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### Propagation and scattering of x-rays in population-inverted medium

When high-intensity XFEL pulses are focused onto matter, they induce strong core-level photoionization and leave the atoms in a transient, inner-shell population-inverted state. The resulting open inner-shell transitions modify the resonant x-ray optical response and give rise to a range of distinctive phenomena. One example is x-ray superfluorescence: spontaneous fluorescence is amplified along the XFEL propagation direction, leading to intense, coherent bursts of radiation. I will present the theoretical formalism we developed to describe this process [1] and show how corresponding simulations enable interpretation of experimental observations [2].

Another manifestation of the modified x-ray–matter interaction in the presence of open inner-shell transitions is an enhancement of elastic scattering for x-rays resonant with these transitions. In this case, the resonant scattering governed by the population difference can become stronger than Thomson scattering set by the total electron density. I will discuss related models and experimental observations in the soft x-ray regime, where we exploited Cu 2p–3d transitions leading to reverse saturable absorption [3], and in the hard x-ray regime, where we used two-color x-ray pulses to create population inversion and probe modified scattering at the Cu 1s–2p transition.

[1] S.Chuchurka, A. Benediktovitch, Š. Krušič, A. Halavanau, and N. Rohringer, “Stochastic modeling of x-ray superfluorescence”, *Phys. Rev. A* 109, 033725 (2024)

[2] T. M. Linker, A. Halavanau, T. Kroll, A. Benediktovitch, et al, N. Rohringer and U. Bergmann, “Attosecond inner-shell lasing at ångström wavelengths”, *Nature* 642, 934–940 (2025)

[3] L. Mercadier, A. Benediktovitch, Š. Krušič, J. J. Kas, et al, B. Ziaja and N. Rohringer, “Transient absorption of warm dense matter created by an X-ray free-electron laser”, *Nat. Phys.* 20, 1564–1569 (2024)

**Host: Ruslan Kurta**



Virtual participation (via Zoom):

<https://xfel.zoom.us/j/64204363232?pwd=k997wMtb2qVGdb2fVkJLHBWVSR3ajO.1>

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