



Contribution ID: 19

Type: **not specified**

## Non-linear X-ray spectroscopy on solids

*Thursday 27 January 2022 11:40 (30 minutes)*

Spectroscopy on solids has fruitful applications, for example in the development of materials for future devices. Using the high intensity and coherence of free-electron lasers offers new opportunities to enhance the information content, but first, one needs to understand the underlying fundamental processes in the (core) electron dynamics, instrumental developments have to be established and methodological advancements in theory and experiment have to be scrutinized.

En route to useful non-linear X-ray spectroscopy applications, important steps have been made in the observation of stimulated processes and in the understanding of electron dynamics that can shield the experimental signatures. Further developments include the implementation of highly efficient intensity normalization schemes that open new opportunities also for other studies. The ultrahigh-vacuum chamber for multi-dimensional spectroscopy and inelastic X-ray scattering (MUSIX, [1]) has been built, offers enhanced flexibility and is being used in various experimental campaigns within many collaborations. New observations include first steps towards also mixing FEL photons with optical laser photons.

[1] Beye, M. et al. Non-linear soft x-ray methods on solids with MUSIX—the multi-dimensional spectroscopy and inelastic x-ray scattering endstation. *J Phys Condens Matter* 31, 014003 (2018).

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**Session Classification:** DESY Photon Science Users' Meeting