STATUS OF HOM DAMPED ROOM-TEMPERATURE CAVITIES FOR THE ESRF STORAGE RING*

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Abstract

At the ESRF, longitudinal coupled bunch instabilities driven by cavity HOM are currently avoided up to the nominal current of 200 mA by precisely controlling the temperatures of the six five-cell cavities on the storage ring. A longitudinal bunch by bunch feedback has recently allowed overcoming the remaining HOM and thereby increasing the current in the storage ring to 300 mA. In parallel, HOM damped room-temperature cavities are being developed for highly reliable passive operation at 300mA. They are designed for a possible later upgrade to higher currents.

INTRODUCTION

The development of the new 352 MHz cavity for the ESRF is based on the 500 MHz European HOM damped normal conducting cavity with three circular double ridge waveguide HOM dampers loaded by UHV compatible absorbing NiZn ferrite material (C48/Countis industries) [1, 2]. The cutoff frequency and the length of the dampers are adjusted for an efficient selective damping of the HOM and a minimum absorption of accelerating mode power. The first units built for the MLS near BESSY and for ALBA have shown that an inevitable gap between the cavity ports and the ridges of the connected HOM dampers can lead to a significant impedance of the TM011 mode and to an overheating of the vacuum flanges by local surface currents [3]. We propose a solution to avoid the gap by splitting the HOM dampers in two parts. A first coupling section will be e-beam welded to the cavity body. The remaining part of the HOM damper including the ferrite load will be connected head on to the coupling section, at a distance where the accelerating mode power is sufficiently decayed and where RF fingers can be implemented safely to ensure a good continuity of the surface currents.

To achieve 300 mA safely, design margins have been taken corresponding to a maximum of 500 mA of stored beam in terms of power, i.e. 2.5 MW of transferred beam power, and to 1 A in terms of HOM damping. In order to provide the nominal accelerating voltage of 9 MV with some operational margin and to limit the copper losses it is foreseen to install 18 new cavities in the ESRF storage ring.

The next section summarizes the numerical optimization of the cavity body and the HOM dampers. We then report on power tests of RF contact fingers for the head on connection of ridge waveguides, using a special WR2300 tapered ridge waveguide fed with 1 MW of RF power.

HOM DAMPING

To anticipate possible discrepancies between numerical simulations and impedance measurements, we require that all HOM impedances remain below a value giving an instability threshold at 1A for 18 identical installed cavities. The use of standard Conflat flanges CF250 imposes a maximum inner diameter of 230 mm for the HOM dampers. For mechanical reasons the damper axes are positioned at least at 150mm from the inner walls of the end discs. As shown in figure 1, after the final precision machining of the assembly, the faces of the coupling sections will follow the inner cavity diameter.

Figure 1: Coupling section seen from inside the cavity.

The beam pipe diameter has been kept at 100 mm as on the existing five-cell cavities to remain compatible with the existing X-ray absorbers and to ease the installation.

In the design process, first a single cell cavity without HOM dampers has been optimized to obtain a maximum shunt impedance of 6.1 MΩ. ($R/Q = 148.5\ \Omega$, $Q_o = 41100$). Then the HOM dampers have been optimized for a wide frequency span from 400 MHz to 4 GHz. Numerical simulations with GdfidL [5] have shown that only two dampers with a cut-off frequency of 452 MHz, separated azimuthally by 120° are required to damp the lowest HOM. They have an inner diameter of 230 mm, a gap between ridges of 69 mm and a ridge width of 60 mm. The ferrite model used in these computations is based on the high power prototype designed at BESSY. It consists of an assembly of small ferrite tiles with a thickness of 2.7 mm over a length of 200 mm [4]. The optimum damping is obtained for one damper at the minimum of 150 mm from the front disc and the second one at 150 mm from the back plane. A third smaller damper with a cut-off frequency at 840 MHz is needed to damp a few remaining HOM at higher frequencies with

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impedances above the specified 1 A limit. This damper is placed azimuthally between the others and has a reduced inner diameter of 160 mm, a gap between ridges of 80 mm and a ridge width of 60 mm. The absorber also uses small ferrite tiles, now over a length of 250 mm. The best results are obtained when the third damper is positioned longitudinally at 63.1 mm from the cavity equator.

The longitudinal HOM impedance spectra computed from 400 MHz to 2 GHz and from 2 GHZ to 4 GHz are plotted on figures 2 and 3, respectively.

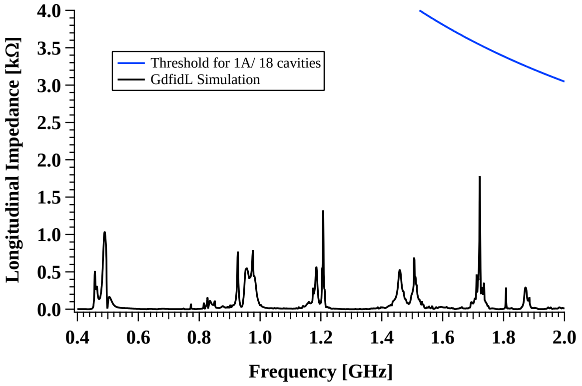

Figure 2: Predicted longitudinal HOM impedances from 400 MHz to 2 GHz.

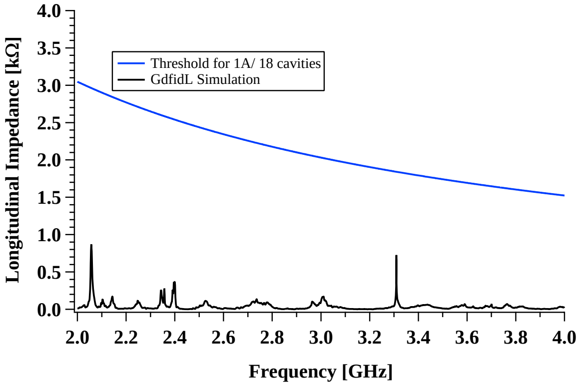

Figure 3: Predicted longitudinal HOM impedances from 2 GHz to 4 GHz.

All the longitudinal HOM are well damped and stay far below the threshold for 1 A and 18 installed cavities. Thanks to the small inner diameter of the third damper, the quality factor of the fundamental mode will be less degraded than with three identical dampers. Moreover, with its high cutoff frequency the third damper can be much shorter than the others.

The transverse HOM impedances still need to be evaluated. However, it is worth noting that during 15 years of operation, HOM driven transverse coupled bunch instabilities have never been observed thanks to the high chromaticity of the storage ring needed to suppress the resistive wall instability. Transverse HOM are therefore not a design constraint for the new ESRF cavities.

The lengths of the dampers have to be designed carefully to limit the absorption of accelerating mode power by the ferrites. To do this, the quality factor of the fundamental mode has been computed with HFSS [6] for various damper lengths. In order to limit the CPU time and the memory consumption, only one damper is included in the HFSS model at the time. The result for dampers with a cutoff at 452 MHz is shown in figure 4. By fitting the data with the coupling factor and the exponential decay at 352 MHz, we could compute the maximum accelerating mode power dissipated in the HOM loads as a function of the damper length.

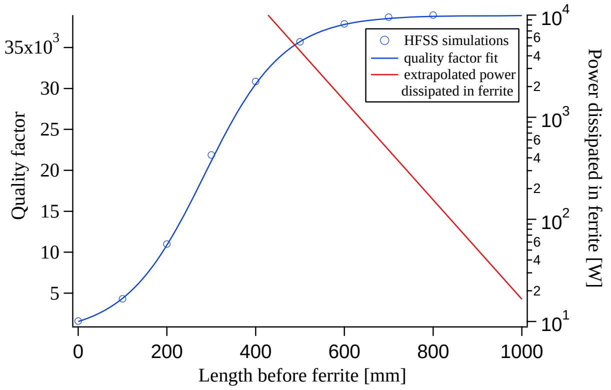

Figure 4: Quality factor and accelerating mode power dissipated in the ferrites for a degraded operation at 9 MV with 12 cavities versus damper length before ferrites.

Requiring less than 100 W dissipation in the ferrites for a degraded operation with only 12 cavities, yields the design length before ferrites of 840 mm. For the third damper a similar study gives a minimum length before the ferrites of 225 mm. This is compatible with the installation of the cavities in the storage ring tunnel, if the third damper is placed on the top of the cavity.

Numerical computations of the complete structure with eigenmode solvers need a large amount of memory with both HFSS or Microwave Studio [7]. To determine the impedance and quality factor of the fundamental mode, computations had therefore to be done with only one damper per simulation. The fundamental mode parameters were then extrapolated for the complete structure and are estimated to R/Q = 145 Ω, Qo = 35000.

RF POWER TESTS OF RF FINGERS FOR THE HEAD ON CONNECTION OF RIDGE WAVEGUIDES

Figure 5 shows surface currents computed with the Microwave Studio eigenmode solver for only one damper connected to the cavity and a maximum accelerating voltage of 815 kV. High surface currents are predicted in the whole cross section of the coupling section. In the flange that will connect the ferrite loaded damper to the coupling section, the copper gasket will guarantee the electrical continuity on the outer cylinder. In the ridge zones, the electrical continuity will be established by means of RF fingers inserted between the head on connected ridges. In figure 5, surface currents start from 2800 A/m close to the cavity and decay exponentially along the damper. The minimum required length of the coupling section is determined by the position at which the surface currents remain below the level, which the RF fingers can withstand without arcing or over-heating. In order to specify this current level, tapered ridges were built into a section of WR2300 waveguides as shown in figures 6 and 7.

Figure 5: Surface current density on the HOM damper

The distance between the flat tops of the ridges was 82 mm and the tapered sections allowed a matching to -28 dB. Microwave Studio simulations showed that for 1 MW of RF passing through this device, surface currents of 600 A/m are induced on the flat top of the ridges.

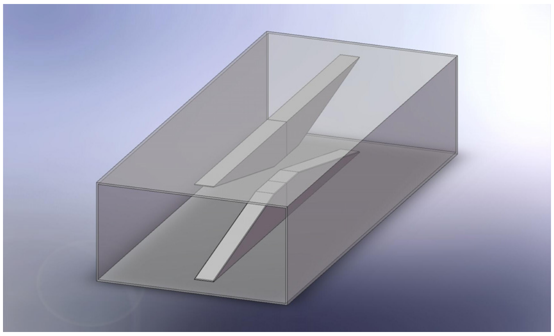

Figure 6: Tapered double ridge WR2300 waveguide with head on connected ridges, for power tests of RF fingers

The top and bottom ridges of this device are built in two parts, which are connected head on. The faces of the front ridges have been machined to receive RF fingers at 2 mm from the edges, as shown in figure 7. The power tests were carried out on the RF system of the ESRF booster. The device was placed after the circulator between an H-bend and the dummy load. An already installed arc detector was placed on the H-bend to interlock the RF power in case of RF finger arcing. Thermal sensors (PT100) were inserted in the top ridges to follow up their temperature. The RF power was increased slowly up to 1.05 MW without arcing of the RF fingers. After 3 hours of test the device heated up to 80º C on the flat top of the ridges, compared to a 40º C heating of the waveguide network around the device. After the first test, the device was dismounted and no trace of over-heating or arcing was observed. No problem was observed after three further tests.

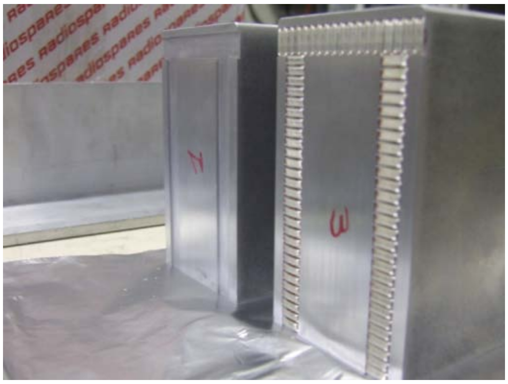

Figure 7: Insertion of RF fingers on the ridge faces

Comparing numerical results and the RF power passing through the device during the tests, we could determine a minimum length of 280 mm for the coupling sections of the 452 MHz cutoff dampers. With this length, we are even safer for the 840 MHz cutoff damper.

CONCLUSION AND OUTLOOK

The design of a strongly HOM damped cavity was optimized numerically. Effective HOM damping is predicted with two HOM dampers having a cut-off frequency of 452 MHz and one with a cut-off frequency of 840 MHz. The smaller damper brings less degradation of the quality factor of the fundamental mode than a design with three identical large aperture dampers. The numerical results will be compared with measurements on an aluminum prototype in the coming months.

Power tests have demonstrated that RF fingers can be used for the head on connection of a ridge waveguide damper on a coupling section of reasonable length, which will be welded on the cavity. This will allow avoiding the gap between the ridges and the cavity port and the associated impedance and heating problems. Tests with different types of RF fingers are planned in order to further optimize the mechanical and electrical interface. Studies of the vacuum system configuration and the thermal behavior are under way. The goal is to launch the fabrication of a high power copper prototype by the end of the year.

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