NEW WAVEGUIDE-TYPE HOM DAMPER FOR ALS STORAGE RING CAVITIES*.

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Abstract

The ALS storage ring 500 MHz RF system uses two re-entrant accelerating cavities powered by a single 320kW PHILLIPS YK1305 klystron. During several years of initial operation, the RF cavities were not equipped with effective passive HOM damper systems, however, longitudinal beam stability was achieved with careful cavity temperature control and by implementing an active longitudinal feedback system (LFB), which was often operating at the edge of its capabilities. As a result, longitudinal beam stability was a significant operations issue at the ALS. During three consecutive shutdown periods (April2002, 2003 and 2004) we installed E-type HOM dampers on the main and third harmonic cavities. These devices dramatically decreased the Q-values of the longitudinal anti-symmetric HOM modes. The next step is to damp the remaining longitudinal HOM modes in the fundamental RF cavities below the synchrotron radiation damping level. This will hopefully eliminate the need for the active LFB system and set the stage for a possible increase in beam current. A "waveguide" type of HOM damper is the only option that does not significantly compromise the vacuum performance of the rf cavity. In this report we further discuss the design process and the results of the low level measurements of the waveguide type damper.

INTRODUCTION

Waveguide type dampers are often used in the RF cavities of the accelerators operating at the frequencies of several hundred MHz due to their simplicity and cost effectiveness. The required frequency range of the new ALS Storage Ring Main RF Cavity HOM damper is 1GHz to 3.2GHz. The lower limit is determined by the resonant frequency of second lowest longitudinal mode (the lowest monopole parasitic mode-TM_{011} at 810MHz is effectively damped by an E-type damper [1]), and the higher limit by the cut-off frequency of the lowest beam pipe TM type mode (TM_{01}). The effectiveness of the damper depends upon two factors: coupling of the particular HOM to the damping waveguide, and the broadband performance of the termination load. The damping waveguide will be attached to the existing port (D=120mm), which is now used exclusively by the vacuum ion pump. In the new lay-out the HOM damper and the vacuum pump will share the same port which will slightly compromise vacuum performance of the rf cavity.

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This effect could be compensated by adding a second vacuum pump if necessary (which would pump the cavity via the power coupler port). The cut-off frequency for the lowest TE mode (TE_{11} mode) of the single ridge circular waveguide, used in our damper, is 890MHz and the total length is 600mm. The single ridge geometry of the waveguide was chosen as it allows to dump both symmetrical and nonsymmetrical HOM's.

DESIGN PROCESS

The design process of the new ALS damper took several steps. First with the help of 2-D SUPERLANS code, the main parameters of the longitudinal HOM spectrum have been determined. Then the cross-section of the HOM damper waveguide was optimized with the help of HFSS S_{11} processor. It has been found that the best overall performance of the damper over 1-3.2GHz range for the given waveguide diameter of 120mm, located at the equator of the rf cavity, could be achieve with the single ridge circular waveguide geometry with the ridge height=60mm and width=40mm. Two ceramic wedge loads made out of Ceralloy 13740Y material (AlN +40% SiC) are used to absorb the HOM rf power transmitted from the cavity. Figure 1 shows performance of the rf absorber over required frequency range (VSWR of the TE_{11} mode).

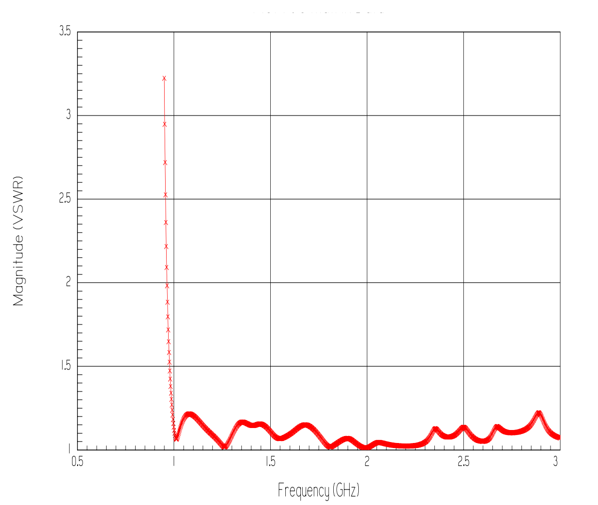

Figure1

Calculations were done and the plot was created with the help of the ANSOFT HFSS code. The total power dissipated in the ceramic loads for the worst-case ALS operation scenario (40mA single bunch or 56mA two bunch mode) will be about 150W that gives the average power density 0.75[W/cm^3]. Thermal stress analysis has not been done yet but it should not be an issue since the same material is operating successfully for years in the PEP-II rf cavity damper with the peak power density up to 5.5[W/cm^3] [2]. The minimum length of the HOM damper waveguide is determined by the required attenuation of the fundamental frequency of the rf cavity (the length of the HOM damper waveguide has no impact on the damper performance since the HOM power is almost completely absorbed in the ceramic). For the waveguide used at the wavelength greater than the cutoff frequency, there is no real propagation and the fields are attenuated exponentially. Power attenuation is:

$$\frac{P}{P_0} = \exp(-2k_{long}z) = \exp\left[-2k_{trans}z\sqrt{1-(\frac{\lambda_{cutoff}}{\lambda})^2}\right] = \exp\left[\frac{-4\pi z}{\lambda_{cutoff}}\sqrt{1-(\frac{\lambda_{cutoff}}{\lambda})^2}\right]$$

or in dB:

$$\frac{P}{P_0} = 54.57\frac{z}{\lambda_{cutoff}}\sqrt{1-\left(\frac{\lambda_{cutoff}}{\lambda}\right)^2}\,[dB] \qquad (1)$$

where:

k_{long} -longitudinal wave number
k_{tran} -transverse wave number $=2\pi/\lambda_{cutoff}$
z -waveguide length
λ_{cutoff}-cutoff frequency wavelength.

for:$\lambda>\lambda_{cutoff}$: $$k_{long} = jk_{trans}\sqrt{1-\left(\frac{\lambda_{cutoff}}{\lambda}\right)^2}$$

The length of the waveguide chosen is 350mm which gives the power attenuation factor for the fundamental frequency of 47dB. The cross section of the new ALS HOM damper is shown in Fig.2

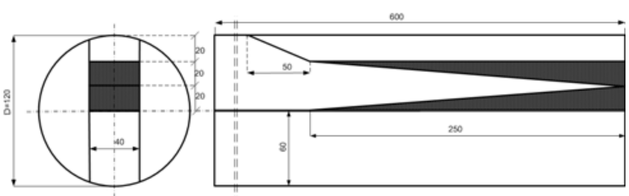

Figure2

TEST RESULTS

The "cold" model of the ALS waveguide damper was build and tested. Test results are presented in Figure 3.

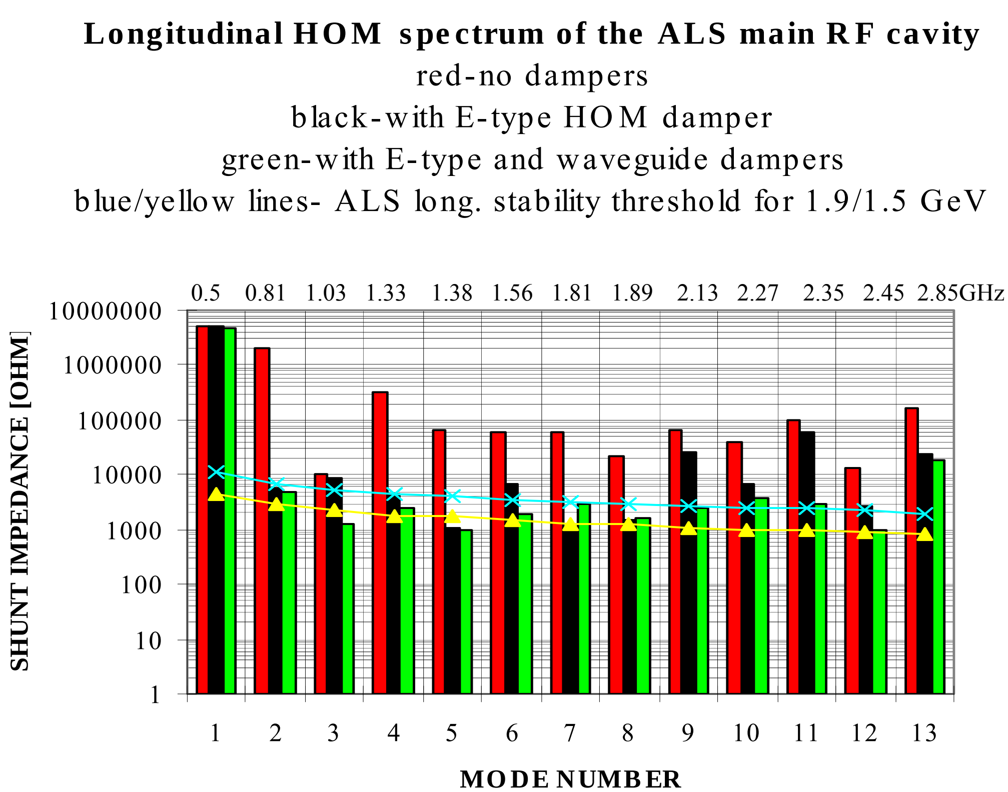

Figure 3

Red bars in Figure 3 represent the results of the measurements of the longitudinal HOM spectrum made before installation of the HOM dampers.

Black bars- same spectrum with E-type damper (installed May 2002).

Green bars- same spectrum with both E-type and new waveguide damper installed.

Blue and yellow lines describe the threshold impedances obtained by equating the longitudinal radiation damping times with the respective longitudinal multibunch instability rise times for 1.9 and 1.5GeV[4].

$$Z_{II}^{thresh} = \frac{1}{N_c} \frac{1}{f_{HOM}} \frac{2 \cdot E_0 \cdot Q_s}{I_0 \cdot \alpha \cdot \tau_s} \quad (2)$$

where:

N_c- numbers of rf cavities

f_{HOM}- frequency of the particular HOM mode

E_0- beam energy

Q_s-synchrotron tune

I_0-average beam current

α-momentum compaction factor

τ_s-longitudinal damping time.

Looking at the Figure 3 one can notice that the impedance of the highest HOM mode (2.85GHz) is still by more than one order of magnitude higher than the synchrotron radiation threshold. Luckily the resonant frequency of this mode is very sensitive to the cavity temperature so it can be moved into a safe position between revolution harmonics spectra with the help of the cavity cooling water temperature control system.

CONCLUSION

The electrical part of the design of the new waveguide HOM damper for the ALS Storage Ring main RF cavities has been finished and the results are presented in this paper. The project has been fully funded and the mechanical design work is under way. We plan to build and install the new dampers in ALS Storage Ring during next shutdown period (May 2005).

REFERENCES

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