Determination of Resonant Frequency and External Q Values for the BESSY II HOM-Damped Cavity

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Abstract

Damping of higher order cavity modes (HOM's) is one way to increase the intensity thresholds for multibunch instabilities in B-factories and state of the art synchrotron radiatron sources. Following the idea of Conciauro-Arcioni [1] one of the simplest geometries is the threefold-symmetry cavity-waveguide structure with a broadband absorber terminating the end of every guide. The iris coupling between the cavity and the waveguide has to be designed so that the fundamental cavity-mode remains nearly unperturbed. The values of the external Q und the shift resonant frequencies due to the waveguide loads is determined and tested by known methods with MAFIA.

I. INTRODUCTION

BESSY II is a 1.7 GeV third generation electron storage ring with 16 straight sections to produce highly brillant synchrotron radiation beams in the spectral range of soft x-ray and vacuum ultraviolet. One of the design goals is a low emittance of 6 nm·rad and a maximum beam current of 200 mA [2], [3]. Therefore it is necessary to reduce all effects which potentially spoil the brilliance of the radiation beam. Especially in RF accelerating cavities, the beam induces parasitic resonant fields which can lead to coherent multibunch oscillation which results in less brilliance. A possible way to suppress the cavity higher order modes (HOM's), is to mount external waveguides on the cavities, and couple strongly to the most dangerous modes. By terminating the end of each waveguide with broadband absorbers the HOM's are damped at a rate depending on the coupling. The accelerating mode is rejected and remains undamped (if the bigger surface is not accounted for). A low power prototype cavity has been built at BESSY II (threefold-symmetry cavity waveguide structure, Fig. 1). For this preliminary investigation the cavity has a pill-box shape with three circular waveguides, distributed on the cavity coat, 120 degrees apart. In order to optimize the design of the waveguide loaded cavity, one has to know the values of the external Q and the shift resonant frequency due to the waveguide loads. These are readily determined by the method of Kroll-Yu [4], with frequencies computed by the MAFIA code [5].

II. NUMERICAL COMPUTATIONS OF Q-VALUES

For the numerical calculation of the BESSY II HOM-Damped Cavity resonance frequency and external Q, we have employed the method developed by Kroll and Yu. We will not elaborate on the method itself, rather share some general views on the method. For further details, consult [4].

Computing Q_{ext} by numerical means is indeed no trivial task, since an infinitely long waveguide would result in an infinite mesh. Note: waveguide boundaries are unknown in frequency domain. With the Kroll-Yu method, a short is inserted into the waveguide, which first of all makes the mesh size finite. Then, resonance frequency shifts are utilized, that occur as the short position is varied. More volume always decreases resonant frequency, but the slope varies, depending on field strength at the

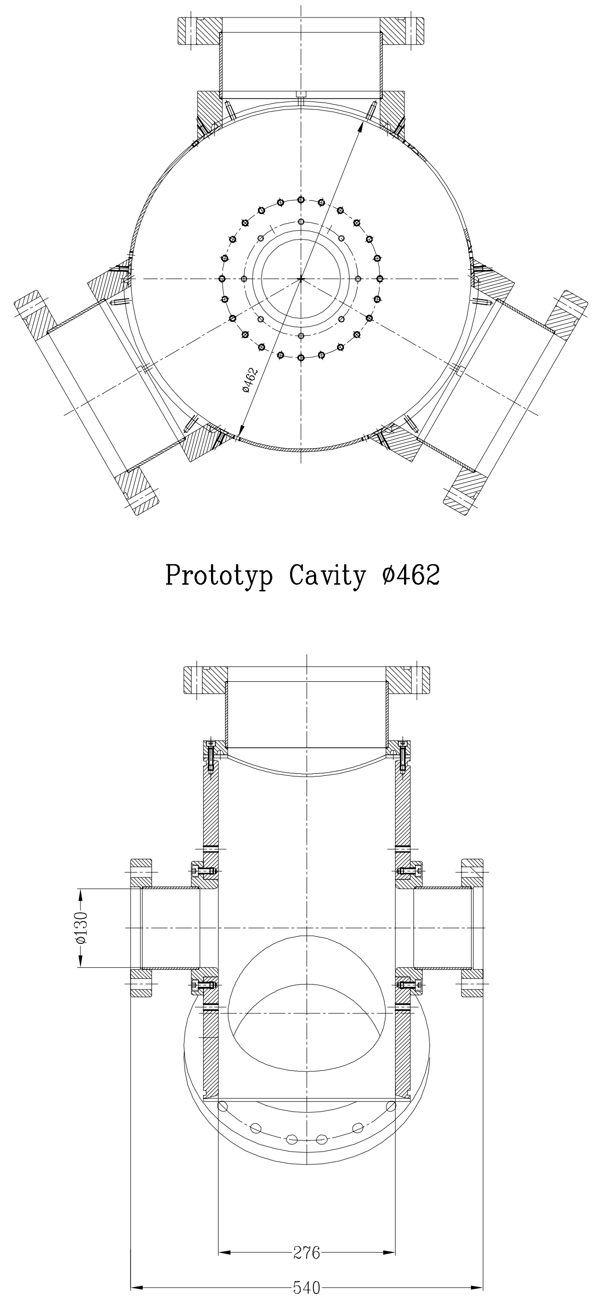

Figure 1. Prototype BESSY II cavity

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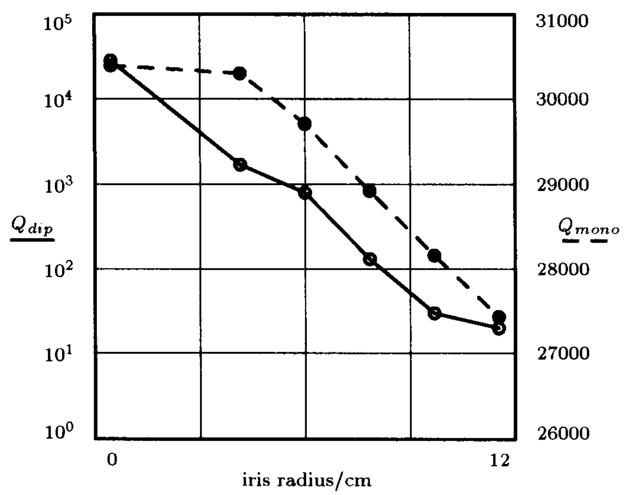

Figure 2. Q_{ext} of the dipole mode and Q_{cond} of the monopole mode versus iris radius. Conductivity is $58 \cdot 10^6\ 1/(\Omega\mathrm{m})$.

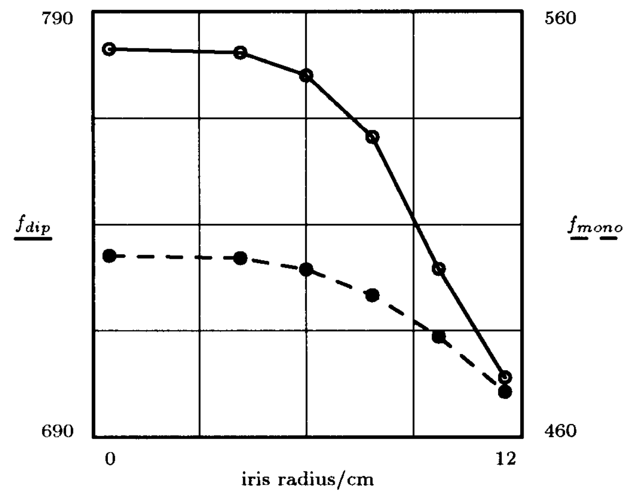

Figure 3. Frequency of the dipole mode and the monopole mode versus iris radius. Conductivity is $58 \cdot 10^6\ 1/(\Omega\mathrm{m})$.

location of change in geometry. Thus, the magnitude of the shift in resonance frequency can be related to the field strength in the waveguide, which again can be related to the external Q of the cavity. We have found the method to be easy to apply.

However, to calculate Q_{ext}, frequency differences are used, which leads to the following considerations. Significant digits are lost when both frequencies are close to one another. By increasing the distance between short positions we may enlarge the frequency shift. However, the wave nature of the waveguide field maps frequencies onto one another, which stem from short positions separated by $n\lambda_g$. Thus, short positions separated by more than λ_g will not improve the situation. Indeed, for each required additional significant Q_{ext}-digit roughly one significant digit in the frequency difference is lost. We employed MAFIA to model our cavity (Fig. 4 and 5). We recognize, that a frequency solution from MAFIA is typically accurate to about three digits and relative frequency to four digits. Thus Q_{ext}-values of up to 1000-2000 can be computed with an accuracy of at least one significant digit. Attempts to compute a $Q_{ext} > 2000$ will fail. Fortunately, one is mostly interested in Q's in the range of tens to some few hundreds.

Fig. 2 summarizes our results, with both Q_{ext} of the first dipole mode and Q_{cond} for the trapped accelerating mode shown. Q_{cond} of the monopole mode was computed assuming the metal to be copper. Fig. 2 provides the design arguments, where a certain Q_{ext} for the dipole mode has to be reached to achieve the design emittance of 6 nm·rad at 200 mA current. At the same time the effects on the accelerating mode Q_{cond} may be observed. An iris radius of 8 cm would certainly satisfy our needs ($Q_{dip} = 130$ and losses in Q_{mono} below 5 %). However, we will investigate further HOM's before we make a decision.

Fig. 3 shows frequency shifts due to the iris coupling. As soon as some iris radius is chosen on the above mentioned grounds, the cavity radius has to be adapted, to keep the accelerating mode resonance frequency at its design value.

III. OUTLOOK

We will engage in investigations on further HOM's in due course, employing the Kroll-Yu method. Decision on the final iris size will be based on results from these investigations. A test model will be installed and measured to verify theoretical results.

References

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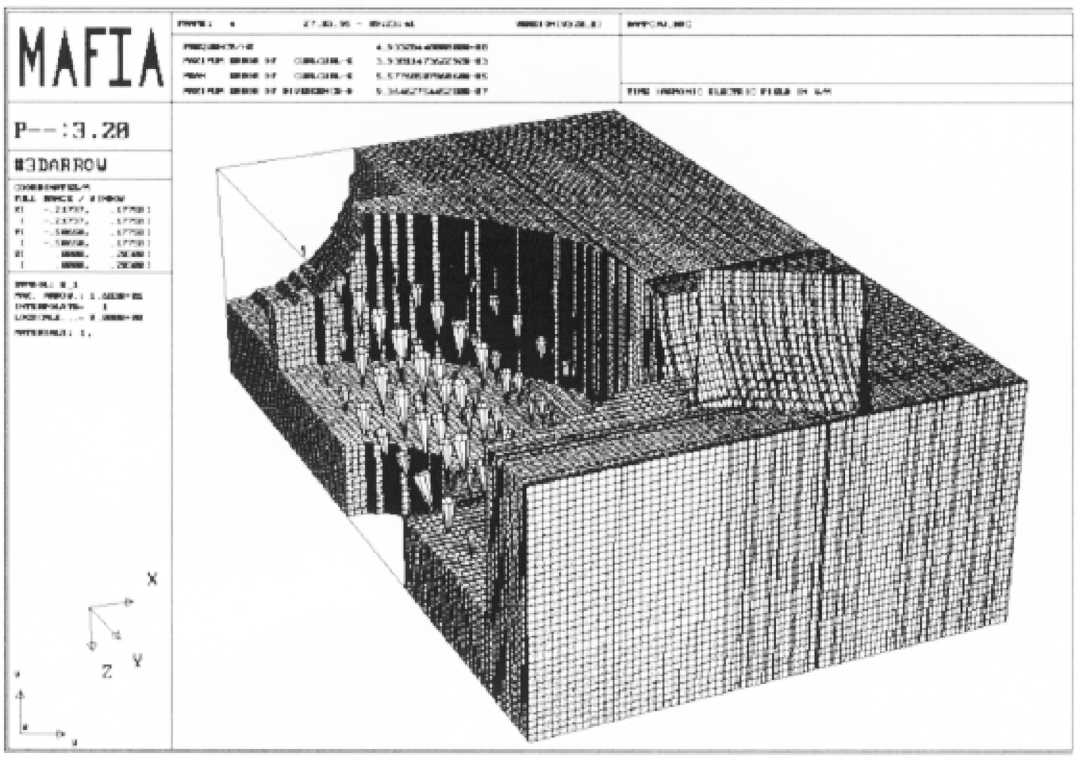

Figure 4. MAFIA mesh (500 000 mesh points) and electric field of the BESSY II cavity and the accelerating (monopole) mode.

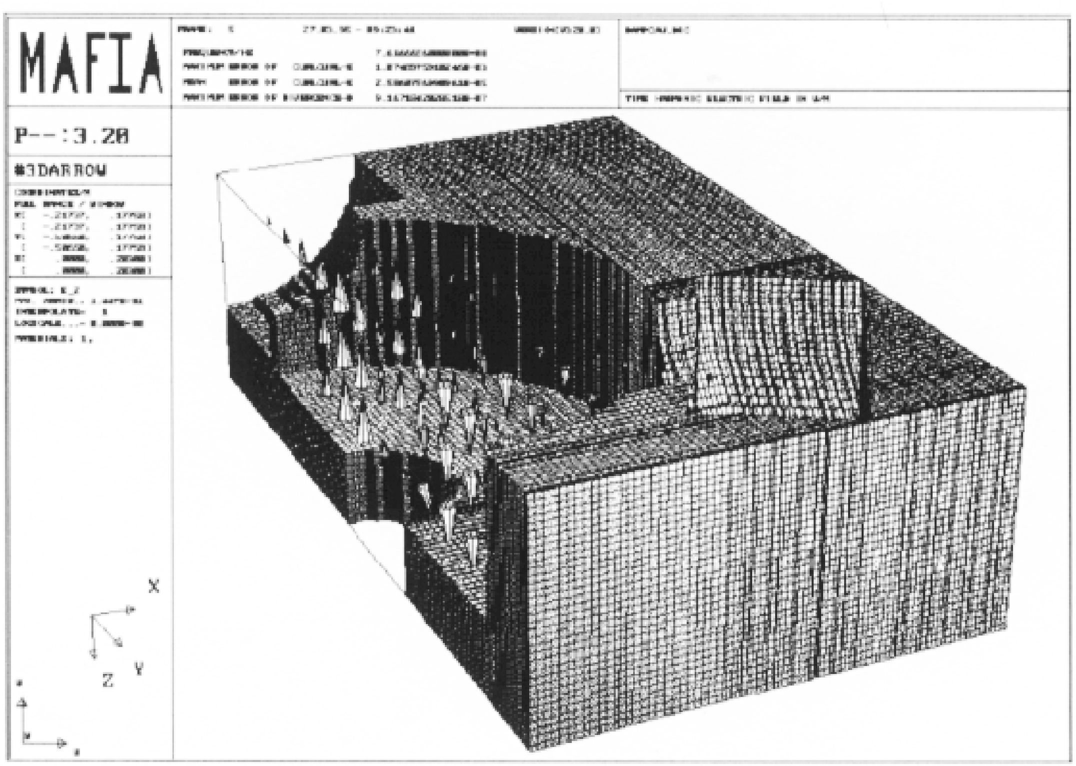

Figure 5. MAFIA mesh (500 000 mesh points) and electric field of the BESSY II cavity and the first dipole mode.