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PARAMETER OPTIMISATION OF RING SLOT COUPLER PICKUP AND KICKER FOR NICA STOCHASTIC COOLING SYSTEM

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Abstract

Pickup and kicker structures for the NICA stochastic cooling system are supposed to be based on ring slot couplers proposed in [1]. However, it differs from the original design by the insertion of a ceramic vacuum chamber that shifts frequency of the structure down to 1-1.5 GHz. Possible design solution of the rings was proposed to shift frequency of the structure to the desired 2 – 4 GHz.

INTRODUCTION

Ring slot coupler structures proposed for HESR stochastic cooling system (SCS) [1] were successfully used for the beam cooling at Nuclotron and COSY [2, 3]. The demonstrated performance within 2-4 GHz frequency band satisfies to requirements of the NICA collider SCS. In the ring structure with octagonal arrangement of shorted electrodes (Fig. 1) the total image current passes the surrounding uninterrupted gap formed by two adjacent rings.

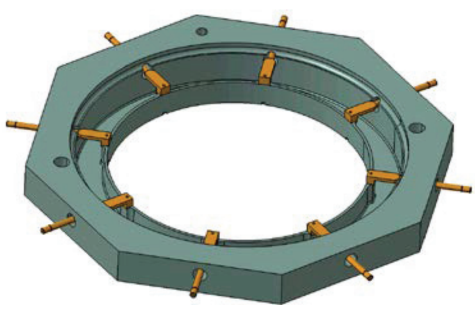

Figure 1: Schematics of single ring of the ring slot coupler structure.

However, the external sealing used in the systems mentioned above makes it problematic to achieve ultra-high vacuum of 10^{-11} Torr which is essential for NICA. Therefore, strict vacuum requirements force us to produce pickups and kickers with internal sealing. In this case, pickup and kicker is assembled over the cylindrical ceramic tube made of Al_2O_3 material (Fig. 2). The ceramic tube shifts frequency of the structure down to 1-1.5 GHz. The goal of this work is to demonstrate possibility to modify design of the pickup and kicker for effective work in the same 2 – 4 GHz band – so in this case we can use the other elements of the system without changes.

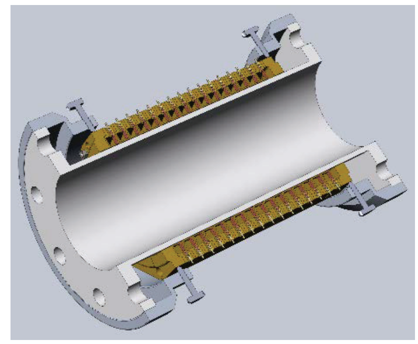

Figure 2: Schematics of pickup (kicker) with internal sealing using ceramic vacuum chamber.

MODELING

Parameters of the Model

The study and design optimisation was done in CST Microwave Studio. The goal was to qualitatively evaluate the field of optimal structure parameters. So maximal simplification of model and calculation settings were done – to make faster calculations even to the detriment of accuracy. Lumped elements and ports were used; the form of feeding loop was not taken into account, lose free materials so as maximal mesh step were used.

Model Benchmarking

To estimate the accuracy of modelling method the original structure was modelled (Fig. 3) and the results were compared with the same obtained earlier [4].

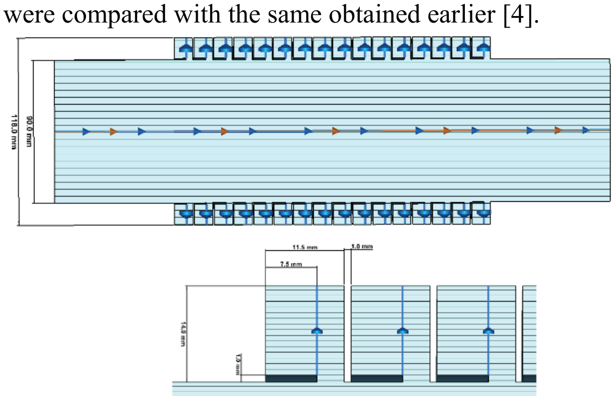

Figure 3: Dimensions of the model.

Electrical field of structure on different frequencies for infinite number of cells and for 17 cells was calculated. The results are given in Fig. 4.

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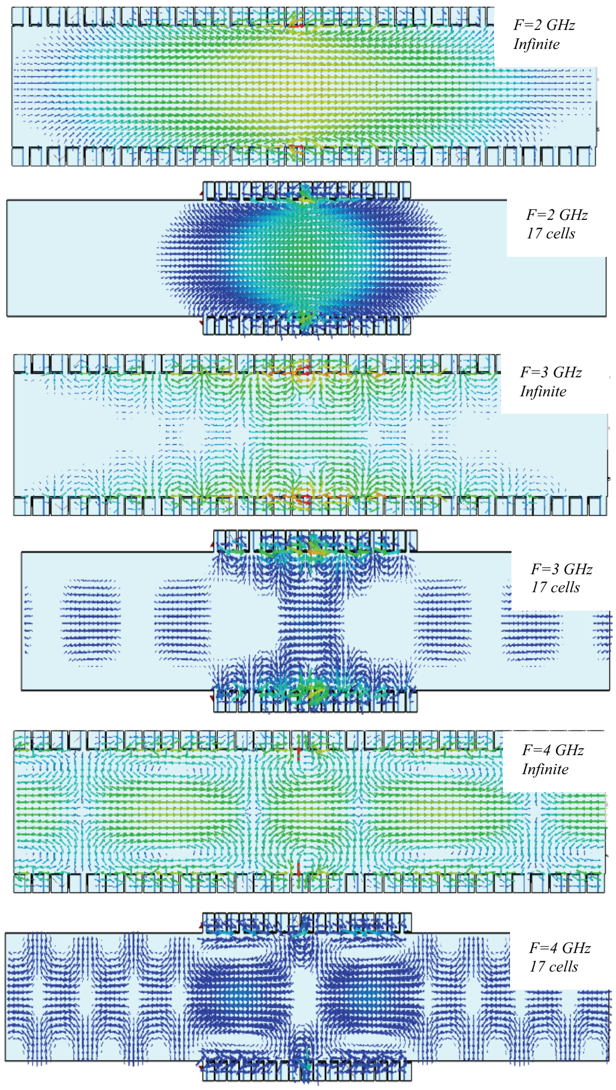

Figure 4: Electrical field on different frequencies for infinite and 17-cell structure.

Also longitudinal wake impedance of finite structure (17 cells) was calculated (Fig. 5).

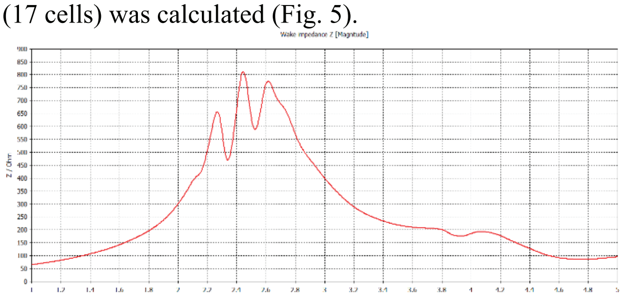

Figure 5: longitudinal wake impedance of 17-cell structure.

Comparison of the results with [5] shows that it is possible to use simplified model for qualitative estimation of structure characteristics and parameters.

Modelling Structure with Ceramic Tube

Minimum internal diameter of NICA vacuum pipe is 98mm – it differs from that on COSY and Nuclotron. Minimal thickness of ceramic tube used for sealing is about 5mm. Dielectric constant of ceramic (Al_2O_3) ε=10.

The list of model optimization parameters (Fig. 6):

- Tube_b – width of tube wall (≥5mm).
- gap_b – air gap between tube and rings.
- Res_b – ring width.
- Res_h – ring depth.
- Res_gap – distance between rings

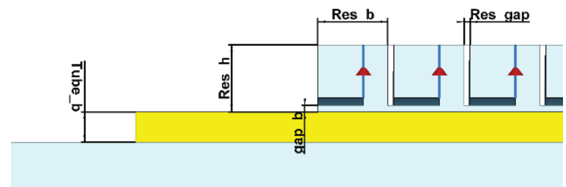

Figure 6: Optimisation parameters.

The results of modelling shows significant influence of a ceramic tube on the structure frequency response (Figs. 7 and 8). The goal of modelling was to optimize the frequency response of structure for working in 2-4 GHz band. Optimization results shows that it is impossible to obtain the required behaviour by parameter optimization of the structure without changes in the design.

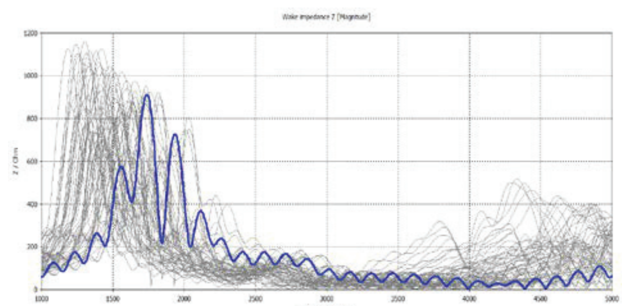

Figure 7: Longitudinal wake impedance of the structure for different parameters.

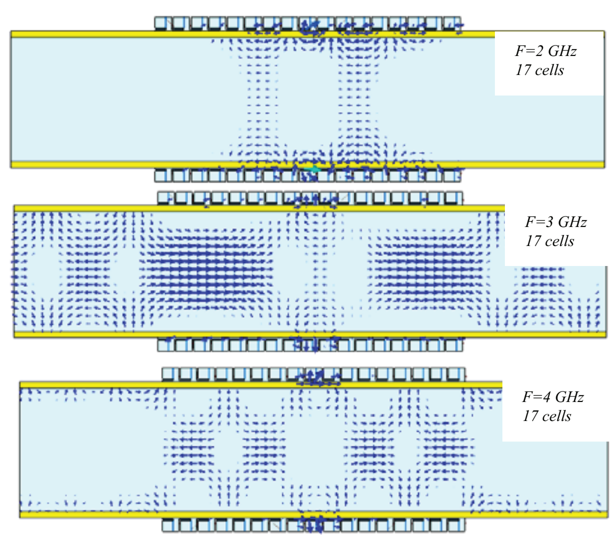

Figure 8: Electrical field on different frequencies.

Design Modification

To compensate frequency decreasing due to ceramic tube influence it is proposed to insert shorts symmetrically

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between electrodes (Fig. 9). The shorts can be made during ring milling or added as separate inserting segments to the original structure. Variation of the short geometry can smoothly tune the resonant frequency of individual rings and the whole structure itself.

List of model optimization parameters:

Short_fi – angular dimension of the short
Short_b – width of short
Tube_D – ceramic tube diameter
Ring_Din – internal ring diameter
Ring_Dout – external ring diameter

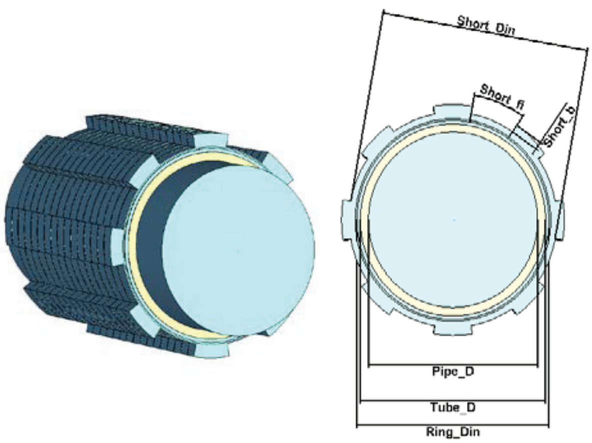

Figure 9: The ring slot coupler structure with additional shorts and optimized parameters.

Optimization was done for maximization of longitudinal wake-impedance in frequency band (2-4 GHz) of the structure consisting of 16 rings (Fig. 10). Length of structure was not changed during optimisation (200 mm) and some dimensions like ring slot width (4 mm) too.

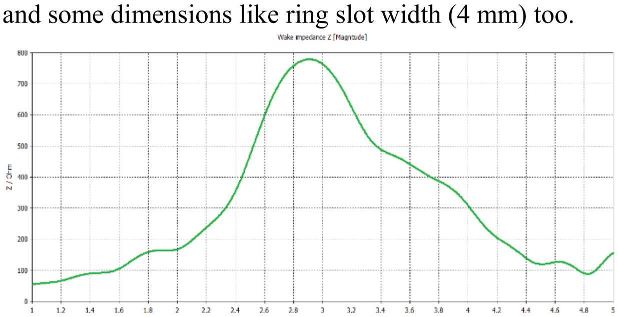

Figure 10: longitudinal wake-impedance of optimised structure.

As a result of optimization the reasonable response of longitudinal wake-impedance was obtained. Therefore, we can make conclusion that it is possible to compensate influence of high dielectric constant ceramic tube insertion by rather simple redesign of ring-slot coupler and make it work in the desired band of 2 – 4 GHz.

CONCLUSIONS

- Ring-slot coupler pickup and kicker can be used in NICA cooling system with internal Al_2O_3 ceramic tube sealing.
- Simple modification of the ring design can compensate ceramic tube influence on frequency of coupler.
- The modification is including shorts in the rings.
- Shorts parameters can smoothly control the design frequency response to get best performance of pickup/kicker.

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