The 200 MHz Accelerating Sructure for UNK.

V.V.Katalev, S.S.Kovalev,V.G.Kudryavtsev,I.I.Sulygin,
Institute of High Energy Physics
Serpukhov.

Abstract

To accelerate a high-intensity proton beam (6×10^{14}ppp) 7 MV and 12 MV RF voltage per turn is required for the first and second rings of the UNK, respectively. The accelerating structure is developed following the modular principle. Each unit consists of two cylinder-shaped single-cell cavities which are fed by their own 850 KW RF power amplifier via a 3 dB hybrid. All of RF power amplifiers are placed in the serviced surface building and connected to the RF structure by a rectangular waveguide about 50 meters long. To avoid the interaction between a high-intensity proton beam and higher-order modes of the accelerating structure, each cavity has 3 HOM suppressors. This damping system reduces the coupling impedance of the accelerating structure to an acceptable value (5 Ω per turn) in the frequency range from 200 MHz to 1500 MHz.

The first ring of the UNK contains 8 RF units, the second one contains 16 RF units. All RF equipment with the exception of a power amplifier is designed and being manufactored at IHEP. The results of the unit tests made at the lab are described.

1 INTRODUCTION

The UNK orbit is filled in series by 12 trains from the existing proton accelerator U-70. Each train consists of 990 bunches. The distance between trains is equal to 120 empty buckets.

With such a complex beam structure, the proton beam has a spectrum rich in revolution frequency (14,4 KHz). The RF harmonics dominate in this spectrum. The first RF harmonic of the beam current may achieve 3 A (for 6×10^{14} ppp) and RF power needed to accelerate a proton beam is 3.4 MW in the first ring of the UNK, and 7.2 MW in the second one. Therefore the beam-loading problem is very important. The accelerating structure for the UNK consists of identical RF units (see Fig. 1). Each RF unit contains two cylinder-shaped cavities, a 3 dB hybrid, a rectangular waveguide and 850 KW power amplifier [1]. The distance between the cavities is equal to 3/4 λ. For a beam loading varying strongly, a part of the RF power reflected from the cavities is directed by the 3 dB hybrid to the dummy load. It means that a power amplifier sees actually the matched load. Therefore all power amplifiers are placed in the serviced surface building. In addition, in the first ring of the UNK the variation in the revolution frequency is rather small, about $\Delta f/f \approx 0.87 \times 10^{-4}$, and the accelerating cavities have no frequency tuning during the proton beam acceleration up to the maximum energy, 400 GeV. In this case one may minimize the necessary RF power for proton acceleration versus the beam current by choosing the cavity detuning and coupling with the feeder.

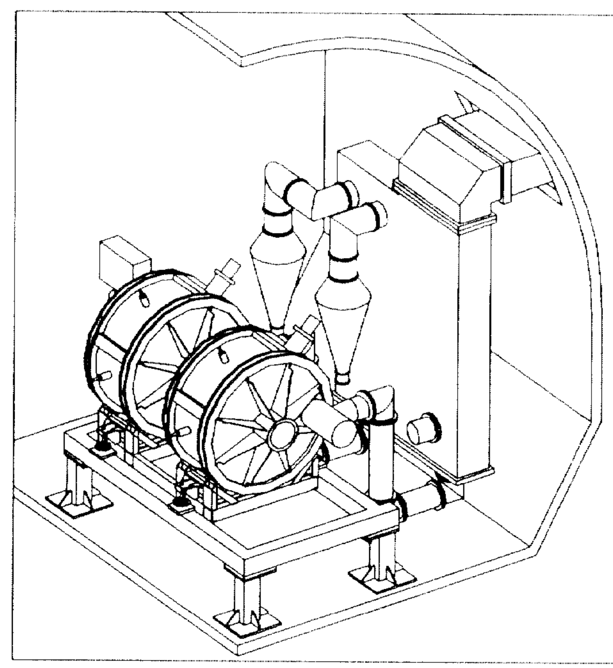

Figure 1: RF unit in tunnel

2 CAVITIES

The cavity length, 500 mm, was chozen from the following requirements:

a) the E higher-order mode impedances should be minimum in the frequency range from 200 MHz to 1000 MHz;

b) the distance between the cavities should be maximum for the comfortable servicing of the auxiliaries.

The beam pipe diameter of the cavity is equal to 240 mm, therefore the HOM with frequences higher than 1000 MHz will pass through these pipes and then their impedances will be decreased by special ferrit absorbers.

12 mm thick oxigen free copper is used for the cavity fabrication. Two plates are welded to the cylindrical section. The cavity body is reinforced by a steel frame. The holes are made by cold forming process and then stainless steel flanges are welded to the cavity. The indium wire is used in the quickly demountable vacuum connections for

Table 1: HOM impedances

F (MGz)	320	463	530	538	682	724	880	967	977	994	1097	1107	1442
Z/n(Ω) without suppressors	56.9	1.2	31.1	8.4	17.2	9.6	6.1	6.0	3.9	11.1	2.14	1.43	1.7
Z/n(Ω) with suppressors	0.2	0.01	0.22	0.04	0.13	0.18	0.07	0.16	0.003	0.4	0.18	0.016	0.01

the auxiliaries. The copper tubes are soldered to the cavity body for water cooling.

Using the standard cavity code PRUDO [2] one obtains the following parameters for one cavity:

the unloaded cavity quality factor - 57 000
geometric factor R/Q - 162 Ω
(also measured by bead pull method)
transit time factor - 0.761

The measured cavity quality factor is about 49 000 and the shunt impedance is around 8 MΩ.

3 CAVITY AUXILIARIES

3.1 *Tuners*

Each cavity has the coarse and the fine tuners. The coarse tuner is a water cooled probe. It is placed at one of the cavity plates. This tuner is used to correct mechanical tolerances in the frequency range of about 0,5 MHz.

The servo-controlled piston tuner (diameter 150 mm, stroke 55 mm) is sufficient to cover the required frequency range of ~ 180 kHz. This tuner corrects thermal expansion, the influence of varying beam conditions. To increase the reliability the piston has no sliding contacts.

3.2 *HOM suppressors*

All cavity E_{onm} modes(no φ-dependence) were calculated with the help of the standard code PRUDO in the frequency range from 200 to 1500 MHz [3]. Some of these (see the second row of the table 1) have the coupling impedance Z/n (where n is the HOM frequency - revolution frequency ratio), whose value exceeds the acceptable one, ~ 0.4 Ω per cavity. Therefore each cavity has three suppressors, one placed on the plate and two others on the cylindrical section.

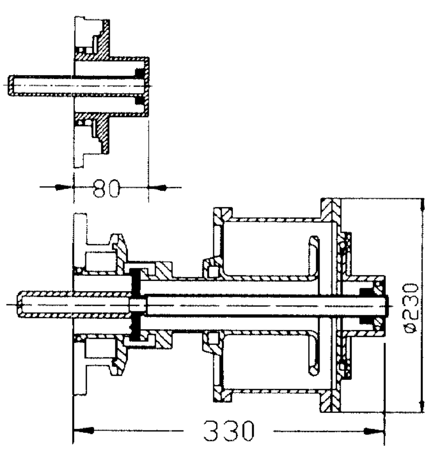

Figure 2: HOM suppressors

Each suppressor has a coupling probe (see Fig.2). The suppressor placed on the cavity plate has a strong coupling with the fundamental mode. To cut off the current of the fundamental frequency, the coaxial cavity loaded on the capacitor is used [5]. The fundamental frequency attenuation is about 60 dB, whereas in the bandwidth for higher order modes, it does not exceed 2 dB.

Two other suppressors coupled with the radial field component of HOM are placed on the cylindrical section of the cavity. One of them is placed in the middle and another one at a quater of the cavity length from the plate. This arrangement allows one to achieve the maximum coupling with the HOM having a different number of field variations over the length. In order to dump the dipole(ϕ-dependence) modes, these suppressors are shifted by 90° in the azimuth.

All three suppressors have a matched ferrite load. It ensures the VSWR not exceeding 2 in the 300 - 1500 MHz frequency range.

The investigations carried out showed a possibility to use a three-suppressor system on each cavity for bringing the beam coupling impedance at HOM down to the acceptable value in the 300-1500 MGz frequency range [4]. See the third row of table 1.

3.3 *Power coupler*

The power coupler uses a probe coupling. To ensure the optimum perfomance of the RF unit it is necessary to vary the coupling between the cavity and feeder. This is achieved by a servo-controlled coupling probe. The probe

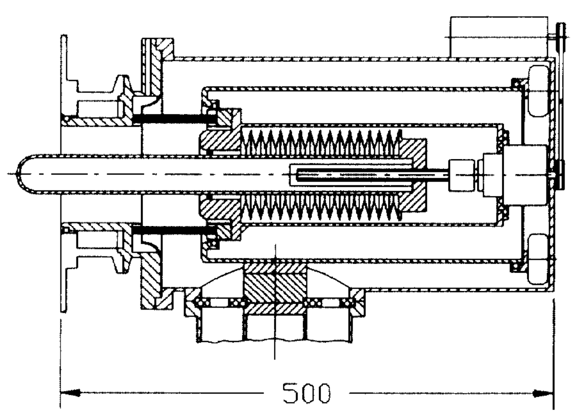

Figure 3: Power coupler

length varies from 15 mm to 70 mm depending on the beam current. In addition, in the case of power amplifier breakdown, the probe length must be about 120 mm in order to ensure a strong damping of the cavity to avoid the beam instability at the fundamental frequency.

The power coupler dimensions are such that its own VSWR does not exceed 1.3. To avoid the multipactor effect a DC voltage of 3-5 kV is applied through the blocking capacitor to the coupling probe.

4 RF POWER DISTRIBUTING SYSTEM.

4.1 *Waveguide feeder*

The wavequide feeder of a cross-section of 860x300 mm^2 is assembled from 2-m straight sections, a few shorter sections and matched E-plane and H-plane symmetrically truncated right-angle corners. Each section is welded from 5 mm thick aluminium alloy plates. At an RF power flow of 1 MW the wavequide loss per meter is about 300 W. The average wavequide feeder length for one RF unit is 50-60 m. To make up for the thermal expansion, special compensators are inserted into the wavequide feeder after each 4-5 linear sections.

All 24 wavequide feeders for the first and second rings of the UNK are placed in 4 vertical shafts and in the satellite tunnel. This tunnel runs parallel to the main ring one at a distance of 5 m.

4.2 *3 dB hybrid*

The 3 dB short-slot hybrids are welded from 10 mm thick aluminium alloy plates. The hybrid is two wavequides linked together by a narrow wall. The slot length is equal to 1120 mm. As measured, this hybrid has a coupling of (3 ± 0.05) dB and an insulation more than 32 dB . The hybrid has two wavequide-to-coax junctions for coupling with the cavities and another one for the dummy load. All hybrids are placed in the main ring tunnel near the cavities.

4.3 *Coax lines and junctions*

Copper coax lines having a diameter of the inner conductor of 85 mm and that of the outer one of 200 mm are used to couple the hybrid with the cavities. The coupling coax line is about 2 m long for the accelerating unit of the first ring and about 1.5 m long for that of the second one. One of two identical waveguide-to-coax junctions (a loop with a gap) may be used as a 180°phase switch [6] to change the direction of particle acceleration in the first ring of the UNK.

4.4 *Dummy load*

The dummy load must dissipate the average power reflected from the cavities during the acceleration cycle, i.e. less than 300 KW. Two cylindrical 50 Ω commercial water-cooled resistors, each designed to dissipate 150 KW on the average, in exponential-shaped screen are used as coaxial matched loads. The power is directed to the loads via two matched probe waveguide-to-coax junctions in the insulated port of the hybrid.

5 EXPERIMENTAL RESULTS

Two cavities, 3 dB hybrid and 15 m long waveguide feeder were installed in the lab. This RF unit was fed by one 200 kW cascade of RF power amplifier [7]. Usually the cavities are conditioned by RF pulsed power. The cavity pressure was better than 3×10^{-7} Torr. In about only 1-2 hours the RF power level achieved 50 kW per cavity. This RF power is more than sufficient to attain the design cavity voltage. We had a few cases of sputtering onto the ceramic window in the power coupler as a result of multipactor effect. But glow discharge conditioning of the cavity filled with argon showed good results.

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