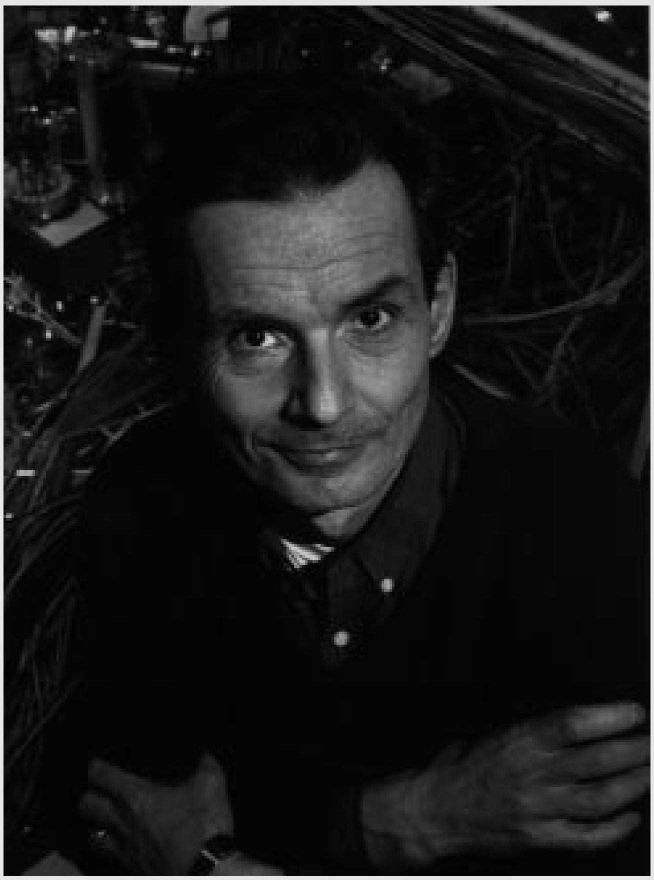
OPERATIONS

VUV MACHINE

Stephen Kramer
VUV Ring Manager



Stephen Kramer, VUV Ring Manager

Figure 1 shows the breakdown of the VUV Ring operating statistics for the Fiscal Year 1996. The monthly breakdown of the most significant operational statistics for the year, are shown in Figures 2 through 6. After the problems with the booster power supplies in FY1995 were overcome, the operating reliability of the VUV Ring improved such that the unscheduled downtime decreased by almost a factor of two to 1.6%, the lowest level achieved to date. Despite this unscheduled loss of user beam time, the actual beam time delivered to the users was 1% greater than originally planned,as the result of a reduction in maintenance, commissioning, injection and studies time from that originally scheduled. The planned operating schedule for the year was one of the lowest in recent years of 62%, this was due to the extended winter shutdown (November 1995 through January 1996). This reduced schedule provided the necessary break for upgrading of the VUV beam ports and the user's beamlines. The VUV Ring returned from this shutdown ahead of schedule and with no change in operational properties of the beam, despite a somewhat longer vacuum conditioning period than originally planned. The entire year of operation was at the higher energy of 808 MeV which was commissioned in FY 1995. Consequently the integrated current delivered to the user's while not being as great as previous years, due to the reduction in the number of hours of operation, actually represents more than a 30% increase in total energy radiated by the beam during the year compared to previous years.

The winter shutdown of the VUV Ring was required to replace two of the ring eight dipole vacuum chambers of the with new chambers having larger aperture beam ports for the two new infrared beamline U10IR and U12IR. These beamlines will more than double the IR research potential of the VUV Ring and help alleviate the long list of users waiting for access to the present IR beamlines. The U12IR beam port is a new beam port similar in design to the world leader beamline at U4IR. This port increases the VUV ring beam ports from 17 to 18, a 12% increase over the originally planned 16 beam ports. This beam port extracts beam with a 45 degrees mirror at the exit from the dipole vacuum chamber, allowing a solid angle of 90(H) X 90(V) mradians to be extracted for the diffraction limited IR beamline. The U10IR beam port replaces the previous small solid angle beam port U10, which provided beam to

U10A and U10B beamlines. The new beam port provides the largest vertical aperture possible in the standard dipole chamber, yielding a solid angle of 100(H)X 48(V) mradians. These two beamlines will use the floor space previously occupied by the U10 beamlines and therefore will not require an elevated platform, with the intrinsic vibration issue faced by the U4IR platform.

The process of replacing these two dipole vacuum chambers required taking two of the spare chambers, machining and welding the new beam ports onto them while maintaining the exacting dimension for the other two unchanged beamlines (U9, U11 and U12) that share the same chambers. Once the new chambers were leak checked and ready for installation, the magnets and shielding had to be disassembled and the old chambers cut-out of the ring. The new chambers were then welded to the ring in situ and then leak checked. The magnets and shielding were re-installed and the alignment checked and adjusted to better than 100 microns. After baking and re-installing the old beamlines, beam was injected and conditioning of the new vacuum chambers began. The old vertical betatron tune of the ring proved to be more sensitive to the poorer vacuum in the ring. By shifting the tune above the quarter integer resonance, good injection and greater freedom from ion problems was obtained. With the higher injection rate available from the booster, conditioning was faster than previous conditioning periods and the distributed ion pumps showed their ion currents leveling off after about 50 Amp-hours, as expected. However, the new ion gauges and the lifetime both showed that it took at least 150 Amp-hours for the vacuum desorption and lifetime to approach within 10% of the old values. The booster performance allowed this to be accomplished more than 3 days ahead of schedule. Prior to that integrated current level U10, U9 and U13U beamlines were able to take beam and verify that the photon beam was off from its pre-shutdown vertical position by less than 50 microns. This upgrade process will be repeated again during the winter 96/97 shutdown, when U2IR is planned to get a new larger aperture beam port, similar to the U10IR port. Although only one dipole chamber will be replaced at that time, the new chamber will go in just ahead of a ceramic vacuum chamber that just started to leak in September 1996. Replacement of the ceramic chamber was added to the task of replacing the dipole chamber without requiring a great deal of additional effort.

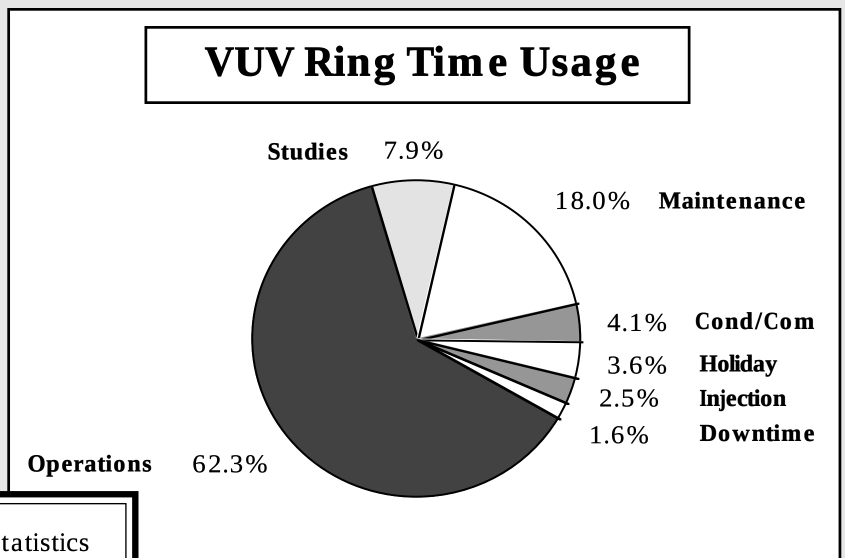


Figure 1: The breakdown of the VUV Ring usage based on total time (not scheduled time) for FY 1996.

FY1996 Ring Performance Statistics

Ave. fill Current: 841 mA
Ave. Charge rate: 110mA/min
Ave. Lifetime at 500 mA: 278 min
Total user integrated current:
2709 A-Hrs (112.9 A-days)
Total hours of operation: 5468 hours
Average operating current: 495 mA

VUV Ring Performance

FY 1996

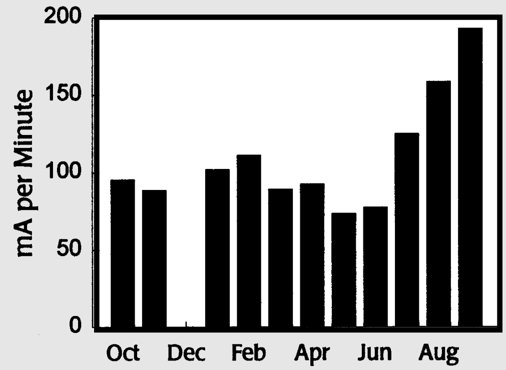


Figure 2: The VUV Ring injection charge rate average over all fills in each month.

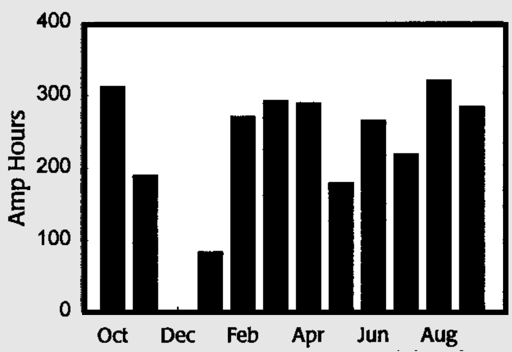


Figure 3: The total integrated current for the VUV Ring accumulated each month.

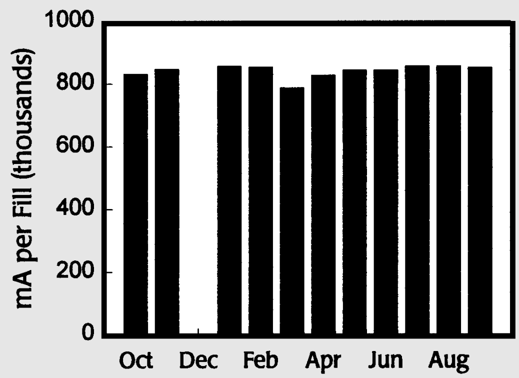


Figure 4: The injection current averaged over all fills in a month for the VUV Ring.

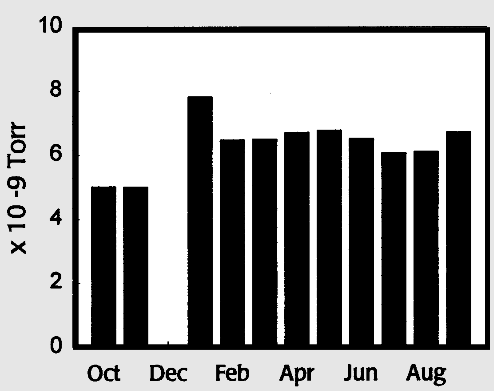


Figure 5: The VUV ring vacuum pressure at 500 mA beam Current averaged over each month.

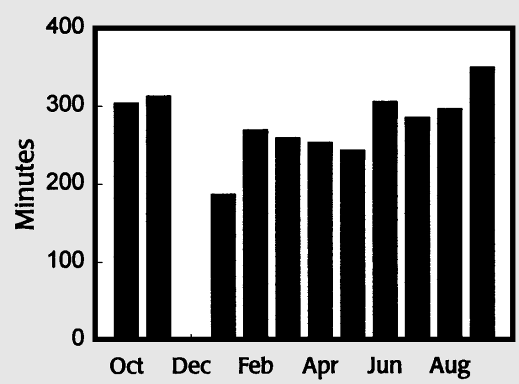


Figure 6: The VUV Ring exponential beam lifetime at 500 mA beam current (seven bunch operation only) average over each month.

Another improvement in the VUV Ring this year was the installation of a new coupling loop in the first harmonic RF cavity. This loop allowed the RF amplifier to be optimized in its coupling to the RF cavity at the higher currents. This increases the RF power efficiency of the system and will allow future improvements in reducing the affects of higher order modes in the cavity. After some initial tuning difficulties were overcome, this system was working as expected, although additional studies will be required to more fully utilize this new capability.

Additional improvements were made in the booster system, which had an increase in its repetition rate from 0.8 Hz to 1.0 Hz for operations and was tested up to 1.2 Hz for studies. The average injection rate into the VUV Ring has shown almost a factor of two increase during this year (Figure 2), with injection time to fill the VUV Ring taking only about 3 minutes instead of 5 to 6 minutes. The faster injection rate will allow the operators to gradually work on improving the injection efficiency, since changes in the rate will appear more instantaneous as parameters are tuned, allowing a smoother search for the parameters which yield greater efficiency of injection. Along these same lines new diagnostics to measure the beam motion and current loss after injection were installed and testing started in FY 1996. These improved diagnostics already have allowed greater understanding of the beam motion and loss during injection. Improved radiation monitoring and shielding have been planned during this past year for installation in FY 1997. When these improvements have been successful in reducing the radiation on the VUV floor and the second floor offices, then additional studies on the testing of the Top-Off method of injection will continue, with a goal of demonstrating the improved orbit stability possible with that method.

VUV Storage Ring Parameters as of November 1996

Normal Operating Energy	0.808 GeV
Peak Operating Current (multibunch ops.)	0.85 amp (0.9 x 10^{12} e^-)
Circumference	51.0 meters
Number of Beam Ports on Dipoles	8
Number of Insertion Devices	2
Maximum Length of Insertion Devices	~ 2.25 meters
$\lambda_c(E_c)$	19.9 Å (622 eV)
B(ρ)	1.41 Tesla (1.91 meters)
Electron Orbital Period	170.2 nanoseconds
Damping Times	$\tau_x=\tau_y$= 13 msec; τ_ε = 7 msec
Lifetime @ 200 mA with 52 MHz	360 min
(with 211 MHz Bunch Lengthening)	(590 min)
Lattice Structure (Chasman-Green)	Separated Function, Quad, Doublets
Number of Superperiods	4
Magnet Complement	8 Bending (1.5 meters each) 24 Quadrupole (0.3 meters each) 12 Sextupole (0.2 meters each)
Nominal Tunes (ν_x, ν_y)	3.14, 1.26
Momentum Compaction	0.0235
RF Frequency	52.886 MHz
Radiated Power	20.4 kW/amp of Beam
RF Peak Voltage with 52 MHz (with 211 MHz)	80 kV (20 kV)
Design RF Power with 52 MHz (with 211 MHz)	50 kW (10 kW)
Synchrotron Tune (ν_s)	0.0018
Natural Energy Spread (σ_e/E)	5.0 x 10^{-4} , I_b < 20 mA
Bunch Length (2σ)	9.7 cm (I_b < 20 mA)
($2l_{rms}$ with 211 MHz Bunch Lengthening)	(36 cm)
Number of RF Buckets	9
Typical Bunch Mode	7
Horizontal Damped Emittance (ε_x)	1.62 x 10^{-7} meter-radian
Vertical Damped Emittance (ε_y)	$\geq$ 3.5 x 10^{-10} meter-radian (2.8 x 10^{-9} in normal ops.)*
Power per Horizontal milliradian (1A)	3.2 Watts

Arc Source Parameters

Betatron Function (β_x,β_y)	1.18 to 2.25 m, 10.26 to 14.21 m
Dispersion Function (η_x, $\eta_{x'}$)	0.500 to 0.062 m, 0.743 to 0.093 m
$\alpha_{x,y}$ = $-\beta'_{x,y}$ /2	-0.046 to 1.087, 3.18 to -0.96
$\gamma_{x,y}$= (1 +$\alpha_{x,y}$)/$\beta_{x,y}$	0.738 to 0.970 m^{-1}, 1.083 to 0.135 m^{-1}
Source Size (σ_x, σ_y)	536 to 568 µm, >60 to >70 µm (170-200 µm in normal ops.)*
Source Divergence ($\sigma_{x'}$,$\sigma_{y'}$)	686 to 373 µrad, 19.5 to 6.9 µrad (55-20 µrad in normal ops.)*

Insertion Device Parameters

Betatron Function (β_x, β_y)	11.1 m, 5.84 m
Source Size (σ_x, σ_y)	1240 µm, >45 µm (130 µm in normal ops.)*
Source Divergence ($\sigma_{x'}$, $\sigma_{y'}$)	112 µrad, >7.7 µrad (22 µrad in normal ops.)*

* ε_y is adjustable

OPERATIONS

BEAMLINE TECHNICAL IMPROVEMENTS

Roger Klaffky
Beamline Technical Liaison

VUV BEAMLINES

There were a number of technical beamline improvements on the VUV Ring during FY 1996. Beamline U3A was in a re-commissioning phase during FY 1996 after extensive changes during FY 1995. New interlocks were installed and the monochromator was interfaced to the beamline control computer. In the next few years there will be a major upgrade of the U4A beamline from a toroidal grating monochromator to a spherical grating monochromator (SGM) design. An upgrade of the angle-resolved photoemission (ARP) chamber has begun with the installation of a cluster of metal evaporators and a thin film thickness monitor. A sample transfer and load lock system will be installed in the future. A new data acquisition computer for the ARP system has been acquired and Labview based software is being upgraded. At U4B a new high photon energy resolution SGM-based beamline was installed with most of its components coming from the U13UA beamline. A magnetic circular dichroism end station was constructed, installed and commissioned.

Construction of the new U5UA SGM-based beamline took place and commissioning of this line was underway. A resolving power of about 10,000 was demonstrated at 30 eV photon energy. After commissioning is completed, the U5UA spin-resolved valence band photoemission program will resume with a 50 % General User allocation.

There was extensive progress at the new U7A soft x-ray photoemission and absorption spectroscopy beamline. The SGM monochromator entrance slit was rebuilt; and installation of the downstream refocusing mirror and the surface chemistry end station with its lifting platform and kinematic mounting plate took place. The upstream refocusing mirror chamber and end station holder were delivered. The initial commissioning and debugging of the surface chemistry station began with preliminary unfocused beam experiments being performed.

The U9B fluorescence detection system development was completed with the addition of a polarizer to the emission optics and the modification of detection electronics to determine photon polarization as well as wavelength and time of arrival.

At the U13UB extreme ultraviolet lithography (EUVL) beamline, the Offner 1:1 Ring Field camera was assembled and commissioned. It was used to image programmed mask defects down to 75 nm. The 10X Schwarzschild EUV camera installation was also underway in FY 1996.

Two modified ring vacuum chambers were installed during the Spring 1996 shutdown. The chambers incorporate a large 100 horizontal by 50 vertical milliradian port for IR microscopes at U10, and a 90 milliradian by 90 milliradian port at U12. Construction and commissioning of IR beamlines at these ports will be underway in FY 1997.

X-RAY BEAMLINES

At X1A new high resolution zone plates were tested and put into operation. Commissioning of a cryogenic scanning transmission microscope and holography instrument began. This equipment is designed to study radiation sensitive biological specimens near liquid nitrogen temperature where the morphology is “frozen in”. At the end of FY 1996, the beamline was shutdown for a major upgrade to achieve higher spectral resolution and independent wavelength control.

The X1B monochromator performance was enhanced after the installation of a new holographically recorded laminar grating in May. Above 500 eV the photon flux increased by a factor of 5 to 10. As a result, high resolution measurements are now possible using first order of the grating over the first harmonic range of the X1 undulator (200 to 800 eV).

The X2B microtomography data acquisition speed and spatial dynamic range were increased with the upgrade of the detector from a 512x512 200 kHz CCD to a 1024x1024 800 kHz CCD.

At X5 equipment development continued in preparation for double-polarization measurements with circularly polarized gamma-rays and longitudinally-polarized nucleon targets. This equipment included: (i) a new frozen-spin hydrogen-deuteride target that provides high polarization for both nuclear species, (ii) a new large acceptance detector array for measuring total reaction cross sections in both neutral and charged-particle channels, and (iii) circularly-polarized gamma-rays extending up to 400 MeV (with 2.584 GeV electrons) and 470 MeV (with 2.80 GeV electrons) using a new ring-laser system.

The X9A beamline resumed operation as a white beamline. Design work was underway to upgrade X9A with the installation of a sagittal focusing monochromator and mirror for MAD crystallography. A new computer system running the NSLS-DAC software was installed on X9B for x-ray absorption spectroscopy. An X9B upgrade planned for 1997 is the installation and testing of larger crystals that can accept over 200 mm of beam (12 horizontal mrad) to increase the flux up to 3 fold.

The X10A hutch was extended to allow higher resolution and a 2D detector was implemented. A major upgrade of the X11A computer system was achieved with the installation of two Macintosh 7500 computers, one for data acquisition using the NSLS-DAC software, and the other for data analysis.

At X12B a robotic fluid sample changer was implemented which allows for the automatic injection of small (100 microliter) liquid samples into a fixed observation cell and for subsequent recovery. An in-vacuum attenuator/shutter mechanism was installed. The flight paths and theta-arm detector mount points were in the process of being rebuilt to accommodate a Mar scan head. Finally, portable visualization and data reduction software for 2D diffraction images was developed.

The X13B beamline was modified to allow experiments to be conducted inside a hutch. A new spherical grating monochromator for X13A was designed and ordered for circular dichroism measurements using the elliptically-polarized wiggler (EPW). The EPW began 100 Hz operation during Summer 1996.

White beam was brought into the X16C hutch and a pair of Kirkpatrick-Baez mirrors were used to produce a 4 micron by 25 micron white or monochromatic focal spot size.

At X19A a solid state multi element detector, developed in collaboration with the BNL Instrumentation Division, was put into operation. The detector has 250 -350 eV resolution and is used for spectroscopy and scattering applications. Also, plans we made to replace the X19A zerodur mirror which was discovered to be damaged by synchrotron radiation.

At the X19C beamline, new motor control electronics were installed. There were a number of changes and upgrades in the x-ray topography hardware. A high precision scanning stage was installed, enabling imaging of six inch diameter wafers. A high resolution digital camera was purchased to enhance image processing capability. Projects that were in progress included the addition of an analyzer crystal axis to the goniometer detector arm. The analyzer will allow analysis of the diffracted beam harmonic content. Also, the attachment of a CCD camera to the goniometer was underway. There were also upgrades in the surface scattering spectrometer. A very high precision, short travel sample stage was installed and the long travel stage was upgraded with an optical encoder. New motorized Huber slits were installed and motorized fixed small gap slits were designed and tested.

The X21 phase II beamline was commissioned during FY 1996. The monochromator is tunable from 5 keV to 10 keV with 0.2 eV energy resolution. On the X22A beamline a vertically-focusing mirror was added which simplifies many experiments by eliminating harmonic contamination. The X22B computer was upgraded. A gear reducer was added to the spectrometer table allowing vertical motion without the loss of steps. Also, a new elevator was added to the spectrometer, enhancing mercury and Langmuir trough measurements. The X23B collimating mirror was replaced providing an improved energy resolution of less than 2.6 eV at 6 keV. The monochromator bearings were replaced and the crystal re-etched, and an additional degree of freedom was provided for crystal alignment.

The X24A beamline was upgraded with the installation of a new first mirror, increasing the flux by a factor of two. At X27A a new control system using Labview with a graphical user interface was under development. A hydraulic powered vertical scan stage was installed to give better control of the exposure rate for micromachining experiments.

Just prior to the December 1995 shutdown, a test was performed which entailed firing the X24 front end fast valve with a 10 mm thick molybdenum blade when there was 408 mA of stored beam current. The exposure time was 1.93 seconds, to simulate the heating that would occur at 500 mA beam current for a 1 second exposure, which is the time it takes for the front end mask to close after a fast valve is fired. The blade successfully withstood the exposure to the x-ray beam, indicating that it will not be necessary to dump the X-Ray Ring when a fast valve fires after the stainless steel blades are replaced with molybdenum blades. During FY 1996 molybdenum blades were installed on the X9, X19 and X24 front ends. More blade replacements will occur during future shutdowns. There has been a major effort to design and build new fast valve sensor boxes and interface boxes. The new sensor boxes have been tested and calibrated. They have CMOS electronics to provide improved noise rejection and they have troubleshooting indicators. The new interface boxes have a capacity of 3 sensors per beamline and provide for individual lock-out of each sensor. The system will be interfaced to the NSLS computer system for display on the present X-Ray Beam Line Status Channel.

OPERATIONS

X-RAY RING

Roger Klaffky
X-Ray Ring Manager

The X-Ray Ring usage for FY 1996 is broken down by categories in Figure 1. There was a 7% increase in operations largely resulting from a 25% decrease in downtime and a 9% decrease in the time allocated to maintenance, studies, and conditioning. There were a total of 1081 Ampere-hours of operations. The monthly integrated Amp-hrs are shown in Figure 2.

The X-Ray Ring active interlock system certification for all insertion device straight sections was completed in Fall 1995 when the calibration and linearity of the last straight section system (X13) was verified up to 350 mA during 25 bunch operation. The active interlock pre-fill test was modified to test the 6 different active interlock chains simultaneously so that only one injection is required for the test. This reduced the testing time from 15 minutes to 2 or 3 minutes. The number of pre-fill test failures was reduced by accounting for the non-linear response of the orbit to the trim strengths.

To enable operation of the orbit measuring pick-up electrodes (PUEs) from 7 mA (for active interlock pre-fill tests) to 434 mA, the AGC dynamic range was extended from 35 dB to 55 dB for all the PUEs. In addition, band pass filters were installed before every PUE switch to prevent saturation of the PUE receivers in single bunch operation. The resolution of the PUEs was increased from 14 to 16 bits, improving the orbit position resolution from 2 microns to 0.5 microns.

During the December 1995 shutdown, a change in the RF2 damping antennae configuration successfully removed the horizontal and vertical beam size changes that had occurred at specific XRF2 tuner positions (i.e. higher order modes) during a fill. Changes in several load resistors on the XRF3 anntennae resulted in a several-fold decrease in the beam size changes occurring at the resonance position.

After studies demonstrated that the effects on the horizontal and vertical orbit of running the Elliptically Polarized Wiggler (EPW) at 100 Hz were compensated, 100 Hz operation commenced in Summer 1996. At 100 Hz, there is a significant improvement in the signal-to-

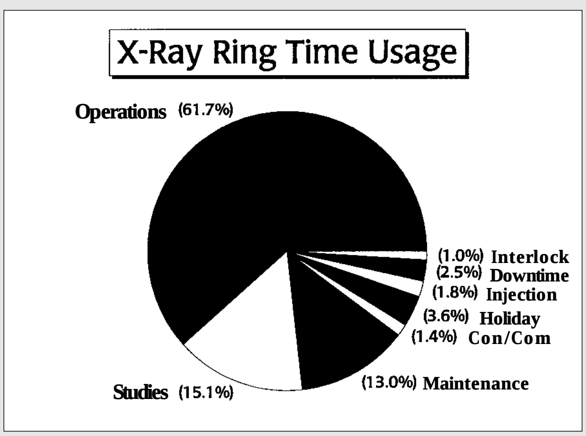


Figure 1: The Breakdown of the X-Ray Ring usage based on total time (not scheduled time) for FY 1996.

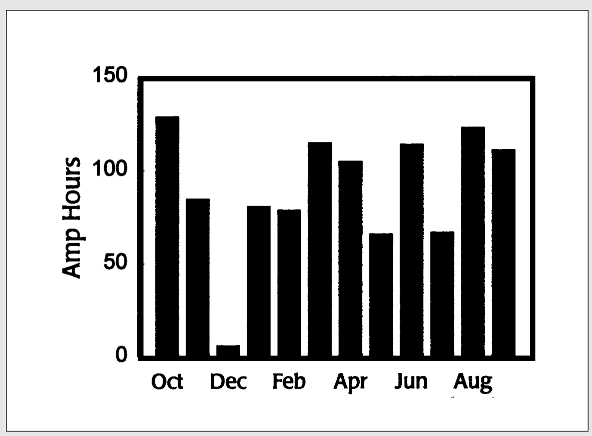
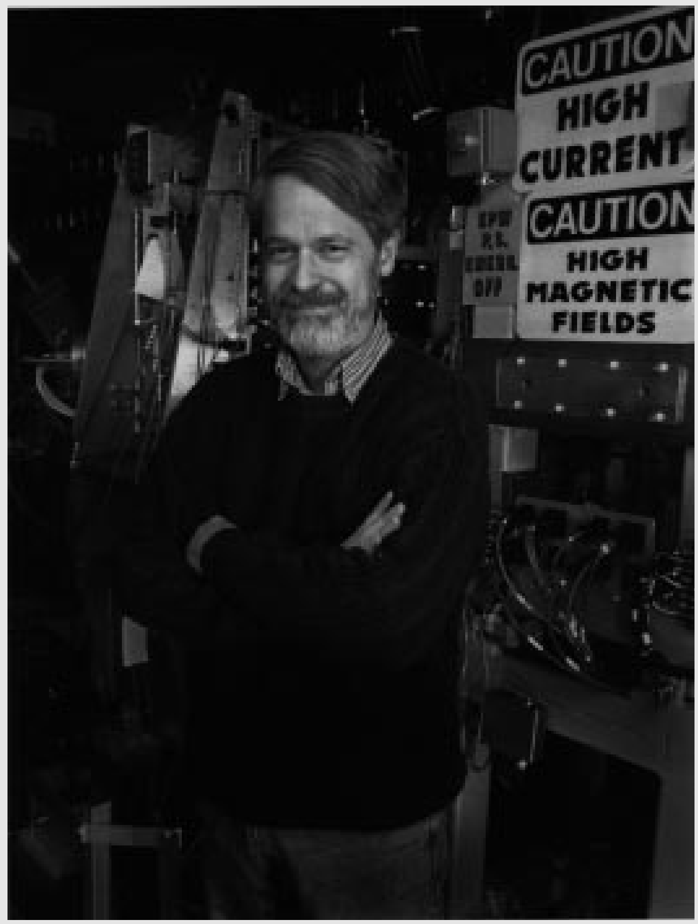


Figure 2: The total integrated current for the X-Ray Ring accumulated each month for FY 1996.

noise ratio for magnetic circular dichroism experiments. Studies on a lattice with a factor of 2 reduction in horizontal emittance continued to progress during FY 1996. During the midnight studies shifts there were several successful trial runs of the digital orbit feedback system in either the horizontal or vertical planes, and also in both planes simultaneously. This sytem is close to an operational state in the vertical plane. In the horizontal plane, studies have shown that even though the digital feedback system does a better job of keeping the orbit fixed at the PUEs, the horizontal ring chamber motion over each 12 hour fill may cause the orbit to show greater horizontal motion with the digital feedback system. This is not a problem in the vertical plane since the chambers show little motion vertically. Sensor stands were fabricated for installation during the December 1996 shutdown. The chamber motion will be mapped out around the ring as a function of ring current. This information will be used to remove the horizontal orbit changes caused by the PUEs moving with the chamber.

There were also studies to demonstrate the feasibility of running the X-Ray Ring at 2.8 GeV and to determine the impact of 2.8 GeV on experimental beamlines. In Spring 1996 a ramp from 744 MeV injection energy to 2.8 GeV was established and skew quadrupoles were adjusted to maintain the small vertical beam size present during 2.584 GeV operation. In August it was demonstrated that 250 mA of beam could be reliably ramped to 2.8 GeV, as had been previously predicted from RF power considerations. In the future, studies will be conducted to determine if the dual hybrid RF power amplifier installation on RF System 2 in December will increase the 250 mA operational limit. The maximum allowable current at 2.8 GeV is 320 mA, as determined by ring vacuum chamber heating limits. Careful beamline measurements were performed on the X19A beamline at 100 mA beam current at both 2.584 GeV and 2.80 GeV. The ratio of the third harmonic to fundamental was determined from rocking curves of the X19A second Si(111) monochromator crystal. The factor by which this ratio increases at 2.8 GeV was in good agreement with calculated flux ratios at the two energies. A 2.8 GeV Users Executive Subcommittee will conduct a survey of users in the future as to the desirability of 2.8 GeV operation.



Roger Klaffky, X-Ray Ring Manager

Beam "drop-out" studies indicated the possibility of producing substantial levels of high energy gamma ray bremsstrahlung radiation in the straight sections during single and five bunch operation. In these few bunch operational modes, the high peak currents heat the injection septum and other straight section ring components causing elevated gas pressures and increased bremsstrahlung radiation. The gamma rays can scatter off beamline optical components producing detectable radiation levels near these components. Radiation monitors were installed on the straight section beamlines to alert users to the presence of radiation.

In addition, levels from these monitors are displayed in the Control Room and are logged on the NSLS computer history program. Operators have been instructed to close shutters if the beam lifetime is reduced to a few hours.

In preparation for the December 1996 shutdown, water lines have been installed that will bring BNL Central Chilled Water Facility (CCWF) water to the NSLS experimental water system in Mechanical Equipment Room A. The control valve/controller installation for this system in underway with completion expected before December. This system will significantly improve temperature regulation with the present NSLS system providing redundancy in case the CCWF goes down for maintenance. Since tuning of the new control system requires operational beamlines, there will be variations in the experimental water temperature when operations first resume in January 1997.

Since the present Biology cold rooms are cooled by the CCWF water, there is a problem on maintaining biological samples if there is a CCWF failure since there is no automatic backup cooling. Over the past year, there have been several instances where samples were lost when the CCWF went down. To address this problem, procedures were established so that Operations Coordinators can valve off the CCWF water when it is down and open valves to provide domestic water for cooling of the cold room compressors. In the future this changeover will be automated.

A major effort during the December shutdown will be the installation of new beryllium windows to enable 350 mA operation in January 1997. The design of the windows was completed and orders placed for delivery in November 1996.

Brazing and welding of the windows will be done by Brush Wellman Electrofusion with the pieces being fabricated by BNL Central Shops. The NSLS will pay for these windows and for any adaptor flanges required to fit the windows to the X-Ray beamlines. A second wave of windows will be installed in 1997 to permit operation up to 438 mA.

All parts were ordered for the dual hybrid RF power amplifier slated for installation on RF System 2 in the December 1996 shutdown. Two 120 kW amplifiers will be combined in this system to enable 438 mA operation and to prevent a beam dump if one of the other three RF systems drops out.

There has been an ongoing effort to replace existing stainless steel frontend fast valve blades with molybdenum blades which can be fired without dumping the X-Ray Ring. There has been a parallel effort to redesign the fast valve electronics. New circuitry will be installed during the December shutdown at beamlines where fast valves are presently operational. Additional fast valves will be hooked up in the future.

Finally, in February 1996 a new X-Ray Ring fill policy was established with scheduled fills at 0700 and 1900 hours.

X-Ray Storage Ring Parameters as of November 1996

Normal Operating Energy	2.584 GeV
Maximum Operating Current	0.30 amp (10^{12} e^-)
Lifetime	~20 hours
Circumference	170.1 meters
Number of Beam Ports on Dipoles	30
Number of Insertion Devices	5
Maximum Length of Insertion Devices	< 4.50 meters
$\lambda_c(E_c)$ at 1.25 T (B)	2.23 Å (5.6 keV)
$\lambda_c(E_c)$ at 5.0 T (W)	0.56 Å (22.2 keV)
B(ρ)	1.25 Tesla (6.875 meters)
Electron Orbital Period	567.2 nanoseconds
Damping Times (2.584 GeV)	$\tau_x = \tau_y = 6$ msec; $\tau_\varepsilon = 3$ msec
Touschek (2.584 GeV, 0.25A)	$\geq$27 hrs (v_{RF} = 700 kV)
Lattice Structure (Chasman-Green)	Separated Function, Quad Triplets
Number of Superperiods	8
Magnet Complement	16 Bending (2.7 meters each) 40 Quadrupole (0.45 meters each) 16 Quadrupole (0.80 meters each)
32 Sextupole	(0.20 meters each)
Nominal Tunes (ν_x, ν_y)	9.15, 6.20
Momentum Compaction	0.0056
R.F. Frequency	52.88 MHz
Radiated Power for Bending Magnets	144 kW/0.25 amp of Beam
R.F. Peak Voltage	1000 kV
Design R.F. Power	400 kW
ν_s (Synchrotron tune)	0.002
Natural Energy Spread (σ_e/E)	8.6 x 10^{-4}
Natural Bunch Length (2σ)	10.5 cm
Number of RF Buckets	30
Typical Bunch Mode	25
Horizontal Damped Emittance (ε_x)	1.0 x 10^{-7} meter-radian
Vertical Damped Emittance (ε_y)	1 x 10^{-10} meter-radian
Power per Horizontal milliradian (0.25A)	23 watts

Arc Source Parameters

Betatron function (β_x,β_y)	1.0 to 3.8 m, 7.9 to 26.5 m
Dispersion function (η_x,$\eta_{x'}$)	0.47 to -0.11, -0.39 to 0.22
$\alpha_{x,y} = -\beta'_{x,y}/2$	-0.49 to 1.62, -3.4 to 4.5
$\gamma_{x,y} = (1 + \alpha_{x,y}^2)/\beta_{x,y}$	0.952 to 0.962 m^{-1}, 0.81 to 0.52 m^{-1}
Source size (σ_x,σ_y)	371 to 565 µm, 27 to 49 µm
Source divergence ($\sigma_{x'}$,$\sigma_{y'}$)	439 to 324 µrad, 8 to 7 µrad

Insertion Device Parameters

Betatron function (β_x,β_y)	1.60 m, 0.35 m
Source divergence ($\sigma_{x'}$,$\sigma_{y'}$)	260 µrad, 35 µrad