THE COMPENSATED PERIODICAL STRUCTURE FOR RF DEFLECTOR

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Abstract

Compensated accelerating structures with longitudinal electric field are well known in the accelerator technology due to high efficiency and parameters stability. For charge particles separation another structures with transverse fields, like travelling wave Disk Loaded Waveguide (DLW) are used. We propose the standing wave compensated structure with transverse fields for particles rf deflection. At operating π-mode two branches of the dispersion diagram are joined to have the compensated structure. The structure has small transverse dimensions. Large value of the coupling coefficient (more than 30provides high parameters stability. Preliminary results of numerical simulation are presented.

1 INTRODUCTION

The compensated accelerating structures are now widely used for acceleration of charged particles. Let remember, that a 'compensated' is named a structure in which at operating frequency coincide frequencies of two modes (0 or π type) with different parity of a field distribution with respect to symmetry plane (accelerating and coupling modes) [1]. Examples of compensated are such structures as side-coupled, disk and washer and so on. These structures combine a high efficiency with a high stability of the field distribution to deviations in cells parameters and beam loading. The main properties of compensated structures are described in [1].

But compensation is a consequence of special approach to the structure dispersion curve formation, which allows to combine attractive features. Never sad this approach has to be applied only for accelerating structures.

2 STRUCTURE FORMATION

During the Disk and Washer structure investigation and development both in Russia and in another laboratories, a lot of passbands for modes with azimuthal dependence of the field distribution were founded below and in the vicinity od operating point [2], [3].

The DAW dispersion properties were systemized [4] and some ideas for the parasitic modes utilization have been considered preliminary.

The modes with azimuthal dependence of the field distribution can be used either for a multi-beam accelerating structure or for a deflecting structure.

To obtain the compensated structure for rf deflector, one should provide the confluence of two modes of π-type at operating frequency. The best candidates are π-modes - TE_{11}-like mode and TM_{11}-like one. For this purpose we should strongly reduce (approximately two times) the frequency of the TM_{11}-like mode, which strongly depends on the disk inner diameter. The disk should be extended to the beam aperture. But it is still not sufficient and for a further TM_{11}-like mode frequency reduction we should reject the disk azimuthal symmetry. Either sectors should be removed from the DAW disks, or disks have to be degenerated in two lugs (Fig. 1). The metal should be removed in the disk region where a magnetic field of the TM_{11}-like mode is maximal. Thus we both reduce the frequency and, additionally, reduce the surface for rf losses. The TM_{11}-like π-mode will be used as the deflecting (operating) one. Because a maximal value of the deflecting electric fields arises at the lugs surface, the ends of the lugs should be rounded.

The frequency of the TE_{11}-like π-mode mainly depends on the washer dimensions and may not be changed. Only a drift tubes have to be removed from the washer.

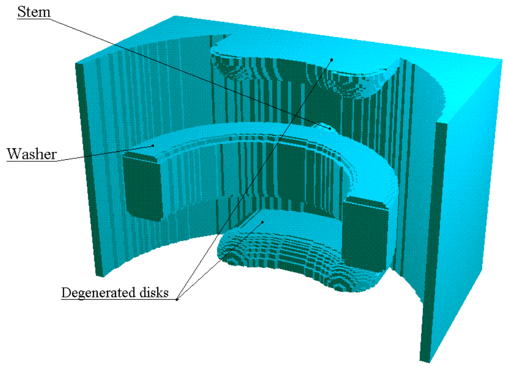

Figure 1. A general view of the deflector.

3 PRELIMINARY RESULTS

Obtained with the transformations, as described above, the structure with confluent π-modes is shown in Figure 1. The electric field distributions in the plane of degenerated disks is shown for operating (deflecting) TM_{11}-like π-mode (a) and coupling TE_{11}-like π-mode are shown in Figure 2.

Due to transformation to reduce the TM_{11}-like mode frequency to the frequency of the TE_{11}-like mode, this struc-

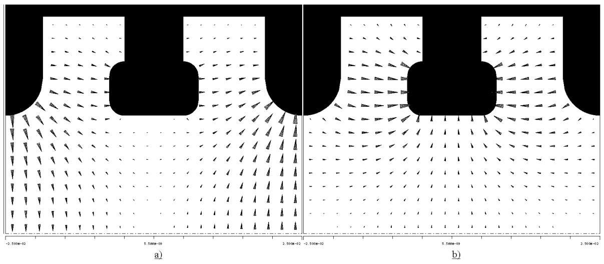

Figure 2. Electric field distribution for confining deflecting mode (a) and coupling one (b).

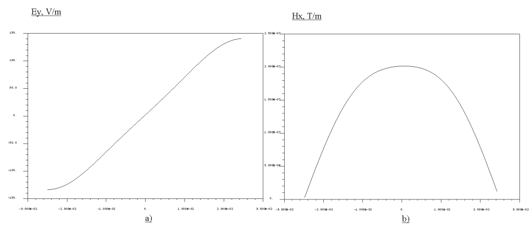

Figure 3. Electric (a) and magnetic (b) fields distribution for the deflecting πTM_{11}-like mode.

ture has a small outer diameter $2R \approx (0.7 \div 0.85)\lambda_0$, where λ_0 is the wavelength at operating frequency.
The confining modes strongly overlaps over the structure period and a coupling coefficient k_c reaches high value $(30 \div 45)\%$. In spite of standing wave operating mode, the travelling wave of the π-type can propagate at operating frequency (as for all compensated structures [1]). The large value of group velocity $\beta_g = \frac{\pi k_c}{4}$ ensures a high stability of the field distribution to deviations in cells parameters and beam loading.
As for all structures with hybrid operating modes, the magnetic field partially cancels the deflecting effect of the electric one. The electric E_y (a) and magnetic B_x (b) fields distributions are shown in Figure 3 for deflecting TM_{11}-like mode. In principle, the TE_{11}-like π mode also can be used, but deflecting efficiency will be several times lower.
It is difficult to compare directly different deflecting structures, for example [5] and [6], because the authors use a different definition for the structure efficiency. (Unfortunately, such parameter as effective shunt impedance for accelerating structures is not established for general use for deflectors). But direct comparison with the rf parameters of the DLW [5] (following [5] procedure) shows our structure several times $(4 \div 6)$ more effective in the rf power consumption for the same deflection angle of the particle.
The reasons for an increased rf efficiency are as follows:
- decreased surface for rf power dissipation;
- standing wave operating mode with a constant field value along the structure;
- no rf power losses in the load (standing wave operation);
- π-type operating mode.

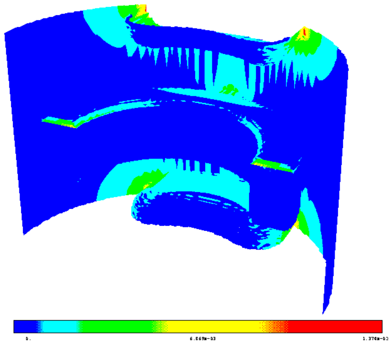

Figure 4. RF losses distribution on the surface.

The rf power losses distribution for deflecting mode is shown in Figure 4. Approximately 15% of the rf power losses take place at the washer surface together with the stems. The quality factor of the structure is near $6\dot{1}0^3$ for S-band frequency range.
The stem orientation with respect lugs is an effective tool for the coupling mode frequency control. Because the inner diameter of the lugs defines the rf efficiency, it should be defined as a beam aperture diameter. The hole diameter in the washer should be not smaller and we have only two effective parameters for coupling mode frequency control. In this structure the beam aperture diameter doesn't effect strongly on group velocity value, in comparison with the DLW, and we have no preliminary limitations on the beam aperture. It may be enough large - for the structure option in Figure 1 the aperture diameter $2a = 40mm$, $\frac{a}{\lambda_0} = 0.2$. Practically it is a half of the structure diameter. For such large aperture opening the coupling mode frequency should be increased to confine with deflecting mode one and the stem should be placed in the plane of lugs, as it shown in Fig. 1. Unfortunately, it increases the total rf power losses. And for small aperture opening the stems should be in a plane perpendicular of the plane of lugs.
As the coupling mode we use the TE_{11}-like one. It is fundamental mode in a cylindrical waveguide, but we use the pi-mode. There is possibility to get passbands overlapping between the passband of coupling TE_{11}-like mode and the same degenerated mode (with field distribution shifted at 90^o in azimuth. With an appropriate choice of the washer outer diameter and the stem diameter it is all time possible to get frequency region at least $\pm 5\%$ clear from parasitic modes.

4 DISCUSSION

As consideration shows, the proposed structure has some advantages in comparison with well known DLW for rf deflection.

This structure has:
- the smaller transverse dimensions;
- the higher rf efficiency;
- match higher parameters stability with respect to deviations in cells parameters and beam loading;
- the higher flexibility in the parameters choice.

From the other side, there are point to be considered as disadvantages. The rf power dissipated in washer is enough high and washer cooling may be necessary. It leads to more complicates construction procedure.

The structure has no azimuthal symmetry, hence the deflecting field is not uniform in the total aperture volume, as it is for the DLW [1]. The non-uniformity value may be small, several percents, but it takes place.

The maximum electric field value arises at the ends of degenerated disks. The ratio of the maximum electric field at the surface to the deflecting field on the axis is higher at $\approx 10\%$ higher as for the DLW.

At present time we done preliminary estimations of the structure parameters both for S-band and for L-band frequency ranges, without deep structure optimization. It keeps the way open to reduce disadvantages, mentioned above.

5 SUMMARY

It this report we propose the compensated periodical structure for rf deflectors. In spite of the compensated structures are well known for particle acceleration, there were no proposals for compensated structures for deflectors. Preliminary consideration shows promising parameters of the structure. This proposal case is a base for further development of the structure.

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