9

High Resolution Spherical Grating Monochromator Beamline

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Principal Contacts

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Beamline Overview

Status	Approved and funded as of December 31, 2001
Source	Linear undulator
Monochromator	Variable line spacing plane grating
Spectral range:	
Grating 1	200–350 eV
Grating 2	250–700 eV
Grating 3	650–1900 eV
Flux	10^{12} photons/s/100 mA
Brilliance	10^{16} photons/mm^2/mrad^2/ 0.1% bandwidth
Resolving power	10^4
Spot size	1 × 1 mm

Science

Photoemission and photoabsorption studies

The Spherical Grating Monochromator (SGM) beamline was commissioned in 1999 at the Canadian Synchrotron Radiation Facility (CSRF, U. of Wisconsin-Madison, WI) with a limited photon energy range (230–700 eV, using only one grating) and low flux (~10^9 photons/sec). Nonetheless, it has yielded some very remarkable results.

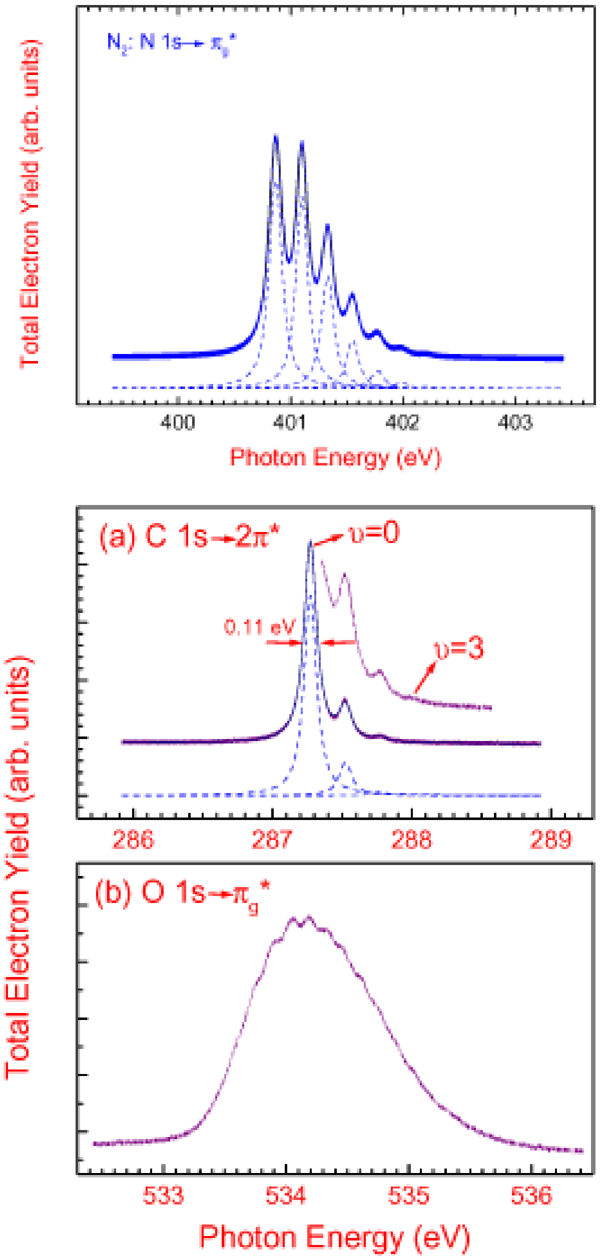

Figure 9·1 *Spectra recorded with the SGM at the CSRF (SRC). Top figure: the Nitrogen 1s absorption spectrum of* N_2*. Middle figure: the carbon 1s spectrum of CO. Bottom figure: the oxygen 1s spectrum of CO.*

At the CLS, the SGM will be the primary beamline for high-resolution spectroscopy in the VUV and soft X-ray range. Three gratings on the SGM will provide high resolution and high flux from 200 to 1900 eV. For several reasons, this is an important energy range for both photoelectron spectroscopy of core levels and absorption spectroscopy of many core and shallow core levels.

Many core levels in this range have relatively long lifetimes, and hence exhibit very narrow linewidths. For example, the L_{23} core levels of elements from sodium to chlorine (30–290 eV binding energy) have natural linewidths of 0.001 to 0.08 eV. The 2p core level natural linewidths for the 3d metals are 0.1 eV (Ti) to 0.4 eV (Cu). With instrumentation producing photon energy widths comparable to or significantly smaller than natural linewidths, high-resolution photoemission techniques can provide extremely detailed chemical analysis. At the existing SGM, the photon resolution is 0.04 eV at 400 eV photon energy with a resolving power of 10 000, as shown by gas phase spectroscopy (see Figure 9·1).

In addition, the photoabsorption/ionization cross-section is very element and photon-energy sensitive. The variable photon energy photoemission of the valence band and core levels provides both elemental identification and chemical information. Analytical selectivity can be had through cross-section optimization. For example, selecting a photon energy at the Cooper minimum for the substrate will minimize the substrate contribution to the photoemission and enhance sensitivity to surface components.

Photoabsorption and resonance spectroscopy of C, N, O and first-row transition elements.

The SGM is well suited for absorption spectroscopy studies of materials containing elements with a low atomic number, such as carbon, nitrogen and oxygen and first row transition metals. At the SRC, the SGM beamline has been used to produce exciting X-ray absorption results on carbon nanotubes, nanowires, nanodiamonds,

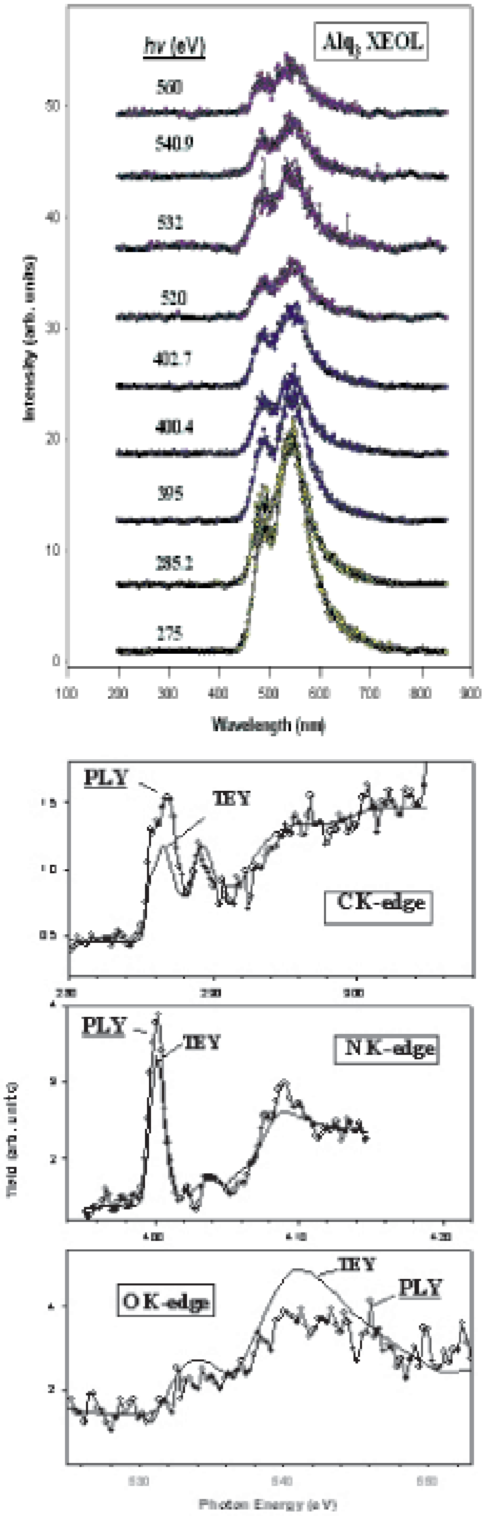

Figure 9·2 *Upper figure: photoluminescence spectra of Alq_3 at selected excitation energies. Lower figure: carbon, nitrogen and oxygen K-edge XANES showing photoluminescence yield (PLY) and total electron yield (TEY). Enhancement occurs at excitation channels coupled to the luminescence chromophore. [Naftel et al.* Appl. Phys. Lett. ***2001,*** 78, *1847.]*

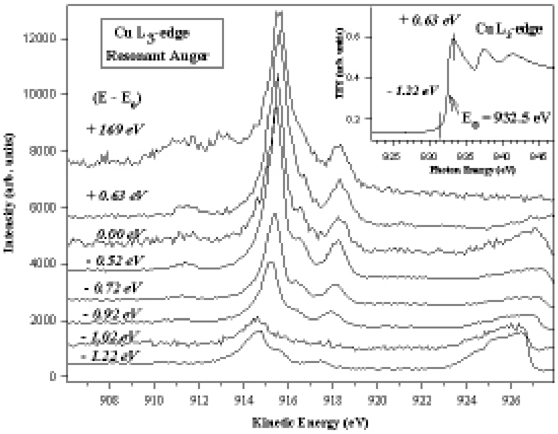

Figure 9·3 *Resonant Auger effects observed at the Cu L_3 absorption edge. Inset figure: the Cu L_3 absorption edge.*

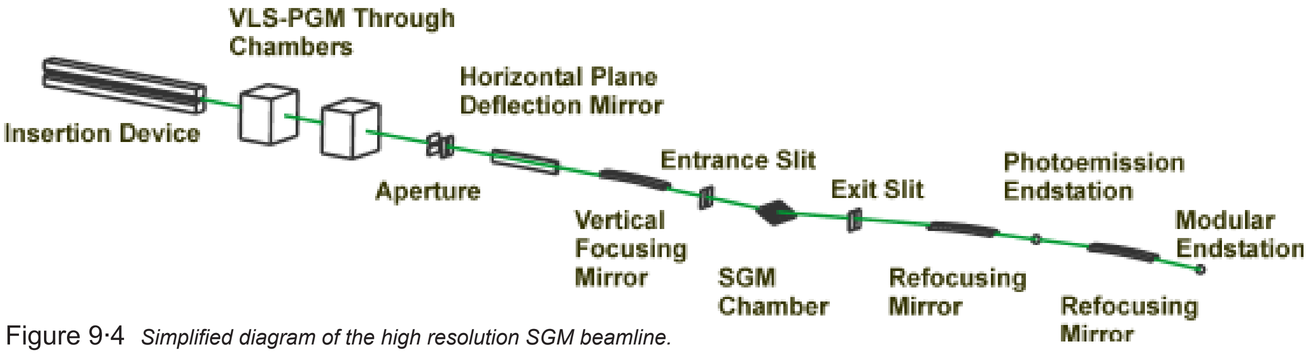

Figure 9·4 *Simplified diagram of the high resolution SGM beamline.*

organic light-emitting films and devices, and biological samples. Gas-phase mass spectrometry and coincidence experiments have been carried out for a number of molecules. Of particular interest is the SGM's capability for resonance spectroscopy at core-level thresholds using Auger, optical luminescence, and ion-electron coincidence detection modes. Figure 9·2 is an example of the latter type of study, in which photoluminescence of tris(8-hydroxyquinoline)aluminum, or Alq_3 (an organic light-emitting-diode material), is compared to electron yield XANES.

Investigating the narrow and information-rich L_{23} edges of 3d transition elements is one of the design objectives for the upgrade of the SGM beamline; this capability will be implemented at the CLS. High resolution and high flux will allow the recording of resonant Auger spectra for the study of electronic structure and core-hole decay dynamics. XANES with sub-natural linewidths obtained

Table 9·1 SGM beamline design and research planning team

Role	Name and e-mail address	Institution	Experience
Beamline Implementation Leader; Staff Scientist	Ian Coulthard ian.coulthard@lightsource.ca	CLS	VUV spectroscopy; instrumentation (SRC, APS)
Consultant, optics and duplexing	Kim Tan ktan2@facstaff.wisc.edu	CSRF	VUV optics; instrumentation (SRC)
Consultant, optics and duplexing	Ruben Reininger ruben@sas-rr.com	Scientific Answers & Solutions (SAS)	VUV optics (SRC, BESSY)
CLS Beamlines Manager	Emil Hallin emil.hallin@lightsource.ca	CLS	Instrumentation; CLS Work Package #6 leader (SAL, SRC, APS)
Beamline Team Leader	T. K. Sham sham@uwo.ca	UWO	Photoemission (SRC, APS, UVSOR, NSLS)
ID design and implementation	Ingvar Blomqvist ingvar.blomqvist@lightsource.ca	CLS	Danfysik; insertion devices
Endstation design and implementation	Yongfeng Hu yhu@uwo.ca	CSRF	VUV; soft X-ray operation (SRC, MAX II, APS)
Consultant, industrial application	Jeff Cutler jeffrey.cutler@lightsource.ca	CLS	Photoelectron spectroscopy; industrial applications (SRC)
Consultant, technical support	Astrid Jürgensen ajurgens@src.wisc.edu	CSRF	Photoelectron spectroscopy; XAFS (SRC, APS)
Ray tracing, optics evaluation	Brian Yates brian.yates@lightsource.ca	CLS	Beamline instrumentation (SRC)
Consultant, frontend and FOE	De-Tong Jiang detong.jiang@lightsource.ca	CLS	XAFS; reflectivity (APS, SRC, SSRL, NSLS)
Consultant, industrial application	Stewart McIntyre smcintyre@uwo.ca	UWO	Director of Surface Science Western
Consultant	Mike Bancroft mike.bancroft@lightsource.ca	UWO; CLS	Photoelectron spectroscopy (SRC); Past Director of the CLS

in this mode will provide enhanced chemical sensitivity that can be used to explore the unoccupied densities of states above the Fermi level. Representative resonant Auger spectra recorded with a similar SGM at the APS are shown in Figure 9·3 to illustrate this approach.

The 3d transition elements play a very important role in construction materials, catalysts, magnetic materials and other industrial applications. They also play a vital role in biological systems. The high-flux, high-resolution soft X-ray capabilities of the SGM beamline will provide unprecedented opportunities for rapid analysis of such materials. In addition, linear polarization of the undulator can be employed for magnetic linear dichroism studies.

Aluminum and Silicon K-edge spectroscopy

With an upper energy of 1900 eV, this beamline provides high-resolution photons with good throughput for studies of the K-edge near-edge structure of Al and Si, which are technologically important elements. In the 1500–2000 eV range, the resolution of a grating monochromator surpasses that of InSb (111), allowing for high-resolution photoemission and resonance studies. Fast analysis of industrial samples containing Al and Si (such as zeolites and related materials) will be possible.

Table 9·2 CSRF users and potential SGM beamline team members

Canadian Light Source, SK	I. Coulthard; J. Cutler; E. Hallin
Dalhousie University, NS	M. A. White
U. of Guelph, ON	J. Lipkowski
INRS, QC	D. Guay
NRC, ON	R. Boukherroub; J. Gupta; J. S. Tse
Simon Fraser University, BC	E. D. Crozier
U. of Alberta, AB	R. Cavell
U. of Saskatchewan, SK	K. Mitchell; S. Urquhart; A. Moews; R. Sammynaiken
U. of Toronto, ON	G. S. Hendersen; Z.-H. Lu
U. of British Columbia, BC	G. Sawatzky; T. Tiedje
U. of New Brunswick, NB	J. Neville
U. of Western Ontario, ON	G. M. Bancroft; M. Fleet; M. Kasrai; R. Martin; N. S. McIntyre; W. Nesbitt; T. K. Sham; M. J. Stillman
U. of Waterloo, ON	T. Leung

Layout and Performance

A simplified diagram of the SGM beamline layout is presented in Figure 9·4. The SGM beamline will span the energy range of 200–1900 eV with three gratings (300 lines/mm, 600 lines/mm, and 1200 lines/mm). It will deliver a flux of ~10^{11} photons/sec (at 100 mA) through 10 × 10 µm slits with a resolving power ($E/\Delta E$) of 3000.

The SGM will be a CLS facility beamline, suitable for both academic and industrial research programs. It will be a state-of-the-art, high-brightness, and high-resolution instrument for VUV spectroscopy (photoemission, photoabsorption, and related phenomena) of solids and surfaces. It will provide light to a fixed, high-performance experimental station equipped with a Scienta SES100 hemispherical electron energy analyzer for photoemission studies. The endstation will be equipped with a preparation chamber and a rapid-turnaround sample transfer system. X-ray absorption MCD (magnetic circular dichroism) and MLD (magnetic linear dichroism) capabilities for 3d metals will also be implemented.

A second in-line endstation location is planned for the SGM. This location will be modular to accommodate a variety of endstations. In Chapter 8, Table 8·1 lists the instrumentation currently operating at the CSRF that will use the second SGM endstation location.

Beamline Team and Design Team

Table 9·1 summarizes the beamline design team and core beamline team members involved in establishing endstation and beamline properties. Table 9·2 lists scientists currently working at the CSRF facility at the University of Wisocnsin-Madison; many of these will be users of the SGM beamline at the CLS. Table 9·3 lists the current milestones for the SGM project.

Table 9·3 SGM beamline milestones

July, 2001	Preliminary design
September, 2001	External review report
November, 2001	BT meeting to discuss implementation strategy
January, 2004	Commissioning