LSU CAMD

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Center for Advanced Microstructures and Devices

The South's Regional Light Source

LSU CAMD

January 2000

Volume 1, Issue 3

Beamlines: Guiding Light at CAMD

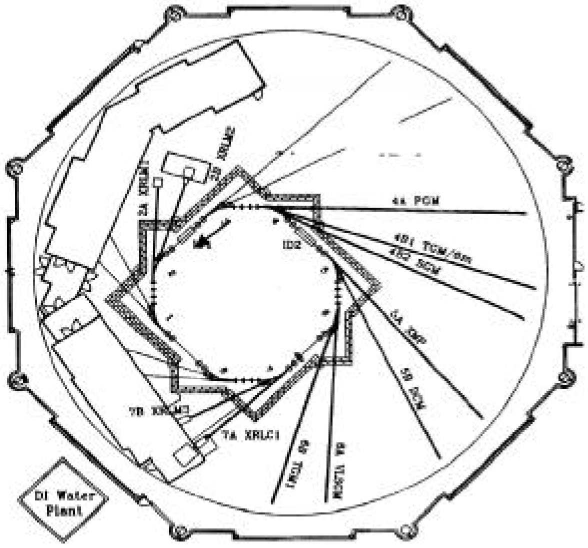


Figure 1 represents a plan view of the experimental hall's storage ring and beamlines.

In the first two issues of the CAMD newsletter, the subject of *beamlines* was a major topic. Because beamlines are involved in almost every aspect of research and development work at CAMD, the subject will continue to constitute a large portion of the newsletter. This article is a discussion of beamlines and the synchrotron radiation they are built to harness. CAMD is built around a synchrotron-radiation source. The source is a high-energy accelerator called an electron storage ring. Figure 1 is a plan view of the experiment hall showing the storage ring and beamlines. A beam of electrons, accelerated to 1.5 billion electron volts (eV), circulates in the roughly octagonal ring. The eight bends in the beam (45 degree arcs of radius = 3 meters) are achieved by high-field electromagnets; this change in the electrons' trajectories produces electromagnetic radiation, a spectrum of which is given in Figure 2. The spectrum of a 100 watt light bulb is shown for comparison.

When graphing the spectrum of a light source, the abscissa of the graph is representative of the fundamental quality "color" that is given quantitatively as radiation wavelength or photon energy. Here, photon energy in *electron volts* is used. The plot's energy scale is logarithmic and not linear.

The following examples are given to describe the link between energy and wavelength and to give some idea of the quantities involved. The region of the electromagnetic spectrum called *visible light* spans the photon-energy range from ca. 1.5 eV to 3.0 eV (A photon of visible radiation of the lowest energy red light has an energy of 1.5 eV and of the highest energy violet light, 3 eV). The radiation at the low-energy limit has a wavelength of 0.775 micrometers (1 µm = 1 millionth of a meter), and at the high energy, 0.413 µm.

The X-rays used to image a human body in medicine consist of photons with energies in the range of 40,000 eV; the wavelength of this radiation is ca. 0.031 nanometers (1 nm = 1 billionth of a meter). The ordinate of the graph must present the amount of radiation having a particular energy or wavelength. The unit chosen here is the increase in power measured at a given photon energy as the photon energy is continuously increased. The power measured for the plot is the power originating in the particular source and intercepting a surface that is 2 cm on a side and is located 1 meter from the source. The surface facing the light bulb is homogeneously covered by all colors of light. The surface facing the storage ring is homogeneously illuminated from side-to-side, but not vertically.

While infrared and visible light completely illuminate the full 2 cm vertical extent, the majority of the power falls in a horizontal line across the surface in the plane of the ring and less than 1 mm in height.

Principally, a beamline conditions the synchrotron radiation from the storage ring and transmits it to the place of application (end station). The beamline also serves the crucial function of mechanical and vacuum interface between the storage ring and the end station. **Conditioning** the synchrotron radiation consists of focusing the beam and selecting a wavelength (or range of wavelengths) to transmit. **Focusing** is done by special precisely ground mirrors. **Selection** of a wavelength -- wavelength range or band of radiation -- can be accomplished

(Continued on page 2)

Inside this issue:

Director's Statement

This is my first contribution to CAMD's quarterly newsletter. On October 1, 1999, I was appointed the new CAMD director. This appointment is an honor and, of course, a challenge for me. I hope that I can start a new phase in the life of this outstanding facility.

The first phase of CAMD's life began in June 1992 when the first light from the storage ring was observed. From that time, beamlines and end stations have been added continuously to the facility. There are now 10 operational beamlines (four in the field of X-ray lithography and six for spectroscopy), and five more are either planned or under construction. These achievements required dedication and diligent work from all of CAMD's staff members and users. I would like to thank everyone who contributed to this development, especially my predecessors, Volker Saile and interim directors John Scott and Erwin Poliakoff.

Looking ahead to the future, I will continue to develop CAMD by adding new beamlines and experimental stations when it is required by interesting scientific problems. In the new phase, however, it is important to focus more on the original mission of CAMD and the goals for which it has been built:

- To enhance the quality of research and education in the various areas of synchrotron radiation (SR)-based research and microfabrication
- To provide the best possible infrastructure for this type of research to be practiced by LSU faculty and other external users
- To offer analytical and various microfabrication techniques to industrial users for the purpose of generating and fostering commercial activities

It will take the efforts of everyone involved with CAMD to achieve our goals. We cannot be successful without the input from our users and external specialists. Therefore, we are establishing a Machine Advisory Committee (MAC) and a User Committee that will work together with the existing External Scientific Advisory Committee (SAC) to overcome actual problems and offer directions for future development.

My vision is to make CAMD, in the second phase of its life, a regional center for the utilization of SR in the Southeast and a national resource for the development of SR-based microfabrication. I am encouraged by the positive feedback I have received in the first weeks in my new position, and I am looking forward to working with the CAMD staff and our users to make these visions a reality.

– Josef Hormes, Director

CAMD BEAMLINES

(Continued from page 1)

by optical filters (broad band) or by energy-dispersing elements (narrow band). Familiar objects used to select bands in the visible-light region of the spectrum are pieces of colored, transparent material (e.g., glass) that pass a single band and block the remainder of the white light; a red-glass filter passes only visible wavelengths in the low-energy red end of the visible spectrum.

A more familiar way to separate the wavelengths of visible radiation is to use a prism. Here, the light is not filtered; all colors or wavelengths get through. They are, however, distributed or dispersed in space. One can imagine an instrument that uses narrow slits and a prism that can be rotated in a narrow beam of white light to produce narrow bands of well-defined wavelengths. Such an instrument is called a *monochromator* (from two Greek words, *monos* meaning single and *chroma* meaning color).

In the X-ray spectral region there are basically two types of optical filters: transmission filters, which are high-pass filters, and reflection filters, or low-pass filters. A low-pass filter has a "cut-off" photon energy. The filter transmits photons with energies greater than this energy and blocks photons with lower energies. The thickness and composition of the filter determines the "cut-off" energy. The higher the atomic weight of the material, the higher the "cut-off" energy; the greater the thickness of the material, the higher the energy. High-pass filters, likewise, have cut-off photon energies; the reflector reflects photons with energies lower than the "cut-off" energy, but it absorbs those with higher energy. Usually, the reflectors (mirrors) are gold-plated metal, glass, or silicon, and the only variable to determine the "cut-off" frequency is the grazing angle that the radiation makes with the mirror surface. The more grazing the angle is (i.e., the shallower the angle), the higher the "cut-off" energy.

In the ultraviolet and soft X-ray spectral regions (out to energies as high as 1,500 eV) the dispersion element generally used is a diffraction grating -- a reflective element with many non-reflecting parallel lines etched on the surface. By taking advantage of two fundamental principles of radiation, *diffraction* and *interference*, a grating disperses radiation and can provide the basis for an excellent monochromator over this important energy range.

Also used in the X-ray region, but effective to much higher energies than the grating, is a device referred to as a Bragg crystal. This is a special type of crystal, having fairly good optical transparency in the specific spectral region and the ability to present to an incident beam of radiation many parallel and equally spaced atomic planes that each reflect the radiation. By changing the angle at which the radiation is incident on the crystal surface, the effective path length between successive reflections changes, leading to interference that causes only certain wavelengths to be reflected at given angles.

In summary, beamlines can be described as focusing or non-focusing and as optical filtering or energy dispersing. The energy-dispersing monochromator beamlines can be classified as grating or crystal monochromator beamlines.

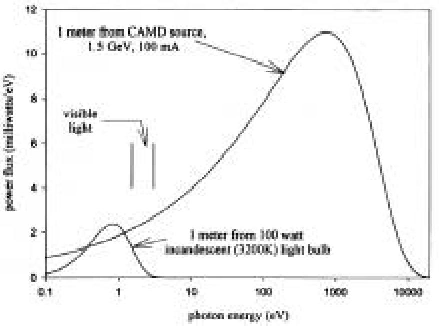
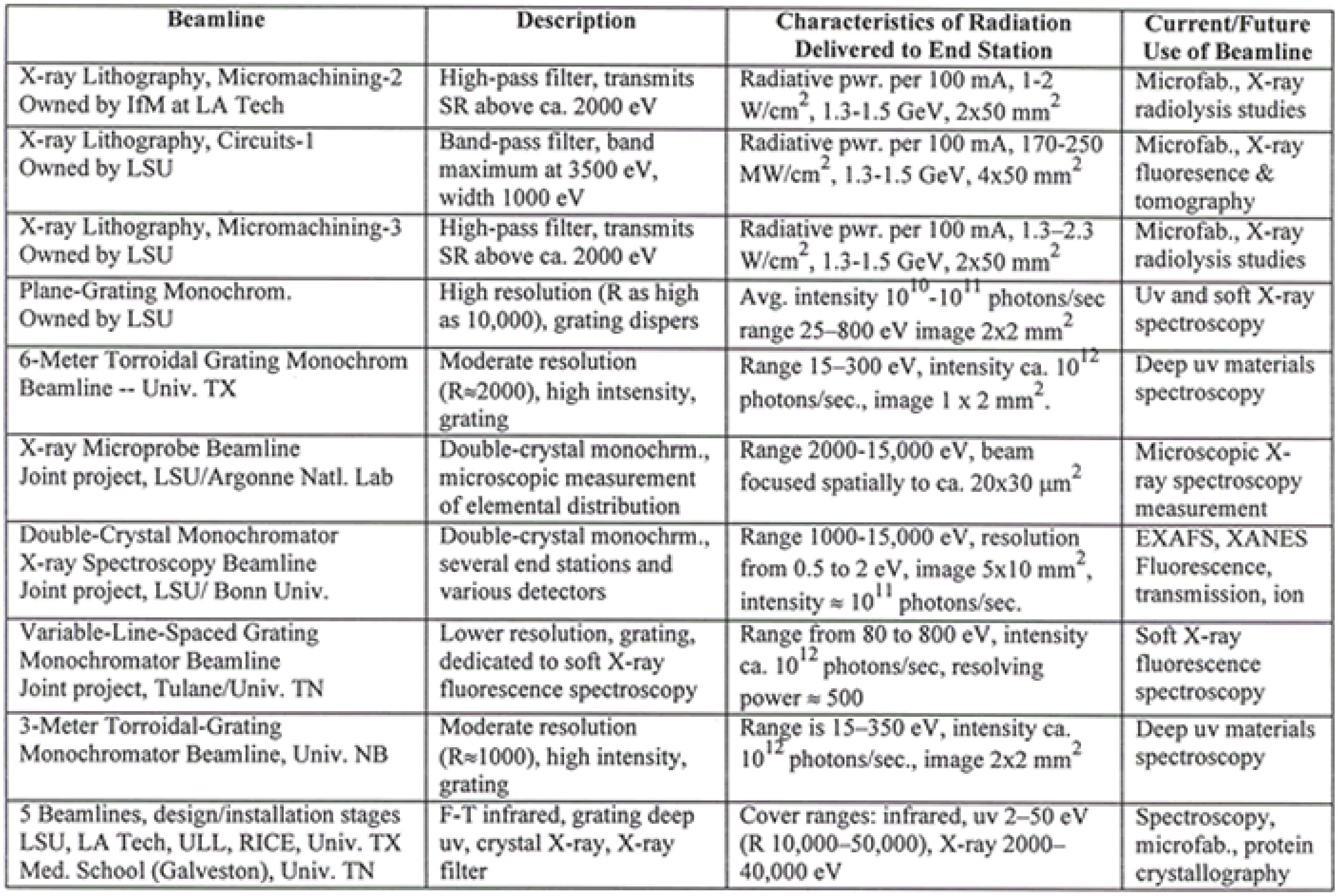


Figure 2 shows an electromagnetic spectrum produced by CAMD and a 100 watt light bulb



Beamline	Description	Characteristics of Radiation Delivered to End Station	Current/Future Use of Beamline
X-ray Lithography, Micromachining-2 Owned by IfM at LA Tech	High-pass filter, transmits SR above ca. 2000 eV	Radiative pwr. per 100 mA, 1-2 W/cm^2, 1.3-1.5 GeV, 2x50 mm^2	Microfab., X-ray radiolysis studies
X-ray Lithography, Circuits-1 Owned by LSU	Band-pass filter, band maximum at 3500 eV, width 1000 eV	Radiative pwr. per 100 mA, 170-250 MW/cm^2, 1.3-1.5 GeV, 4x50 mm^2	Microfab., X-ray fluoresence & tomography
X-ray Lithography, Micromachining-3 Owned by LSU	High-pass filter, transmits SR above ca. 2000 eV	Radiative pwr. per 100 mA, 1.3–2.3 W/cm^2, 1.3-1.5 GeV, 2x50 mm^2	Microfab., X-ray radiolysis studies
Plane-Grating Monochrom. Owned by LSU	High resolution (R as high as 10,000), grating dispers	Avg. intensity 10^{10}-10^{11} photons/sec range 25–800 eV image 2x2 mm^2	Uv and soft X-ray spectroscopy
6-Meter Torroidal Grating Monochrom Beamline -- Univ. TX	Moderate resolution (R≈2000), high intsensity, grating	Range 15–300 eV, intensity ca. 10^{12} photons/sec., image 1 x 2 mm^2.	Deep uv materials spectroscopy
X-ray Microprobe Beamline Joint project, LSU/Argonne Natl. Lab	Double-crystal monochrm., microscopic measurement of elemental distribution	Range 2000-15,000 eV, beam focused spatially to ca. 20x30 μm^2	Microscopic X-ray spectroscopy measurement
Double-Crystal Monochromator X-ray Spectroscopy Beamline Joint project, LSU/ Bonn Univ.	Double-crystal monochrm., several end stations and various detectors	Range 1000-15,000 eV, resolution from 0.5 to 2 eV, image 5x10 mm^2, intensity ≈ 10^{11} photons/sec.	EXAFS, XANES Fluorescence, transmission, ion
Variable-Line-Spaced Grating Monochromator Beamline Joint project, Tulane/Univ. TN	Lower resolution, grating, dedicated to soft X-ray fluorescence spectroscopy	Range from 80 to 800 eV, intensity ca. 10^{12} photons/sec, resolving power ≈ 500	Soft X-ray fluorescence spectroscopy
3-Meter Torroidal-Grating Monochromator Beamline, Univ. NB	Moderate resolution (R≈1000), high intensity, grating	Range is 15–350 eV, intensity ca. 10^{12} photons/sec., image 2x2 mm^2	Deep uv materials spectroscopy
5 Beamlines, design/installation stages LSU, LA Tech, ULL, RICE, Univ. TX Med. School (Galveston), Univ. TN	F-T infrared, grating deep uv, crystal X-ray, X-ray filter	Cover ranges: infrared, uv 2–50 eV (R 10,000–50,000), X-ray 2000–40,000 eV	Spectroscopy, microfab., protein crystallography

Employee Profile: **Larry H. Oliszewski**

Larry H. Oliszewski

Larry H. Oliszewski joined CAMD in April 1991. He is now a Research Specialist 2. His responsibilities include accelerator operations and repair. He also assists in modifications and redesign.

Larry's career began when he joined the United States Coast Guard. His decision to pursue a career in the U.S. Coast Guard proved to be advantageous. They sent him to the RCA Institute for two years to study electronic technology. During his 23 years in the Coast Guard, Larry also had many opportunities to travel, with tours to the South Pacific, Germany, Scotland, Thailand, Vietnam, as well as six stateside bases.

After retiring from the Coast Guard, Larry began a second career with ITT, Federal Electric. The company sent him to work in Saudi Arabia for four years where he was responsible for testing and operation of a 10-land-based navigation system, LORAN C.

After his work in the Middle East, Larry was contracted by ITT to work in Venezuela as the Test Engineer and then Operations Manager of eight troposcatter communications stations.

Upon returning to Louisiana, Larry began a third career, this time at CAMD. He is married to Pearl, his wife of 35 years. They have two children and two grandchildren.

Pearl manages M.A. Allen Inc. Real Estate advertisement. In his spare time, Larry continues to rely on his Coast Guard experience when he commands his boat or serves as first mate on Pearl's boat. His only enemies now, however, are the bass of Cyprus Lake in the backyard of his and Pearl's newly built dream home.

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CAMD News Briefs

Georg Aigeldinger, CAMD

- Conducted the first test exposures using radiation from the super conducting Wiggler. CAMD scientists Ben Craft, Louis Rupp, and Yongzhang Huang assisted, along with help from Phil Coane and Sam Ledger of Louisiana Tech University's Institute for Micromanufacturing.

Professor Leslie G. Butler, LSU Department of Chemistry

- Presented an invited talk, "Synchrotron X-ray Microtomography and Solid-State NMR of Environmental Wastes in Cement," at the SPIE meeting in July

Professor Peter Dowben, Department of Physics and Astronomy, University of Nebraska

- Submitted a patent application with the help of CAMD scientists Harish Manohara, Eizi Morikawa, and Phil Sprunger on "X-ray Pattern Transfer in Poly Vinylidene Fluoride, and Poly Vinylidene Fluoride Masks"
- Worked with CAMD scientist Alex Moewes to complete installation of a 3-meter TGM beamline at CAMD and assisted CAMD scientists Phil Sprunger and Jaewu Choi to install and commission the angle-resolved photoemission end station to be used at the 3-m TGM beamline

Professor Erwin Poliakoff, LSU Department of Chemistry and recent Interim Director of CAMD

- Served as a member of the Advisory Committee for the director of the Lawrence Berkeley National Laboratory to evaluate the Advanced Light Source at Berkeley, California.
- Organized and chaired a new Gordon Conference on Photoions, Photoionization, and Photodetachment
- Wrote a book chapter titled "Molecular Photoionization Dynamics" for *Chemical Applications of Synchrotron Radiation*

Professor Jeong-Bong Lee, LSU Department of Electrical and Computer Engineering

- Received $160,000 from the State of Louisiana Board of Regents Support Fund for "Novel Approaches to Micromachined Inductors and Tunable Capacitors for High Frequency Applications" (July 1999–June 2000)

Professor Carl A. Ventrice, Department of Physics, University of New Orleans

- Received a grant for $98,000 funded by the State of Louisiana Board of Regents Support Fund for "Growth and Characterization of Epitaxial Metal-oxide Films" (July 1999–June 2000)

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