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Chapter 1.2

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Facilities

Federico Boscherini*

Dipartimento di Fisica e Astronomia 'Augusto Righi', Alma Mater Studiorum – Università di Bologna, Viale C. Berti Pichat 6/2, 40127 Bologna, Italy. *Correspondence e-mail: federico.boscherini@unibo.it

An overview is provided of the facilities available for X-ray absorption fine-structure measurements worldwide.

1. Introduction

The purpose of this chapter is to provide an overview of the facilities available for X-ray absorption fine-structure (XAFS) measurements worldwide. There are many variants of XAFS instruments, ranging from the relatively standard general-purpose hard X-ray beamlines for measurements in transmission, fluorescence and (possibly) electron-yield modes to more specialized beamlines. Examples of the latter include the following.

(i) Surface-science instruments, which often offer X-ray absorption near-edge structure (XANES) measurements for the determination of the orientation of adsorbed molecules or ultrathin films on a substrate, often in a grazing-incidence geometry.

(ii) Nano-analysis beamlines and dedicated experimental stations, which provide fluorescence mapping and spatially resolved XAFS for the study of highly heterogeneous materials, devices, biostructures, cultural heritage artefacts and samples relevant for environmental studies.

(iii) Experimental stations specifically designed for *in situ* and *operando* measurements in the field of (photo)electrochemistry, catalysis and batteries, possibly in combination with X-ray diffraction (XRD).

(iv) Beamlines exploiting circular polarization, which is of great importance for the study of magnetic materials.

(v) Specialized setups for pump-and-probe measurements allowing time-resolved XAFS measurements on a range of timescales, which are important in materials science, photochemistry and photobiology.

(vi) Experimental stations which allow a high-resolution spectroscopic analysis of photons scattered by a sample, which therefore allow resonant inelastic X-ray scattering (RIXS) and high energy resolution fluorescence-detected (HERFD) measurements, which are of interest in catalysis, environmental science and investigations of highly correlated materials, among others.

(vii) Specialized setups for the study of high energy density matter, *i.e.* conditions of high pressure, temperature, magnetic or electric fields (to study striction effects), often including high-power lasers for sample conditioning.

(viii) Instruments combining XAFS with variants of XRD, possibly including diffraction anomalous fine-structure (DAFS) measurements.

(ix) Experimental stations on free-electron laser sources, offering the possibility of time-resolved XAFS measurements on the femtosecond timescale, which is very relevant for the study of fundamental processes in photophysics.

The above non-exhaustive list is suggestive of the wide applicability of XAFS to various fields of scientific investigation and of the many interested scientific communities.

In the following, a list of facilities at which XAFS measurements are possible is provided. Because changes in beamlines and instruments are quite frequent, no attempt has been made to provide this level of detail. Facility websites often include a search engine from which beamlines dedicated to a particular technique can be extracted.

A very useful resource is provided by the Lightsources.org collaboration (https://lightsources.org/). At the European level, a detailed catalogue is offered by the WayForLight project (https://www.wayforlight.eu/).

2. Europe and Middle East

2.1. Synchrotron-radiation sources

(i) ALBA, Barcelona, Spain: https://www.cells.es/en.

(ii) ASTRID2, Center for Storage Ring Facilities (ISA), Aarhus University, Aarhus, Denmark: https://www.isa.au.dk/facilities/astrid2/astrid2.asp.

(iii) BESSY II, Helmholtz Zentrum Berlin, Berlin, Germany: https://www.helmholtz-berlin.de/forschung/quellen/bessy/index_en.html.

(iv) DAΦNE-Light, Laboratori Nazionali di Frascati, Istituto Nazionale di Fisica Nucleare (INFN), Frascati, Italy: https://dafne-light.lnf.infn.it/.

(v) Diamond Light Source, Harwell Science and Innovation Campus, Didcot, Oxfordshire, United Kingdom: https://www.diamond.ac.uk/Home.

(vi) ESRF – The European Synchrotron Radiation Facility, Grenoble, France: https://www.esrf.fr/.

(vii) Elettra Sincrotrone Trieste, Trieste, Italy: https://www.elettra.eu/.

(viii) KIT Light Source at Karlsruhe Institute of Technology, Karlsruhe, Germany: https://www.ibpt.kit.edu/KIT_Light_Source.php.

(ix) Kurchatov Institute, National Research Center, Moscow, Russian Federation: http://kcsni.nrcki.ru/en.shtml.

(x) MAX IV, Lund University, Lund, Sweden: https://www.maxiv.lu.se/.

(xi) PETRA III, Deutsches Electronen Synchrotron (DESY), Hamburg, Germany: https://photon-science.desy.de/facilities/petra_iii.

(xii) SESAME, Allan, Jordan: https://www.sesame.org.jo/.

(xiii) Swiss Light Source (SLS), Paul Scherrer Institut (PSI), Villigen, Switzerland: https://www.psi.ch/en/sls.

(xiv) SOLARIS National Synchrotron Radiation Center, Krakow, Poland: https://synchrotron.uj.edu.pl/.

(xv) SOLEIL Synchrotron, Saint Aubin, France: https://www.synchrotron-soleil.fr/en.

2.2. Free-electron laser sources

(i) European XFEL, Schenefeld, Germany: https://www.xfel.eu/index_eng.html.

(ii) FERMI at Elettra, Trieste, Italy: https://www.elettra.eu/.

(iii) FLASH at Deutsches Electronen Synchrotron (DESY), Hamburg, Germany: https://photon-science.desy.de/facilities/flash.

(iv) SwissFEL, Paul Scherrer Institut (PSI), Villigen, Switzerland: https://www.psi.ch/en/swissfel.

3. Americas

3.1. Synchrotron-radiation sources

(i) Advanced Light Source (ALS), Berkeley, California, USA: https://als.lbl.gov/.

(ii) Advanced Photon Source (APS), Argonne National Laboratory, Argonne, Illinois, USA: https://www.aps.anl.gov/.

(iii) Center for Advanced Microstructures and Devices (CAMD), Louisiana State University, Baton Rouge, Louisiana, USA: https://www.lsu.edu/camd/index.php.

(iv) Canadian Light Source (CLS), Centre Canadien de Rayonnement Synchrotron, Saskatoon, Canada: https://www.lightsource.ca/index.php.

(v) Cornell High Energy Synchrotron Source (CHESS), Ithaca, New York, USA: https://www.chess.cornell.edu/.

(vi) National Synchrotron Light Source II (NSLS II), Brookhaven National Laboratory, Upton, New York, USA: https://www.bnl.gov/nsls2/.

(vii) SIRIUS, Laboratorio Nacional de Luz Sincrotron (LNLS), Campinas, São Paolo, Brazil: https://lnls.cnpem.br/home/.

(viii) Stanford Synchrotron Radiation Laboratory (SSRL), SLAC National Accelerator Laboratory, Menlo Park, California, USA: https://www-ssrl.slac.stanford.edu/.

3.2. Free-electron laser sources

Linear Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory, Menlo Park, California, USA: https://lcls.slac.stanford.edu/.

4. Asia and Australia

4.1. Synchrotron-radiation sources

(i) Aichi Synchrotron Radiation Center, Aichi Prefecture, Japan: https://www.aichisr.jp/en/index.html.

(ii) Australian Synchrotron, Clayton, Victoria, Australia: https://www.ansto.gov.au/facilities/australian-synchrotron.

(iii) Beijing Synchrotron Radiation Facility (BSRF), Beijing, People's Republic of China: http://english.bsrf.ihep.cas.cn/.

(iv) Hiroshima Synchrotron Radiation Center (HiSOR), Hiroshima University, Hiroshima, Japan: http://www.hsrc.hiroshima-u.ac.jp/english/index.html.

(v) Indus-2, Raja Ramanna Center for Advanced Technology, Indore, India: https://www.rrcat.gov.in/technology/accel/indus2.html.

(vi) National Synchrotron Radiation Laboratory (NSRL), University of Science and Technology of China, Hefei, People's Republic of China: https://en.nsrl.ustc.edu.cn/main.htm.

(vii) Photon Factory (PF) and Photon Factory Advanced Ring (PR-AR), High Energy Accelerator Research Organization (KEK), Tsukuba, Japan: https://www2.kek.jp/imss/pf/eng/.

(viii) Pohang Light Source II (PLS-II) at Pohang Accelerator Laboratory (PAL), Pohang, Republic of Korea: https://pal.postech.ac.kr/paleng/.

(ix) SAGA Light Source, Saga Prefecture, Japan: https://www.saga-ls.jp/main/207.html#gsc.tab=0.

(x) Spring-8, Hyogo Prefecture, Japan: http://www.spring8.or.jp/en/.

(xi) Siam Photon Source, Synchrotron Light Research Institute, Nakhon Ratchasima, Thailand: https://www.slri.or.th/en/.

(xii) Singapore Synchrotron Light Source (SSLS), National University of Singapore (NUS), Singapore: https://ssls.nus.edu.sg/.

(xiii) Shanghai Synchrotron Radiation Facility (SSRF), Chinese Academy of Sciences, Shanghai, People's Republic of China: https://lssf.cas.cn/en/facilities-view.jsp?id=ff8080814ff56599014ff599b8550033.

(xiv) Synchrotron Radiation Center, Ritsumeikan University, Shiga Prefecture, Japan: https://en.ritsumei.ac.jp/research/organizations/sr-center/.

(xv) Taiwan Light Source (TLS) and Taiwan Photon Source (TPS) at National Synchrotron Radiation Research Center (NSRRC), Hsinchu Science Park, Taiwan, Republic of China: https://www.nsrrc.org.tw/english/index.aspx.

(xvi) UVSOR-III, Institute for Molecular Science, Okazaki Prefecture, Japan: https://www.uvsor.ims.ac.jp/eng/.

(xvii) VEPP-3 and VEPP-4M, Siberian Synchrotron and Terahertz Radiation Center (SSTRC), Budker Institute of Nuclear Physics, Novosibirsk, Russian Federation: https://ssrc.biouml.org/.

4.2. Free-electron laser sources

(i) Pohang Accelerator Laboratory X-ray Free-Electron Laser (PAL-XFEL), Pohang, Republic of Korea: https://pal.postech.ac.kr/paleng/.

(ii) SACLA XFEL, Hyogo Prefecture, Japan: http://xfel.riken.jp/eng/index.html.