



Synchrotron Radiation: The Most Versatile Spectroscopic Source

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As a B.Sc. and M.Sc. chemistry student at the University of Manitoba, I was fascinated by experiments involving spectroscopic measurements that characterize (or determine) the atomic and electronic structure of chemical compounds. I was especially interested in the theory of spectroscopy, although I had very little theoretical background.

In 1963, while looking for a topic and place for my Ph.D., I stumbled across the first book on a new form of spectroscopy known as “Mössbauer Spectroscopy,” named after Rudolph Mössbauer, the German physicist who discovered it by accident in 1957 and won the Nobel prize in physics shortly after. I was hooked.

From that day on, I became very interested in this new spectroscopy, which used gamma rays from radioactive sources such as ^{57}Co (cobalt) or ^{119}Sn (tin). After a Shell Scholarship enabled me to study at the University of Cambridge, I contacted an old friend, Ian Smith (who began his Ph.D. studies at Cambridge in 1962) about possible research opportunities at Cambridge. Fortuitously, he found out that a chemistry department radiochemist, Dr. A.G. Maddock, had an opening. And as luck would have it, he was planning to build a Mössbauer spectrometer. It appeared that I had ended up in the right place at the right time.

Dr. Maddock welcomed me to his group in October 1964. And in my first week at Cambridge, he scribbled down on the back of an envelope what he considered would be the important components of this new Mössbauer spectrometer. I had my first mission. Fortunately, with a lot of help from the electronics shop at the chemistry department, I was able to get an automated spectrometer working well in about six months. Since it was a novel technique, several chemists and mineralogists soon became very interested in characterizing iron-containing chemicals and minerals using this spectroscopy. It was the beginning of several very productive collaborations.

And it is exactly this type of research with my collaborative partners that initiated a valuable strategy that I still follow today: collaborative research in several different scientific fields, with both very basic components (including simple theory) and very applied components. For example, with any new spectroscopy there are opportunities to develop the spectroscopic method—by discovering new phenomena and devising simple theories to explain and predict both the new features (peaks) and the previously known features. A good understanding of spectroscopy can then be applied to gain an enhanced understanding in both basic and applied research areas. I have always felt strongly that it is possible to do outstanding basic and applied research, and that one enhances the other.

After my stint at Cambridge, I returned to Canada in 1970 and headed to the University of Western Ontario (UWO) where I set up an active chemistry and mineralogy program

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using Mössbauer spectroscopy. But new challenges were looming. I wanted to begin research in another novel form of spectroscopy, photoelectron spectroscopy, which had been developed in the 1960s mainly by groups at Uppsala University in Sweden and Oxford University in England.

With support from the National Research Council (NRC) and the Department of Chemistry at UWO (and with groups from the University of Toronto and Windsor involved in a Southwestern Ontario consortium), in 1972 I purchased a photoelectron spectrometer for research using far ultraviolet and X-ray photons. This newest instrument supported a very diverse program of investigation—from the observation and characterization of a new effect in the spectra (the ligand field splitting); to determining the order of molecular orbitals in organic and organometallic molecules; to the absorption of metals on minerals; to applied industrial surface science, with support from a number of steel companies.

Towards the Canadian Synchrotron

In 1973-74 a Canadian synchrotron facility was first proposed by Bill McGowan, Director of the Centre for Chemical Physics at the University of Western Ontario. Synchrotron radiation (SR) or synchrotron light (SL) (an intense, focussed source of radiation covering over one-half of the electromagnetic spectrum from the far infrared (IR) through the IR, visible and ultraviolet (UV) to the soft and hard X-ray region) is produced when high-energy electrons are bent in a magnetic field.

Why did SL excite me to the extent that it did? That's because it was apparent that I could do much better photoelectron spectroscopy experiments with SL than with laboratory sources of radiation. I was able to conduct preliminary experiments in 1975 at the small Tantalus Laboratory at the University of Wisconsin outside Madison, Wisconsin, followed by a six-month sabbatical there. Even with this small low-energy synchrotron, I saw the amazing possibilities of SL for research in many areas.

In 1979, with funding from the Natural Sciences and Engineering Research Council (NSERC) and the NRC, and with great support from UWO, I was able to establish a soft X-ray beamline at the Tantalus synchrotron (and later the Aladdin synchrotron) at the University of Wisconsin. The Canadian Synchrotron Radiation Facility (CSRF) was formed. With further funding from Materials and Manufacturing Ontario and NSERC, the CSRF now includes three soft X-ray beamlines (covering the energy range 20 eV to 4000 eV). It has produced some 40 reviewed publications per year over the last decade from a diverse Canadian user community—mainly from chemistry, geology, and physics departments.

I have spent the past 22 years using synchrotron radiation in the far UV and soft X-ray region in many different basic and applied research areas. Numerous M.Sc. and Ph.D. students, postdoctoral fellows, and research scientists have routinely travelled 10 hours by car from London, Ontario, to the CSRF outside Madison to do their research, often working 20-hour days for two to three weeks at a time. Using techniques such as high resolution photoelectron, Auger and absorption spectroscopies, their research has spanned a number of diverse areas of chemistry, physics, geology, and tribology.

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Over 150 research papers and several large reviews have been published on this research in the last 20 years in international chemistry, physics, geology, and engineering journals. I am particularly grateful to the management of the Synchrotron Radiation Center (SRC) in Madison, Wisconsin, for enabling us to build beamlines at the SRC (often with a great deal of help from their employees), and for allowing us to use the synchrotron beams for no charge over 20 years. This has been an incredible gesture of international collegiality. We must also recognize the impressive work of the UWO employees permanently at the CSRF over the years (Kim Tan, Brian Yates, B.X. Yang, X.H. Feng, Emil Hallin, Greg Retzlaff, and Y.F. Hu) who have been central to the success of the CSRF.

With the formation of the Canadian Institute for Synchrotron Radiation (CISR) in 1990, the science community once again began concerted lobbying to fund a Canadian national synchrotron facility. After a great deal of effort by many people (particularly Dennis Skopik, George Ivany, Dennis Johnson, and their team at the University of Saskatchewan), on March 31, 1999, it was announced that the Canada Foundation for Innovation would provide 40 percent (\$56.4 million) of the cost of the Canadian Light Source (CLS) project at the University of Saskatchewan. As the news release at the time said, "the CLS represents an unprecedented level of collaboration among governments, universities, and industry in Canada." In addition to the University of Saskatchewan, 18 Canadian universities endorsed the CLS project on behalf of the 300 users (at that time) of synchrotron light in Canada. After 25 years of promoting SL and a Canadian synchrotron, I was thrilled that this facility would finally be constructed.

The Canadian Light Source—the most versatile spectroscopic source

The Canadian Light Source is the largest scientific project—both in size and cost—in Canada in at least the past 30 years. CLS Inc. (CLSI) has been incorporated as a not-for-profit corporation, wholly owned by the University of Saskatchewan, to carry out national mandates in synchrotron research and development.

Due to strategic planning by the University of Saskatchewan, and the tremendous efforts of a dedicated CLS staff and many academic users, the progress in the past three years has been quite remarkable. The immense new building (84 metres by 83 metres in area, and 20 metres high at the centre) was opened on time and on budget on February 26, 2001.

The storage ring and at least six beamlines at the CLS are expected to be operating by 2004. Numerous projects are already planned, and each beamline will have an important and unique purpose.

In addition to the research projects underway and in development at the CLS, groups have been forming to initiate unique medical research that could one day have a significant impact on our ability to diagnose and treat disease. For example, a medical research and imaging beamline and a MEMS (micro-electrical mechanical systems)/lithography beamline are under consideration. And at workshops in Saskatoon, Professor J. Chikawa from Spring-8 in Japan, and Professor W. Thomlinson from ESRF in Grenoble, France, showed remarkable improvements in imaging techniques

Synchrotron Radiation: The Most Versatile Spectroscopic Source

for angiography, mammography, and bronchiography. The latter two techniques show great promise for early detection of breast cancer and lung cancer.

By 2015, we expect the mature CLS facility to be operating with 25 to 30 beamlines. It will also have about 100 scientists in almost every scientific discipline, and from practically every point on the globe, all working on the CLS floor together one day; it is expected that the facility will host close to 2000 users in one year. Watching all this unfold, it gives me great satisfaction to know that not only will the interdisciplinary research on the CLS floor lead to important basic and industrial research, with significant industrial spin offs, it will also demonstrate the value of team work and collaboration to help achieve extraordinary goals. And that is a lesson I learned at the University of Cambridge almost 40 years ago.