IR Spectroscopy and Microscopy Beamlines at the CLS

CLS-IR-lines.doc (5-Sep00)

National Coordinator: T.H. Ellis, Université de Montréal

Members of the Canadian infrared spectroscopy community are planning to develop a high-level infrared spectroscopy facility at the Canadian Light Source, to be known as the Canadian Consortium for Synchrotron InfraRed Spectroscopy (C^2SIRS). The purpose of C^2SIRS is to provide a comprehensive facility to perform spectroscopic experiments using synchrotron IR radiation which will be easily accessible to the entire Canadian spectroscopy community. In light of the national character of the facility, the beamline teams have representation from the three major spectroscopic communities; academic, industrial and government.

One beamline will be devoted to far-IR and high resolution experiments. It is led by NRC-SIMS, in conjunction with a large number of academic labs. Here, we have a unique opportunity to build the world's finest facility of this type. This is partly because we are the first third generation facility to design IR beamlines from the earliest stages of the project. In addition, Canada has one of the world's strongest IR communities, with an established international reputation dating back to Herzberg and Polanyi. The team that will build this beamline is well placed to put Canada in a leading position in this "final frontier" for IR spectroscopy.

Two other beamlines will specialize in mid-IR microscopy. One microscope will be primarily for academic users and government laboratories. The NRC Institute for Biodiagnostics, the University of Manitoba, the Université de Montréal and the CLS are the key players at present. A team of three researchers from the NRC, NRCan and Nortel Networks will manage the other microscope. Each of these individuals currently runs an analysis facility that serves both in-house needs as well as external clients on a fee-for-service basis.

IR-1: A Far IR Beamliine for High-Resolution Spectroscopy.

Coordinator: A.R.W. McKellar, Steacie Institute for Molecular Sciences, NRCC

Far infrared light, with wavelengths around 0.1 mm, lies between the visible/infrared regions on one side, and the radio/microwave regions on the other side. In many ways, the far infrared (FIR) region is a sort of <u>last frontier</u> for scientists, because measurements here are considerably more difficult than at longer or shorter wavelengths. There are a number of reasons for these difficulties, including the weakness of ordinary ("hot body") sources of FIR light, the lack of practical lasers in this region, and difficulties with detectors for FIR. The CLS can provide FIR light that is <u>100 times brighter</u>, compared to other sources.

Studies of gases with the CLS far infrared beamline will help answer the following questions. How does energy flow among different parts of a molecule? What is the nature of the weak attractive forces that exist among atoms and molecules? How do metal atoms bond to other chemical groups? What are the structures of long carbon chain molecules, and why do astronomers find so many of them in outer space? Studies of tiny samples of liquids and solids at extremely high pressures (equivalent to millions of atmospheres) will help to probe the conditions of matter at the center of the earth and other planets. And infrared studies of surfaces and other interfaces with high spatial precision will be valuable in the development of miniaturized sensors for optoelectronic and biochemical applications.

IR-2: A Fee-for-Service IR Microscope

Coordinator: Farid Bensebaa, ICPET, NRCC

The infrared spectrum of most materials is one of the most highly characteristic properties of that material. This, combined with the fact that samples in any form may be analysed, has led to IR spectroscopy becoming one of the most powerful analytical techniques available. One problem that is encountered in IR studies of some materials is poor quality of data, due to the small size of the sample or to intrinsic limitations in the method of data acquisition used. Data can be improved by using a much more intense source of infrared light. This may be achieved in practice by using the infrared light that is generated by a synchrotron. This light is about 100 times brighter than the light that is used in standard laboratory experiments. The result of this is that much smaller samples can be analysed.

The practical advantages of being able to analyse very small samples, or small areas of larger samples, are many and varied. Applications range from semiconductor analysis to art conservation. For example, it means that small impurities on the surfaces of materials such a semiconductors can be detected, which helps in quality control of microelectronics. It also allows difficult materials such as clay, which are composed of very small particles, to be studied. In the field of art conservation, it allows tiny fragments of important artefacts (documents, books, paintings, statues) to be examined to assess the state of the artifact, for example before, during and after cleaning.

The proposed beamline will be used by a wide variety of industrial, government and academic.

IR-3: Biological Microscopy

Coordinator: Mike Jackson, Institute for Biodiagnostics, NRCC

For complex samples such as human tissues, the wavelengths of light absorbed by a sample i.e. its infrared spectrum, provides a direct indication of sample biochemistry. In essence, it is a biochemical fingerprint. With the correct choice of sampling methodology (usually an infrared microscope) information on the biochemical nature of disease states can be obtained from tissue samples, information which can often be useful diagnostically. Variations in spectral signatures arising from nucleic acids, proteins and lipids can provide important information in a number of disease states.

With traditional instrumentation, samples of 20 μm or greater must be analysed, meaning that spectra are acquired from groups of cells within tissues, rather than individual cells. Spectra may therefore represent an average of normal and abnormal cells. Using a synchrotron as the source of the infrared light, spectra may be acquired from samples as small as 5 μm, allowing studies of tissues to be conducted on single cells. The potential applications of this technique are enormous. For example, it will allow the molecular nature of a number of forms of cancer and Alzheimer's disease to be probed. Equally important, it will allow the interaction of new drugs with individual human cells to be studied, providing a new method for assessing the effectiveness of these agents.

IR-0: Canadian Membership in U10B Beamline at Brookhaven NSLS

Coordinator: K. Gough, University of Manitoba

A memorandum of understanding (MOU) between the CLS and the U10B IR beamline at NSLS, Brookhaven was signed in March 2000, making the CLS a member of the U10B Participating Research Team (PRT). This line, which is equipped with a Nicolet 860 FTIR and a Spectra-Tech Continuum microscope for near- mid- and far-IR microspectroscopy, is operational 24 hours a day. Research support at the NSLS site will include an infrared expert from CLS, as one of the beamline management team. In return, the CLS is allocated 20% of the available IR beam time, to be shared among members of C^2SIRS.

There are numerous advantages to the CLS participation in this PRT. The CLS on-site employee will be available to assist in experiment design and can run experiments on samples that are sent down. We are guaranteed a significant amount of access time and can develop our research programs to actively incorporate the use of synchrotron IR. NSLS currently has six operational IR beamlines, supporting programs in such diverse fields as biological microspectroscopy, solid state physics, time-resolved spectroscopy, surface physics, geophysics, materials at extreme pressures, and extreme far IR. Further information about the beamlines may be found at their web site: http://infrared.nsls.bnl.gov/. While the MOU applies only to the U10B beamline, there is ample opportunity for Canadian scientists to explore research applications and techniques with their experts. In the years prior to the CLS start-up in Saskatoon, Canadian scientists will have ready access to a world-class facility and will acquire expertise that will carry over to the CLS.