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STATUS OF THE NATIONAL SYNCHROTRON LIGHT SOURCE

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Abstract

An overview of the present capabilities of the NSLS 750 MeV VUV ring and the 2.5 GeV X-ray ring is presented. Emphasis is placed on performance of the now operational facility, the efforts to improve this performance, a description of the "Phase II" upgrade, and outlook for the future.

Introduction

The National Synchrotron Light Source (NSLS) is the nation's largest facility dedicated solely to the production of synchrotron radiation. During the past two years,[1] most of its design parameters were achieved, and the facility now accommodates more than 800 scientists, representing over 71 universities, industries, and government laboratories. Both basic and applied research are being done by groups from a variety of disciplines which include physics, chemistry, materials science, metallurgy, biology, and medicine (see Table 1). The present rate of usage of both VUV and X-ray storage ring beam is in excess of 40,000 operational user shifts per year. This number is expected to rise to 60,000 eight-hour shifts per year with the completion of "Phase II", when more and more beam lines become available. A plan view of the NSLS, including the Phase II expansion, is shown in Figure 1. Figure 2 shows a view of the VUV ring experimental floor.

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Present Performance

Table 2 summarizes the present performance of the NSLS storage rings. The VUV ring has met or exceeded all its design parameters. The X-ray ring has not yet achieved its design current, due to injector limitations.

The extremely small beam sizes of the VUV ring, determined with a profile monitor having ≈25μm resolution, yield horizontal and vertical emittances of $1.45 \times 10^{-7}\pi$ m-rad and $2.9 \times 10^{-10}\pi$ m-rad respectively. Taking the ratio of these two numbers gave a very low coupling of about 0.2%. This vertical emittance, the lowest of any synchrotron radiation source, resulted from an accurate alignment survey performed in the fall of 1984. Our users, however, cannot resolve this extremely small source, and the VUV ring is usually operated with skew quadrupoles energized to increase the coupling, producing a vertical beam size of $\sigma_v \approx 150\mu$m. This also reduces the bunch charge density and the consequent intra-bunch scattering, leading to an increase in lifetime. The X-ray ring beam profiles were determined with a pinhole camera at X10, and also demonstrate the achievement of the desired high-brightness source.

The uncompensated beam orbit motions in both rings are of the order of 100μm, and are caused by various sources; e.g., changes in magnet cooling water temperatures, and mechanical vibrations of the magnetic elements caused by a compressor operating

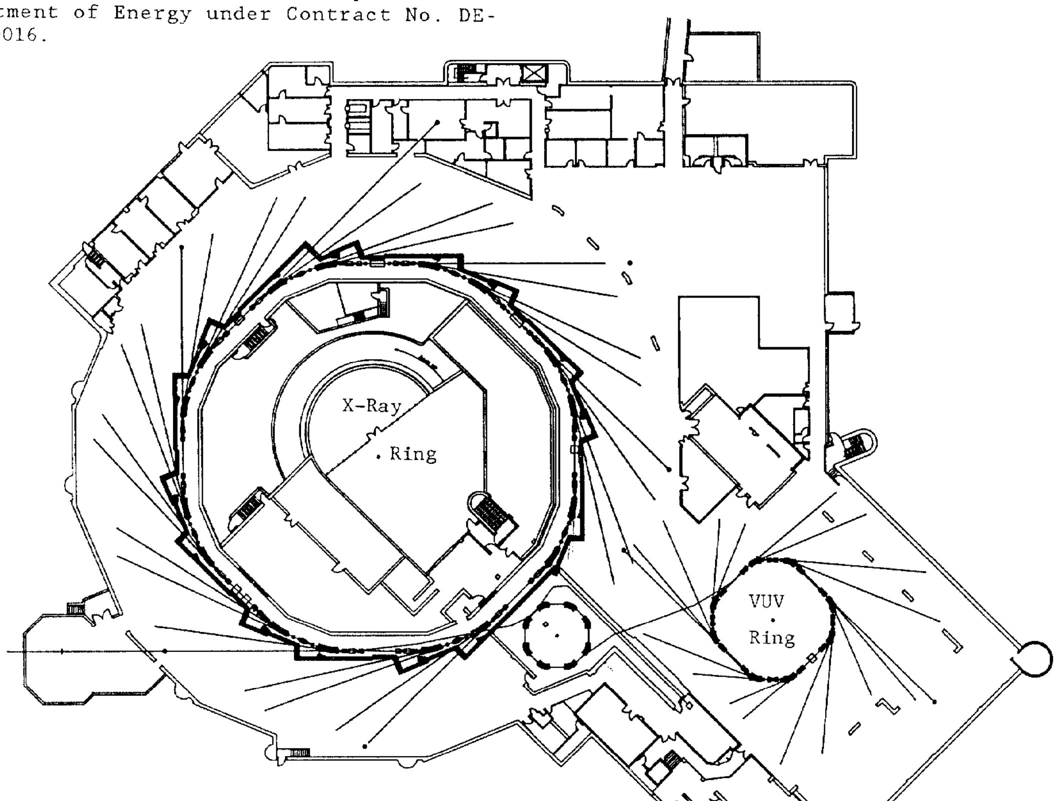


Figure 1 Floor plan of NSLS Ring Level.

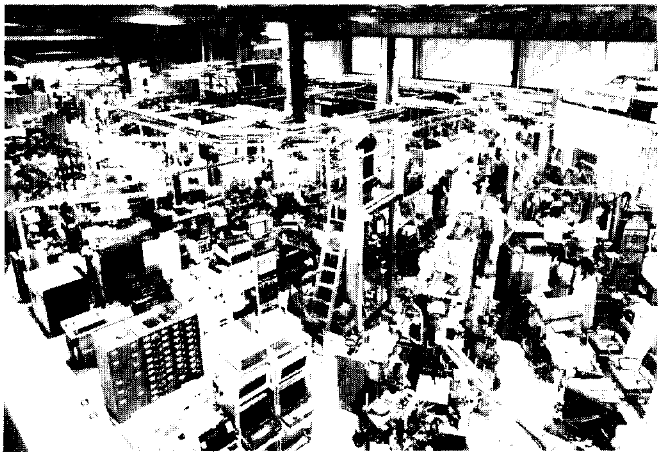


Figure 2

Table 1

Circular Dichroism	U9B
Energy Dispersive Diffraction	X13A, X23A3
EXAFS, NEXAFS, SEXAFS	U1A, U4A, U7A, U7B, U8A, U8B, U10A, U15, U16A, X4C, X9A, X10C, X11A, X11B, X15B, X17B1, X18B, X19A, X20A, X20C, X21A, X21B, X23A1, X23A3, X23B
Gas Phase Spectroscopy/ Atomic Physics	X24A, X26A, X26C
Infrared Spectroscopy	U4IR, U12C
Lithography/Microscopy	U6, U8D, U15, X1A, X15A
Medical Research	X17B2
Nuclear Physics	X5
Photoionization	U9A, U11, X4A, X26A, X26C
Radiometry	U3B
Reflectometry	U8C, X24C
Research & Development/ Diagnostics	U10B, U14B, X12A, X27, X28, X29
Time Resolved Fluorescence	U9A, U9B
Topography	X17B1, X19C, X23A3
Transverse Optical Klystron	U13TOK
VUV & X-Ray Photoemission Spectroscopy	U1A, U2A, U2B, U3A, U4A, U4B, U4C, U5U, U7A, U7B, U8A, U8B, U10A, U12A, U12B, U13U, U14A, U16A, U16B, U16C, X4A, X14A, X15A, X19A, X24A, X24C
X-Ray Crystallography	X10A, X10B, X12C, X13B, X14A, X17B1, X21A, X21C, X23B
X-Ray Fluorescence	U10A
X-Ray Scattering/Diffraction	X4C, X9B, X10A, X12B, X13B, X14A, X16A, X16B, X16C, X17B1, X18A, X20A, X20C, X21A, X21C, X22B, X22C, X23A1, X23B, X25

Primary Research Areas of VUV and X-Ray Beam Lines

Table 2

	VUV RING	X-RAY RING
Design Energy	700 MeV	2.5 GeV
Present Operation	750 MeV	2.52 GeV
Future	up to 1GeV*	2.8-3.0 GeV
Design Current	1000 mA	500 mA
Maximum Achieved	1013 mA	224 mA @2.5GeV
Future	>1000 mA	500 mA @2.5GeV 200 mA @2.8GeV** 100 mA @3.0GeV**
Beam Size	σ_H = 510μm	σ_H = 381μm
(at profile monitor)	σ_V = 61μm	σ_V = 123μm
Design Beam Stability	100μm	100μm
Achieved	10μm***	10μm***
Future	<10μm globally	<10μm globally
Beam Lifetime(1/e)	≈120 min @600 mA (3 bunch fill)	≈720 min @100 mA (25 bunch fill)

* or as high as dipole saturation will allow.
** current limited due to thermal considerations.
*** in selected areas only.

in a building 1/2 km away. Very successful compensation of these motions have been achieved in local regions by feedback using the light beam. The method is described in another paper at this conference.[2]

Long lifetimes in a synchrotron light source have meaning only if the beam stays in the machine for at least one lifetime. Ion trapping in the electron beam often led to "short lifetime modes" in both rings, until the facility went to non-symmetric bucket fill sequences. The X-ray ring typically runs with 25 consecutive filled buckets, followed by five empty ones. The VUV ring is more and more susceptible to ion trapping as the number of consecutive bunches are increased. However, since the lifetime in the VUV ring is normally Touschek dominated, the lifetime (for a given current) increases with the number of bunches and a compromise is necessary. Normal operations are three to six consecutive bunches filled (out of nine), depending on the ring vacuum conditions. Figure 3 and 4 show some of the ring statistics for the last two years. The operations part of both pie charts show only the time with the shutters open and beam on user targets. The total accumulated ampere-hours give a graphic illustration of the facility performance over the last two years (the split bars in Figure 4(b) give total ampere-hours for the higher part and high-energy ampere-hours for the lower part). The close connection between machine performance parameters such as filling current or lifetime and the ring vacuum is illustrated in the remaining bar graphs. An accidental venting of the VUV ring to atmosphere at the end of January 1986 caused severe ion trapping problems immediately thereafter, forcing operation with fewer bunches and reducing the beam lifetime. The X-ray ring was affected by hurricane Gloria in September 1985, when a cryopump regurgitated gas through a leaky valve during a total power shutdown, causing poor performance in October 1985; the recovery from the January 1986

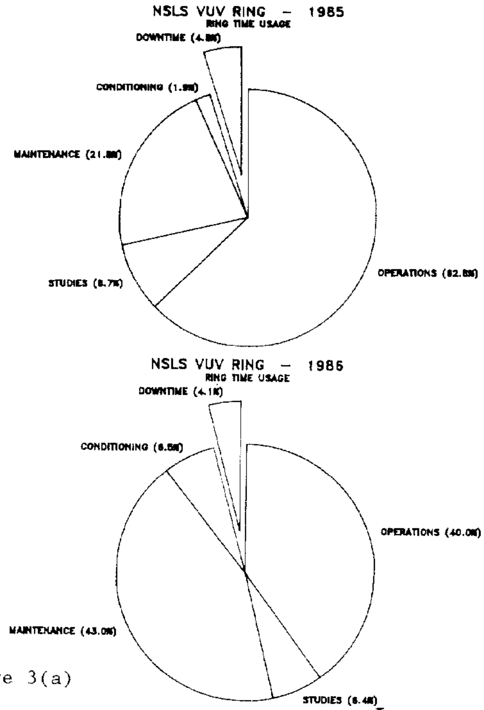


Figure 3(a)

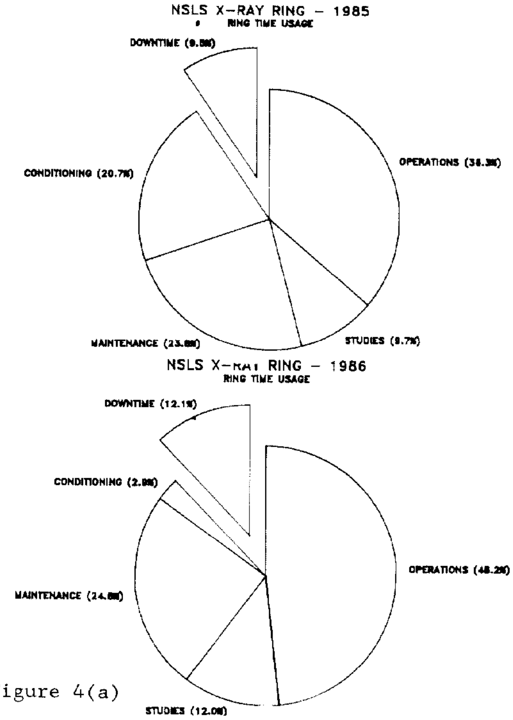


Figure 4(a)

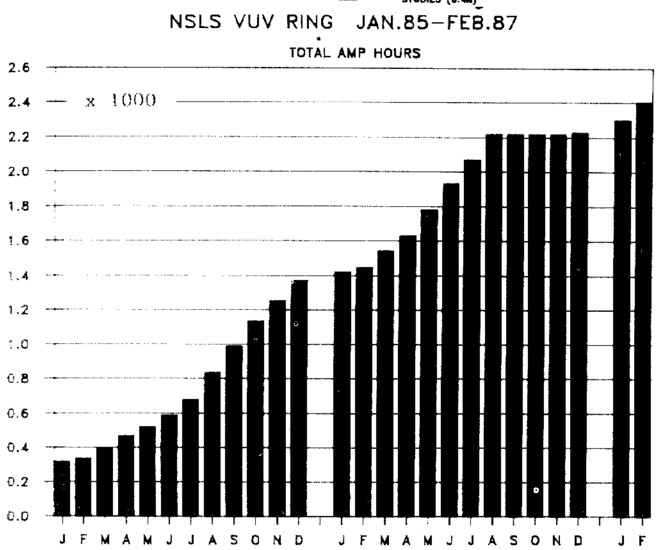


Figure 3(b)

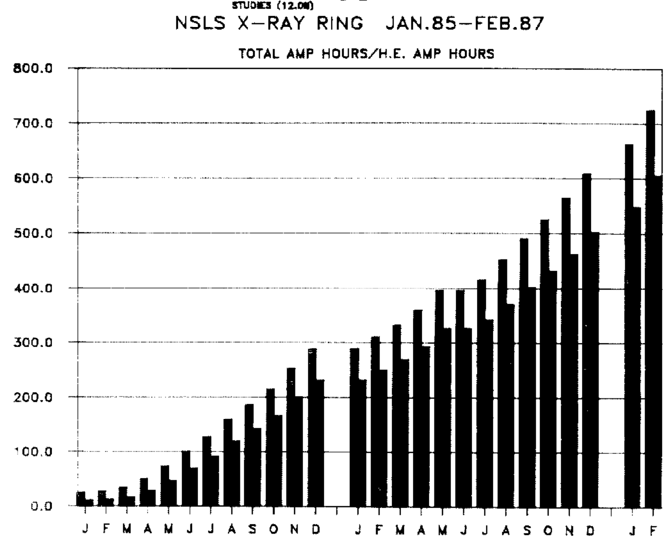
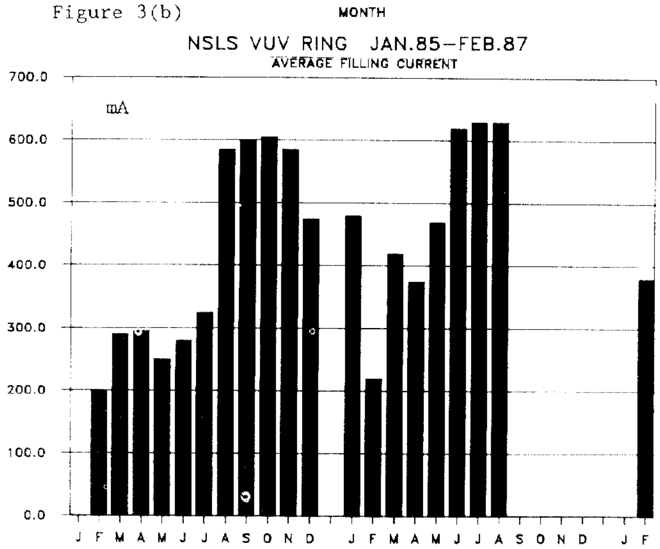


Figure 4(b)



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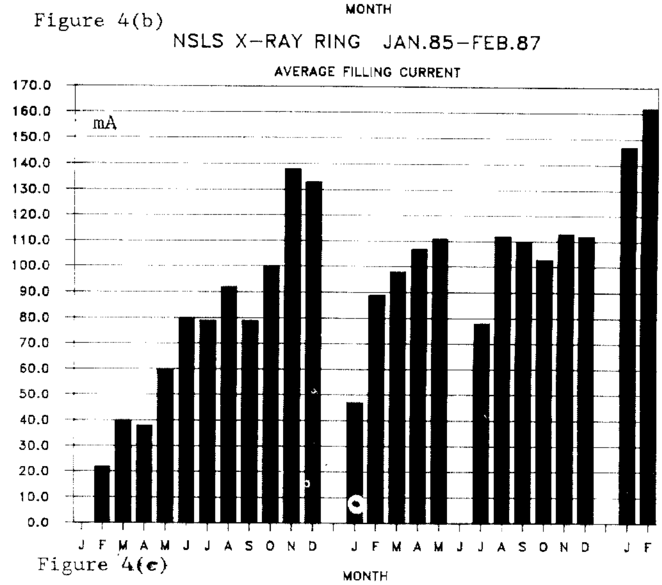

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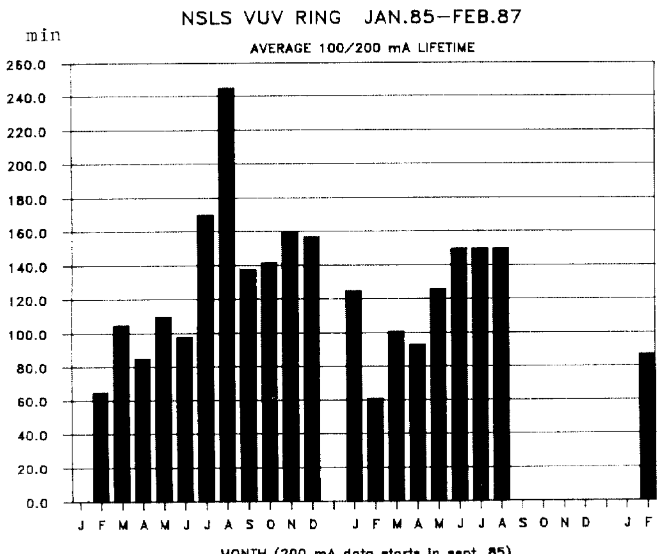

Figure 3(d)

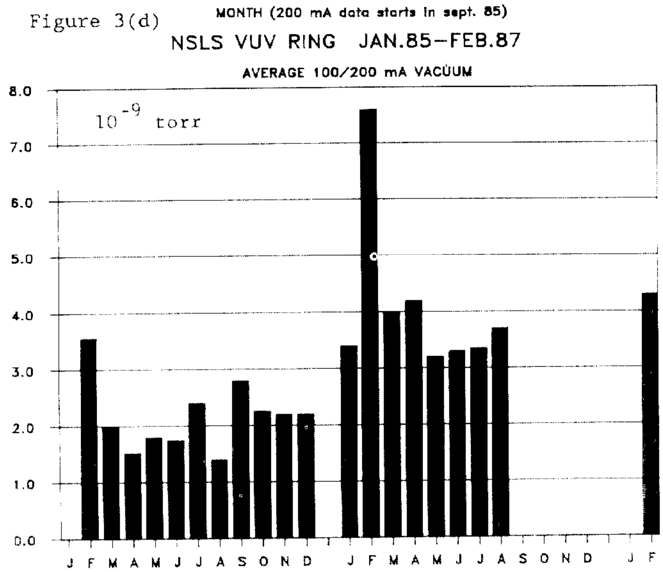

Figure 3(e) MONTH (200 mA data starts in Sept. 85)

shutdown is also demonstrated. The increase in lifetime of more than 50% in November 1986 occurred after the repair of a "fortuitous" leak in the seal of one of the RF cavities. Apparently this had always leaked, thus causing a local pressure bump and ion trapping.

Figure 5 shows 24-hour histories of the VUV ring before and after the four-month Phase II shutdown. Figure 5(b) demonstrates the ring conditioning procedure - the injection system is kept running, while the stored beam is oscillated vertically to clean the chamber by photodesorption. Ring pressure is indicated by the fuzzy area above the current history.

Figure 6 is a recent 24-hour history of the X-ray ring, showing a 14-hour fill and its decay.

Accelerator Upgrades

Increases of injection rates to both storage rings due to upgrades of the injection system have been mainly responsible for achieving the design parameters of the facility. The NSLS injection system consists of a two-section, two-klystron, S-band linear accelerator, feeding a small booster synchrotron operating at 0.67 Hz, the beam transport

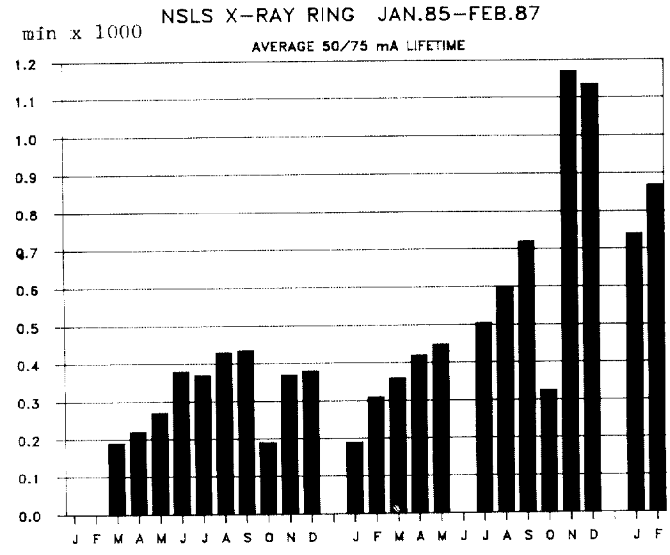

Figure 4(d)

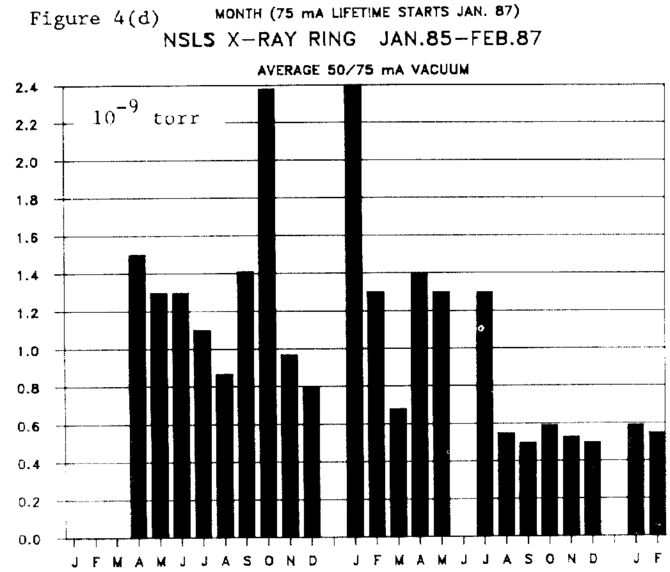

Figure 4(e) MONTH (75 mA VACUUM STARTS JAN. 87)

lines and the associated injection and extraction hardware on all three rings.

Improvements of the injection system have been many. Some of the main ones are: (1) installation of a new triode electron gun and low energy beam transport system, (2) precise temperature control of the linac accelerating sections and pre-buncher cavity, (3) overall timing system stabilization, (4) elimination of ripple in transport line power supplies, (5) booster dipole power supply stabilization, (6) re-survey of injection and extraction hardware, (7) reduction of injection septa stray fields and shortening of injection orbit bump time.

Initial injection rates of 40 ma/min in the VUV ring and 10 ma/min for the X-ray ring are now easily achieved.

The VUV ring successfully stored a current of 1 A in June 1986. Along with the improvements in the injection system described above, the VUV ring received upgrades in the following areas: (1) better control of the RF cavity tuner position and temperature (2) improvement of the longitudinal feedback system, (3) opening of the horizontal aperture in the injection septum area, (4) the replacement of a kicker ceramic chamber which had a defective coating, with the consequent reduction of the ring

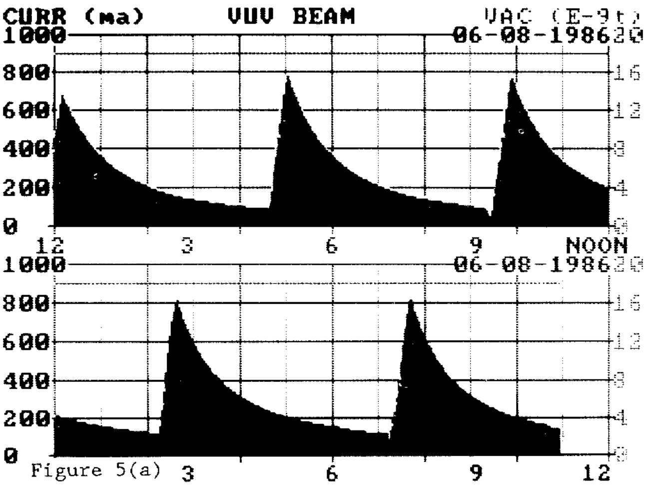

Figure 5(a)

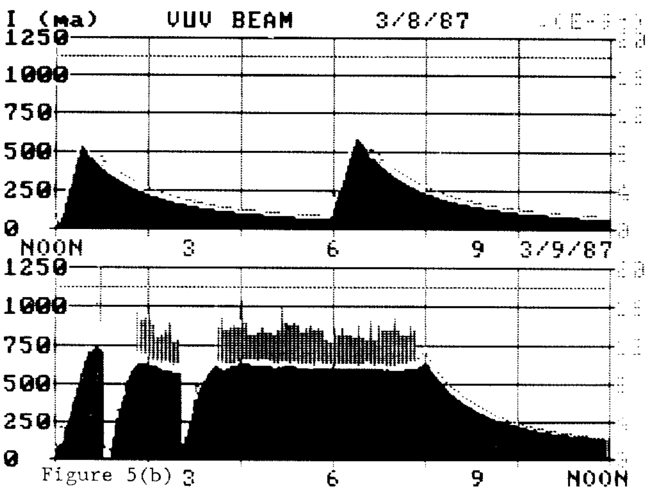

Figure 5(b)

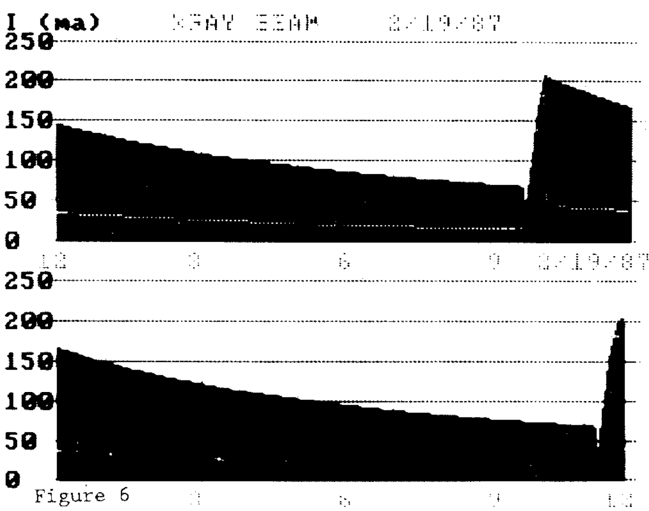

Figure 6

longitudinal coupling impedance from 10 ohms to about 2 ohms, and (5) running the ring with more positive chromaticity.

The X-ray ring operating energy was raised from 2.4 GeV to the design energy of 2.5 GeV in August 1985 by replacing the undersized dipole power supply. A lot of engineering went into the RF cavities and drive system, to improve their reliability, a new loop tuner and RF/vacuum seal were incorporated in the third installed cavity. Orbit stability was improved by installing laminated trim magnets with better hysteresis properties and locating faults in the trim magnet power feeds.

Both machines have benefitted from the unequal bunch filling procedures, the development of better feedback systems (both longitudinal and transverse) and improvement of the vacuum system.

Phase II and Future

Figure 1 shows the floor plan of the facility after the Phase II expansion. In addition to more floor and office space, Phase II also includes the following:

In the VUV ring:

(1) Installation of the TOK wiggler and IR beam line,
(2) Computer control of the RF system with a new loop tuner and vacuum/RF seals on the cavity,
(3) A 211 MHz, 10kW 4th harmonic RF system,
(4) New dipole and quadrupole power supplies,
(5) New distributed pumps,
(6) Upgraded Hall probe system for magnet monitoring,
(7) Clearing electrodes,
(8) Laminated trims and high stability trim supplies.

In the X-ray ring:

(1) Installation of new beam lines X1 to X8, X29, X30 and their associated front ends,
(2) Insertion devices:
X1 soft X-ray REC magnet undulator
X5 laser-electron gamma scattering line
X17 superconducting wiggler
X21 high energy resolution beam line hybrid wiggler
X25 high momentum resolution beam line hybrid wiggler
(3) Upgrade of RF cavities, including loop tuners, new seals,
(4) A 211 MHz 4th harmonic cavity,
(5) New dipole and quadrupole supplies,
(6) New distributed pumps,
(7) Laminated trims and high stability trim supplies,
(8) Redesigned injection system.

The VUV ring has just come back on from its Phase II shutdown, the X-ray ring shutdown is proceeding at this time.

The problem of global orbit stability has to be the next major problem that must be addressed in both rings as more and more sophisticated high-resolution experiments come on line to take advantage of our high-brightness beam. The injection system will be upgraded in the near future to shorten injection times and push to the current limits in both machines.

Acknowledgements

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