

RF Power System – RC Version

RF AMPLIFIERS

MICE requires 1 MW of power to each of the eight cavities at 201.25 MHz with a duty cycle of .1% (1mSec pulse per second). The ideal solution would be to provide each cavity with its own independent amplifier system. This has benefits of independent phase and amplitude control for each cavity. On the other hand this option is expensive (but would allow an incremental build). As an alternative, the collaboration has sought cost savings by re-using existing equipment. Power systems using triode vacuum tubes are typically found at (older) accelerator complexes (CERN, ISIS, KEK). These systems range in power levels of 2 to 4 MW using (e.g.) the Thomson TH 116 (or equivalent TH 516 tubes) or the lower rated TH170 tube.

Originally it was suggested that 2 x 4MW amplifiers should provide the power for MICE cavities. This would require each amplifier to operate at 5MW not 4MW to provide power in hand for losses in feed systems and power in hand for R.F. pulse levelling. To operate in this configuration the available circuits would have to undergo major re stressing. Thales do not consider the TH116 is suitable for these power levels with a 1mSec pulse in fact there is some doubt about it operating at these power levels anyway. In future the TH116 will have limited availability unless special provision is made. A lower risk option is to use 4 x 2.5MW to provide the required power. The following gives a summary of the status of available equipment.

At CERN a “spare” amplifier system (originally running at 201.25 MHz) has been modified to run at 88MHz. This circuit would be capable of refitting to the original frequency and is a candidate for use in MICE. Additionally, most of the components to rebuild an amplifier of the old Linac 1 type exist. Work on refurbishing the 88MHz system would provide information allowing any parts missing from the second amplifier to be remade. These two amplifiers can be used with either a Thomson TH170 or TH116 water cooled tube. Both tubes are capable of an output power in excess of 2.5MW. To achieve this output power, however, requires a modification to the output circuit. It is expected that CERN will provide two “2.5MW” power systems.

There are also systems at LBNL which are being made available for use in MICE. These consist of two 2.5MW amplifiers and three 300kW driver amplifiers. In the near future these systems will be shipped to the UK (Daresbury) where they will be stripped down, cleaned and an assessment made of the work needed to refurbish them. It is planned to build a test stand which will be used to commission the RF systems.

Finally, ISIS has a stock or “retired” TH116 tubes which should be capable of delivering 2MW and are likely to be available for MICE. A representative “old” tube has been tested at an output power of 1.25 MW.

A fourth driver system can be obtained from CERN by combining several low power driver amplifiers. An HT supply for the driver stages has been made available for MICE at LANL.

Additional equipment (mainly low level RF and control systems) will be required and can be obtained by duplicating existing designs.

With four 2.5MW amplifiers it is possible to drive MICE stage V with one system per cavity. When stage VI is reached the output from one amplifier will drive two cavities.

CERN uses delay line type modulators for both Linac 1 and Linac 2 but it is felt that cathode switching is a more convenient and cheaper method for our application. Both R.A.L. and CERN are using this type of switching successfully. Cathode switching will be applied to either the TH 116 or TH170 final amplifiers.

Using cathode modulation the anode of the power tube is continuously powered, to maintain the tube in a near cut off state the cathode has a large resistor in series to ground. In the case of ISIS TH116 tubes this is 15k. Assuming an efficiency of 50% with a power output of 2.5MW the anode dissipation at .1% duty cycle is 2.5kW

The power amplifiers will require 33kV power supplies to charge the H.T. storage capacitors, their value and the current rating of the power supply will depend on the chosen P.R.F.

The driver amplifiers require 18kV power supplies to charge a storage capacitor and are switched with a screen grid pulser.

In the future, further equipment may become available (e.g. at KEK) and this will be investigated

Flexibility in the RF pulse output

Assuming a .1% duty cycle (1mSec pulse at 1P.P.Sec) a certain amount of flexibility can be achieved. A pulse length of 100uSec at 10 P.P.Sec represents the same average power and so is within the amplifiers capabilities. In fact the pulse would be 150uSec long to allow for cavity rise time representing a slightly increased duty cycle. The value of storage capacitor and its charging current would be chosen to give some degree of flexibility allowing for a 1kV droop during the pulse.

RF distribution system

R.F. power from each amplifier would be sent to the R.F. cavities via standard 9-inch rigid coaxial transmission lines; smaller diameters are possible using (e.g.) Nitrogen or SF₆ insulation. The lines are large enough to handle the required RF power, but may give small reflections.

Directional couplers to monitor forward and reflected R.F. power will be installed. In the case where one amplifier feeds two cavities a phase shifter will be required in one of the cavity feeds. This will adjust the inter cavity phase, the initial phase being set by the phase loop. The feed line length must be such as to avoid high voltages at the amplifiers in case of breakdown in a cavity or the initial cavity fill bad match condition..

At stage VI, the power from each amplifier will be “split” using hybrid devices to split the power from one amplifier to power two cavities.

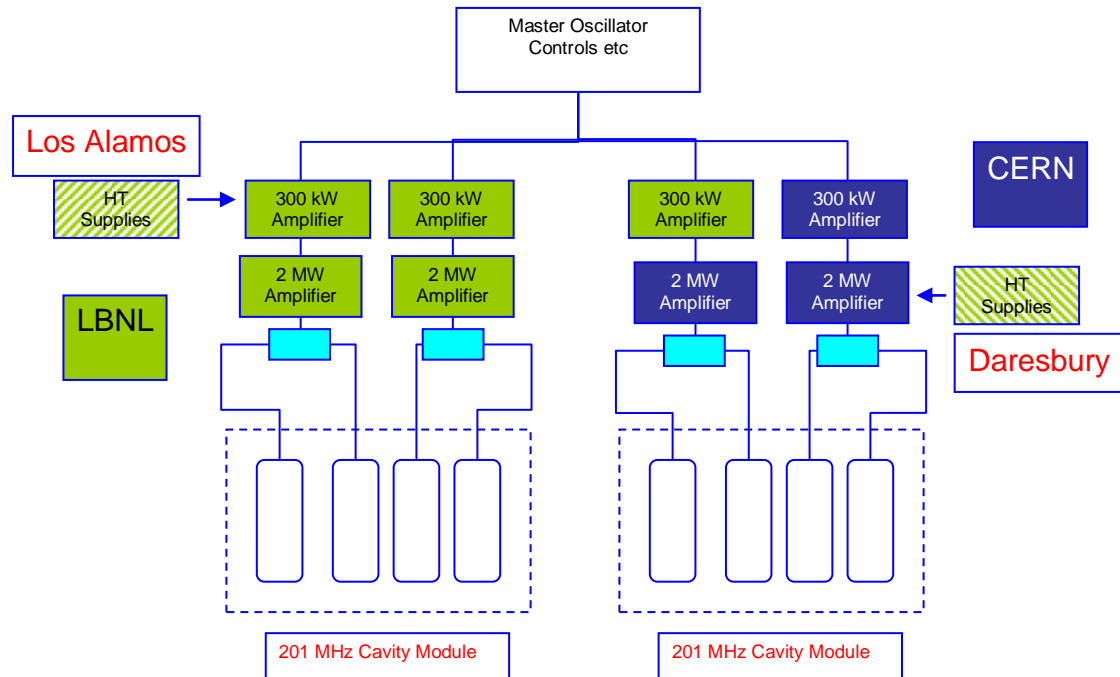


Figure 1: Schematic of the RF Power for MICE showing sources of equipment.

RF control system

Feedback is necessary to control amplitude and phase to a precision of the order of 1% and 1° . A loop in the cavities (coupling factor of -60db to give approximately 10V peak into 50ohms for 1MW in) is split in a four way 6db splitter for the relative control loops. For the cavity tune loop the phase in the cavity is compared with the phase of the R.F. in the feed line. The derived error signal will be used to adjust the fast and slow tuner. Note that each of the eight cavities needs its individual tuner loop to achieve phase and amplitude stability. The general amplitude and phase feedback is applied to modulators in the low level R.F. drive stage.

RF Power System Summary

Four power amplifiers have been identified. These amplifiers should be capable of providing a total power of 8MW for MICE (10MW for losses and levelling). Further work is required to bring the existing equipment up to specification and a development programme will be required to do this.

MICE RF SYSTEM
(VI) 8 MW/ 8 Cavities
 10/06/2004

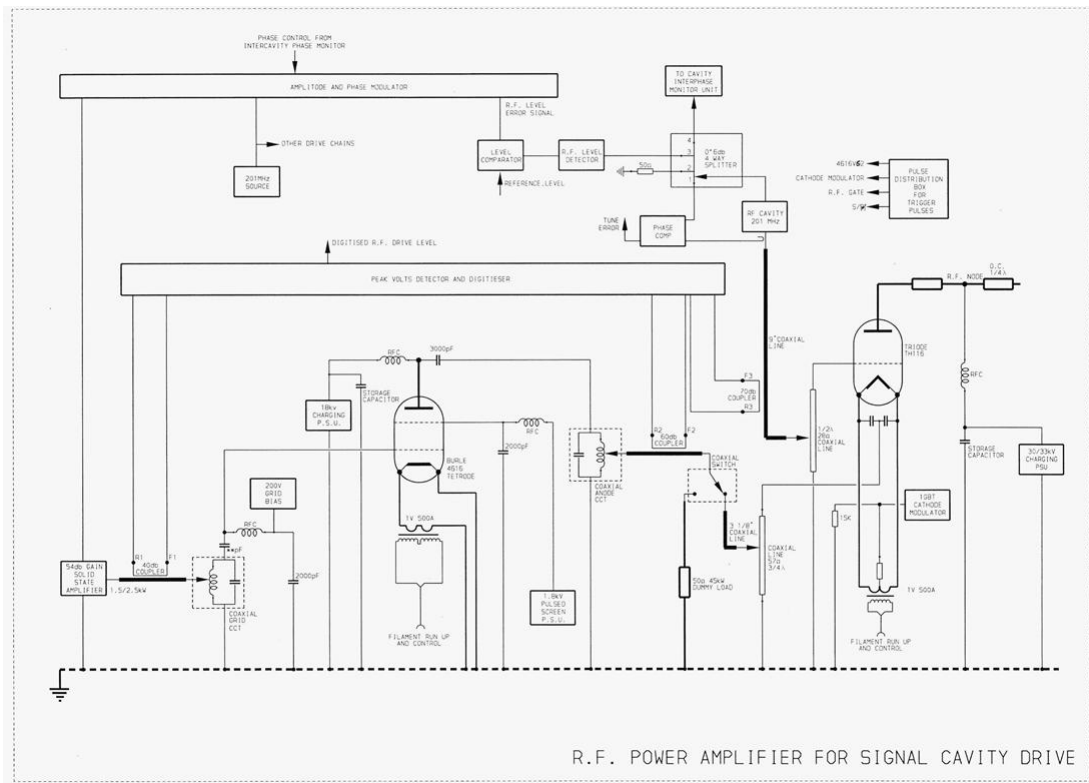
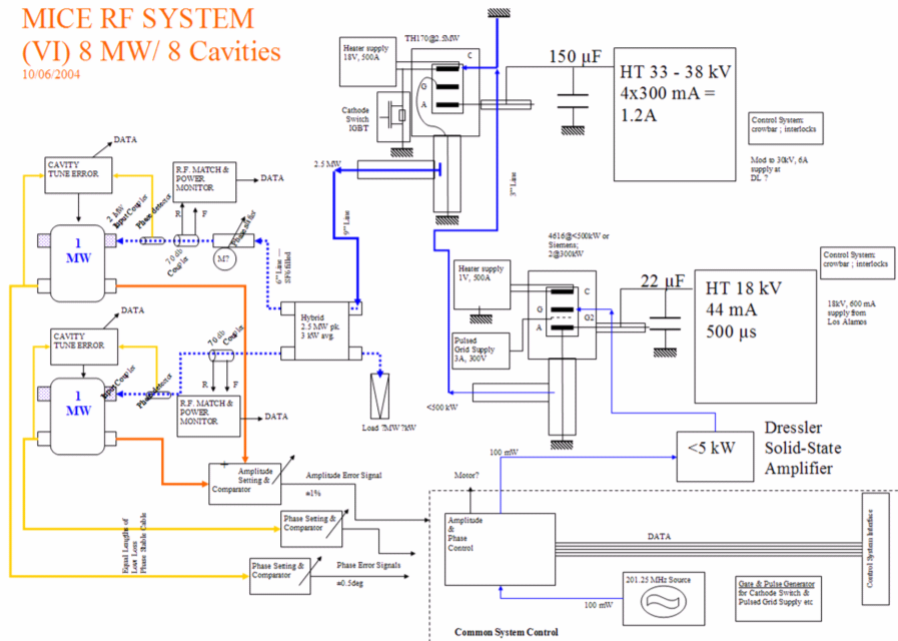


Figure 2. Schematic of the RF power system, showing details of distribution and control (top) and electrical details (bottom). The lower diagram is applicable at stage V.