Beamline 8: Infrared spectroscopy

08

Potential Research Fields

Life sciences

- Biological research and drug design
- Biotechnology and bio-sensors
- Biomedical and medical imaging

Physical sciences

- Sustainable environment
- Forensics
- Advanced materials
  - Functional polymers
  - Ceramics
  - Nanomaterials and composites
  - Micro-electronic and magnetic materials
  - Biomaterials
- Mineral exploration and beneficiation
- Earth sciences
- Oil and gas production and distribution
- Food technology
- Chemical reactions and catalysts

Introduction

This beamline will cover the infrared spectrum. The absorption of near infrared light by samples provides information about the chemistry and structure of materials in a non-contacting, non-destructive manner by probing the molecular vibrations.

Developments in Fourier Transform (FT) techniques in the latter part of the twentieth century led to the introduction of infrared microscopy and very high resolution instruments.

Infrared vibrational spectroscopy is very widely used in Australia. Every reputable research or analytical laboratory (chemistry, physics, materials, biochemistry and microbiology) would possess an infrared system. Many industrial production facilities use the techniques for quality control.

Advantages of a Synchrotron Source

Laboratory based instruments are driven by black body sources such as globar. Synchrotron light, which is highly collimated, polarised, tunable and much more intense (at least 100 times more intense), will vastly increase the potential of the techniques, especially in microspectroscopy, in the far infrared and at high resolution. Time-dependent studies of fast reactions will be possible, higher spatial resolution of three-dimensional images can be obtained, and it will be possible to image biological cells chemically without using fluorescent tagging.

The high intensity will enable very fast throughput of large numbers of mineralogical samples.

Australian User Community

Infrared spectroscopy is a relatively new technique for a synchrotron – the first line was built at the National Synchrotron Light Source, Brookhaven, USA, in 1994. Demand from US researchers has been heavy, and access to the beamlines for non-US researchers has been minimal, so there has been very limited opportunity for Australian researchers to gain experience in this field to date.

Initial biospectroscopic studies using infrared by Australian scientists were carried out at SRS (Daresbury, UK). Access has recently become available for Australian researchers to the SRRC (Taiwan) through the Australian Synchrotron Research Program, and this will stimulate the growth of the user community.

A Synchrotron Radiation Infrared (SRIR) Users Group has been formed in Australia. The range of interests represented by members of the SRIR Users Group is very wide. The current membership comprises 15% industry, 25% Australian Government institutions, and 60% universities and academic research institutions. A relatively large proportion of the academic research is also industry related.

Interest has also been expressed by a number of researchers from New Zealand and the size of the SRIR User Group is expected to grow. Based on the ASRP and overseas experience, it is anticipated that the user base could be more than 200 by 2007. This beamline is thus the start of what should be an extended program.

Research Applications

When combined with other synchrotron techniques, particularly diffraction, vibrational spectroscopy is highly effective for characterising the structure, composition and state of samples – from minerals through to biological tissue.

In Australia infrared spectroscopy and microspectroscopy are used in:

- geology and mineralogy – detection of mineral species without complicated specimen preparation, separation of real from artificial diamonds, studies of inclusions in gemstones
- environmental science – identification of the contents of aerosol and steam-flow filters, studies of combustion processes, atmospheric monitoring, exhaust gas monitoring
- biology – monitoring the uptake of drugs into cellular structures, in particular anti-cancer drugs; identification of tumours; following in real time the conformational changes of proteins (this complements protein crystallography studies)
- medicine – monitoring and researching biopolymers and implants
- beer and wine production – understanding the subtleties of yeast and fermentation
- materials science – in situ studies of corrosion at surfaces, development of materials to protect metal surfaces, studies of aging mechanisms in high performance polymers and fibres
- national security – identification of drugs (recreational and narcotic) from police raids and/or customs
- forensic science – study of fibres, dyes, paints, pigments and gunshot residue; measuring the rate of aging of fibres to establish the time of a crime
- museums and the National Trust – in situ studies of antiques (e.g. paintings, manuscripts, textiles and statues), studies of inks to understand how best to store manuscripts or identify fakes, measuring the degradation of film and photo negatives
- semiconductor physics – band-gap studies of new classes of semiconductor materials and large scale deficiencies in the manufacturing process
- engineering – study of the build-up of deposits on pistons in engines.

Beamline Design

A very wide range of techniques and applications can be met with the Infrared Spectroscopy Beamline, which will provide users with access to:

- infrared (IR) microscopy to the diffraction limit
- confocal IR imaging of biological samples, composite materials and surfaces
- high resolution gas-phase spectroscopy.

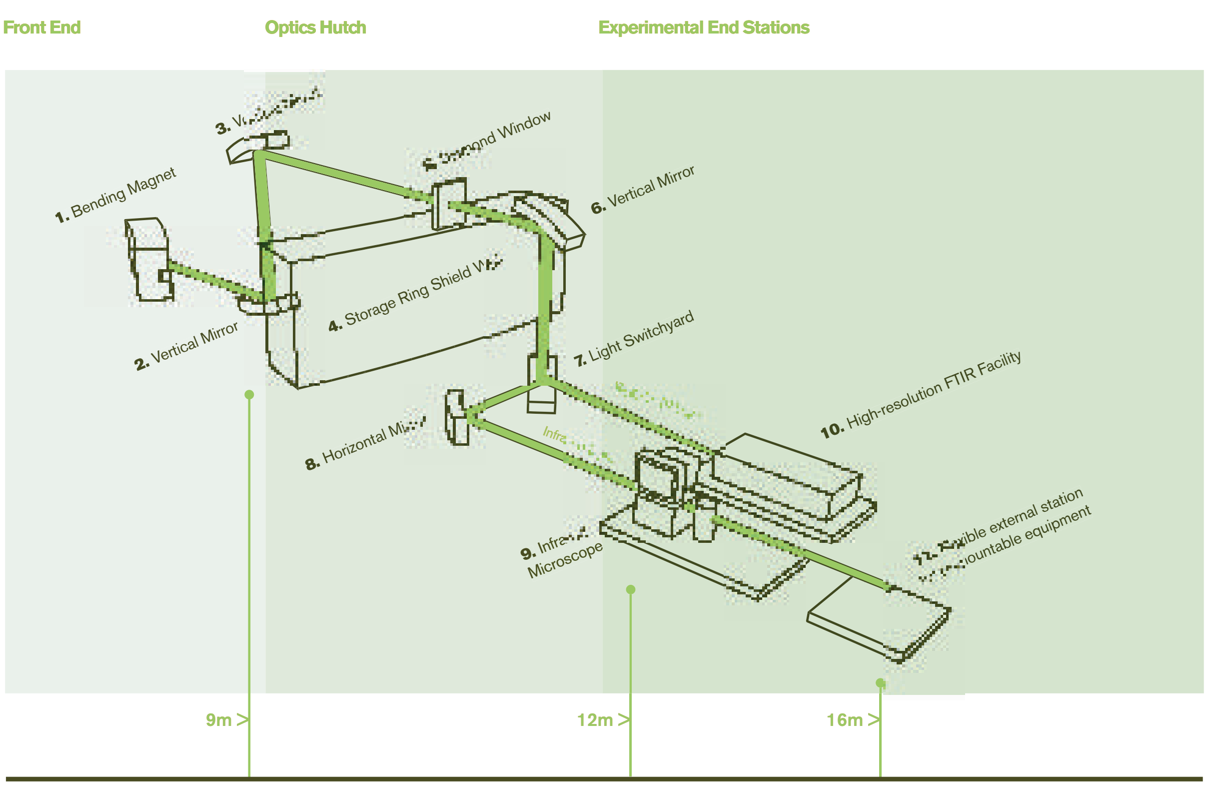

Figure BL8.1. *Schematic of the infrared spectroscopy beamline*

At least two beamlines will be required to satisfy eventual user demand. The first beamline will be designed for mid IR microscopy and high resolution spectroscopy. The second line, to be built later and not included in the initial suite of beamlines, should be for further IR microscopy and also specialised for terahertz (THz) technology. Because it is anticipated that the use of synchrotron-based infrared spectroscopy will grow dramatically, a third window will be reserved for later.

The first beamline will be designed to accommodate conventional commercially available FT spectrometers based on Michelson-Morley interferometers, to scan the spectrum of absorbed radiation from samples under test.

The photon source for the beamline will be from a bending magnet and cover the energy range from 0.001 to 1 eV, 2–10,000 cm^{-1}. The flux will be the maximum possible. This involves collecting as large an angular beam spread as possible from the dipoles – apertures of 70×17 $mrad^2$ are envisaged.

The exit window will be diamond, and the first mirror will be water-cooled silicon carbide. This mirror will be as close as possible to the exit aperture of the storage ring and within the radiation shielding walls. It should reflect the light upwards, to be reflected again along an evacuated beamline. It will have a facility for beam splitting and will feed two large dust-free end stations.

The hutches will be set up to give maximum flexibility in the types of experiments that can be undertaken. Provision will be made for spectrometers to be moved to the beam ports as required, and it will be possible for researchers to bring in specialised equipment.

It is envisaged that the second beamline will make use of electron beam binding techniques in the ring to maximise THz radiation.

Beamline 8 – Infrared Spectroscopy	
Source	Bending magnet
Energy range	0.001–1 eV (2–10,000 cm^{-1})