PERFORMANCE OF THE HIGH POWER RF SYSTEM FOR THE NIST-LOS ALAMOS RACETRACK MICROTRON

R.I. Cutler
National Institute of Standards and Technology
Gaithersburg, Md. 20899

L. Young
Los Alamos National Laboratory
Los Alamos, NM. 87545

Introduction

The high power RF system of the NIST-LANL RTM has been tested at nominal full power levels and has accelerated electron beams successfully[1]. RF stability and calibration measurements have been made using the accelerated electron beam. These measurements have been used to calculate the effective shunt impedance of the side-coupled accelerator structure. RF stability measurements were also performed using power meters and phase detectors.

RF System Description and Operation

The high power RF system for the NIST-LANL RTM consists of a single 500 kW CW klystron at 2380 MHz that powers four separate linac sections. Two are in the injection line and two are in the microtron. The first linac section in the injection line is the capture section, a 1.1-meter long, tapered-β (0.55 to 0.95) section with an energy gain of 1.3 MeV. The nominal power level of the capture section with no beam loading is 25 kW. The other linac section in the injection line is the preaccelerator section, a 2.7 meter long, tapered-β (0.95 to 0.99) section with an energy gain of 3.7 MeV. The nominal power level of this section with no beam loading is 63 kW. The two linac sections in the microtron are each 4 meters long, β = 1 sections with an energy gain of 6 MeV. Their nominal unloaded RF power levels are 100 kW each.

The RTM RF system uses two separate control methods for power and phase regulation, one for the capture section and the other for the remaining three accelerating sections. A block diagram of the high power RF control system is shown in figure 1. The feedback control loop of the capture section monitors the phase and power level in the capture section via a 50 dB coupling loop and varies the input signal to the klystron to reach the desired values. This control loop uses low-level ($\approx$1 watt) amplitude and phase controls with an open loop gain bandwidth of 40 kHz. Details of this control system are in Reference 2. The

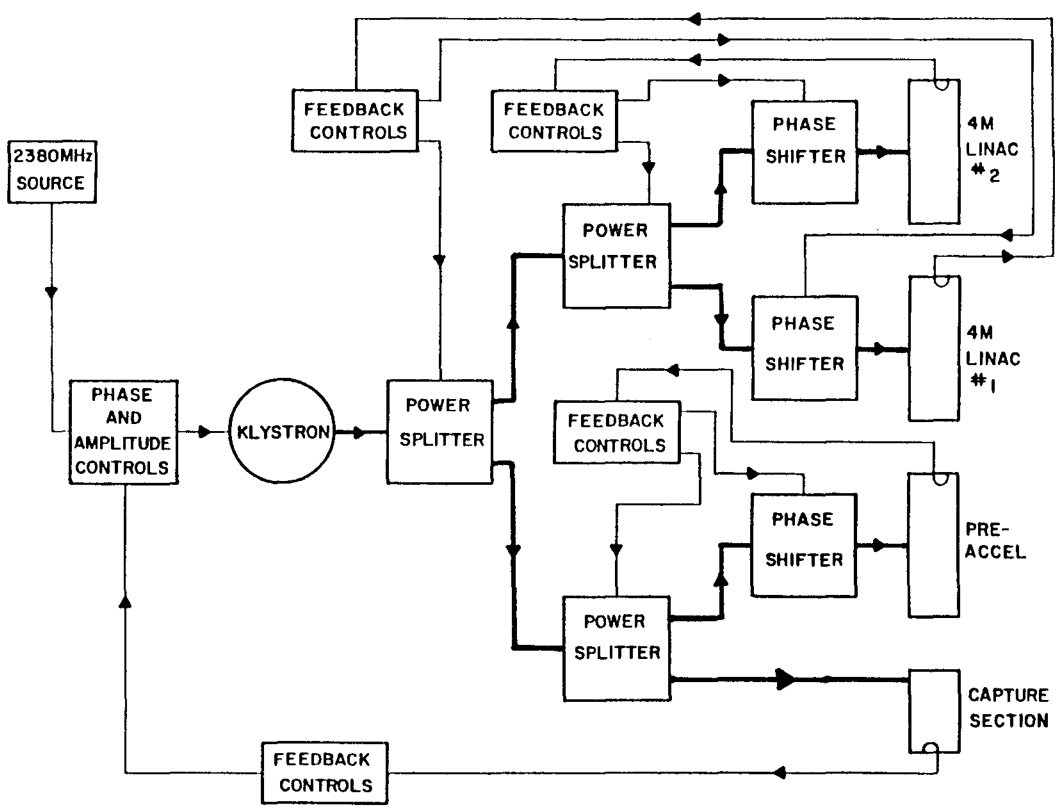

Figure 1. Block diagram of RTM RF control system.

other three linac sections use high power waveguide power splitters and phase shifters as their control elements. The waveguide power splitters allow a < 1% to 99% power split. The waveguide phase shifters have a 140° range. Since these waveguide elements employ large mechanical shifters with stepping motor drives, the control loops containing these elements have an open loop gain bandwidth of 3 Hz. As the power level in the preaccelerator or in either of the two microtron linacs is changed, the RF drive to the klystron is controlled by the capture section control loop to maintain the proper total power requirements of the RF system. Because the capture section control loop has a much faster response time than the other three linac sections, there are no control loop problems in increasing power. A complete description of the high power waveguide feedback system is presented in Reference 3.

A separate temperature control system is used on each linac section to maintain the RF resonance at the operating frequency of 2380 MHz. These temperature control systems vary the cooling water flow into each linac section to maintain resonance at all RF power levels. This keeps the reverse power at each accelerating section window to a minimum, typically less than 1 kW in steady state operation. A block diagram of this control system is shown in Figure 2. A description of this system is presented in Reference 4.

The RTM uses a computer control system[5] to monitor and control all accelerator parameters. All accelerator devices have hardware protection to prevent damage. The status of all hardware protection interlocks is monitored by the computer control system. Software may be written to allow computer automated monitoring and control of any combination of the accelerator parameters. The program AUTORF ramps the power up from zero to preset values for all four linac sections simultaneously. The program usually can reach full power in less than 10 minutes.

RF Measurements

Measurements were made of phase and energy stability of the four accelerator sections at full power. Phase measurements were made by mixing a signal obtained from a 50 db coupling loop in each accelerating cavity with a reference signal in a double balanced mixer. The output of this mixer, near the null, is proportional to phase. The maximum phase deviation in a 20 minute period was found to be ±0.15°. Energy stability measurements were made using a low barrier Schottky diode detector at the output of the 50 db coupling loop. The voltage deviation of each accelerating section was measured to be less than 1 part in 1000, and the voltage variation of the 1.3 MV capture section was less than 1 part in 2000. Energy stability was also measured by observing energy variations in an electron beam accelerated by all four accelerating sections. This electron beam was then energy-analyzed by a 180° bending magnet and the position of the beam measured using a wire scanner[6]. The 15.5 MeV electron beam was found to have a width of about 20 keV. Also observed was a slow (approximately a few Hertz) energy fluctuation of ±10 keV, which is due to energy variations in the preaccelerator and the two RTM linac sections. This is illustrated by figures 3 and 4, which show several super-imposed wire scanner electron beam profiles for the X (energy analyzed) and Y (non-energy analyzed) planes. The wire scanner, which operates at 10 profiles per second, detects multiple images corresponding to energy shifts of ±10 keV in the X plane, but not in the Y plane. These data are consistent with the energy stability of each

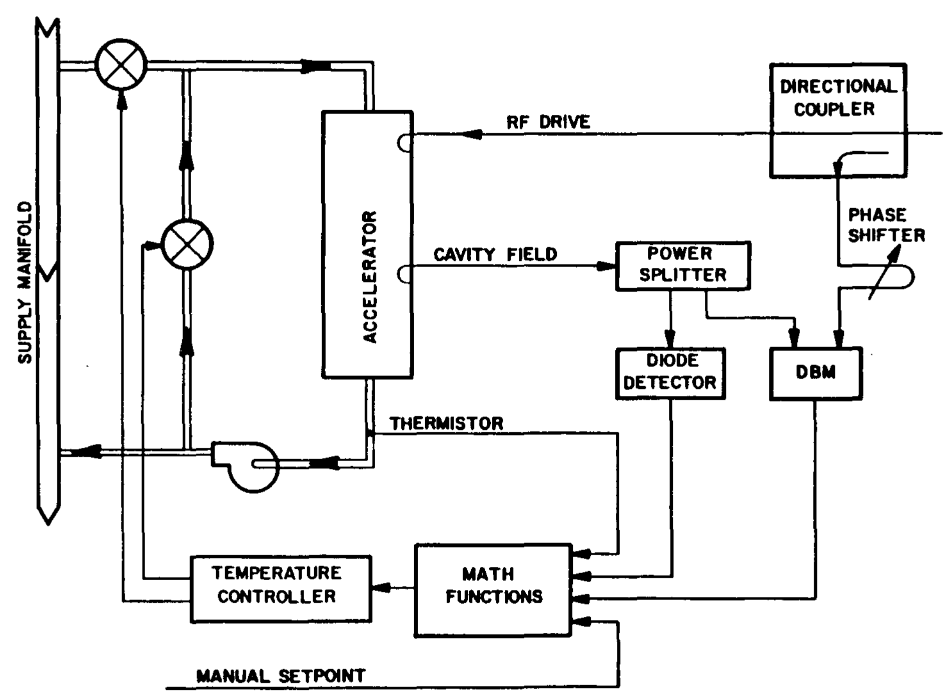

Figure 2. Block diagram of RF resonance control system.

accelerating section measured using the detection diode.

The energy gain of each accelerator as a function of input power was also measured using the 180° analyzing magnet and a wire scanner. The absolute energy calibration of the 180° analyzing magnet was ±1.5%. The input power was measured in several ways. Wave guide directional couplers were used with an RF power meter for one set of measurements. These measurements are only absolutely accurate to ±10% due to the uncertainty in the calibration of the waveguide couplers. Measurements of power were also made by using the RF power meter with the accelerating cavity field probes, which also have an absolute calibration of about ±10%. Finally, calorimetric measurements of the temperature rise of the cooling water were performed for each accelerating section. The calorimetric measurements, which were accurate to ±6%, agreed with the previous two measurements and were used to calculate the effective shunt impedance for the two RTM linac sections and the preaccelerator. The values obtained, 76±5, 77±5, and 80±5 MΩ/meter are in good agreement with the value of 82.5±1 MΩ/meter from low power measurements on the pre-accelerator[7].

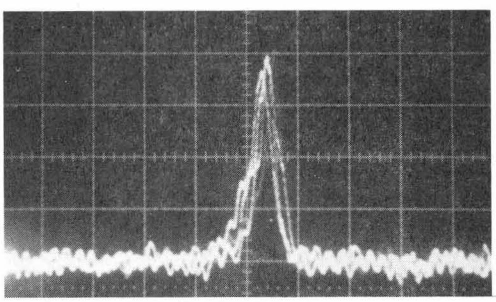

Figure 3. Wirescanner output X (energy analyzed) plane. Horizontal scale is 2.15 mm per division, or 50 keV. Vertical scale is current, in arbitrary units.

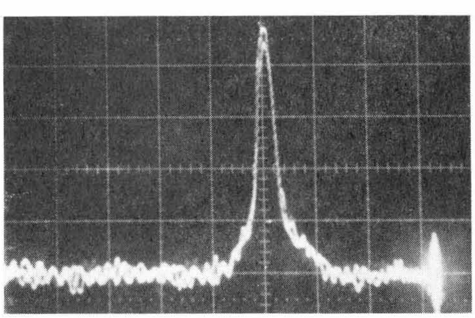

Figure 4. Wirescanner output Y (not energy analyzed) plane.

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