Status Report on the ELETTRA R.F. System.

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Abstract

The results of the R.F. system development are presented. A complete power plant has been tested on a dummy load. The cavity feedthrough has been developed and the progress work on the accelerating cavity is described.

I. INTRODUCTION

ELETTRA is a Synchrotron Light Source under construction in Trieste (Italy) working with beam energies in the range from 1.5 and 2 GeV. It will be constituted of a full energy linac directly injecting the electrons in the storage ring.

Four cavities at 1.5 GeV (six at 2 GeV) operating at 499.654 MHz will be installed in the storage ring [1]. Each one will be fed by a separate independent plant providing up to 60 KW cw RF power (fig. 1).

II. RF POWER SYSTEM STATUS

A. Power Plant.

The power amplifier prototype supplied by TVT Cambridge U.K. has been installed in the laboratory. A complete power plant has been assembled using for the measurements at 60 KW a dummy load instead of the cavity. All the prototypes of the components (circulator, 6 1/8" cables, directional couplers, etc) , which are foreseen for the definitive installation in the storage ring, have been tested at full output power with satisfactory results. This power plant will be used as a test facility for the measurement of all the components before their installation in the machine.

B. RF Cavity.

The Elettra 500 MHz cavity has a smooth shape, with a radius of 263 mm and an axial length of 302.6 mm. [2]. The measured resonating frequency is 500.1 MHz. The measured Q value is 42000, which with a measured R/Q of 167 Ohm leads to a R_{sh} of 7.0 MΩ. ($R_{sh} = V_{gap}^2/2P$)

The cavity will be tuned by means of a mechanical tuner acting on the length L of the cavity. The prototype structure for the mechanical tuning system has been realized and tested on the cavity for Elettra. The variation of resonant frequency obtained is 8 KHz for one hundredth of mm. of compression or stretching. This is in good agreement with the computer simulation results [2]. Since the maximum frequency shift needed in order to compensate the beam loading is 58 KHz at 1.5 GeV or 82 KHz at 2 GeV, roughly one tenth of mm. of variation in axial length will be sufficient to cover all this range (fig. 2).

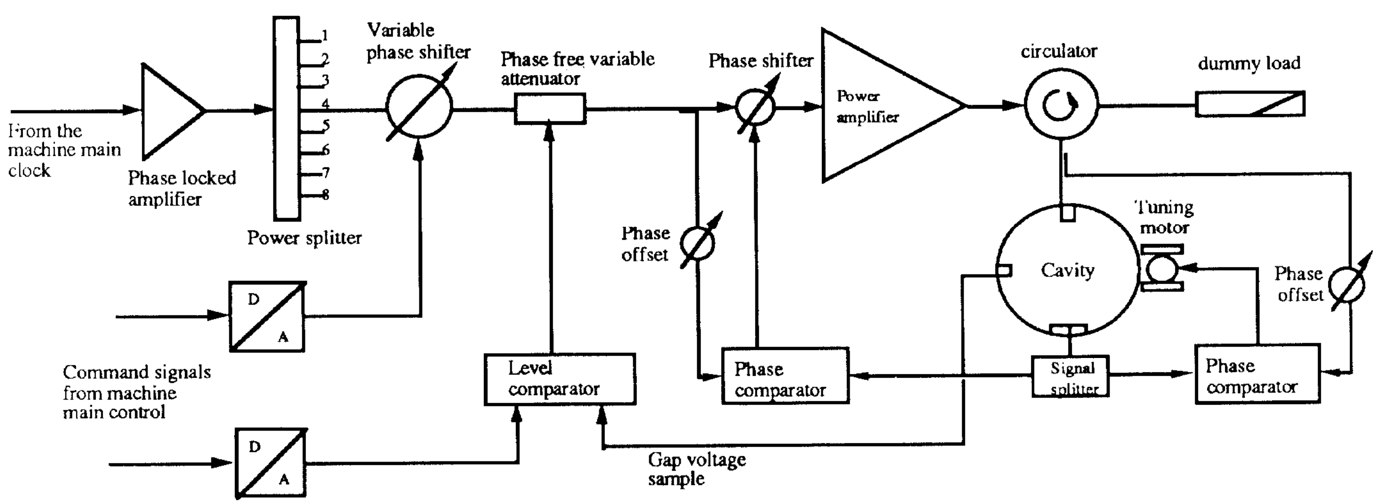

fig.1 Block Diagram of the RF Power Plant.

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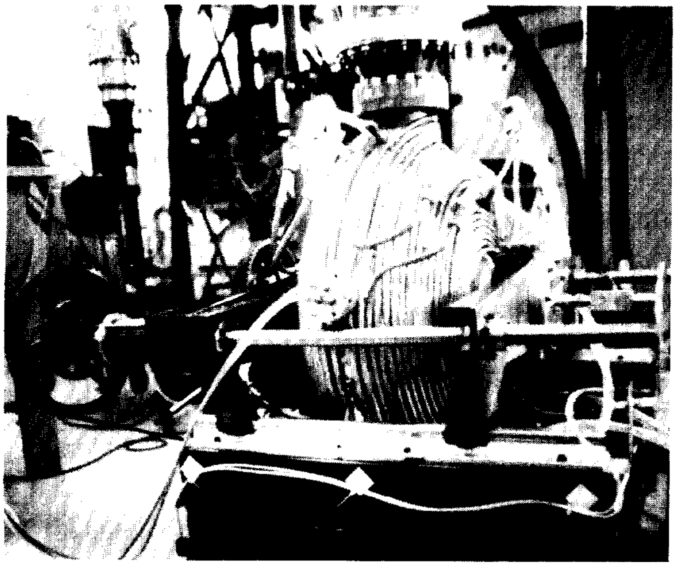

Figure 2. Cavity with mechanical tuning and cooling pipes.

The first prototype of the cavity provided with cooling system has been constructed. In order to carry off up to 36 KW, which is the estimated maximum wasted power in the cavity, the needed waterflow is 180 lit/min. The water input temperature can be varied for tuning purposes between 32 and 52 °C; the temperature difference between input and output is less than 5 °C.

The cavity has been tested in air with the power plant. The input power was raised up to 26 KW (which corresponds to a gap voltage of about 600 KV) without any sparking.

C. Low Level.

The low level control of the cavity will be made of a slow mechanical tuning system and a faster electronic phase loop. An advanced prototype of the first one has been assembled and tested on the Elettra cavity. The satisfying results obtained show that the resonant frequency of the cavity can be kept at ±200 Hz from the operative one. The tuning speed is 200 Hz/sec.

The fast electronic phase control system has been designed and tested on bench, operating on a 500 MHz pill-box cavity, with a response time better than 5 μsec for 1° of phase variation.

The low level distribution system has been designed. The reference signal which is provided by the machine main clock will be first amplified and then splitted in eight independent channels: four of them will be used to drive the RF plants.

III. The H.O.M. Suppressor for the Elettra R.F. Cavities

A. The waveguide suppressor

The beam characteristics of the ELETTRA synchrotron light source [1] require an adequate damping of the H.O.M. spectrum of the RF cavity, despite the open profile chosen for the cavity [2], in order to avoid multibunch instabilities [3]. Therefore the RF cavities should be provided with H.O.M. suppressors. In many other laboratories 'dedicated' devices have been developed, in order to damp some particular dangerous modes [4], [5], as well as broad-band couplers [6]. Anyway, a total damping of the H.O.M. hasn't been yet obtained; and, to prevent instabilities, active feedback systems are foreseen, for example in ALS [6].

The concept of broadband damping, with the final goal of a total suppression of the H.O.M. spectrum has been developed for the Elettra cavities. Our basic idea has been to couple waveguides directly to the cavity, through large coupling apertures. The waveguides have a dominant mode cut-off frequency quite above the resonant frequency of the cavity accelerating mode, but below that of the first H.O.M.; they are terminated on matched terminations. In this way the H.O.M. power excited by the beam can flow through the apertures to the dummy loads, while the accelerating mode power is confined into the resonant cavity.

To evaluate the performance of such a structure we chose a pill-box cavity which has the great advantage of a geometry simpler than the Elettra cavity one. First we studied a scaled prototype in the S-band. Since the results have been encouraging we went on with a 500 MHz prototype, which confirmed these good results [2], [7].

At the conclusion of the preliminary tests with this cavity, the performance of the suppressor has been increased, also with the support of MAFIA simulations, by choosing the most convenient shape and size of the coupling aperture.

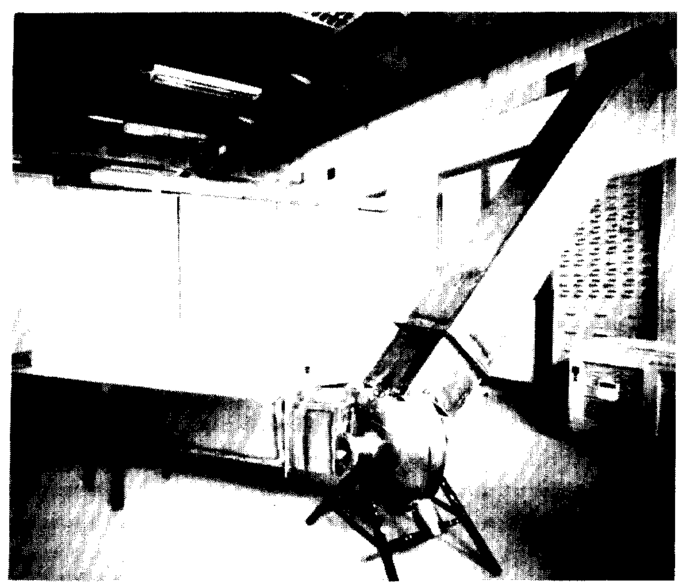

Figure 3. Cavity with prototype of the waveguide suppressor.

Then we studied the problem of the coupling of waveguides to the Elettra cavity. The resulting geometry is rather complex, hence the CPU-time limitations haven't allowed us to perform a complete simulation with MAFIA. Nevertheless, a first coupling geometry, with a coupling aperture of 75 mm, has been designed with MAFIA. The damping effect was not satisfactory, hence the suppressor has been further developed with a cut and try method in the laboratory, by enlarging the aperture, changing its shape and giving different inclinations to the waveguide. Despite the mechanical difficulties, mainly due to the particular geometry of our cavity, we finally obtained a configuration with satisfying coupling; it is shown in Figure 3. In the cut section the aperture has a square shape with a diagonal size of 230 mm, the inclination angle is 50°.

B. The H.O.M. free structure

Up to this point only one waveguide has been coupled to the cavity. This could be enough for monopole (longitudinal) modes, which have no azimuthal variations and thus have no preferred polarization. But dipole modes, which are responsible for transverse instabilities, have one azimuthal variation and are allowed to have more polarizations in the cavity. Therefore, with only one waveguide, there is still one dipole mode polarization trapped into the cavity, typically with the magnetic field maximum at 90° from the aperture.

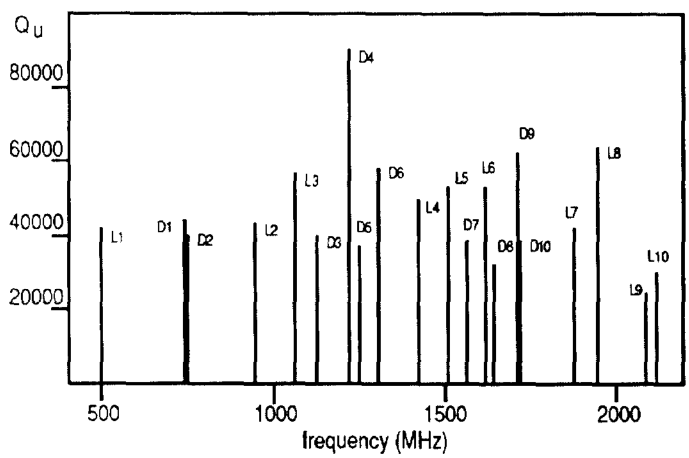

Figure 4a. Undamped cavity modes spectrum.

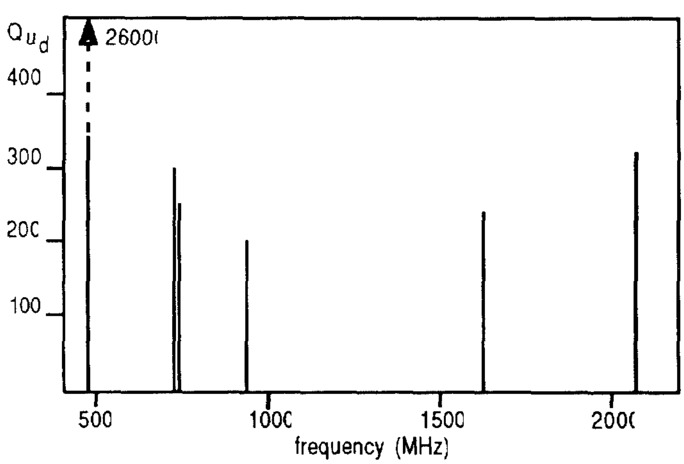

Figure 4b. Damped cavity modes spectrum (scaled by 200).

In order to have a completely H.O.M. free structure it is then straightforward to couple a second waveguide to the cavity, rotated by an angle of 90° from the first one; the coupling aperture should be just the same for the two waveguides.

This final configuration has been tested at our laboratories. Its effectiveness can be easily seen by comparing the damped and undamped mode spectrum in figure 4. Since the Q values of the few resonances measured in the damped cavity are strongly reduced, the scale in figure 4b is enlarged by a factor 200. The resonance around 950 MHz comes out in the new resonating structure and should not be mistaken for the first longitudinal (L2) H.O.M., that seems to be completely damped. Practically all H.O.M. are eliminated, while the fundamental mode is still useful for accelerating purposes ($Q=26000$, $R_{sh}=3.8\ M\Omega$).

It is to be noted that, coupling two waveguides at 90° to a resonant cavity, we obtain an asymmetrical structure. The accelerating electric field could be consequently distorted. Preliminary calculations show that the distortion can be compensated by locating two cavities close to each other, but rotated by 180° and decoupled through 200 mm long, 50 mm diameter drift tubes. A second solution is to leave the cavities in their present position, but with adequate rotation angles [8].

IV. CONCLUSIONS

The cavity will be tested under vacuum at the design gap voltage before next summer. The cavity tuning system, the phase control system and the RF signal distribution system are either already tested or in advanced design status.

In order to produce a H.O.M. free cavity to be mounted on the Elettra Storage Ring, the engineering of the prototype is now foreseen. Along with this we are studying the behaviour of this suppressor with a pill-box cavity with nose-cones.

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