ESRF	**Experiment title:** *Innovative applications of soft x-ray resonant Raman scattering: studying the ground state properties in strongly correlated systems and related compounds*	**Experiment number**: HE1534
Beamline: ID08	**Dates of experiment**: LONG TERM PROJECT from: 29/4/05-3/5/05, 4-9/9/05	**Date of report**: 8/10/2007
Shifts: 12+12	**Local contact(s)**: N.B. Brookes	*Received at ESRF:*

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Report:

This report completes the one presented in 2005. As most of the measurements lead to publications, we provide here those bibliographic references.

IRRS (4-9/9/05)

Magnetic Circular Dichroism (MCD) in perpendicular geometry

Interesting results on the dynamics of the spin polarized screening of a core hole in magnetic metals could be obtained, and are presented in L. Braicovich, G. Ghiringhelli, A. Tagliaferri, G. van der Laan, E. Annese, and N.B. Brookes, "Femtosecond dynamics in ferromagnetic metals investigated with soft x-ray resonant emission," Physical Review Letters **95**, 267402 (2005), and in FIGURE 1

Linear Dichroism (LD) in 90° scattering.

The data on Ce compounds already presented in the previous report were completed. The results are presented in L. Braicovich, A. Tagliaferri, E. Annese, G. Ghiringhelli, C. Dallera, F. Fracassi, A. Palenzona, and N. B. Brookes, "Spectroscopy of strongly correlated systems: Resonant x-ray scattering without energy resolution in the scattered beam," Physical Review B **75**, 073104 (2007), and in FIGURE 2.

RIXS (29/4/05-3/5/05)

dd excitations of simple 3d metal oxides.

We have published data on NiO and MnO:

G. Ghiringhelli, M. Matsubara, C. Dallera, F. Fracassi, R. Gusmeroli, A. Piazzalunga, A. Tagliaferri, N.B. Brookes, A. Kotani, and L. Braicovich, "NiO as a test case for high resolution resonant inelastic soft x-ray scattering," Journal of Physics: Condensed Matter **17**, 5397-5412 (2005), FIGURE 3

G. Ghiringhelli, M. Matsubara, C. Dallera, F. Fracassi, A. Tagliaferri, N.B. Brookes, A. Kotani, and L. Braicovich, "Resonant inelastic x-ray scattering of MnO: $L_{2,3}$ edge measurements and assessment of their interpretation," Physical Review B **73**, 035111 (2006), FIGURE 4

Crystal field excitations in cuprates.

W. A. Little, M. J. Holcomb, G. Ghiringhelli, L. Braicovich, C. Dallera, A. Piazzalunga, A. Tagliaferri, N.B. Brookes, *A determination of the pairing interaction in the high Tc cuprate superconductor $Tl_2Ba_2CaCu_2O_8$ (Tl2212)* arXiv:cond-mat/0608583, FIGURE 5

FIGURES

PRL 95, 267402 (2005) PHYSICAL REVIEW LETTERS week ending 31 DECEMBER 2005

Femtosecond Dynamics in Ferromagnetic Metals Investigated with Soft X-Ray Resonant Emission

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(Received 18 January 2005; published 19 December 2005)

We present measurements of the magnetic circular dichroism in x-ray resonant emission in the perpendicular geometry (circularly polarized x rays at normal incidence to the magnetization) for the $L_{2,3}$ absorption region in Fe, Co, and Ni metal. The results show that spin-dependent screening of the core hole takes place within the scattering time scale, which is supported by the absence of the effect in ionic systems. This allows an assessment of the time scale for the screening process (up to a few femtoseconds). The process is almost complete within the scattering time for Fe and Co, but this is not the case for the narrow band metal Ni which shows a much slower dynamics.

Figure 1

PHYSICAL REVIEW B 75, 073104 (2007)

Spectroscopy of strongly correlated systems: Resonant x-ray scattering without energy resolution in the scattered beam

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(Received 27 November 2006; published 16 February 2007)

The total emission of photons excited by x rays (90° between incident and detected photons) is measured vs the incident photon energy at the Ce $M_{4,5}$ edges in $CeIn_3$, $CeSnIn_2$, $CeAl_2$, $CePd_3$, and $CeRh_2$, and at the Ni $L_{2,3}$ edges in NiO. The results show the signature of a second-order process; these experiments must be interpreted as genuine resonant inelastic scattering (though without energy resolution of the emitted photons) and not as absorption spectroscopy measured by the total fluorescence yield. In Ce compounds, information on bulk hybridization can thus be obtained simply and with high sensitivity. The branching ratio between the different scattering channels is also measured. This approach opens innovative perspectives in resonant inelastic x-ray scattering.

.FIGURE 2

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J. Phys.: Condens. Matter 17 (2005) 5397–5412 doi:10.1088/0953-8984/17/35/007

NiO as a test case for high resolution resonant inelastic soft x-ray scattering

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FIGURE 3

PHYSICAL REVIEW B **73**, 035111 (2006)

Resonant inelastic x-ray scattering of MnO: $L_{2,3}$ edge measurements and assessment of their interpretation

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The resonant inelastic x-ray scattering (RIXS) of MnO measured with high energy resolution across the $L_{2,3}$ absorption edges of Mn is characterized by a very rich spectral structure due to the local electronic excitations. The spectra are dominated by *dd* and charge transfer excitations, both dipole allowed in the RIXS process. The spectra strongly depend on the energy and polarization of the incident photons. This vast experimental basis allows an accurate determination of the main parameters of theoretical models used to describe highly correlated electron systems like MnO. We show the results for the single impurity Anderson model and the single ion crystal field model and we compare them. Both models reproduce well the *dd* excitation spectrum, but the former can also predict satisfactorily the charge transfer excitations.

FIGURE 4.

A determination of the pairing interaction in the high T_c cuprate superconductor $Tl_2Ba_2CaCu_2O_8$ (Tl2212)

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Abstract

We have measured the near-normal reflectance of $Tl_2Ba_2CaCu_2O_8$ (Tl2212) for energies from 0.1 to 4.0 eV at room temperature and used a Kramers-Kronig analysis to find the complex, frequency dependent dielectric function, $\varepsilon(\omega)$ from which the optical conductivity $\sigma(\omega)$ was determined. Using Thermal-Difference-Reflectance (TDR) Spectroscopy the reflectance of the sample in the normal state just above the superconducting transition, and in the superconducting state were then obtained. From these data we determined the ratio of the superconducting- to normal-state optical conductivities, $\sigma_S(\omega)/\sigma_N(\omega)$. Mattis and Bardeen had calculated this function within the BCS theory, where the gap is a fixed energy-independent quantity. Taking into account the retarded nature of the electron-phonon coupling results in a complex, energy dependent gap $\Delta(\omega)$ causing deviations from the Mattis-Bardeen plot at energies where the phonon coupling function $\alpha^2(\omega)F(\omega)$, is large. We find a typical deviation near the phonon energies in Tl2212, and in addition, at 1.2 and 1.7eV. The phonon, and these electronic terms can each be described by a coupling constant λ_i. None of which by itself gives rise to a high transition temperature, but the combination does. Using Resonant Inelastic X-Ray Scattering (RIXS) we find that the d-to-d excitations of the cuprate ion in Tl2212 fall at the same energies as the dips in the Mattis-Bardeen plot. We conclude that the high superconducting transition temperature of the cuprates is due to the sum of the phonon interaction, and interactions with the Cu-ion d-shell.

FIGURE 5