Sparse Collection of XAFS data via Plasma X-rays

*Yousuf Hemani[1, 2], Kilian Koch[1], Sriharsha Panuganti[1], Marco Galimberti[3] and Davide Bleiner[1, 2]

*yousuf.hemani@empa.ch

[1]Empa - Swiss Federal Institute of Material Sciences and Technology, Ueberlandstrasse 129, 8600 Duebendorf, Switzerland, [2]CMSZH - University of Zurich, Winterthurerstrasse 190, 8057, Zuerich, Switzerland, [3]Central Laser Facility, Rutherford Appleton Laboratory, STFC, Didcot, Oxfordshire, United Kingdom

X-ray absorption spectroscopy (XAFS) is used to fingerprint materials via the detection of absorption edges as well as structure, even in amorphous materials. XAFS is readily used to study catalysts, soil samples, metals and various chemical processes. Most of the XAFS experiments are performed at synchrotron beamlines, which are large facilities with a limited access based on proposal acceptance. Therefore, tabletop setups are useful, as they can provide an experimental access 24/7, for in-situ chemical analysis. One such facility (EMPULSE) is under development at EMPA in Switzerland.

EMPULSE is a terawatt laser facility developed to generate coherent/incoherent X-rays for the purpose X-ray spectroscopy and X-ray imaging by means of chirped pulse amplification [1]. X-rays are generated by shooting a high intensity, short laser pulse on a solid target, to induce a plasma. The output wavelength and energy of the emitted X-rays depends on the drive pulse characteristics and the target material. The characterization is done by a useful set of optical diagnostics.

A unique approach to quick noise-free XAFS measurements on tabletop based on the principle of Bayesian Compressed sensing is proposed. The technique relies on sparsely acquiring the raw data and using optimization algorithms to reconstruct the final signal. XAFS signals are sparse in discrete cosine transform domain and if the data is collected randomly, mathematical optimization techniques such as L1 normalization can be used to reconstruct the raw data. This can shorten the acquisition time to a few minutes without sacrificing the resolution. The proof of concept is presented, as implemented by a python code and a post-processing analysis of a case study on a Co foil. The results demonstrate that a 75% rate of compression for NEXAFS region and a 50% compression rate for EXAFS region, is possible, from which signals are accurately reconstructed to study the chemical information.

References:

[1]Hemani, Y., Galimberti, M. and Bleiner, D., "EMPULSE: a compact terawatt chirped pulse amplification laser for generating coherent x-rays," International Conference on X-Ray Lasers 2020, D. Bleiner, Ed. (2021).