BABE at IOM-CNR, Trieste, Italy
BACH BEAR beamlines for AHEAD

Responsible and contact person: Elena Magnano magnano@iom.cnr.it

Infrastructure description

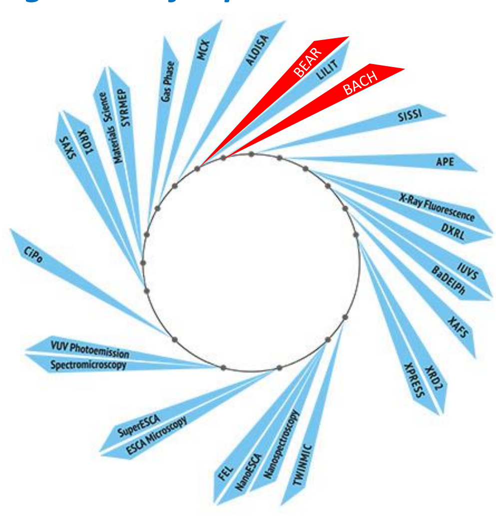
BABE infrastructure* provides a suite of installations and related experimental techniques and methodologies for photonic characterization and microscopic diagnostics of optical elements, optical devices and related constituent materials.

The approach is based on the interaction of a beam of photons of variable polarization ranging from linear to circular in the energy (wavelenght) range 2.8-1600 eV (443-0.775 nm) delivered by the two synchrotron radiation beamlines BACH and BEAR of the Italian National Council of Research (CNR) installed at Elettra synchrotron facility (Trieste, Italy).

Control and acquisition of apparatuses is PC controlled. Control PCs are connected to web and remotely accessible permitting the remote management of experiments.

The beamlines are operated by the Istituto Officina dei Materiali (IOM-CNR) (https://www.iom.cnr.it/)

*See also https://babe.iom.cnr.it/



Infrastructure location

BABE infrastructure is located in the premises of the Institute of matters IOM-CNR and Elettra synchrotron radiation facility, located in Basovizza - Trieste, close to the border with Slovenia. It is served by Trieste airport, which is 46 km far and offers regular flights to Munich and London. The most important European hubs can also be accessed from Venice, Treviso and Ljubljana airports, which are also at close distance.

Physical and technical information

Quantities and physical properties obtainable at BABE are presented below.

Apparatus control and data acquisition are PC controlled. PCs are connected to web and remotely accessible permitting the remote management of a number of experiments.

All items are obtainable versus photon energy, polarization state, electron kinetic energy and momentum, incidence and collection geometries with possible photon dose control per experimental point.

	Light spot BACH (source: undulators)	Light spot BEAR (source: bending magnet)
ENERGY	35 - 1650 eV	2.8 - 1600 eV
SPOT SIZE	Focal point Vertical → ~50-400 μm Horizontal→ ~100-400 μm	Focal point Vertical→ 15-400 μm Horizontal→ 5-400 μm
DIVERGENCE	0.5×0.1 (H × V) μrad^2	<20×20 (H × V) $mrad^2$
POLARIZATION	Variable polarization: linear (horizontal and vertical), circular (right and left)	variable polarization: from ~ linear to elliptical (right and left)
FLUX	80-200 eV → ~10^{12} ph/s (peak) 600-1500 eV →~10^{11} ph/s (peak)	2.8-40 eV →~10^{10} ph/s (30 eV) 35-1600 eV (G1200) → ~10^{11} ph/s (150 eV)
RESOLUTION	at 50 eV → ΔE/E = ~16000 (peak) at 400 eV → ΔE/E = ~12000 (peak) at 800 eV → ΔE/E = ~7000 (peak)	at 20 eV → ΔE/E =~10000 (peak) at 100 eV →ΔE/E~3000 (peak)
HIGHER ORDERs REJECTION	---------------	Filters (SiO_2, LiF, In, Sn, Al, Si)

	PREPARATION	DURING MEASUREMENTS
SAMPLE ENVIRONMENT	UHV (base pressure ≥ 5 × 10^{-10} mbar)	UHV (base pressure ≥ 5 × 10^{-10} mbar)
SAMPLE PREPARATION	Ion Sputtering and implantation Annealing ≤ 1000°C Cleaving Scraping (Ultra)thin film deposition (e^--beam, thermal evaporators) Gas exposure ≤ hundreds mbar	Annealing ≤ 700°C Cooling: LHe (60 K) - LN2 (100 K) LHe cryostat (Coolstar) (30 K) (Ultra)thin film deposition (e^--beam) Gas exposure ≤ 1 × 10^{-6} mbar
SAMPLE DIMENSIONS	Standard dimensions→ 20×20×10 mm^3 Oversized samples mounting to be agreed with the responsible of the installation	

Installation 1: *Electron yield*
Installation 2: *Photon yield*
Installation 3: *Optical transmission and reflectivity and light scattering*
Installation 4: *Optical metrology*

Installation1: *Electron yield*

- ✓ Total Electron Yield (TEY) : total electron emission current, energies of optical transitions and qualitative relation with surface sensitivity of optical absorption coefficient together with PEY, EAY, OLY and XFY providing data entry for optical spectroscopy and local structure analysis as in NEXAFS, EXAFS
- ✓ Partial Electron Yield (PEY): TEY in a selected electron kinetic energy band, surface to volume ratio tunability
- ✓ Electron yield resolved in kinetic energy and momentum: providing entry data for angle integrated and resolved UPS and XPS spectroscopy and related microscopic information including binding energies, energy bands and photoemission cross sections
- ✓ Electron Auger Yield (EAY): electron emission distribution in kinetic energy of a selected Auger line, providing entry data for Auger Electron Spectroscopy (AES) and surface sensitive evaluation of absorption coefficient of a selected chemical species together with TEY, PEY, UPS, XPS providing tools for surface analysis of materials

How to measure:

- ✓ Total Electron Yield (TEY) emission current (drain current) is measured in the usual set up grounding the sample through a picoammeter with highest sensitivity of the order of tenths of fA .
  Sample biasing (positive, negative) is available.
- ✓ Partial Electron Yield (PEY) can be obtained by selecting using electron analyzers (see below) a kinetic energy band.

  Two hemispherical electron analyzers of mean radius 135 mm (Scienta R3000 – BACH) and 60 mm (home made – BEAR) are available for kinetic energy and momentum resolved measurements of emitted electrons as produced by photoemission and Auger processes and of use in related spectroscopic analysis.

	Mean radius r (mm)	Kinetic Energy (eV)	Pass Energy E_p (eV)	Energy resolution	Angular resolution (deg)
BACH	135	1-2000	2,5,10,20, 50,100,200	~0.1-1% E_p (slit×E_p/2×r)	±0.1
BEAR	60	0-1000	1-100 eV	~1% E_p	±1

Installation2: *Photon yield*

- ✓ Optical luminescence Yield: providing entry data for XEOL (X-ray Excited Optical Luminescence) spectroscopy
- ✓ Fluorescence Yield : providing entry data for XFYS (X-ray Fluorescence Yield Spectroscopy)

How to measure:

- ✓ Optical luminescence yield is collected by a quartz fiber placed in front of sample confocal with light spot (default BEAR, BACH light spot can be considered) with a wide choice of incidence and collection geometries

  Acquisition modes include:
  - Total Optical Luminescence Yield (TOLY) vs energy collecting the total signal transmitted by the optical fiber by a suitable optical detector (default Photon-electron Multiplier Tube /PMT or photo-diode). Scanning in energy beamline monochromator excitation curves can be obtained
  - Energy/Lambda Resolved Optical Luminescence analyzing in photon energy at fixed synchrotron excitation energy the emission spectrum by visible-near UV monochromator in the transmission band of quartz fiber (default detection include PMT and diode)

- ✓ Fluorescence yield can be acquired through two acquisition setups:
  - Total Fluorescence Yield (TFY) acquiring by a detector (electron multipliers or photodiode) placed in front of sample illuminated by the synchrotron beam with a wide choice of incidence and collection geometries
  - Energy Resolved Fluorescence Yield (ERFY) acquiring by a Silicon Drift Detector (SDD) placed in front of sample illuminated by the synchrotron beam with a wide choice of incidence and collection geometries

Installation 3: *Optical transmission and reflectivity and light scattering*

- ✓ Optical transmission: allowing optical absorption coefficient determination and imaginary part of refraction index
- ✓ Gas absorption (Samson cell): allowing gas optical absorption cross sections determination
- ✓ Optical reflectivity: allowing material optical reflectivity determination and providing entry data for determination of real and imaginary parts of dielectric constant (e.g. by Kramers-Kronig relations or fitting to the experiment) in cubic and anisotropic materials
- ✓ Light scattering: providing entry data for roughness determination and optical slope errors

How to measure:

- ✓ Optical transmission and related absorption coefficient can be obtained in a variety of modes, incidence geometries and polarization state in the photon energy range covered by BABE including:
  - Transmission set up (Lambert's law), suitable for thin self standing samples or gases
  - Electron emission (Total Electron Yield, Partial Electron Yield, Auger Yield) for solid samples (and surfaces)
  - Photon Yield (Total Optical Luminescence Yield, Energy Resolved Optical Luminescence Yield, Total Fluorescence Yield, Energy Resolved Fluorescence Yield) for solid samples (and surfaces)

  Codes for analysis of anisotropic materials transmission can be provided

- ✓ Optical reflectivity together with access to material optical constants can be obtained in a variety of modes, incidence geometries and polarization state in the photon energy range covered by BABE
  Detection of incident and reflected light can be accomplished by photodiodes or electron multiplier detectors

- ✓ Diffuse reflectivity – Light scattering providing access to surface roughness and slope errors in the photon energy range covered by BABE including rocking scan and detector scan modes with a typical wave vector resolution of the order of 10^{-2} nm^{-1}.
  Light detection is accomplished by photodiodes or electron multipliers, custom detection systems – e.g. by CCD detector – can be considered

Installation 4: *Optical metrology**

BABE in terms of instrumentation and related spectroscopic capabilities can be directly exploited to obtain calibration data and characterization of optical elements and optical devices the offer includes:

- specular reflectivity of mirrors
- roughness and slope errors of optical surfaces
- transmission of filters
- grating calibration
- detector calibration
- scintillators calibration
- gas absorption coefficient of gases and absorption cross section
- materials photon yield in emitted photons per solid angle and per incident photon
- materials electron yield in emitted electrons per solid angle and per incident photon

* Only related to development of instrumentation in the framework of AHEAD 2020 activities