Power Conditioning of the RF Cavities for ELETTRA

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Abstract

The cavities for the Synchrotron Light Source Elettra have been conditioned at full power. The OFHC copper cavities have a smooth shape, working at 499.654 MHz. The conditioning has been performed in the laboratory with a prototype power plant. The RF power provided by the klystron amplifier is fed to the cavity by means of a coupling loop. The cavities have been conditioned starting from pulsed operation; the power and the duration of the pulse have then been raised till the requested CW gap voltage was reached. The whole conditioning procedure, starting from the bakeout of the cavities, and the test results are described here.

1. INTRODUCTION

Four cavities working at 499.654 MHz will be installed in the ELETTRA storage ring. The required gap voltage for each cavity at beam energy equal to 1.5 GeV is 607 kV, thus leading to a wasted power into the cavity of about 26.5 kW [1].

The cavities have been built in OHFC copper and are water cooled by means of cooling pipes brazed on the cavity walls (fig. 1).

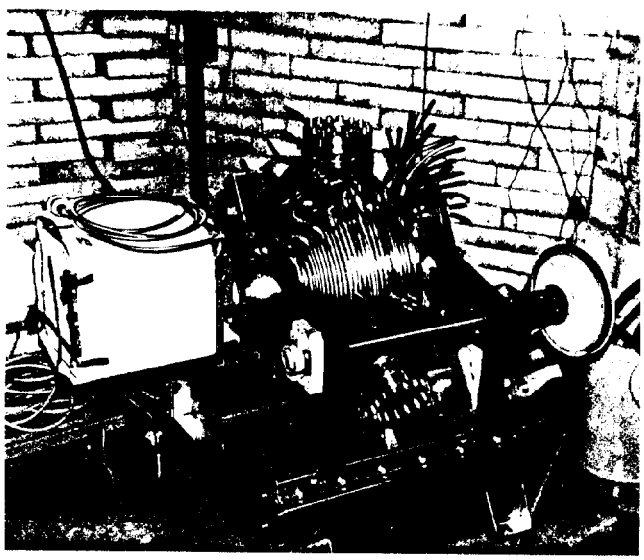

Fig. 1 The cavity with cooling pipes brazed on the outer surface, the tuning cage and one vacuum pump

Before starting with the installation of the cavities in the storage ring, each cavity has been conditioned at full power by using the RF 60 kW power plant mounted in the laboratory.

The RF power is fed to the cavity via a coupling loop. The feedthrough is copper made and water cooled.

To start the conditioning of each cavity, a fast rise time, low repetition rate and short RF pulse has been used. At the beginning the cavity has been fed with a low RF power level. The power level and/or the pulse duration have been increased once stable RF operation and safe vacuum condition of cavity were reached. The conditioning procedure has been stopped at 35 kW CW RF power corresponding to a gap voltage of 700 kV.

A duration test of several hours has been performed at this input power level to ensure the reliability of the conditioning procedure.

2. RF UNIT ASSEMBLY AND BAKEOUT

The 500 MHz cavity is a smooth shape one [2]. The RF power is fed into the cavity via a coaxial copper power coupler. An alumina ceramic window brazed to the inner and outer conductors of the coaxial line provides the vacuum insulation.

The last step of the mechanical construction of the cavity as well as of the vacuum feedthrough was the brazing in the high temperature vacuum oven. Afterwards the cavity and the vacuum feedthrough have undergone a further surface ultra high vacuum cleaning procedure.

Then the RF unit has been assembled in the laboratory. The coupling coefficient between the feedthrough and the cavity has been adjusted to 1.0.

The vacuum system for the first conditioning procedure consists of a turbo molecular pump of 180 l/s and two ion pumps of 120 l/s each. The vacuum pressure is monitored with a Pirani gauge for the lower vacuum range and a Penning cold cathode gauge head for the high and ultra high vacuum range.

The RF units were baked out for 48 hours. The cavity body and the feedthrough were heated up to 150 °C with hot water circulating in the cooling pipes. The stainless steel parts like the flanges were heated up to 180 °C with electrical heaters. The ion and turbo pumps were baked out at 200 °C and 100 °C respectively.

After five hours of cool down a pressure level of 2.2 10^{-10} mbar has been achieved in the cavity.

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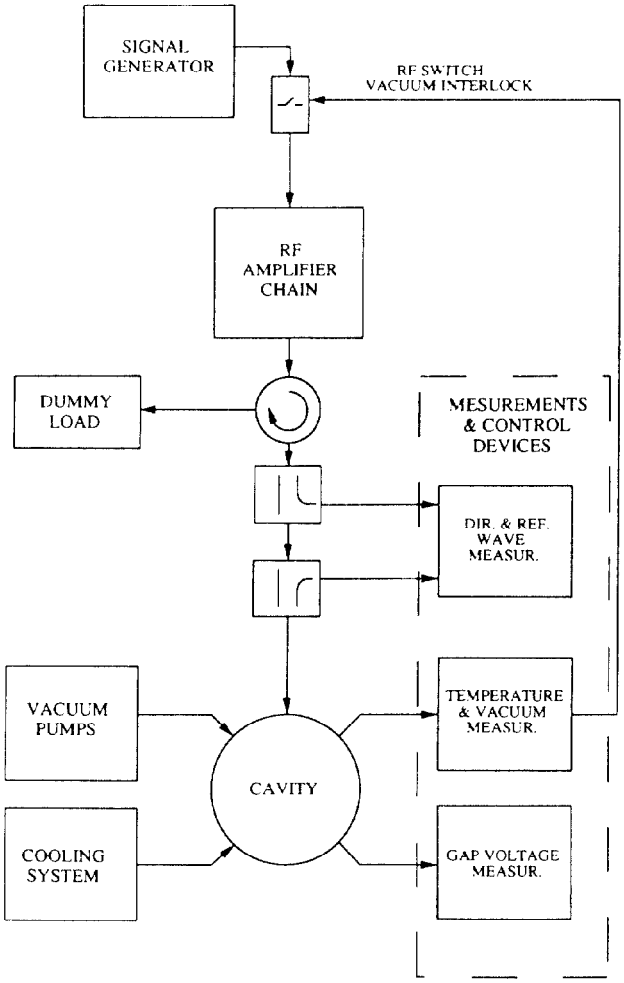

Fig. 2 Layout of the RF plant for the conditioning

3. RF UNIT CONDITIONING

The RF plant of the laboratory is a prototype of the RF storage ring plants [3]. It is made up of a 60 kW amplifier, a 500 MHz power circulator with a dummy load on the third port and a 6 1/8" coaxial line to feed the RF unit. A sketch of the whole plant is shown in fig. 2.

The vacuum equipment for the conditioning is the same installed for the bakeout.

The cavity and the power coupler are water cooled. The water flow is about 13 m^3/h for the cavity and 0.5 m^3/h for the vacuum feedthrough. A temperature mapping of the RF unit has been provided during the test.

The cavity tuning is performed changing its axial length by means of a tuning cage which is driven by a dc motor. The tuning range is ±100 kHz; within these limits the mechanical stress of the cavity remains below the elastic limit [2].

The RF power is interlocked with the vacuum level of the RF unit. The vacuum gauge controller switches the RF off when the threshold of 1.0 10^{-7} mbar is exceeded.

The RF conditioning has started with a short RF pulse at a period of 100 Hz. The starting length of the pulse was 80 μs. The peak power has been increased up to the final value of 35 kW. Once the peak power was reached, the duty cycle has been slowly increased from 0.8% to 100%.

During the whole power raising procedure the pressure level has been kept in the $10^{-8} + 10^{-9}$ mbar range.

The cavity gap voltage was monitored on a oscilloscope as well as the direct and reflected wave, to detect any possible discharge in the resonator.

The typical duration of the conditioning procedure is between 40 and 50 hours. The peak and average cavity input power plot versus the conditioning time for one of our RF unit is shown in fig. 3. It should be noted that the conditioning procedure is not continuous; it is shared during more days. The turning off of the procedure is indicated with zero power points. It can be seen that in the first 15 hours the peak power has been increased with the minimum pulse length. In the following hours the pulse has been lengthened till the CW operation has been reached.

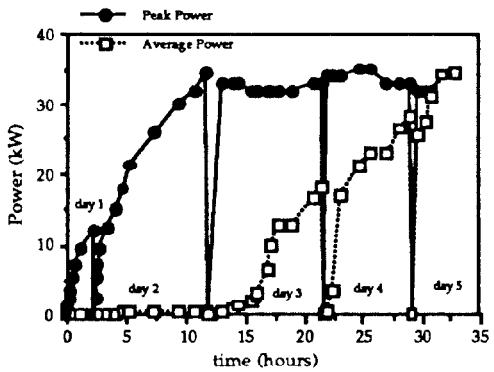

Fig. 3 Peak and average power versus conditioning time

The pressure versus time plot for the same RF unit can be found in fig. 4. The "plow" points indicates the cavity pressure level before a power increase. The "phigh" values have been recorded after one minute of each power increase. These plots refer to an RF unit in which the pressure as always been lower than 1.10^{-8} mbar, while other RF units have shown a worse pressure curve (see fig. 5).

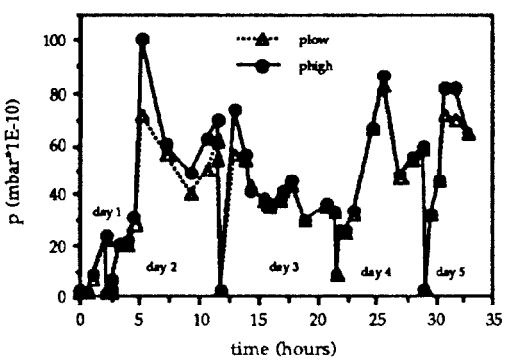

Fig. 4 Pressure versus conditioning time. Best results

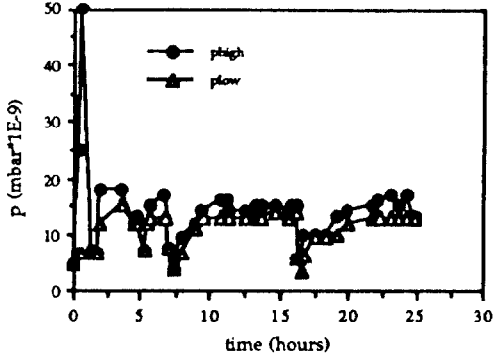

Fig. 5 Pressure versus conditioning time. Worse results

After achieving CW full power level, each unit has been operated at this level for several hours. During the duration test no significant trouble rose, thus we concluded that the unit was successfully conditioned.

The final pressure level at the end of the test improved to the 5.0 10^{-9} mbar range with 35 kW CW fed to the RF unit.

In these conditions a maximum x-ray dose rate of 130 μS/h has been measured nearby the cavity.

Neither multipacting or discharge phenomena have occurred during the whole conditioning. Thus no metalization on the ceramic windows should have taken place. Actually the temperature gradients of the vacuum feedthrough remain constant also after several operating hours at full power.

Is is interesting to note that, during the conditioning, if the cavity is excited at its resonant frequency, the pressure level slightly increases. This happens also for frequencies below the resonance, while detuning the cavity at higher frequencies the vacuum pressure reaches the minimum values. Thus, to avoid any risk of ceramic window contamination we operate the cavity at slightly higher frequency than the resonant one [4]. This occurence disappears at the end of the conditioning, operating the cavity in the continuous wave mode at a power level just below the maximum value achieved in the pulse mode operation.

4. CONCLUSION

The RF cavities for ELETTRA have been successfully conditioned to the required peak power.

The conditioning procedure has avoided any multipacting or discharge phenomena in order to prevent any sputtering of the ceramic window surface.

The RF units are therefore ready for installation on the storage ring. In the meantime they have been stored in nitrogen atmosphere to avoid any possible and further contamination of the surfaces.

Thus we exspect to repeat quikly and without trouble the conditioning procedure once the cavities will be installed in the storage ring.

5. REFERENCES

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