

Introduction to X-ray imaging and X-ray Microscopy

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X-ray imaging and microscopy have become indispensable tools for investigating the structure, composition, and chemistry of matter across a broad range of scientific disciplines, including life sciences, environmental research, materials science, and cultural heritage. The unique properties of synchrotron radiation—high brilliance, energy tunability, and coherence—enable a variety of imaging techniques capable of probing specimens over multiple length scales with high spatial resolution and chemical sensitivity.

These lectures will introduce the fundamental principles of X-ray imaging and microscopy, discussing the mechanisms underlying image formation and contrast generation, as well as the main imaging approaches based on absorption, phase contrast, fluorescence, and spectroscopy. Particular attention will be devoted to synchrotron-based X-ray microscopy techniques, highlighting how the combination of imaging and spectroscopic information provides complementary structural, elemental, and chemical insights into complex samples.

The lectures will present an overview of modern X-ray microscopy instrumentation, including scanning and full-field approaches, and will introduce emerging coherent imaging methods such as ptychography. The potential of multimodal X-ray microscopy will be illustrated through selected examples, including the TwinMic soft X-ray microscopy station at the Elettra Sincrotrone Trieste facility. TwinMic combines bright-field and phase-contrast imaging with low-energy X-ray fluorescence and X-ray absorption spectroscopy, enabling the correlation of sample morphology with elemental and chemical information at the sub-micrometre scale.

Recent developments in X-ray microscopy, including advanced acquisition strategies, computational imaging, and data-driven approaches, will also be discussed to illustrate how current technologies are expanding the capabilities of synchrotron-based imaging. Representative applications from life sciences, environmental science, materials science, and cultural heritage will demonstrate the role of X-ray microscopy in addressing contemporary scientific challenges and enabling multimodal characterization across different length scales.