TEST RESULTS OF THE LOS ALAMOS FERRITE-TUNED CAVITY*

C. C. Friedrichs, (MS-H827) R. D. Carlini, G. Spalek, and W. R. Smythe**
Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract

An rf accelerating cavity appropriate for use in a 20% frequency bandwidth synchrotron has been designed,[1] fabricated, and is now being tested at Los Alamos. The cavity-amplifier system was designed to produce a peak rf gap voltage of 90 kV over the range from 50 to 60 MHz. Special features of the system are the transversely biased ferrite tuner,[2] capacitive coupling of the amplifier to the cavity, and a 15-cm beam pipe. High-power rf testing of the cavity-amplifier system started in August 1986, using an adjustable dc power supply to bias the ferrite. This paper describes the cavity-amplifier circuit and the test results to the present time. Future plans are also discussed.

Circuit Description

A cross-sectional drawing of the cavity-amplifier system is shown in Fig. 1. The resonator is essentially a quarter-wave resonant circuit. The high-voltage end is at the accelerating gap, and the high-current end contains the ferrite tuner. It should be noted that SUPERFISH plots have shown the wave propagation to be essentially radial in the ferrite region and axial or TEM in the remainder of the cavity. The amplifier is capacitively coupled to the cavity center conductor near the gap end of the resonator. The amplifier tube is a 4CW 150 000 E tetrode. The ferrite-bias magnet is constructed so that the ferrite-bias field lines are parallel to the cavity axis and the rf magnetic field in the ferrite is in the circumferential direction, perpendicular to the bias field.

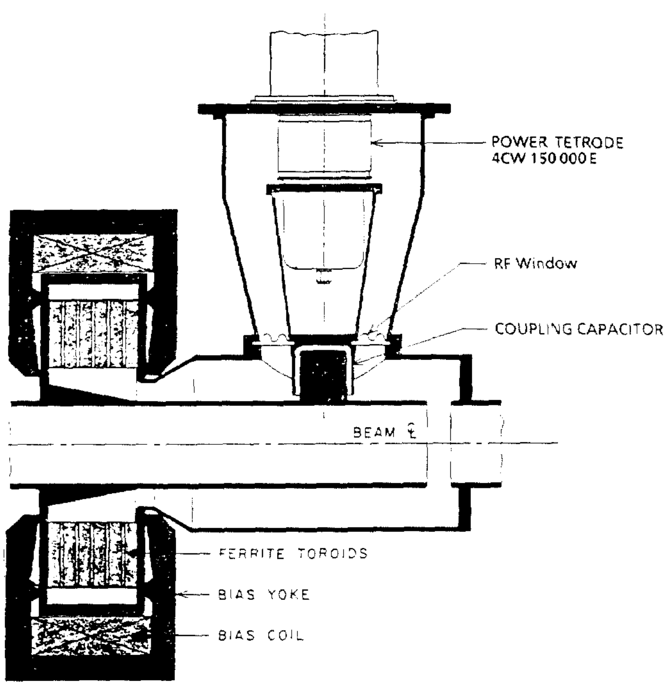

Fig. 1. Cross section of cavity amplifier.

The tuner is made up of six ferrite toroids. Each toroid is 1 in. thick, separated by five 1/4-in.-thick beryllium oxide spacers. Beryllium oxide was selected for its high thermal conductivity; the inside radius of the toroids is 6.3 in. and the outside radius is 11.8 in. The outside radius of the beryllium oxide spacers is slightly larger than that of the ferrite toroids to ensure their contact with a water-cooled copper circumferential clamp. All operation to date has been performed with the tuner in the vacuum. A cylindrical ceramic window that fits inside the inner radius of the ferrite will be installed soon, and sulphur hexafluoride will be used to fill the tuner region.

Provisions are included on the cavity for external resistive damping, which consists of two 50-kW, 50-Ω, water-cooled coaxial loads that are capacitively coupled to the cavity center conductor in the region between the tuner and the amplifier. A 55-dB directional coupler is included with each load. The load-coupling capacitors are set so that each load will absorb about 6 kW when the gap voltage is 90 kV peak.

Gap-Voltage Calibration

The damping-load directional-coupler outputs are used as the primary cavity waveform monitoring points. The following procedure is used to establish the relationship between the gap voltage and the directional-coupler output voltage: The gap insert plates (Fig. 2) are installed inside the beam pipe on each side of the gap. Measurements are made at 2-MHz intervals from 50 to 60 MHz. At each frequency the bias-magnet current is set to its previously determined resonating value for that frequency.

The recorded data include the forward and reflected voltage from the 200-W source directional coupler and the forward voltage from the damping load-directional coupler.

In all cases the voltage-standing-wave ratio (VSWR) seen by the 200-W source is within the range of 1.06 to 1.08. Because of the low VSWR, the gap voltage is assumed to be the same as the 50-Ω-load voltage that is calculated from the forward voltage sample of the source directional coupler. A constant ratio of 65 000 to 1 exists over the range from 50- to 60-MHz gap voltage to damping load-directional-coupler voltage.

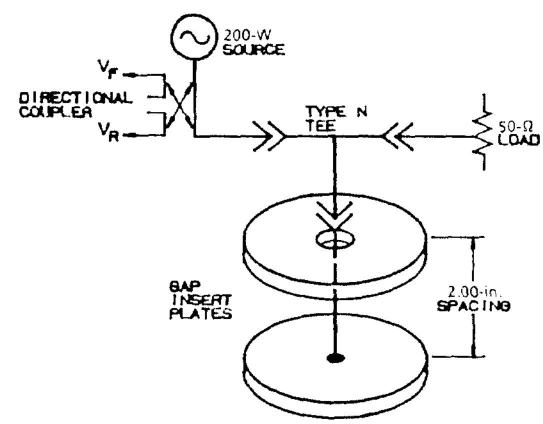

Fig. 2. Gap voltage calibration circuit.

*This work was supported by Los Alamos National Laboratory Institutional Supporting Research and Development Funds.
** Permanent address: University of Colorado.

Test Program

First data from the rf accelerator test stand were obtained in mid-August 1986, and testing continued until mid-September 1986, at which time our shared-anode power supply was returned to its primary mission of supporting LAMPF. The power supply became available again in late October 1986 and has generally been available since that time. During the August-September period, the cavity walls were either aluminum or stainless steel, but all inside surfaces were sputtered with titanium nitride to reduce multipacting. The system was pumped with a 250-ℓ/s turbine pump. We were able to operate over the frequency range from 48 to 64 MHz using short pulses, typically 200 ms at 10 pps. The observable gap voltages ranged from 30 to 100 kV peak. Resonance at a given ferrite-bias current was determined by adjusting the amplifier frequency to obtain a peak in the cavity voltage. Measurements of circuit Q were attempted by measuring the fall time of the rf waveform. The frequency-vs-current tuning data resulted in a smooth monotonic curve that was always closely repeatable. The Q-vs-current data did not result in the expected curve, and the curve was only repeatable in its general shape. Interaction of the final amplifier anode supply rf filter with the circuit was at first suspected of causing the Q-curve anomalies, but this was soon ruled out. No satisfactory explanation had been found by mid-September when the power supply became unavailable.

The objective in late October was to obtain increased average power. We quickly found that at even moderate levels, 10% of normal, the stainless steel circuit members were approaching 200°F. Testing was suspended in early November in order to copper-plate all center conductor pieces and all stainless steel outer conductor pieces. Water cooling of the center conductor was also added. Gap voltages above 130 kV peak were recorded during this period.

The value of the capacitor that couples the amplifier to the cavity essentially determines the step-up ratio between the amplifier rf voltage and the gap rf voltage. The circuit was designed so that a peak anode voltage of 17.5 kV would result in a peak gap voltage of 90 kV. The lowest anode voltage available from the anode power supply is 31 kV dc, making peak rf anode voltages of 28 or 29 kV feasible and making possible gap voltages far in excess of the 90-kV original design value.

Copper plating of the cavity parts was completed and testing was resumed in early February of 1987. A 1500-ℓ/s cryogenic pump was added. The February tests, conducted under higher average power conditions, resulted in the following milestones: The circuit was operated over the frequency range of 50 to 60 MHz at gap voltages between 130 and 140 kV. Then, the circuit was operated at 140 kV, at 60% duty cycle at 57 MHz, for a period of about 10 min. When the cavity outer-conductor temperature approached 200°F, this test was terminated. The circuit was operated for 2-1/2 h with 60 kV across the gap at 30% duty cycle at 54 MHz and the cavity outer conductor stabilized at approximately 180°F during this test. The tuner cooling clamp absorbed about 2 kW during this test.

The source of errors in the Q-measurements was finally discovered, but a cure has not yet been implemented. The circuit for the final amplifier includes kapton sandwich capacitors that bypass the screen grid and the control grid to one another as close to the socket as is practical. The circuit lengths from the active regions of the screen and control grids out to the bypass capacitors are not negligible, and some rf voltages exist between these elements, resulting in imperfect output to input isolation.

The fall time of the final amplifier driving waveform is less than 300 ns until the final amplifier is activated. When the final amplifier is activated, the driving waveform fall time develops a tail that severely affects the amplifier fall time and thence the Q-measurement. We have demonstrated that manipulations of the input circuit parameters noticeably and repeatably affect the amplifier output fall times. Ultimately these effects must be corrected.

The cavity tuning curve is given in Fig. 3. The curve is a plot of resonant frequency as a function of ferrite-bias current. The bias magnet contains 140 turns.

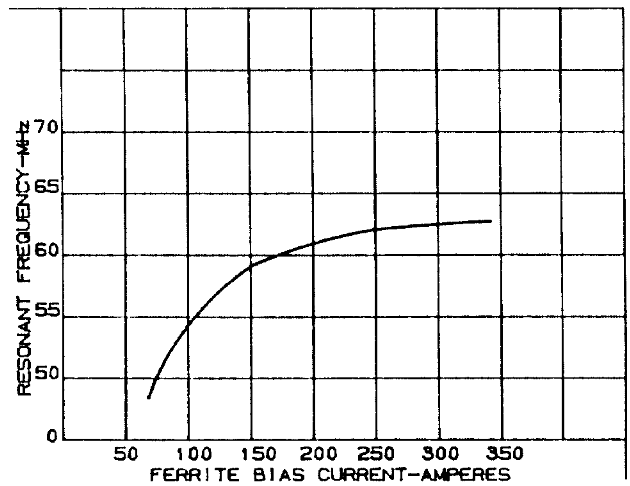

Fig. 3. Cavity tuning curve.

No Q-curve data are given for reasons previously described. The area for concern would be at the low-frequency end of the band where the bias current is lowest and, therefore, the ferrite magnetic Q is lowest. Qualitatively, we have seen no effects that would give rise to concern, even down to 48 MHz.

Future Plans

The next generation of tests will include an ac bias magnet with ramped bias and swept-frequency operation. The ac bias magnet is now being designed. We plan to begin these tests during FY 88.

Plans for the present phase of the test programs include the installation of the vacuum window to isolate the ferrite from the vacuum; resolution of the Q-measurement problem; and improved instrumentation to better measure various parameters such as ferrite temperature, ferrite power, and amplifier input power.

Acknowledgments

The authors wish to express their appreciation to Mark Doub and Dave Guenther, the technicians whose dedication to excellence helped in making this project a success.

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