

NOVEL SITE-SELECTIVE X-RAY SPECTROSCOPY FOR CRYSTALS USING A NEW STANDING WAVE METHOD

A.-P. Honkanen^{1,2}, K. O. Ruotsalainen¹, S. P. Collins³, G. Monaco^{4,5}, M. Moretti Sala⁴, M. Krisch⁴, K. Hämäläinen¹, M. Hakala¹ and S. Huotari¹

¹Department of Physics, University of Helsinki, Finland

²Department of Chemistry, University of Helsinki, Finland

³Diamond Light Source, United Kingdom

⁴ESRF – The European Synchrotron, Grenoble, France

⁵University of Trento, Italy

A creation of an x-ray standing wave is possible under diffraction conditions, where a coherent superposition of the incident and diffracted waves is formed [1]. Such a standing wave may have its nodes at the crystal planes, and thus the wave field amplitude can be minimized at the atom locations. If there is no amplitude at the atomic sites, dipolar absorption is greatly diminished and macroscopically thick crystals may become nearly transparent for x-rays. This is known as the anomalous transmission of x-rays, or the Borrmann effect, after the German x-ray physicist Gerhard Borrmann who discovered the effect.

Interestingly, while dipolar absorption at atoms can be minimized as described above, quadrupolar absorption is proportional to the gradient of the wave field amplitude at the absorbing atom, and in the above case it is in turn maximized. This enables novel studies of materials' electron states that cannot be studied by the dipole term alone [2].

We show for the first time that the x-ray standing wave method and the Borrmann effect can be combined in resonant x-ray emission spectroscopy to yield novel information on condensed-matter systems where *d*- and *f*-electrons play a decisive role of magnetic and electronic properties. We demonstrate this on gadolinium gallium garnet (Gd₃Ga₅O₁₂) in the case of quadrupolar electronic *2p* – *4f* transitions of Gd [3].

X-ray standing wave methods form a widely used range of tools to achieve atomic-site selectivity [1]. Such techniques can be used for site- and element-specific depth profiling, analyses of surfaces, thin films and multilayers. The new method may open up novel applications of studies of electronic states and chemistry in these systems.

[1] The X-ray Standing Wave Technique. Principles and Applications. Edited by J. Zegenhagen and A. Kazimirov (World Scientific, 2013).

[2] R. F. Pettifer, S. P. Collins, and D. Laundy, Nature 454, 196 (2008).

[3] K. O. Ruotsalainen, A.-P. Honkanen, S. P. Collins, G. Monaco, M. Moretti Sala, K. Hämäläinen, M. Hakala, and S. Huotari, submitted.