AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

BNL-48285

1993 Particle Accelerator Conf., Washington, D.C., May 17-20, 1993.

Test Results of the AGS Booster Low Frequency RF System*

R.T. Sanders, P. Cameron, R. Damm, A. Dunbar, M. Goldman, D. Kasha, A. McNerney, M. Meth, A. Ratti, R. Spitz

AGS Department, Brookhaven National Laboratory
Upton, NY 11973 USA

Abstract

The Band II RF system was originally built to support the Booster operations during the acceleration of heavy ions. Designed to sweep from 0.6 to 2.5 MHZ, it was build and successfully tested over a much broader range reaching 4 MHz. Voltages up to more than 20 kV were reached over the design frequency range. The system consists of two stations, each of which is made of one single gap cavity directly driven by a grounded cathode push pull power amplifier. The low Q high permeability ferrites needed in the coaxial cavity in order to reach the lower end of the band make tuning extremely easy. Both systems were thoroughly tested both at single frequencies and on a sweep and are now installed in the ring, ready for operations. Static measurements showed no high-loss effects. The Band II system has been fully described in a previous paper [1]; presented here are the results of the "bench" tests that lead to important performance improvements.

I. SYSTEM DESCRIPTION

The Booster RF systems are built with the twofold purpose of accelerating both protons at a 7.5 Hz repetition rate and ions as heavy as gold. The fast cycle and high intensity of protons ($5 * 10^{12}$ protons per bunch), requires a high total gap voltage and a low gap impedance. Gold ions impose the requirements of a large frequency swing, since the relative velocity β goes from 0.047 to 0.68. These dissimilar needs are fulfilled by two different types of RF systems. The first system, termed Band III [2,3], covers the voltage requirements of proton acceleration, 90 kV provided on four gaps (two per station), and a frequency sweep of 2.4 to 4.2 MHz. The second system, Band II, provides 35 kV on two gaps (one per station), and a frequency sweep of 0.6 to 2.5 MHz to accommodate the low β ions.

A. *The Band II Cavity*

Each of the band II stations consists of a single gap ferrite loaded quarterwave coaxial resonator. In order to achieve the low frequency resonance in reasonable dimensions, the cavity uses 66 TDK SY7 ferrite rings [4], with a remnant permeability of 1100. Tuning bias is applied via two figure of eight windings connected in series to obtain the maximum biasing field and thus the maximum frequency range. The low frequency end was reached without the need for additional external gap capacitance.

B. *The power amplifier*

The cavity is driven by an adjacent push pull power amplifier capable of an output power in excess of 200 kW. It employs two EIMAC Y567B power tetrodes, remotely driven by two solid state class A drivers each capable of 500 W of RF power. Input cross coupling is ensured via an input trans-

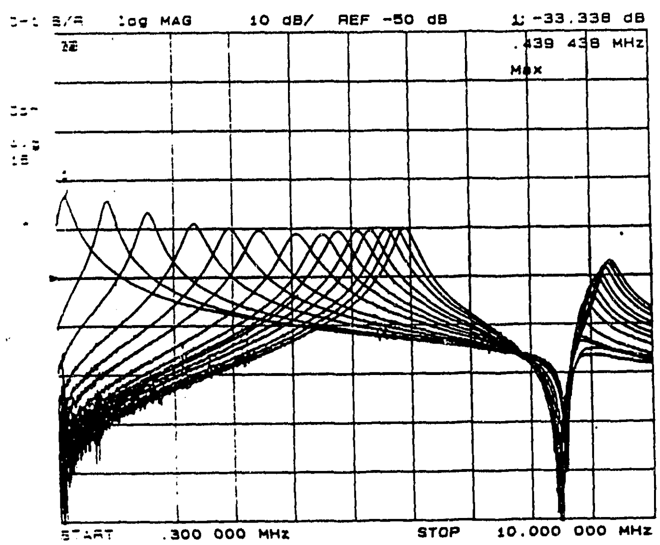

Figure 1. Cavity resonant frequency for increasing bias current at low power - single turn bias (I ranges from 0 to 520 A in 40 A increments)

* Work supported by the U.S. Department of Energy

former, which also provides resistive matching to the 150 ohms input low pass filter. The cavity biasing figure of eight windings also guarantee the load cross coupling and help improving the push-push mode rejection.

II. BENCH TEST

The system has been fully tested with very satisfactory results. The full design voltage of 17 kV was comfortably achieved, and the required frequency range greatly exceeded: sweeps from 0.6 to 4.0 MHz were performed using the available 200A of current power supply, which was the only limit that prevented a larger frequency swing. Both static and dynamic measurements were performed by calorimetry to study the ferrite losses. Table 1 shows the measured static losses of the system in the design operating frequencies; the maximum measured power was 123 kW at the high frequency end, whereas the dynamic losses are very moderate and do not contribute for more than an additional 10% to the total power dissipation. With an input drive of 212 volts to obtain 10kV on each side of the gap, the final stage gain is about 33.5 dB. Dynamic tests showed no need for neutralization of the internal feedback capacitance in the power tubes.

Table 1: Static measurements results (calorimetry)

Freq [MHz]	Power @ 10kV [kW]	Power @ 20kV [kW]	Vdrive @ 10kV [V]	Vdrive @ 20kV [V]	I tuning [A]
0.6	15.6	56	75	145	10
1.0	17.8	70.2	83	155	30
1.5	19.8	94.2	94	177	50
1.9	22.3	114	98	205	70
2.3	28.3	118	110	221	90
2.7	31.3	123	120	212	110

Sweeps were also performed at a much faster rate than originally requested [5]: the system was swept from 0.6 to 2.5 MHz in 45 ms, which corresponds to a rate of 42 MHz/sec. No measurements are available though on the power dissipation during this fast sweeps. The quality factor Q ranges from 1.5 to 3; no sign of the well known high loss (Q-loss) effect has been found during the tests. The large bandwidth corresponding to such a low Q makes tuning particularly easy. Fig. 2 shows the response of the phase detector during a full frequency sweep and indicates an error of much less than 10 degrees throughout the whole cycle.

The inductance of a single turn bias winding was measured to be ranging from 470 µH to18 µH for a 200 Ampere bias current. When the two bias windings were connected in series the inductance scaled according to the square law. The bandwidth of the tuning system, is approximately 20 kHz.

III. BEAM EXPERIENCE

After the first cavity was installed in the Booster ring, its impedance has been measured by circulating a beam focussed with the Band III system and reading the voltage induced in the properly tuned Band II cavity. This does not take into account the amplifier damping (not available at that time).The cavity shunt impedance as measured with the beam is on average 2.0 kΩ, and is in reasonable agreement with the one calculated via calorimetry (1.7 kΩ).

IV. COMMENTS

The encouraging results of the bench tests on the system, originally build to cover the initial portion of the acceleration of heavy ions, open the possibility of using it in other applications. For example it can be used to perform the entire heavy ion cycle, since its operating range has reached the higher frequencies required to accelerate the ions to the top energy. Also it can be used as a second harmonic system during the injection of protons, by extending the frequency range to reach 5 MHz. This would only require modifications on the power amplifier input low pass filter and a larger bias current supply.

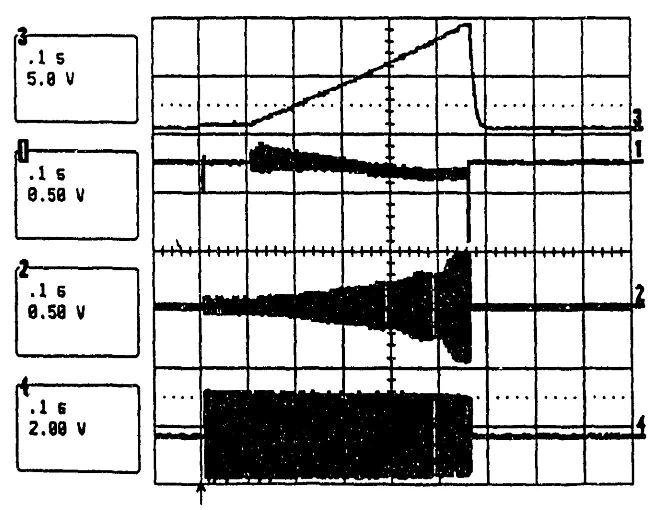

Figure 2. **Full 0.6 to 4 MHz sweep at 17kV: 1. phase detector (10deg/V), 2. Low level drive, 3. Frequency program, 4. Cavity voltage (3550:1)**

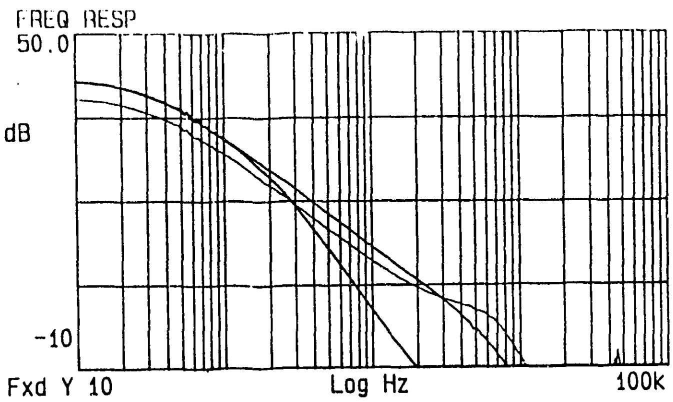

Figure 3. **Dynamic response of the tuning system phase loop (at biasing currents of 10, 50 and 110 A)**

V. CONCLUSIONS

The low frequency RF system for the AGS Booster has been build. Its broad band characteristics make it a very attractive feature that can actively contribute both in the heavy ions and in the proton operations. Further improvements are possible to taylor its characteristics to the most urgent needs that can arise during operations.

Installation is now completed for both Band II stations; they will be commissioned during the next scheduled heavy ions run this summer.

VI. ACKNOWLEDGMENTS

The work presented here benefits from contributions from the whole AGS community. In particular, P. Benjamin, C. Gardner, K. Rogers and S. Valentino provided an excellent technical support. The help of M. Blaskiewicz during the beam experiments was very important. The crucial support from J. M. Brennan and N. Laloudakis is also acknowledged.

VII. REFERENCES

[1] R.T. Sanders, et al., "The AGS Booster low frequency RF system", Proc. of the 1991 IEEE Particle Accelerator Conference, Vol 2, pp.739-741, S. Francisco, CA, May 1991

[2] R.T. Sanders, et al., "The AGS Booster high frequency RF system", Proc. 1987 European Particle Accelerator Conference, Rome, June 1987

[3] R.T. Sanders, et al., "The AGS Booster high frequency RF system", Proc. of the 1991 IEEE Particle Accelerator Conference, Vol 2, pp.681-683, S. Francisco, CA, May 1991

[4] M.A. Goldman, et al., "Studies of ferrite materials for the Booster synchrotron", Proc. of the 1989 IEEE Particle Accelerator Conference, Vol. 1, pp. 165-167, Chicago, IL, March 1989

[5] Booster Design Manual, Rev. 1, Oct 1988

[6] D. P. Deng, J.M.Brennan, private communication.

DISCLAIMER

DATE
FILMED
8 / 18 / 93

END