Ultrafast spectro-microscopy and coherent scattering of functional nanomaterials: harnessing the power of soft X-ray light

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Ultrafast coherent X-ray imaging, scattering and spectroscopy are essential tools for understanding and quantifying the functionality of nanoscale systems in space and time domains. In particular, Soft X-ray/EUV light from compact High-Harmonic Generation (HHG) sources [1, 2] has proved extremely powerful for investigating dynamic electronic, phononic and magnetic properties in complex nanostructured systems [3-5], with nanometer spatial resolution and pulse durations in the femtosecond (fs)-to-attosecond (as) range. Specifically, the combination of HHG EUV light with ptychographic coherent diffractive imaging (CDI) [6, 7] enabled revolutionary capabilities, spanning a broad range from Bragg coherent small-angle scattering to ultrafast and hyperspectral imaging.

In this talk I will present my work in ultrafast coherent diffractive imaging and scattering using pulsed EUV and electron sources. I will provide examples of soft Xray-CDI applications in ultrafast full-field imaging of thermal and acoustic dynamics in individual nanostructures [8, 9]. Next, I will discuss how order/disorder correlations in colloidal crystals can be retrieved with small-angle scattering from highly coherent EUV light [10] and from partially coherent pulsed electron sources [11, 12], showing how the two approaches enable the visualization of complementary information in the spatial domain. The combination of these cutting-edge ultrafast techniques with advances in coherent imaging can be harnessed to carry out full-field non-destructive imaging of dynamically functioning nano-assemblies and interfaces, with exquisite amplitude (i.e. material composition) and phase (i.e. height) contrast.

References:

1. A. Rundquist, Science **280**, 1412–1415 (1998).
2. R. A. Bartels et al., Science **297**, 376–378 (2002).
3. Z. Tao et al., Science **353**, 62–67 (2016).
4. K. Hoogeboom-Pot et al., Proc. Natl. Acad. Sci. **162**, 341–344 (2015).
5. E. Turgut et al., Phys. Rev. Lett. **110**, 1–6 (2013).
6. A. Maiden, J. M. Rodenburg, Ultramicroscopy **109**, 1256–1262 (2009).
7. A. Maiden, D. Johnson, P. Li, Optica **4**, 736 (2017).
8. R. Karl Jr*, G. F. Mancini*, et al., Science Advances **4**, eaau4295 (2018).
9. D. F. Gardner, G. F. Mancini et al., Nat. Photonics **11**, 259–263 (2017).
10. G. F. Mancini et al., Opt. Express **26**, 11393–11406 (2018).
11. G. F. Mancini et al., Nano Lett. **16**, 2705–2713 (2016).
12. G. F. Mancini et al., Structural Dynamics **6**, 024304 (2019).