[Lecture 1]
Synchrotron radiation and its application

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In this lecture, the principles of synchrotron radiation generation, the differences and similarities with lasers, and an overview of experimental methods using synchrotron radiation will be explained. Among various experimental methods, soft X-ray absorption spectroscopy and its derivative techniques will be particularly detailed. These techniques are applied in a wide range of fields, including condensed matter physics, chemistry, biology, and earth and planetary sciences. Microspectroscopy, time-resolved measurements, and magnetic spectroscopy that utilize the various characteristics of synchrotron radiation (high brilliance, wide energy range, various polarization, and pulsed nature) will be introduced. Additionally, the application of AI and machine learning techniques to synchrotron radiation measurements, so-called synchrotron-radiation measurement informatics, which has become increasingly important in recent years, will be discussed.

[Lecture 2]
Probing the electronic structure of quantum materials by ARPES

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With its direct correspondence to the electronic structure, angle-resolved photoemission spectroscopy (ARPES) is a ubiquitous tool for the study of quantum materials [1,2]. When extended to the temporal domain, time-resolved ARPES offers the potential to move beyond equilibrium properties, exploring both the unoccupied electronic structure as well as its dynamical response under ultrafast perturbation [3]. In this lecture, I will discuss how ARPES – at equilibrium as well as in its time-resolved variance – can probe the momentum-dependent electronic structure of solids providing detailed information on band dispersion and Fermi surface, as well as on the strength and nature of many-body correlations which profoundly affect the one-electron excitation spectrum and in turn the macroscopic physical properties.

[1] A. Damascelli, *Probing the electronic structure of complex systems by ARPES.* Phys. Scr. **T109**, 61 (2004).

[2] A. Damascelli, Z. Hussain, Z.X. Shen, *ARPES studies of the cuprate superconductors*. Rev. Mod. Phys. **75**, 473 (2003).

[3] F. Boschini, M. Zonno, A. Damascelli, *Time-resolved ARPES studies of quantum materials.* Rev. Mod. Phys. 96, 015003 (2024).

[Lecture 3]
Introduction to Attosecond Science: Fundamentals and Applications

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This lecture provides an introduction to the fundamentals of attosecond science, a field that enables the observation and control of electron dynamics on ultrafast timescales. We will cover the generation of attosecond pulses using high-harmonic generation, basic measurement techniques, and theoretical background. Applications in probing ultrafast phenomena in atoms, molecules, and solids will also be discussed.

[Lecture 4]
Recent progress in soft X-ray spectroscopic instrumentation

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This lecture is devoted to reviewing selected recent advances what you need to know in soft X-ray spectroscopy instrumentation including brief basic introduction but attendees are encouraged to familiarize themselves with the references beforehand. The specific topics are as follows: (1) New definition of resolving power for design of high resolution spectrometers compatible with traditional Rayleigh's criterion, (2) Definition of spectral flux, SF, derived by multiplying diffraction efficiency and Lambert's cosine law which is consistence with sensitivity of spectrometric instruments, (3) Aspherical Wave Front, AWF, recording method to fabricate precisely controlled Varied-Line-Spacing, VLS, grooves of holographic diffraction gratings indispensable for high resolution spectrometers, and (4) Graded Refraction Index, GRI, multilayer enhancing diffraction efficiency of soft X-ray diffraction gratings in a wide energy band width. Also, a Soft X-ray Emission Spectrograph, SXES, for general purposes electron microscopes is described as a typical instrument in which the technologies mentioned above are successfully applied.

1) D. Attwood and A. Sakdinawat, "*Soft X-Rays and Extreme Ultraviolet Radiation: Principles and Applications*, 14 2nd Edition," Cambridge University Press, Cambridge, 2017, ISBN: 978-1-107-06289-4. 15

2) J. A. Samson and D. L. Ederer, eds., "*Vacuum Ultraviolet Spectroscopy*," Academic Press, San Diego, 2000, 16 ISBN : 978-0-126-17560-8. 17

3) A. G. Michette, "*Optical Systems for Soft X Rays*," Plenum Press, New York, 1986, ISBN: 978-1-4612-9304-0.

[Lecture 5]

Characteristics of X-ray free-electron laser and novel X-ray Source from plasma irradiated by intense laser

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In this brief lecture, we treat two X-ray generation mechanisms and the characteristics of the X-rays, which differ from the atomic high-order harmonic generation (HHG) and synchrotron radiation from a storage ring. These two methods are X-ray free-electron lasers and a technique called BISER, both of which are coherent, ultra-short pulse X-ray sources.

XFEL is already well-established, with several facilities currently operational worldwide. It achieves high flux and high brightness by introducing high-quality electron beams into an undulator. BISER (Burst Intensification by Singularity Emitting Radiation), on the other hand, is a less familiar and still developing light source. Unlike HHG, it is driven by the relativistic motion of electrons in a laser field at relativistic intensities, enabling the generation of pulses in the range of tens to hundreds of attoseconds.

Both methods confine electrons in an extremely small region and generate coherent X-rays by causing them to emit light coherently.

The characteristics of the XFEL and BISER will also be presented, along with typical applications.