Infrared spectroscopy with synchrotron and FEL radiation

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The no-damaging nature of the infrared (IR) light is a unique feature in Synchrotron Radiation (SR) and FEL facilities, which allows the safe investigation of vibrational and vibro-electronic transitions for a wide variety of materials. Hence, the applications of infrared cover a wide range of research fields including material science, biochemistry, cultural heritage, forensics, geology, biomedical diagnostics, and many others. SISSI-Bio and SISSI-Mat are the two branches of the infrared beamline at Elettra Synchrotron, while TeraFERMI is the THz beamline of the FERMI Free-Electron-Laser (FEL) facility.

The present lecture is intended to present the most relevant characteristics of IR-synchrotron and FEL-THz radiation and associated instrumentations, through exemplary spectroscopy and microscopy studies, exploiting both diffraction-limited and sub-diffraction approaches.

The first part of the lesson will be focused on IR spectroscopy, microscopy and nanoscopy with IRSR. Specifically, the fundamental characteristics of synchrotron infrared radiation will be outlined, with a focus on the mid-infrared region. In addition to far-field Fourier Transform IR microscopy, the most advanced microscopy techniques – both far-field and near-field – will be presented, namely, IR s-SNOM and O-PTIR. Through a series of scientific examples taken form the experimental activity of SISSI-Bio, it will be highlighted how the complementarity of spectral ranges and spatial resolution domains may help to shed light on complex systems, such as biological materials and artistic artefacts.

The second part will be dedicated to the THz spectral range. We will discuss how the unique properties of synchrotron radiation can be exploited for THz spectroscopy under “extreme” experimental conditions. We will then address how free-electron lasers can generate ultrashort, intense THz pulses with high electric fields, enabling access to nonlinear regimes in which collective excitations such as plasmons, polarons, or magnons can be driven and manipulated.