efficiencies have to be obtained by comparing with materials with known Raman efficiencies as, e.g., BaF$_2$ and carefully correcting for different indices of refraction and absorbance coefficients. Our measurements are performed in the Raman microscope in order to select undisturbed parts of the sample surface and the laser power was kept less than 1mW at the sample. Using the 'Scanning Multichannel' technique the spectral sensitivity was calibrated using an OSRAM Wi17G standard lamp and absolute efficiencies were obtained by comparing with the phononic values in the Y123 system.

The correction of refraction and absorption has been done considering the small depth of focus of the Raman microscope.

2. PHONONS

The Raman vertex of phononic scattering is well known. The electron phonon interaction via the deformation potential couples the phononic states to the photon-excited electron-hole states. In some approximation this electron phonon interaction is described by the change $d\epsilon/dQ$ of the dielectric function with the phonon normal-coordinate and can be calculated by ab-initio band structure methods. A first successfull comparison of measured