NSLS X-RAY SYSTEM RF SYSTEM UPGRADE *

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Abstract

Presently (Dec. 1992) three RF systems power the electron beam at the NSLS X-Ray storage ring to 250 mA at 2.58 GeV. A fourth RF cavity and system is being installed to increase the machine reliability over pre-shutdown operational conditions (3 cavities). It also permits new levels of beam intensity and energy to be achieved in the X-Ray ring. Intensities of 500 mA at 2.5 GeV as well as 250 mA at 2.8 GeV are anticipated. A description of the hardware, the installation and the modes of operation will be outlined in this paper. X-Ray ring operations are scheduled to resume January 1993. Injection performance and high energy reliability will also be discussed.

INTRODUCTION

The National Synchrotron Light Source (NSLS) is a national user facility in which proprietary research may be done by groups within and outside of Brookhaven National Laboratory. Two electron storage rings are currently operating: a 750 MeV VUV ring with 16 ports for VUV and IR research, and an X-Ray ring with 28 ports for X-Ray research.

The NSLS X-Ray ring is dedicated to the production of high brightness, synchrotron radiation that normally operates at 2.58 GeV at 250 mA. Power to return the energy lost to synchrotron radiation is supplied by 125 kW transmitters driving 52.88 MHz resonators.

Present operation with three RF systems is at 2.584 GeV and 250 mA with an average lifetime that exceeds 20 hours. The radiation loss per turn is 574 keV, thus the beam power is 0.25 amp x 574 kV = 143.5 kW or 48 kW per cavity. The beam power to cavity copper loss ratio, P_b/P_c = 48 kW/31 kW = 1.55, and the total power per system is 79 kW; as shown in Table 1a. With the addition of a fourth RF system, reliability can be improved in either of two modes of operation. If the excitation power of each cavity is left at 31 kW, the beam loading is reduced to 36 kW each. Note, that a fault in one system still allows enough remaining power to retain circulating stored beam. However, if the power/cavity is reduced to 17.5 kW (same O.V.F. as 3 systems), the total power requirement is only 53.5 kW as shown in 1b.

Each RF system is capable of producing 100 kW of power reliably, so there is ample power for higher beam currents or higher energy operation, as mentioned above. Operation at 500 mA is summarized in Table 1c. The beam power to cavity power ratio is rather high for the second mode, but presently the VUV cavities are run at P_b/P_c ratios greater than 7:1. This mode requires additional study.
Higher energy parameters are shown in Table 1d.

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2.584 GeV with 3 CAVITIES								
V_{rad}	Vgap / CAV	× O.V.F.	Vgap / CAV	P / CAV	I_b	P_b	P_{tot}	P_b/P_{cav}
574 kV	191.3 kV	1.3	250 kV	31 kW	0.25 A	48 kW	79 kW	1.55

1a.

2.584 GeV with 4 CAVITIES								
V_{rad}	Vgap / CAV	× O.V.F.	Vgap / CAV	P / CAV	I_b	P_b	P_{tot}	P_b/P_{cav}
574 kV	144 kV	1.7	250 kV	31 kW	0.25 A	36 kW	67 kW	1.2
574 kV	144 kV	1.3	187 kV	17.5 kW	0.25 A	36 kW	53.5 kW	2.1

1b.

2.5 GeV with 4 CAVITIES								
V_{rad}	Vgap / CAV	× O.V.F.	Vgap / CAV	P / CAV	I_b	P_b	P_{tot}	P_b/P_{cav}
503 kV	126 kV	2.0	250 kV	31 kW	0.5 A	63 kW	94 kW	2.0
*503 kV	126 kV	1.5	187 kV	17.5 kW	0.5 A	63 kW	80.5 kW	* 3.6

1c.

2.8 GeV with 4 CAVITIES								
V_{rad}	Vgap / CAV	× O.V.F.	Vgap / CAV	P / CAV	I_b	P_b	P_{tot}	P_b/P_{cav}
791 kV	198 kV	1.3	257 kV	33 kW	0.25 A	50 kW	83 kW	1.5

1d.

Table 1

CAVITY HARDWARE AND INSTALLATION

A Varian Y-567B (4CW100,000E) tube was chosen as the final amplifier to power the new installation. This tube has functioned reliably to above 90 kW in a Varian-built transmitter since 1986 (>50000 hours) in daily operations, without replacement. A new printed circuit RF processor was installed which includes all the low level processing, such as the phase and amplitude loops, signal detection and monitors, and tuning control. A frequency control loop drives the tuner to compensate for reactive beam loading. Linking to the computer is done via a newly designed VME crate, for level-setting, monitoring, and communications with control-room operators.

The resonator is a capacitively loaded, copper-clad steel cavity, with loop coupling and a shorted loop, motor-driven tuner. 80% of the total power is dissipated in the water cooled electrode which is made of OFHC copper. Due to the relatively large surface area, each cavity has a 440 lit./sec. ion pump, a 45 lit./sec. Star cell ion pump and a titanium sublimation pump. Water cooled apertures were placed upstream of each RF cavity in order to intercept unwanted synchrotron radiation before impinging onto the accelerating gap surfaces. Cavity 4 installation in the beam line, paired with cavity 3, is shown in Fig. 1.

Inner surfaces of the cavity have been coated with a 300-400 angstrom layer of titanium/titanium nitride. It was concluded during initial testing that the coating was sufficient to prevent multipactoring, but after installation, a persistent, low level, 2 kW multipactoring level still exists. Future testing of the loop window and cavity should determine the exact source of this problem.

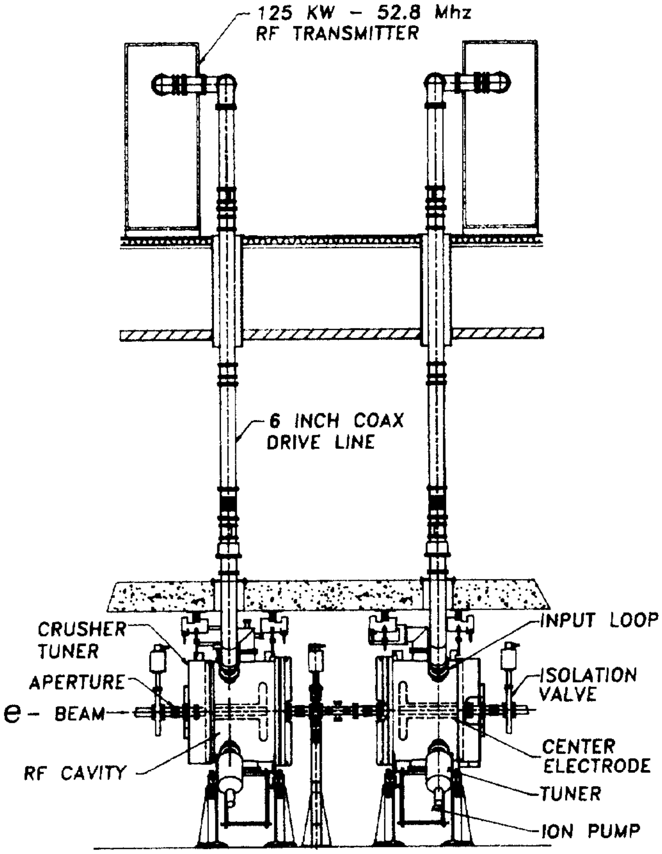

Fig. 1. System 3 and 4 RF Cavities

HIGHER ORDER MODE SUPPRESSION

Higher order modes (HOMS) are damped using five electric field probes inserted into the cavity. The probe locations provide coupling to the Homs while minimizing their effect on the accelerating mode. Each probe is terminated with a water cooled, 50 Ohm load. The approximate shunt impedances of the HOMS were measured using on-axis E and H field[1] probes to obtain the undamped (Q_o) and damped (Q_D) quality factor of the mode. The approximate damped shunt impedance of the mode can be found by scaling the value of the shunt impedance as calculated by URMEL. This assumes that the value of R/Q does not change with damping.

Another impedance measurement technique[2,3] was implemented using a central wire to simulate the electron beam. This method was used to characterize the cavity modes up to 1 GHz and confirmed the effectiveness of the damping antennae. Scattering parameters were measured using a network analyzer (HP 8510B) with a PC as a controller. System analysis based on S and T parameters was used to solve for the cavity impedance, $Z(\omega)$, as a function of the measured transmission response, $S_{12}(\omega)$. Search techniques were used to find the shunt resistance, R_{sh}, and Q from the calculated $Z(\omega)$ different modes. Results for R/Q showed good agreement with URMEL simulations. The values of Q for undamped and damped modes for the 52 MHz cavity were compared with the above probe technique and were in good agreement. Results of both methods for the monopole modes are summarized in Table 2. Similar results were achieved for the dipole modes using the probe technique.

Impedance Measurement			Probe Q-Measurement		
f(MHz)	Q	Qd	f(MHz)	Q	Qd
53.235	10,471	7,598	52.948	16,100	13,800
275.101	36,122	145.0	273.673	33,050	160
338.092	26,663	--	338.002	26,500	30
387.249	32,385	45.5	396.859	26,800	30
511.212	23,342	--	506.514	26,450	200
534.308	17,366	722.6	--	--	--
546.576	35,337	1,474	--	--	--
567.980	33,142	567.9	578.808	34,150	400
586.102	29,447	333.7	--	--	--
663.574	37,092	1,697	663.403	37,500	1900
713.817	44,822	--	713.534	44,000	180
756.819	35,746	3,355	756.709	37,100	3,600
792.287	14,806	1,737	788.966	10,750	1,900
878.156	22,260	817.7	861.651	22.680	420
954.737	30,329	2,729	954.783	48,900	200
975.377	6,471	1,493	972.216	6,080	340

Table 2.

CONCLUSIONS

X-Ray operations have resumed with 4 systems since early January with good results. Injection at 745 MeV and 502 mA has been achieved during limited study periods. A beam current of 410 mA has been accelerated to 2.528 GeV with 12 hour lifetime. The lifetime will improve as the ring vacuum conditions at the new higher current. Presently, beam-line shutters and insertion devices (undulators and wigglers) are disabled during these studies because of possible heating due to increased photon power. Calculations are being made to determine operational limits. X-Ray energy has also been ramped to 2.8 GeV with a 20 mA test current for a radiation survey. Plans for the future are to optimize injection and to determine the RF parameters necessary to reach 500 mA at 2.5 GeV and 250 mA at 2.8 GeV.

REFERENCES

[1] NSLS Tech Note #482 - Higher Order Mode Damping in X-Ray Ring Accelerating Cavity, W. Broome, R. Biscardi - 1993.

[2] S.M. Hanna and P. Stefan, "Application of Impedance Measurement Techniques to Accelerating Cavity Mode Characterization", submitted to Nucl. Instr. and Meth. in Physics Research, 1993.

[3] S.M. Hanna and P. Stefan, "Characterization of NSLS Accelerating Cavities Using Impedance Measurement Techniques," to be published in the Proc. of the 1993 IEEE Particle Accelerator Conf., 1993.