Status Report on the ELETTRA R.F. System.

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Abstract

A survey of the status of the ELETTRA RF system is given. The low level RF distribution system and the development of the control electronics are presented. The results of the operation of the complete prototype power plant are described.

1. INTRODUCTION

Four cavities are required in the ELETTRA Synchrotron Light Source RF system at 1.5 GeV, while six will be installed at 2 GeV [1]. Each cavity will be fed by a separate independent plant. Since a full energy injection linac will be used, the RF system must only restore the losses in the storage ring. The main parameters of the RF system are summarized in table 1.

One prototype of the power plant has been mounted and tested [2]. The power tests on the cavity have started and the development of the low level systems is in an advanced status.

Table 1. RF main design parameters

Energy (GeV)	1.5		2
Beam current (mA)		400	
RF frequency (MHz)		499.654	
Harmonic number		432	
Total losses (keV/turn)	127.6		320
Total voltage (MV/turn)	1.7		1.8
Number of cavities	4		6
Cavity quality factor		42000	
Cavity shunt impedance ($V^2/2W$) (MΩ)		7	
Power installed per plant (kW)		60	

2. RF CAVITY POWER TESTS

The testing of the prototype cavity under vacuum has begun. To start the conditioning of the cavity, a fast rise time, 100 Hz repetition rate, RF pulse has been used, starting to feed the cavity with a low RF power level. The conditioning process was continued by gradually increasing the duration of the pulse or the power level, once stable RF operation and safe vacuum conditions of the cavity were reached.

In this way the input power of the cavity was raised up to 30.5 kW cw, which corresponds to a peak gap voltage of 650 kV. It must be noted that the design gap voltage is 607.1 kV. The cavity was also tested at 55 kW (about 877 kV of gap voltage) up to a pulse duration of 2.8 msec, since the prototype cavity was not equipped with the more efficient cooling system foreseen for the definitive cavities.

More tests are required in order to obtain a higher reliability also at the maximum output power supplied by the RF amplifier, even if in this case the gap voltage is much higher (about 50 %) than the value requested.

The first definitive cavity provided of cooling system and tuning cage will be available before the end of April. Soon afterwards, its conditioning will start together with the tests of the auxiliary systems (temperature stabilized water cooling system, definitive tuning cage, etc.).

3. RF DISTRIBUTION SYSTEM

As well known the distribution system must provide the driving input for the power amplifier which feeds the resonant cavity. This signal is a 499.654 MHz, 10 mW, phase and amplitude controlled signal.

The reference signal for all the RF plants is provided by a signal generator located in the linac klystron hall.and then it is first amplified by a 20 W solid state amplifier. The amplifier is composed by two stages: the first is a 10 dB UTO561 amplifier by AVANTEK, the second has been designed by paralleling two MHW710-3 modules via a hybrid ring. The output power is controlled by an input attenuator for the coarse regulation, while the fine regulation is performed by the setting of the power supply. The amplifier has been already built and tested in the laboratory. The overall gain is 31.6 dB, the phase and amplitude stability versus time (four hours test) at room temperature are respectively 0.05 dB and 2° total (1° after the warm-up). The room temperature variation range was around ± 3°C, then it was wider than what foreseen in the linac klystron hall. The overall spurious response is below 60 dB.

The transmission of the output signal from the klystron hall to the service hall of the storage ring is performed by a coaxial cable running along the transfer line. In order to maintain the phase stability required to the distribution system, the coaxial cable will be 7/8" Flexwell. As it is well known, these cables have an air dielectric (the content of dielectric being limited to the support of the central conductor). The main causes for electrical length changes are related to temperature variations and also to the pressure and humidity of the contained air. Since the variations in ambient conditions are expected to be small, and the mechanical length of the cable is fixed, the phase variations are expected to be negligible. If needed, an improvement of the performance of the cable could be easily achieved by operating the line under a slight overpressure.

In the service hall, the RF signal is then splitted into eight channels: four of them will be used to drive the RF plants, two are foreseen for the upgrade to six plants and the remaining two are spare ones. The splitter is a simple system to match the final impedance (1/8 of 50 Ω, that is 6.25 Ω) into a 50 Ω load. The matching system is composed by a quarter wavelength coaxial transformer. The insulation between the output channel is assured by eight circulators and the final adjustment of the output levels is performed by fixed attenuators.

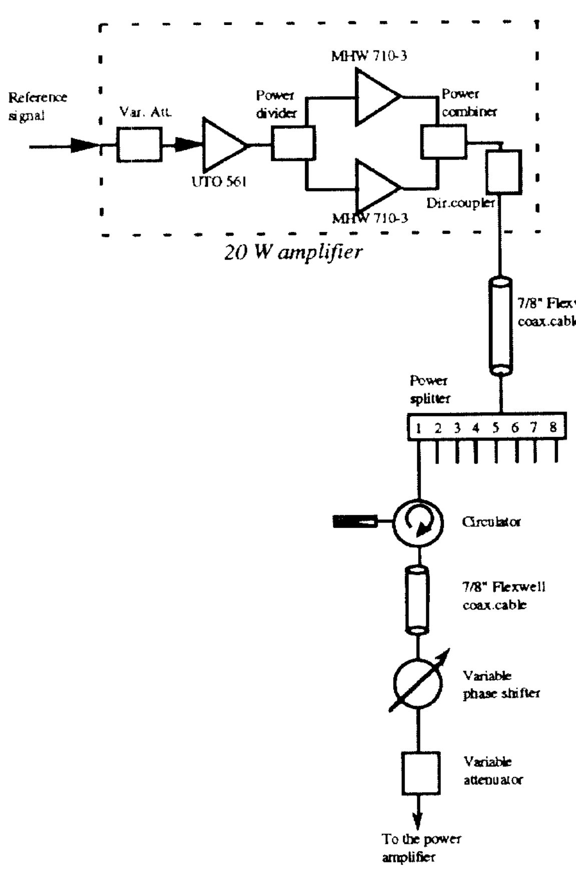

Fig. 1 Block diagram of the RF distribution system

Using the same kind of air filled coaxial cables, the reference signal is supplied to the driving units of each plant. The fine adjustment of the phase is performed by a voltage controlled temperature compensated phase shifter with a resolution better than 0.1°. The speed of the equipment will be around 1 μsec.

The fine regulation of the input level of the power amplifier is accomplished with a voltage controlled phase free attenuator which allows a minimum changing step of the input level of about 0.032 dB. The speed of the equipment is about 10 μsec. The phase variation vs. attenuation will ± 1.5° over a 20 dB attenuation range.

One complete channel of the distribution system will be mounted in the laboratory in the next month and then, after the completion of the bench measurements, will be tested to drive the prototype power plant.

4. MECHANICAL TUNING LOOP

The slow mechanical tuning system has been successfully tested under power conditions at a tuning speed equal to 200 Hz per second, which corresponds to about 1° of phase per second. The block diagram is shown in fig. 2.

Working on the feedback loop gain, a maximum sensitivity equal to ± 90 Hz has been obtained, getting a 10 mV D.C. signal out of the phase detector. We take two counter phase signals as reference from the cavity and we compare them with the RF derived from the directional coupler just at the input of the resonating cavity.

A higher sensitivity could be reached by further increasing of the closed loop gain, but the mechanical stresses transmitted to the structure become origin of instability in the loop working. In order to damp the vibrations induced by the belt drive of the tuning stand, two vibration - dampers have been specially designed.

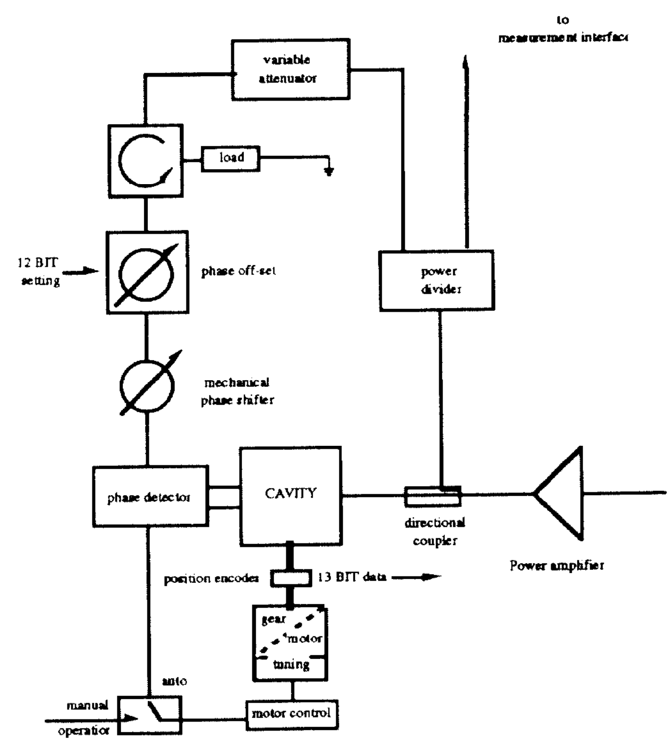

Fig.2 Block diagram of the mechanical tuning loop.

In the loop chain, a programmable phase shifter has been included to introduce a phase off-set in the tuner; this kind of programmable detuning is meant in order to have a programmable phase offset for the reference signal.

In the end, a position encoder has been introduced in the mechanical chain both to have a recording of the mechanical stresses of the cavity and to memorize the pretuned positions of the cavity itself, which will be of use in the start up procedure of the R.F. plant.

5. FAST PHASE AND AMPLITUDE LOOP

A detailed diagram of the fast phase and amplitude feedback loop is shown in fig. 3.

Most of the components involved in the feedback chain have been chosen and tested in a quite ultimate configuration, while some uncertainties still exist in the choice of the fast phase shifter.

The synchrotron oscillation period has been calculated to be equal to 77 μsec, our aim is to keep the time response of the phase feedback loop faster than 1° in 5 μsec.

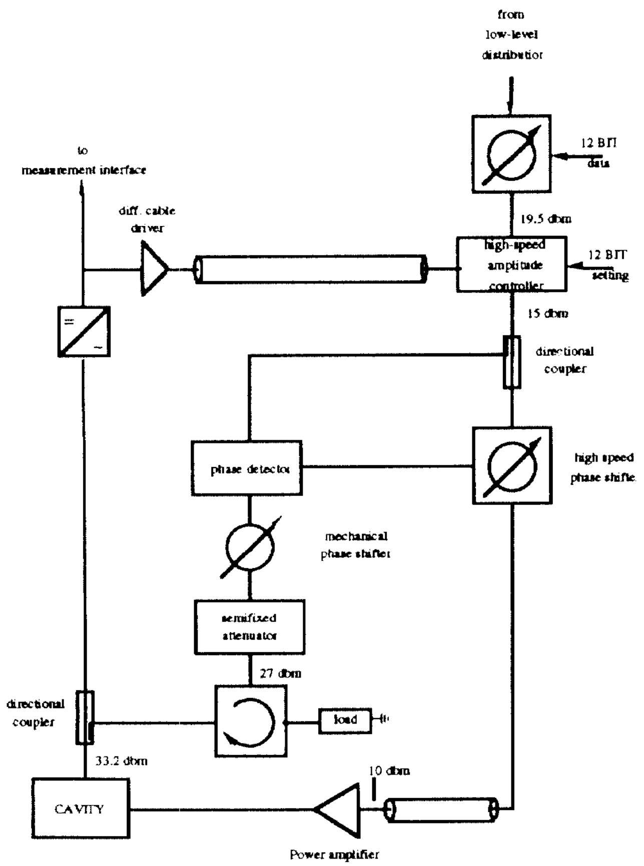

Fig. 3 Block diagram of the fast phase and amplitude feedback loops

We previously tested the whole chain on a pillbox cavity using a commercial electronic phase shifter. The response time of the circuit under stable operation was less than 3 μsec (this response time does not take into account the response time of the pill box cavity) , but an unacceptable amplitude variation of the R.F. signal was observed. In fact about 10 % of the modulating voltage went to the R.F. output, also depending on the pulse rise time. In order to try to avoid the use of one further amplitude variable attenuator after the phase shifter, we built and are now testing a line type phase shifter .

With this kind of high speed phase shifter we are confident to be able to keep the amplitude of the R.F. signal quite constant at the output in the phase range of ± 15° around the stable phase working condition.

In the phase feedback diagram it is sketched the programmable phase shifter which gets the principal phase reference from the machine control system and sets the phase for the single plant.

The phase detector is a double balanced mixer type MCLSRA - 1MH.

A first complete prototype of the low - level control system is being assembled at our laboratories and we expect to test it on a whole R.F. plant in the very next months.

The high speed amplitude controller, which controls the cavity voltage, is an analogical loop whose reference is set by a 12 bit DAC. The reference is given by the machine control system. The dynamic range of this circuit is 30 dB and the loop is expected to set the level in tens of μsec. with a precision of 1 %.

6. CONCLUSIONS

The measurements and the conditioning of the first definitive cavity will start as soon as this will be available at the end of April. Subsequently the tuning system and the phase and amplitude loops will be tested on the power plant.

Then, by driving the plant using the first prototype channel of the distribution system, it will be possible to completely test a RF plant in the laboratory, before the starting of the mounting of the storage ring.

REFERENCES

[1] A. Massarotti et al., "RF Power System for the Trieste Synchrotron Light Source ELETTRA", in *Proceedings of the 2nd EUROPEAN PART. ACC. CONF.*, Nice, France, June 1990, pp. 913-915.

[2] A. Massarotti et al., "Status Report on the ELETTRA RF System", in Proceedings of the 1991 PARTICLE. ACC. CONF., S.Francisco, USA, May 1991.