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Section II. Synchrotron experiments

EXPERIMENTAL PROGRAM AT THE NATIONAL BUREAU OF STANDARDS SYNCHROTRON ULTRAVIOLET RADIATION FACILITY (SURF)

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New beamline development on SURF features toroidal grating instruments for Surface Science studies and Far UV photodiode calibration. The progress and capabilities of these lines will be discussed along with the developments on the high resolution normal incidence spectrometer beam line under construction by the University of Maryland. The ongoing programs in Surface Science and Photoelectron Spectroscopy will be briefly reviewed with a more detailed discussion of the latest results in calibration efforts using electron counting and the calculable spectral distribution of synchrotron radiation.

1. Introduction

The National Bureau of Standards (NBS) Synchrotron Ultraviolet Radiation Facility (SURF-II) is a dedicated radiation source which serves a wide range of NBS users and other groups from national laboratories, universities, and industries. The facility has monochromators which can be used to provide radiation from approximately 50 Å through the visible spectrum if desired. Two new toroidal grating monochromators have been constructed, one for use in NBS calibration activities and another for use in research efforts by the Surface Science Division at NBS and for gas phase photoabsorption and photoionization studies by the Far Ultraviolet Physics group. An additional new spectrometer, a 6.65 m radius of curvature normal incidence instrument, is being installed by the University of Maryland. This instrument will provide, for the first time, an extremely high resolution instrument at a US synchrotron facility. An intercomparison of the absolute radiometric scales obtained from synchrotron radiation, standard lamps, and silicon detectors was made to the 1% level. These results were obtained through a collaboration between the SURF staff and staff from the NBS radiometric Physics Division.

The activities of the SURF user groups and the

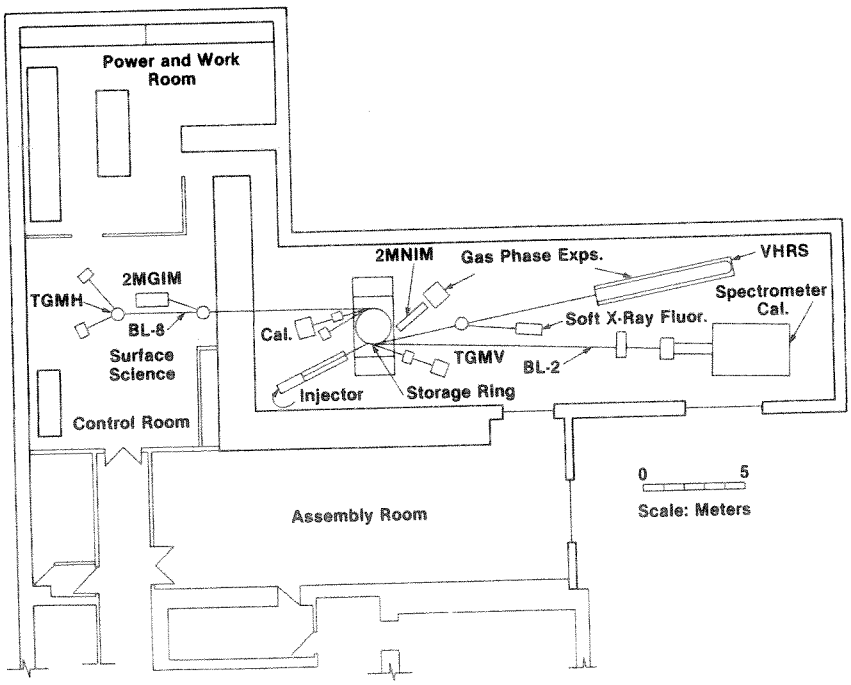

Fig. 1. This is a schematized layout of SURF and its associated space. The abbreviations are: TGMH – Toroidal grating monochromator horizontal dispersion; 2MGIM – 2 meter grazing incidence monochromator; Cal. – Diode calibration beamline; 2MNIM – 2 m normal incidence monochromator; TGMV-Toroidal grating monochromator vertical dispersion; VHRS – Very high resolution spectrograph.

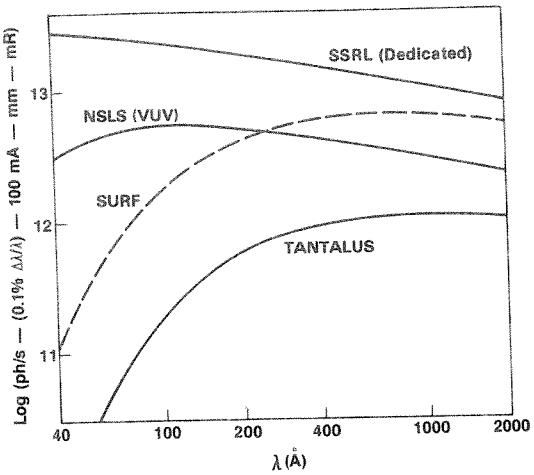

Fig. 2. Flux output of US VUV storage rings given in terms of spectral brightness i.e. photons/s per 0.1% bandpass per 100 mA of beam current per millimeter of beam height per horizontal milliradian. The beam height, h, used from each facility is as follows: SSRL $h = 0.2$ mm, NSLS $h = 0.4$ mm, SURF $h = 0.1$ mm, and TANTALUS $h = 0.5$ mm.

operations of the facility have been reported at previous gatherings of this conference and in the literature [1–5]. Several new beamlines have been added to the facility since the last report. These are: (1) installation of a very high resolution spectrometer (VHRS), (2) installation of a toroidal grating monochromator with vertical dispersion (TGMV), and (3) installation of a diode calibration beamline. Another beamline for soft X-ray fluorescence is under construction. The physical layout of the present SURF-II facility is shown in fig. 1. The facilities on beamline 8 (BL-8), the 2 m normal incidence beamline (2MNIM) and the spectrometer calibration facility, have been covered in previous talks and will only be discussed in a brief manner here.

Operating characteristics of the ring itself have undergone steady improvement with a new record beam of 103 mA achieved this past year. It is expected that a typical operating current of 40 to 60 mA can be maintained. Plans for machine improvement for the coming year include the installation of new, more powerful power supplies in the RF circuit which should result in realizable stored beam energies of 300 MeV.

One way to demonstrate the performance of SURF II is to compare its spectral output to other storage ring facilities in the US. Fig. 2 gives the spectral brightness (photon/s - 1% bandpass - 100 mA stored current - horizontal mrad - mm of vertical beam size). This is a useful comparison in that the spectral brightness of the source is a measure of the available light per unit size of an entrance slit for a vertically dispersing monochromator. This quantity is a direct figure of merit for evaluating the output characteristics of a monochromator. Inspection of the figure shows that SURF is a useful source of radiation in the 50–2000 Å range and above 400 Å is brighter than all other US facilities except SSRL.

2. Radiometric program

The circular nature of SURF's electron orbit enables one to accurately measure the bending radius, R, of the electron beam (accuracy of R is $\pm 0.1\%$). This quantity and the beam energy are required for a calculation of the spectral flux distribution per electron from theory [6]. If the current can be measured and the geometry is known, the absolute irradiance can be obtained. The results of such calculations are as indicated in fig. 2. Saloman et al. [7] have developed techniques which exploit the highly linear nature of a silicon photodiode and direct counting of $10–10^3$ stored electrons. As a consequence of the measured linear response of the diode, a photocurrent due to radiation from $10^8–10^9$ circulating (1–10 mA) electrons can be determined directly. This method results in the stored current being measured to an accuracy of better than 0.5%. The orbital radius, electron energy, and other parameters can be determined sufficiently accurately such that the combined uncertainty in spectral output is less than 2% in wavelength regions above 100 Å [9].

Over the past several years an effort between SURF staff and the NBS Radiometric Physics Division has resulted in an intercomparison between SURF and other NBS radiometric standards utilizing a silicon photodiode radiometer as a transfer. An absolute silicon photodiode is used in conjunction with a calibrated interference filter in an integrating sphere to produce a radiometer which is relatively insensitive to spatial distribution and coherence of the light directed upon it [10]. The radiometers, with filters, have a response centered at 6000 Å and have about a 100 Å bandpass. The intercomparisons between SURF-II and a set of spectral irradiance standard lamps [9] give agreement between SURF and these standards to within 1% which is within the individual uncertainties of SURF (2%) and the spectral irradiance scale (1.2%).

These results imply that SURF can be considered an absolute irradiance standard which covers a wide spectral range i.e. from 50 Å to the infrared region. This utility has been exploited for the past several years on beamline 2 (BL-2 in fig. 1) which contains the spectrometer calibration facility. This facility has a large (1.2 m × 1.2 m × 2.5 m) vacuum vessel which has an internal rotational mount and is externally displaceable in x and y in a plane perpendicular to the incident synchrotron beam. The geometry of the light beam is known and hence there is a calculable flux available for calibration purposes at the chamber. Angular and spatial dependence of the spectral response of spectrometers or other

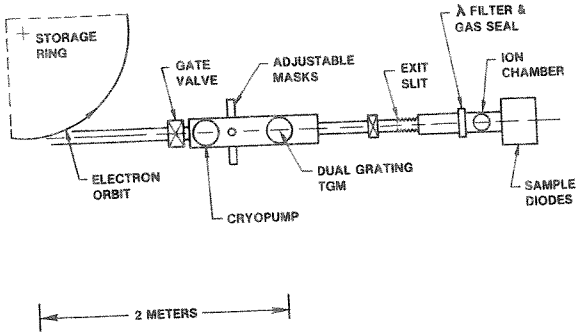

Fig. 3. Schematic of the NBS Far UV diode calibration system. (Cal. in fig. 1).

detection devices can be determined in this system [9,11].

A new monochromator for use in the NBS diode calibration program has been constructed and installed on beamline 9 (Cal. in fig. 1). This instrument is shown schematically in fig. 3. The monochromator is a vertically dispersing instrument which features a grating carriage holding two toroidal gratings. The short wavelength (1200 l/mm) grating is designed to have a bandpass less than 0.35 Å bandpass from 30 Å to 120 Å and the long wavelength grating (300 l/mm) is designed to have a bandpass of less than 2 Å from 120 to 500 Å. The large and small radii of the gratings are 1267 cm and 14.72 cm respectively. The exit slit is coupled optically to the ionization chamber by a capillary tube which, in addition to conducting the light, provides differential pumping for experiments having a gas load. There are provisions for internally calibrating the filter by introduction of additional filters just forward of the exit slit region. The filters provide gas isolation and order sorting functions. A double ion chamber provides an absolute flux monitor which is used to calibrate a standard diode. This diode is used in a separate measurement to calibrate the response of up to 5 transfer standard diodes. The calibrated diodes are of an aluminum photocathode type with a controlled growth oxide layer. The diodes are calibrated from 500 Å to 1200 Å using conventional laboratory light sources. When fully calibrated, the diodes serve as traceable standard detector for photon fluxes from 10^5 to at least 10^{11} photons/s. The upper flux limit is due to charging of the insulator surface (aluminum oxide). These diodes are available from the Far UV Physics Group at NBS for a nominal charge covering cost of fabrication and calibration. This facility and its operation is under the operational responsibility of L. Randall Canfield.

3. USER beamlines

Two major new installations are in progress: (a) the 6.65 m high resolution spectrometer on beamline 3 (VHRS in fig. 1) and (b) the toroidal grating vertically dispersing monochromator on Beamline 1 (TGMV in fig. 1). Also discussed briefly will be the instruments previously available, namely the 2 m normal incidence monochromator (2M NIM), the toroidal grating monochromator with horizontal dispersion (TGMH), and the 2.2 m grazing incidence monochromator (2 MGIM).

4. VHRS

This instrument, a vacuum 6.65 m vertically dispersing normal incidence spectrometer, is being installed by a user group headed by Marshall Ginter of the University of Maryland and Charles Brown of the Naval Research Laboratory. Fig. 4 shows a side view of the apparatus and its beamline connecting to SURF. The mirrors M_1, M_2, and M_3 are cylindrical mirrors and focus the storage ring on the entrance slit with an acceptance of 60 mrad horizontally and 6 mrad vertically of the storage ring light. The gratings will be made with high density rulings (3000–6000 l/mm). The resolving power of the instrument should be in the 100 000 to 200 000 range and the realizable bandpass for the high density gratings should be less than 0.01 Å with 10 μm slits. Due to the brightness of SURF, the light throughput of this instrument will be comparable to or even greater than if it had been installed at one of the large synchrotron sites.

The facility is to be used by a variety of user teams which will exploit its high resolution capability to study the absorption of small molecules, metal vapors and to study the effects of applied external fields on the absorption. Additional experiments using photoelectron spectroscopy and photoionization techniques will be developed.

5. TGMV

This facility, on beamline 1, consists of a toroidal grating monochromator which has been optimized for

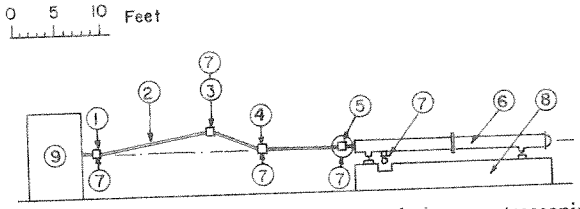

Fig. 4. Block diagram of the high resolution spectroscopic facility at SURF II. Indicated items are: (1) mirror box M_1 (2) beam transport and gas isolation line (3) mirror box M_2 (4) mirror box M_3 (5) spectrometer entrance slit housing (6) 6.65 m spectrometer (7) pumping station (8) base block (9) SURF magnet.

light flux and resolution in the wavelength region of 150 to 500 Å. It features moveable masks to effect resolution changes and unlike the calibration monochromator in fig. 3, this monochromator has only one grating installed at a time. The horizontal acceptance is 55 mrad which, with a 600 l/mm grating, gives a nominal bandpass of 3–4 Å. The moveable masks may be remotely set to select a higher resolution mode of operation with a corresponding loss of flux. The system operates in negative first order and is fully automated by a CAMAC based computer system.

The NBS surface science group consisting of Roger Stockbauer, Ted Madey, and Richard Kurtz will be the primary users of this station initially. Design of the system has provided flexibility to allow other types of experiments to be installed. There are plans to use this beamline by the gas phase photoelectron spectroscopy group at NBS as well as outside users.

6. 2MNIM

This instrument continues to be used for high resolution angular resolved photoelectron spectroscopy by an NBS-Argonne user group. A new high resolution photoelectron spectrometer has recently been installed and is reported on by Dehmer et al. in another paper in these Proceedings.

7. TGMH

The Surface Science division at NBS is the primary user of this toroidal grating monochromator. Their experiment is a study of photon stimulated desorption of surface atoms and molecules and they also employ variable wavelength photoemission as a probe of the surface condition. The scientific aspects of this program were reported on previously [1].

8. 2MGIM

This 2.2 m Rowland circle grazing incidence monochromator is being used by NASA and other user groups to study a variety of problems including the reflectance of substrates and multilayers as a function of angle of incidence, photoemission, and absorption of metal films impregnated with helium bubbles. The useful range is 80–600 Å the lower limit being set by the angle of incidence on the collecting mirror. We anticipate using a higher angle of incidence collector in the near future which should extend the useful range to below the carbon K edge.

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