Symposium Atomic Physics, Molecular Physics, and Quantum Optics with X-ray FELs (SYXR)

jointly organized by
the Atomic Physics Division (A),
the Molecular Physics Division (MO), and
the Quantum Optics and Photonics Division (Q)

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Overview of Invited Talks and Sessions

(Lecture room U Audimax)

Invited Talks

SYXR 1.1	Thu	14:00–14:30	U Audimax	**Superradiance of an ensemble of nuclei excited by a free electron laser** — •Aleksandr Chumakov
SYXR 1.2	Thu	14:30–15:00	U Audimax	**Quantum imaging with incoherently scattered light from a Free-Electron Laser** — •Joachim von Zanthier
SYXR 1.3	Thu	15:00–15:30	U Audimax	**Stimulated X-Ray Emission Spectroscopy for Chemical Analysis** — •Nina Rohringer
SYXR 1.4	Thu	15:30–16:00	U Audimax	**X-Ray Multiphoton Ionization of Atoms and Molecules** — •Daniel Rolles

Sessions

SYXR 1.1–1.4	Thu	14:00–16:00	U Audimax	**Atomic Physics, Molecular Physics and Quantum Optics with X-ray FELs**

SYXR 1: Atomic Physics, Molecular Physics and Quantum Optics with X-ray FELs

Time: Thursday 14:00–16:00 Location: U Audimax

Invited Talk SYXR 1.1 Thu 14:00 U Audimax

Superradiance of an ensemble of nuclei excited by a free electron laser — •Aleksandr Chumakov — ESRF-The European Synchrotron, Grenoble , France

In 1954 Dicke predicted the accelerated initial decay of multiple atomic excitations, laying the foundation for the concept of superradiance. Further studies suggested that emission of the total energy was similarly accelerated, provided that the system reaches the inversion threshold. Whereas, superradiant emission of the total energy has been confirmed by numerous studies, the acceleration of the initial decay has not yet been experimentally demonstrated. Here we use resonant diffraction of x rays from the Mössbauer transition of 57Fe nuclei to investigate superradiant decay, photon by photon, along the entire chain of the de-excitation cascade of up to 68 simultaneous coherent nuclear excitations created by a pulse of an x-ray free-electron laser. We find agreement with Dicke's theory for the accelerated initial decay as the number of excitations is increased. We also find that our results are in agreement with a simple statistical model, providing a necessary baseline for discussing further properties of superradiance, within and beyond the low-excitation regime.

Invited Talk SYXR 1.2 Thu 14:30 U Audimax

Quantum imaging with incoherently scattered light from a Free-Electron Laser — •Joachim von Zanthier — Universität Erlangen-Nürnberg, Erlangen, Germany

For more than 100 years, X-rays have been used in crystallography to determine the structure of crystals and molecules via coherent diffraction methods. However, these techniques rely on coherent scattering where incoherence due to fluorescence emission or wavefront distortion is considered detrimental. Here we show that methods from quantum imaging, i.e., exploiting higher order intensity correlations, can be used to image the full 1D, 2D and even 3D arrangement of sources that scatter incoherent X-ray radiation, e.g., arrangements of atoms in crystals or molecules that scatter X-ray fluorescence photons [1-4]. We discuss a number of properties of this incoherent diffraction imaging (IDI) method that are conceptually superior to those of conventional coherent X-ray structure determination and point out that current FELs are ideally suited for the implementation of the approach [3]. 1.S. Oppel, T. Büttner, P. Kok, J. von Zanthier, Phys. Rev. Lett. 109, 233603 (2012). 2.A. Classen, F. Waldmann, S. Giebel, R. Schneider, D. Bhatti, T. Mehringer, J. von Zanthier, Phys. Rev. Lett. 117, 253601 (2016). 3. A. Classen, K. Ayyer, H. N. Chapman, R. Röhlsberger, J. von Zanthier, Phys. Rev. Lett. 119, 053401 (2017). 4. R. Schneider et al., Nature Phys. 14, 126 (2018); News & Views, Nature Photon. 12, 6 (2018).

Invited Talk SYXR 1.3 Thu 15:00 U Audimax

Stimulated X-Ray Emission Spectroscopy for Chemical Analysis — •Nina Rohringer — DESY, Notkestr. 85, 22607 Hamburg

X-ray free-electron lasers (XFEL) deliver X-ray pulses of fs duration, at unprecedented intensities that open avenues for studying nonlinear optical effects and stimulated X-ray emission and scattering. An intriguing future perspective is the development of coherent attosecond nonlinear pump-probe techniques, to study charge and energy transport in chemical reactions and photocatalysis. Stimulated X-ray emission and stimulated X-ray scattering are the fundamental building blocks of these nonlinear spectroscopic techniques. Here we present results on amplified spontaneous K-alpha spectroscopy of Mn compounds in solution [1]. The stimulated emission spectrum was studied as a function of amplification strength. Despite the stark differences to the spontaneous X-ray spectra, stimulated X-ray emission spectroscopy prevails the chemical sensitivity and opens the door to more advanced nonlinear X-ray spectroscopic techniques.

[1] T Kroll, C Weninger, R Alonso-Mori, D Sokaras, D Zhu, L Mercadier, V P Majety, A Marinelli, A Lutman, M W Guetg, F-J Decker, S Boutet, A Aquila, J Koglin, J Koralek, D P DePonte, J Kern, F D Fuller, E Pastor, T Fransson, Y Zhang, J Yano, V K Yachandra, N Rohringer and U Bergmann, Phys. Rev. Lett. 120, 133203 (2018)

Invited Talk SYXR 1.4 Thu 15:30 U Audimax

X-Ray Multiphoton Ionization of Atoms and Molecules — •Daniel Rolles — J.R. Macdonald Laboratory, Kansas State University, Manhattan, KS, USA

X-ray free-electron lasers (XFELs) provide extremely intense, short-pulse X-ray radiation, making it possible to study X-ray-matter interaction at intensities close to 10^{20} W/cm^2. To explore the response of atoms and molecules to these unprecedented X-ray intensities, we have extended our investigations of the multiphoton ionization of heavy atoms and of high-Z atom containing molecules from the soft into the hard X-ray range and to higher peak fluences than in previous studies. The results provide important benchmarks, e.g, for calculating radiation damage effects in XFEL-based X-ray imaging experiments. We observe a significant enhancement of the degree of ionization in molecules as compared to the equivalent, individual atoms and trace this effect to ultrafast charge transfer from the neighboring atoms in the molecule [1]. The comparison to new calculations, which quantitatively reproduce the experimental data at all photon energies and intensities, also highlights the role of resonant and relativistic effects in the X-ray multiphoton ionization of heavy atoms [2].

[1] A. Rudenko et al., Nature 546, 129 (2017) [2] B. Rudek et al., Nature Commun. 9, 4200 (2018)