DOUBLE-CELL NOTCH FILTER FOR SRF GUN INVESTIGATIONS

E. Zaplatin, Forschungszentrum Juelich, Germany
A. Kanareykin, Euclid TechLabs, Ohio, USA
J. Knobloch, A. Neumann, Helmholtz-Zentrum Berlin, Germany
V. Yakovlev, FNAL, Geneva, IL, USA

Abstract

Some projects of SRF guns apply the design where the cathode can be easily and quickly removed. One of the disadvantages of this design is the RF power leakage from the accelerating gun cavity cells to the cathode housing that result in the excessive cathode heating. To minimize the RF power leak different kinds of choke filters are used to protect the cathode structure. These choke filters represent resonant circuits with zero input impedance and installed at the entrance of the cathode structure that shunt the cathode housing.

Still, since the choke filter frequency shift under working conditions is bigger than its bandwidth a filter tuning during assembly only in the warm stage seems insufficient and requires also fine-tuning during operation.

To eliminate the problems of the choke filter fine-tuning and hence ensure its stability during operation, a combination of the resonance choke elements can be implemented. In the paper we demonstrate advantages of the double-cell notch filter using B*ERL*inPro SRF gun cavity as an example with its simple design modifications.

CHOKE CELL GAP SIZE

First development of the SRF gun with choke-cell filter was done at FZDR [1]. The choke cell represents a cavity cell of a special shape surrounding the cathode and preventing the RF power from leaking out of the cavity. In this manner it works as a bandpass filter. The operation of the choke-cell is the same like quarter wave choke with similar S_{21}-parameter distribution [2]. An advantage of choke-cell is better possibilities for the cleaning and less probable and less stable multipactor discharge in the choke-cell. For the choke-cell structure the tuning procedure is simpler to compare with coaxial chokes and can be realized with well-developed SRF cell tuners. In HZDR and HZB [3] projects the SRF gun cavity frequency tuning is designed for the choke cell, half-cell and TESLA cells (Fig. 1). Since the half-cell and TESLA cells differ in their mechanical properties it was decided to use two separate tuning systems.

Still, caused by the narrow cathode channel and a small choke-cell gap chosen in HZDR and HZB projects, the standard buffered chemical polishing (BFP) and the high pressure rinsing (HPR) are not effective for the choke cell. This resulted in the lower quality of the surface treatment, which in its turn results in the higher probability of the electron resonance discharge (multipactor – MP), a high residual resistance and the residual impurities penetration into accelerating cells.

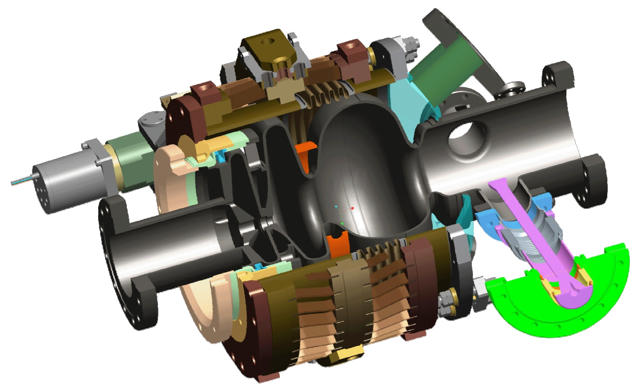

Figure 1: HZB 1.4.cell SRF gun.

To overcome the cleaning issue, the calculations have been provided to investigate the structure parameters on the choke-cell gap size. The simulation model that included half-cell, choke-cell and cathode coaxial transmission line was built using HZB SRF gun geometry (Fig. 2). The choke-cell gap size was varied from 6 mm (HZB project value) to 30 mm (full choke cell length) during simulations.

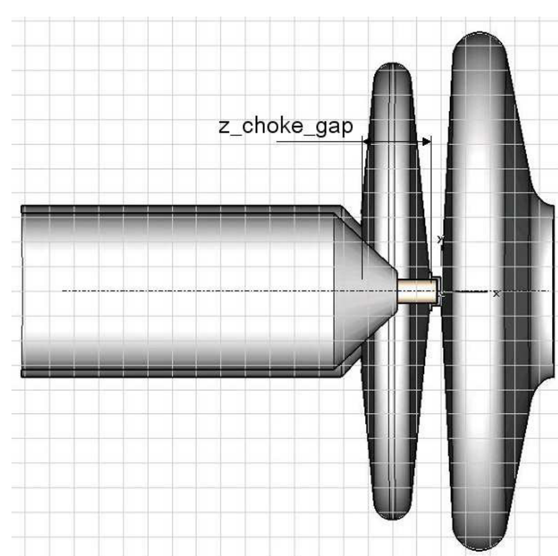

Figure 2: Choke-cell gap investigation simulation model.

The results of these calculations are presented on (Fig. 3-4). The choke-cell frequency was changed by about 150 MHz and the minimum of S_{21}-parameter was around –45 dB for all choke-cell gaps within the simulation accuracy. The RF power dissipated in the cathode was calculated only in the small initial part that enters half-cell where the cooling is most problematic.

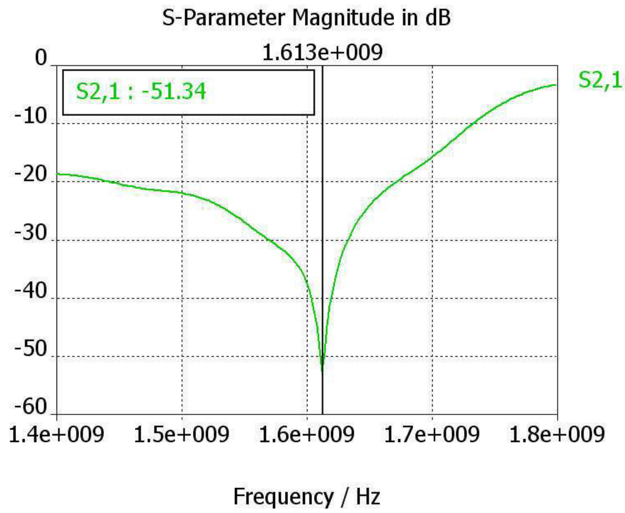

Figure 3: Typical S_{21}-parameter frequency dependence of 1.4- and choke-cell structure (z_choke_gap = 21.5 mm).

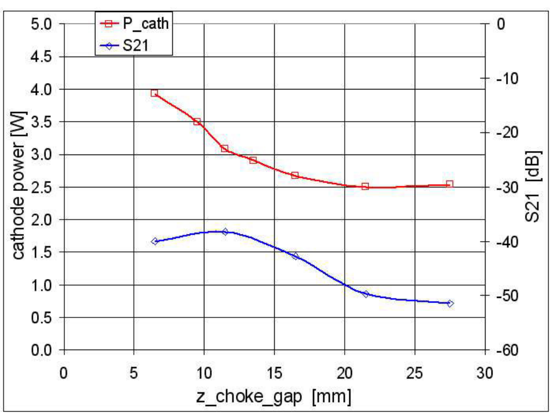

Figure 4: S_{21}-parameter and cathode power dissipation of 1.4- and choke-cell simulation results (W=1 J).

The results of these simulations define the possibility to use full size of the choke-cell gap that in its turn will secure the best possible conditions for the choke-cell cleaning.

GUN CAVITY WITH SPLIT CHOKE-CELL STRUCTURE

To eliminate the problems of the notch filter fine tuning and hence ensure its stability during operation, an additional resonance choke element can be implemented. The notch filter consisted of two choke cells represents two coupled resonant circuits [4]. The main advantage of the coupled circuits is its resonance wide bandwidth. Every choke cell parameters can be adjusted independently to the required frequency in the warm stage.

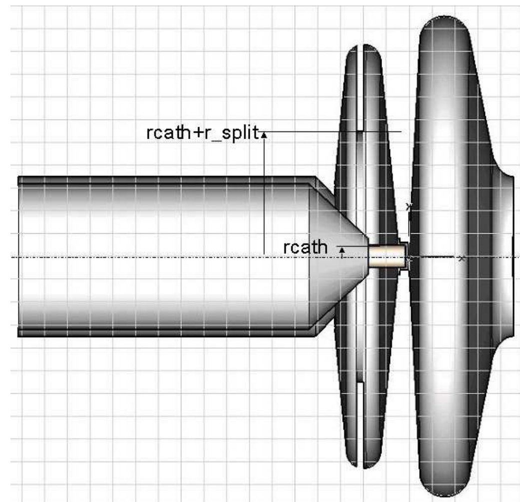

Figure 5: Split choke-cell simulation model.

The same model with the maximal choke-cell gap size (z_choke_gap=30 mm) was used for double choke-cell idea investigation [2] (Fig. 5). To simulate the double choke-cell concept the split wall in the choke-cell was installed. The radius "r_split" defines the depth of the cell division. For the big "r_split" radii the choke-cell is still working as a single cell even in the presence of the split wall. Starting from a certain r_split value the former single choke-cell represents separate coupled cells excited in π-mode.

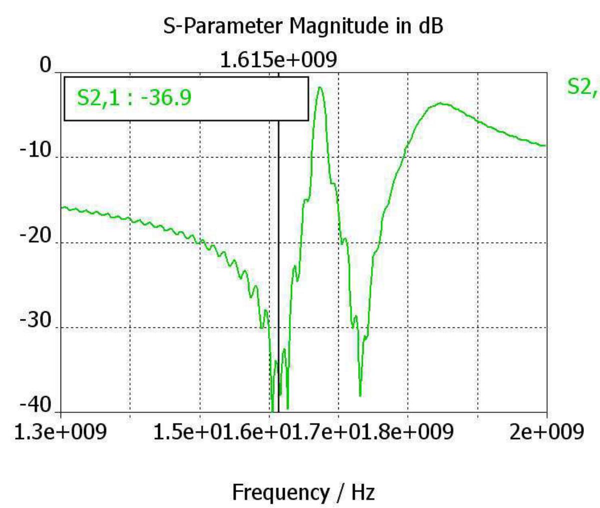

Figure 6: S_{21}-parameter of the split choke-cell notch filter.

The S_{21}-parameter plot (Fig. 6) shows two resonance curves corresponding to the coupled choke-cells. The minimum value of S_{21} is close to 0 dB since the split wall changes the parameters of both cells simultaneously.

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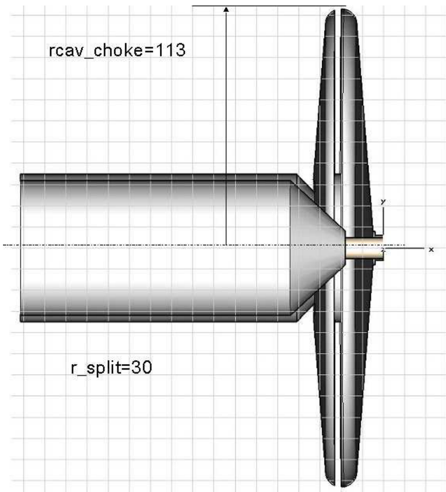

Figure 7: Split choke-cell notch filter tuned to 1.3 GHz.

To tune the split cells to the project 1300 MHz frequency the choke-cell radius (rcav_choke) was increased up to 113 mm (Fig. 7). The S21-parameter plot reflects an extremely wide frequency range on the level of –60 dB (Fig. 8).

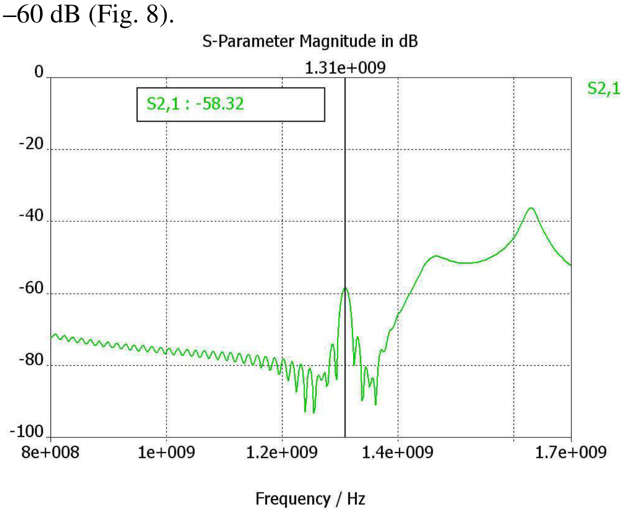

Figure 8: S_{21}-parameters simulation results (r_split=30 mm) for increased choke-cell radius.

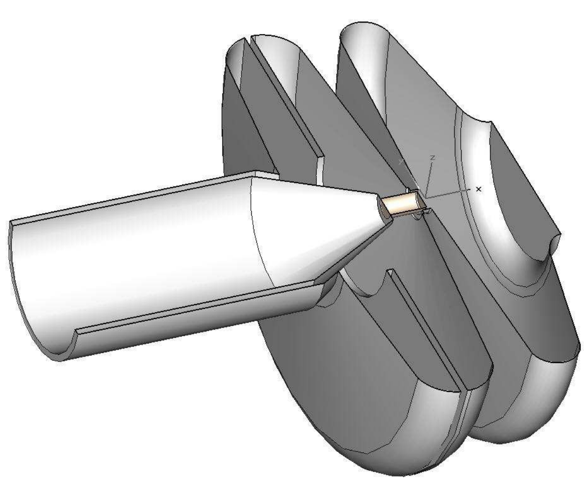

Figure 9: Large split choke-cells tuned to 1.3 GHz.

CONCLUSIONS

Based on an existing HZB SRF gun geometry we provided step by step the choke structure modification proving an idea of more effective double-cell notch filter scheme. The real gun cavity design should be made taking into account manufacturing specifics and requirements on cavity mechanical stability. To simplify the cleaning of narrow choke cells the choke gap can be increased allowing wider cell geometries with required filter efficiency (Figs.9-10).

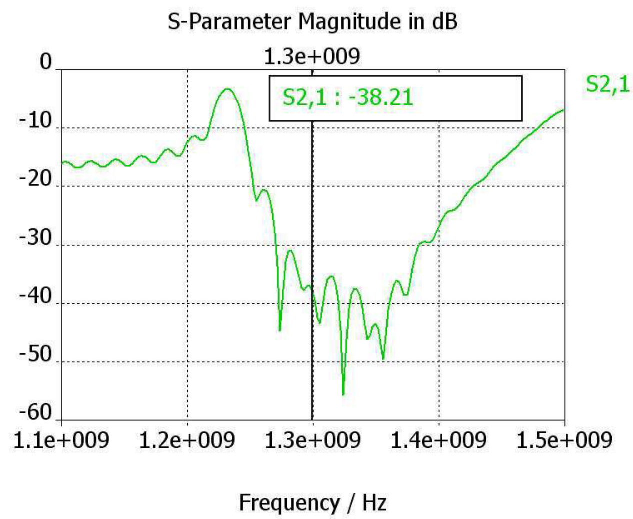

Figure 10: S_{21}-parameters of large split choke-cells.

Realization of this idea will provide the following features:

a) The cathode housing protection from the accelerating cell power leak in the wide frequency range (up to 100 MHz) on the level of lower than –30 dB;
b) Elimination of consequences of the choke-cells frequency dependence caused by the external mechanical loads;
c) Best possible choke-cell cleaning conditions;
d) Minimization of the multipactor probability;
e) Simplfication of the liquid helium vessel together with tuning system design because of minimization of the choke cells frequency shift consequences caused by external mechanical loads on the cavity walls.

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