Bull. Inst. Chem. Res., Kyoto Univ., Vol. 69, No. 1, 1991.

The RF Power Amplifier System for a Heavy Ion RFQ Linac

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Received February 8, 1991

A 33.3 MHz radio frequency cw power amplifier (P.A.) system has been installed in the Accelerator Lab. of ICR, Kyoto University. The system comprises of three major subsystems operating in the same frequency: a 50 kW P.A. for a RFQ linac, a 5 kW P.A. for a post accel./decelerator and a phase-shifting unit, which adjusts the phase relationship between the two P.A.s. The system is fully tested using dummy loads and is confirmed to satisfy our specification. This work is part of the continuing program for the development of a commercial heavy ion MeV RFQ linac.

KEY WORDS: RF amplifier system/RF power supply/Heavy Ion Linac/

1. POWER ESTIMATE

A question of "how much power do I need for this accelerator ?" is rather difficult to estimate in theoretical calculations only. From the results of our proton 4-rod RFQ accelerator experiment, the power requirement of our heavy ion 4-rod RFQ can be deduced and used as a more realistic guideline[1]. This information is very important because the costs of RF amplifiers are going to take up a large portion of the budget of this accelerator program. The shunt impedance - here defined as a figure that correlates the inter-electrode voltage to the power spent for exciting the resonator- of the proton accelerator is around 50 k ohm per resonator. We can expect the equivalent value for the heavy ion RFQ as well and considering that the inter-electrode voltage is increased to 60 kV (10 kV for our proton RFQ), the minimum power requirement is estimated to be 36 kW.

The maximum power that can be fed to the post accel./decelerator structure is mostly limited by the RF sparking limits between the electrode gaps. From the Kilpatrik's sparking empirical formula, the field strength at 33.3 MHz is around 7.8 MV/m[2]. This corresponds to 164 kV per gap in our accel./decelerator resonator. We choose a rather conservative design gap voltage, 80 kV and an expected shunt impedance of the resonator, 4.4 M ohm[3]. Then the power requirement for the resonator is estimated to be 5.8 kW.

2. SYSTEM COMFIGULATION

Figure 1 is the block diagram of and photo. 1 is the photograph of the RF P.A. system taken at the installation site. Both the 50 kW P.A. and the 5 kW P.A.s have a local as well as a remote controller. The RF P.A. system is installed in the Ryushisen-Hassei-Kiki Shitsu except for a signal generator, a 360 degree phase-shifting unit, and

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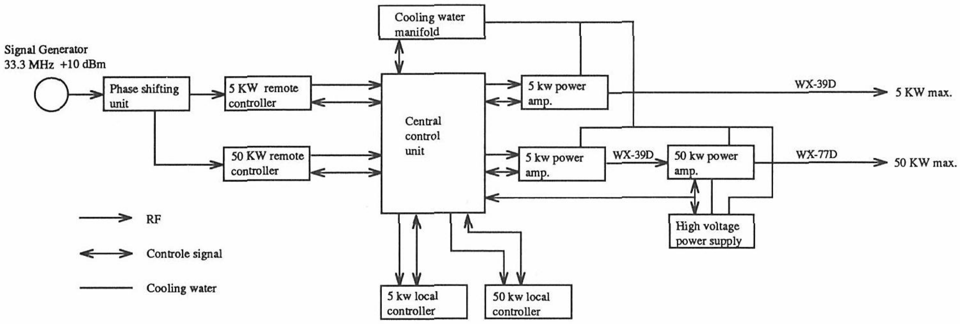

Fig. 1 Block diagram of 33.3 MHz RF P.A. system

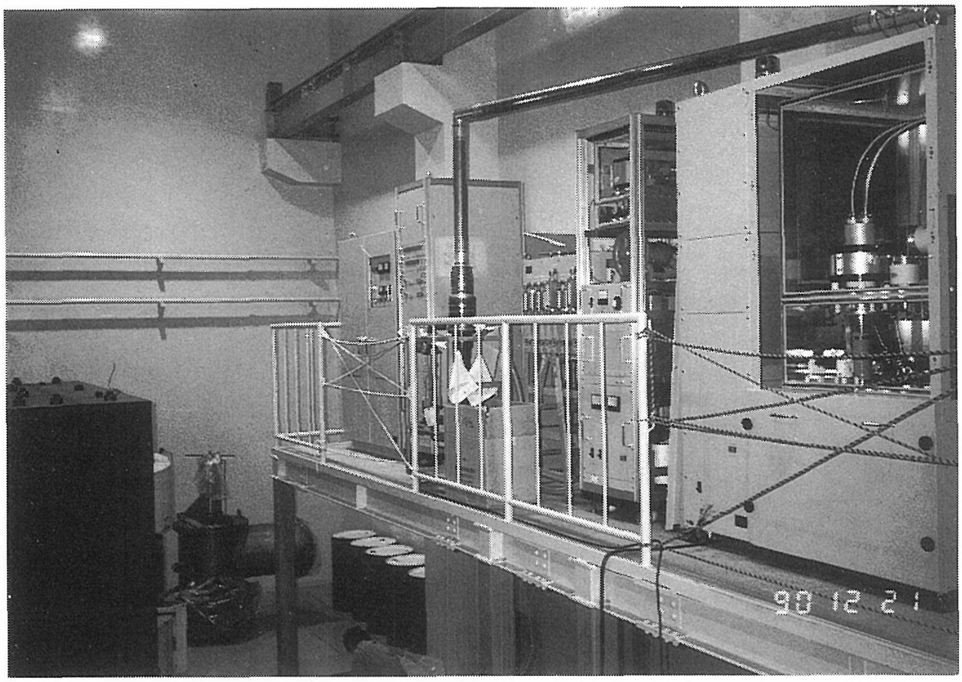

Photo. 1 Photograph of 33.3 MHz RF P.A. system at the installation site in the Ryusisen-Hassei Kiki Shitsu of the Accelerator Lab., ICR, Kyoto University. The cabinets and racks are arranged on the 2.4 m height deck of 2.4 m by 8.4 m floor area: from the left, a high-voltage power supply, a central control unit, a water-cooled dummy load, a cooling water manifold, a 5 kW P.A., and a 50 kW P.A.

the remote controllers. They are installed in the remote control room located south of the experiment room. The two 5 kW P.A.s are identical: one is used as a driver amp. for the 50 kW P.A. and the other is used as a final-stage P.A. for the post accel./ decelerator resonator. Each P.A. consists of a 500 W solid-state amplifier and a Siemens RS3021 CJ triode P.A. The 50 kW P.A. is also a tube-amp. equipped with a Siemens RS 2058 CJ tetrode. RS3021 CJ and RS 2058 CJ have the maximum anode dissipation of 20 kW and 90 kW, respectively. The reason we have chosen such large tubes is that a small-size circulator is not available in this frequency regime. That is one practical way of "protecting" the expensive tubes from the power reflected at the accelerator cavity in case of total reflection caused by sparking.

The total power required for the full power operation of the 50 kW and 5 kW system is approximately 140 kVA. A 150 kVA 200 volts 3 phase power line is newly installed in the experimental area. The P.A.s also require 100 liters/min. of deionized water for cooling. A 400 liters/min. deionized cooling water circulator system (called "Sokutei-kei") supplies cooling medium for the RF P.A. system as well as for the RF accelerator cavities. This is one of four deionized cooling systems in the building and it has more than adequate specification for our purpose: a 230 kW heat exchanger, a 70 m total-head pump, and a 450 kW cooling tower.

This P.A. system can be expanded for a multi-post accel./decelerator linac by adding the phase shifting units and P.A.s to the existing P.A. system. An upgrade in the linac's maximum energy or its energy range can be accomplished without change in the P.A. system configuration.

3. 50 kW FINAL STAGE P.A.

This P.A. is classified as cathode-driven class AB grounded control and screen-grid RF amplifier. Fig. 2 is the circuit diagram of the 50 kW P.A. The driver amp.'s output is fed to the cathode via WX-39D and the output is transmitted to the RFQ cavity in WX-77D coaxial tube. The forward power calibration is done with −60dB directional coupler that is installed in the WX-77D coaxial line and the results are compared with the values obtained by the calorimetric measurements of the 50 ohm water-cooled dummy load. The power efficiency that is defined as RF power output divided by power fed to the RS-2058 CJ's anode is approximately 70% at 50 kW output. The calorimetric measurement gives 48.5±.3 kW at the same output.

The output ripple is suppressed to less than ±2% at the full power by a feed-back loop. Higher harmonics are kept below −30 dB at the same output. The cabinets of

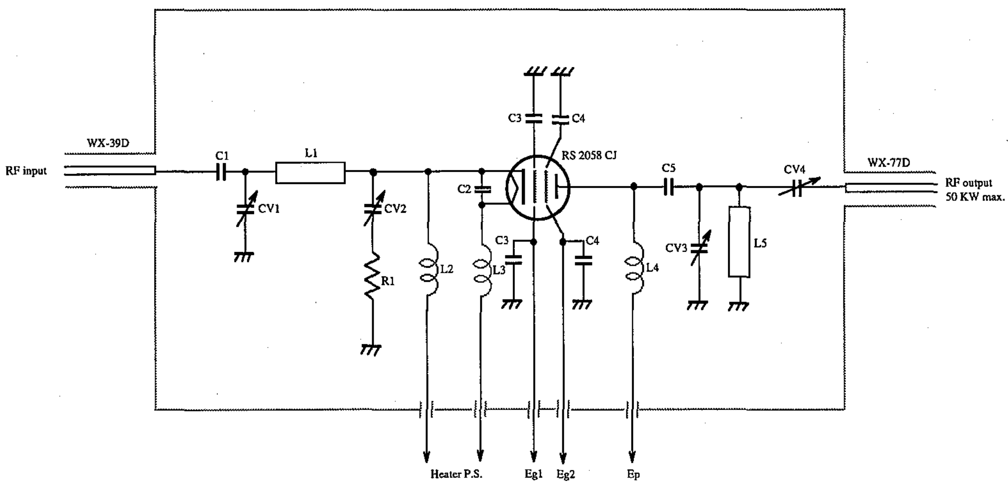

Fig. 2 Circuit drawing of 33.3 MHz 50 kW final stage P.A.

P.A.s are properly RF shielded to satisfy the applicable regulatory standard. This is checked with a commercial RF survey meter and by more sensitive electric field strength measurement with an antenna and a spectrum analyzer. At 50 kW output loaded into a dummy, E-field power density is undetectable anywhere in the vicinity even in the lowest range (full scale being 2.65 10^{-2} mW/cm^2) of the survey meter. An alternative E-field strength measurement with a spectrum analyzer gives below 40 dB μ/m in both horizontal and vertical direction 12 meter off the 50 kW P.A. cabinet.

4. ACKNOWLEDGEMENT

The author expresses his thankfulness to Emeritus Professor Hidekuni Takekoshi, Professor Makoto Inoue, and Yoshihisa Iwashita for continuing support and encouragement. He is also grateful for many engineers and technicians who have been involved in this work. Special thanks go to Nihon Koshuha for designing and manufacturing a beautiful RF P.A. system.

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