SIMULATIONS OF THE DAMPING OF THE POWER EXTRACTION AND TRANSFER STRUCTURE (PETS).

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Abstract

The Power Extraction and Transfer Structures (PETS) of CLIC operate with high currents (~ 270 A) to produce about 0.5 GW of RF power/m in the 30 GHz decelerator. To avoid beam break-up in the decelerator, strong damping of the transverse modes is needed. The most dangerous is the first dipole mode, which has practically the same frequency as the decelerating mode because of the PETS specific geometry. Consequently, the usual damping method for a classical accelerating structure, based on a frequency-selective interception of the longitudinal wall current, is not applicable. Corrugated longitudinal damping slits that intercept the transverse image current of the TE-type hybrid mode has therefore been adopted [1,2]. This paper presents the results of the recent computer optimisation of the damping slit geometry for 6 waveguides PETS. Because of the practical difficulties linked to the MAFIA eigenvalue solver for modes with quality factors of a few hundred, the simulations were done by postprocessing the data from the HFSS program. Finally the equivalent Q-factor of the modes of interest was reduced to less than 50, a value that can insure the stable transfer of the drive beam through the whole decelerator [3].

1 INTRODUCTION

The #7 release of the HFSS provides new options, which make it possible to solve the eigenvalue problem for the geometry, which includes the lossy material [4]. This opportunity was used to do careful simulations for the transfer modes damping of the PETS. The initial optimisation of the geometry had been done earlier [5]. The parameters for optimisation were the damping slit and SiC box geometry. In this paper we discuses the method that was used to postprocess the HFSS data and the final results of the simulations.

2 TRANSVERSE MODES IN PETS

The specific features of the PETS (Fig. 1), are based on the fact that all the energy for most of the modes is concentrated at the waveguides area (see Fig. 2). That is why the frequencies of the modes are quite close. The only way to organise the damping of the transverse modes is the resonant coupling to the damper through the interception of the RF image current with the longitudinal damping slit.

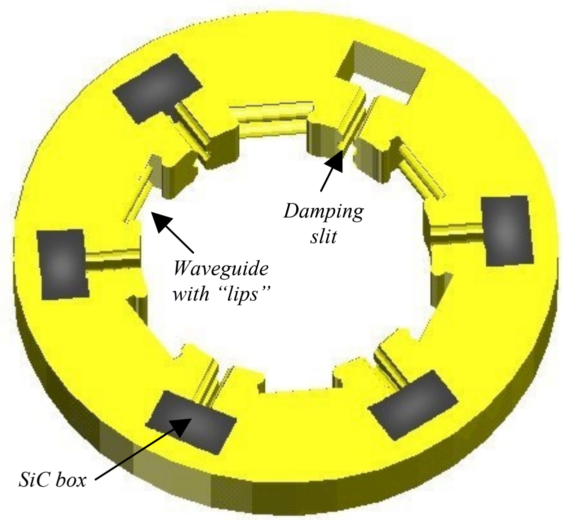

Figure 1. General layout of the PETS cros-section.

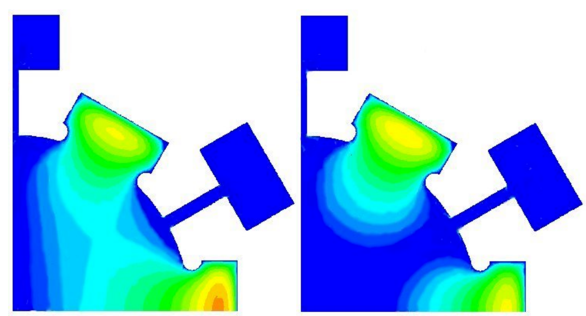

Figure 2. The electric field pattern of the dipole (left) and sextupole (right) modes.

The PETS geometry optimisation was done to provide the strongest transverse modes coupling at frequencies close to 30 GHz. In the presence of the damping slits the modes are split into two similar ones (compare figures 3a and 3b). The dispersion characteristics, q-factors and group velocities for the modes of interest are shown in Figure 3. In our case the first dipole and sextupole modes are the most dangerous, because of their synchronous frequencies are close to 30 GHz.

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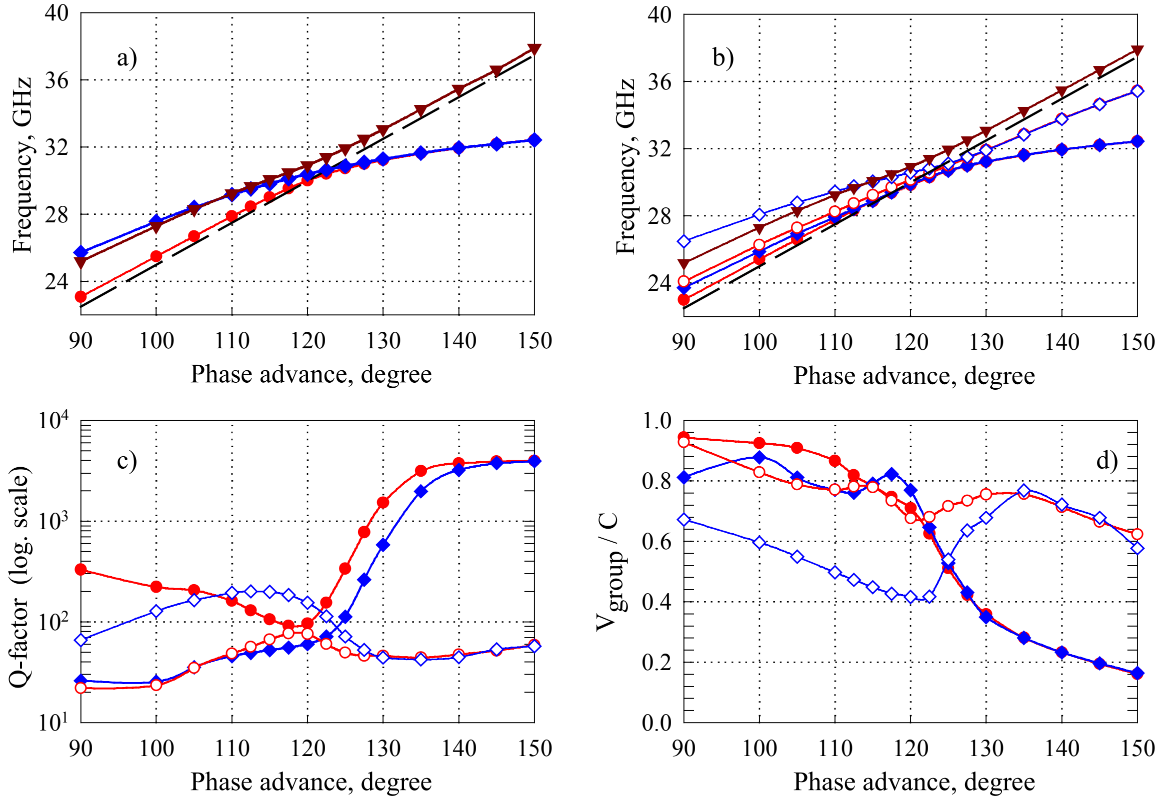

Figure 3. The dispersion characteristics (a) and (b), Q-factors (c) and group velocities (d) for the transverse modes, simulated with the HFSS. Circles for the dipole mode, diamonds for the sextupole modes, triangles for the second dipole mode. The dash line corresponds to the speed of light line.

In the structure without damping, the beam sees the transverse impedance value along the speed of light line, whose real part is non zero only at discrete frequencies. In the case of strong damping, the resonances spread out such that there is interaction with the beam for a continuous range of synchronous phases and frequencies [6,7]. Thus, the consistent description is no longer a Brillouin diagram giving the eigenfrequency as a function of the phase advance, but a two dimensional impedance function depending both on frequency (ω) and phase (α). Now we can reconstruct the longitudinal impedance distribution for both modes in the form:

$$Z_{//}(\alpha,\omega) \approx \sum_{i=1,2} \frac{Z^0{}_i(\alpha)}{1+\left(2Q(\alpha)\dfrac{\omega-\omega_i(\alpha)}{\omega_i(\alpha)}\right)^2} \qquad (1)$$

The impedance at a certain radial offset for the given phase advance can be derived from HFSS data:

$$Z^0(\alpha) \approx \frac{E_z^2(\alpha)Q(\alpha)}{\omega(\alpha)W(\alpha)} \qquad (2)$$

Index i in (1) corresponds to one of the two split modes. Note that, without damping, the impedance of the transverse mode is just equal to the sum of the two split ones. This simply means that the amplitude of the short-range wake will never be changed because of the damping.

The two-dimensional distributions of the impedance for the both modes are shown in Fig. 5. Finally the impedance coupled to the beam can be defined as amplitude of the two-dimensional impedance distribution, measured along the speed of light line.

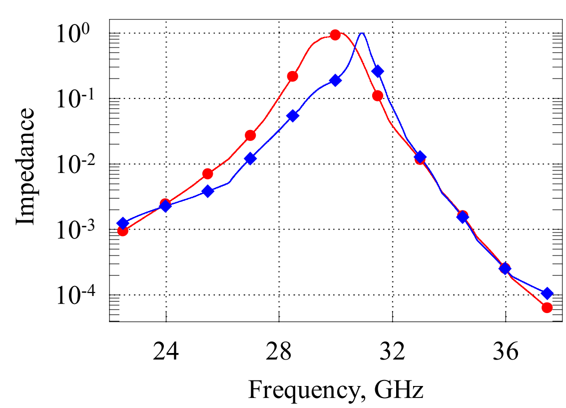

Figure 4. The normalized coupled impedance vs. frequency for the dipole (circles) and sextupole (diamonds) modes.

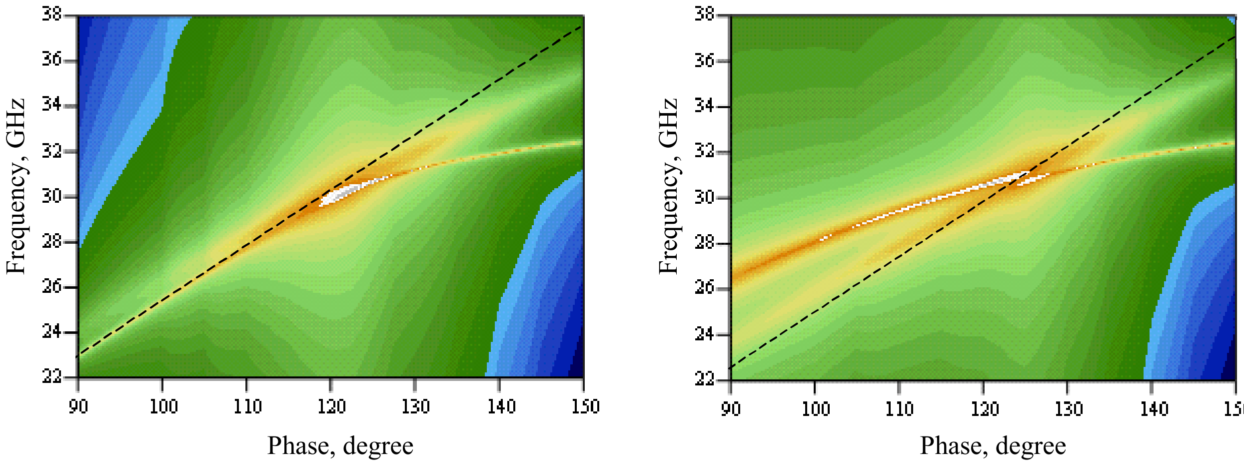

Figure 5. The two-dimensional distribution of the longitudinal impedance for the dipole (left) and sextupole (right) modes. The plot is done in a topography manner. The dotted line corresponds to the speed of light line.

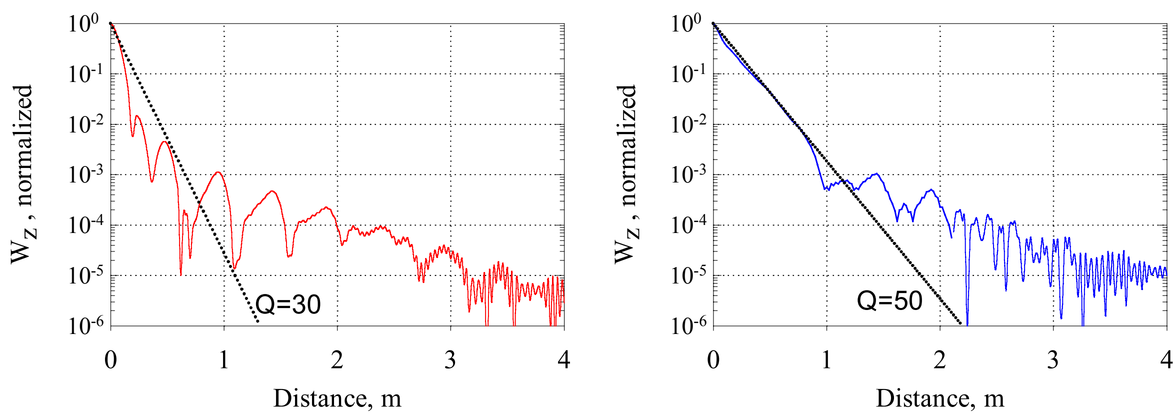

Figure 6. The longitudinal wake envelopes of the dipole (left) and sextupole (right) modes. The dotted line shows the decay of the oscillation with the Q-factors specified.

The resulting coupled impedance distributions are shown in Fig. 4. The Fourier image of the coupled impedance gives us the envelope of the wake potential, as shown in Fig. 6.

3 CONCLUSION

The procedure introduced for the postprocessing of data obtained through the direct computer simulation of the RF periodic structures appears to be valid for the study of the heavily damped structures.

With the optimised geometry of the damping slits, the equivalent Q-factor of the potentially dangerous transverse modes in a six waveguides PETS is reduced to less than 50. This practically satisfies the requirements for the stable transportation of the drive beam through the whole decelerator.

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