B*ERL*inPro SRF GUN NOTCH FILTER INVESTIGATIONS*

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Abstract

B*ERL*inPro is an ERL project currently under construction to demonstrate energy recovery with a high-brightness, short pulse beam and very low beam loss [1]. These goals place stringent requirements on the SRF cavity (1300 MHz, β=1) for the photo injector, which has to deliver a small emittance 100 mA beam with at least 1.8 MeV kinetic energy while limited by fundamental power coupler performance to about 230 kW forward power.

The SRF gun cavity features 1.4 λ/2 cell resonator with a normal-conducting CsK_2Sb cathode. To prevent RF power propagation from the cavity cells down the cathode stalk and to reduce its component heating a high-frequency notch filter was investigated. We present results of different schemes of choke-cell combinations to optimize the filter parameters. The goal for the filter design was RF power attenuation better than -30 dB in the required frequency range.

INTRODUCTION

SRF guns represent a merging of the well-established normal conducting RF (NCRF) technology and superconductivity. Different approaches are being applied to overcome additional difficulties encountered in the SRF gun development as compared to NCRF guns. One of the main problems is that a cathode expected to have a limited lifetime. Hence, it is advantageous to stick to a technical design of the SRF gun where the cathode can be easily and quickly removed and substituted by a fresh one.

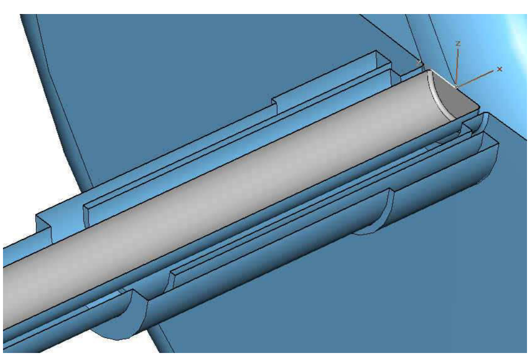

Figure 1: External coaxial quarter-wave length chokes design.

In projects with removable cathodes there is a risk for RF power leaking out of the cavity along the cathode channel (i.e., the mechanical gap between the cathode and the gun cell body that build a coaxial RF line). For this reason, different types of choke filters to reject the accelerating mode's RF power.

In signal processing, a band-stop filter or band-rejection filter or notch filter is a filter that passes most frequencies unaltered, but attenuates those in specific range to very low levels. A notch filter, usually a simple LC circuit, is used to remove or greatly reduce a specific interfering frequency. Series and parallel resonant circuits can be used to construct the band-pass and band-stop filter circuits.

This paper will briefly review the RF designs of the coaxial quarter wave chokes, the resonant choke cell and their combination to achieve the most effective RF power attenuation (better than –30 dB) in the wide frequency notch filter bandwidth.

GUN CAVITY WITH COAXIAL CHOKE STRUCTURE

The quarter wave choke, as shown in Fig. 1, represents a resonance quarter wavelength coaxial transmission line connected in parallel with a gun cathode line. Such systems were implemented, for example, in BNL's photoinjector [2]. Having zero input impedance such choke shunts the cathode line and prevents the distribution of RF power from the cavity along the cathode line. This substantially reduces the cathode heating.

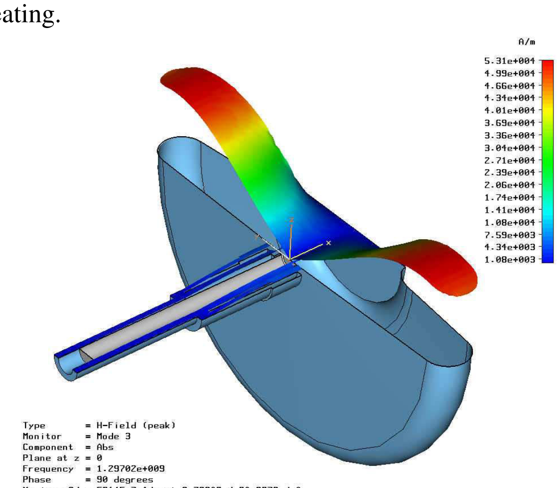

Figure 2: Magnetic field distribution in half-cell and external coaxial quarter-wave length choke.

The magnetic field distribution in half-cell and external quarter wave choke is shown on Fig. 2. There are two options of the quarter wave choke design – external (Fig. 3a) relative to the cathode line and internal (Fig. 3b). The S_{21}-parameter defining the efficiency of the choke (Fig. 4)

*Work supported by Bundesministerium für Bildung und Forschung and Land Berlin

ISBN 978-3-95450-142-7

is the same for both options and the choice of the design should be defined together with the design of the cathode stack housing. The resonance frequency of the quarter wave choke is defined by the choke line wave impedance and length.

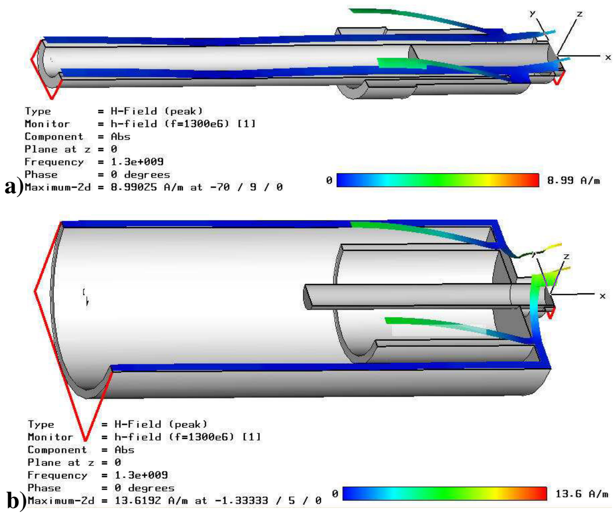

Figure 3: Magnetic field distribution in a) external and b) internal coaxial quarter-wave length choke.

Such quarter wave chokes have an advantage of their manufacturing simplicity but inherent of the problems of the good cleaning and resonant multipacting discharge (MP). A cathode stack biasing can be applied to suppress MP in the coaxial line of the cathode housing. But since quarter wave choke represents the pocket of the line outer conductor with the same constant biasing voltage between surfaces where MP happens, it does not help to suppress MP in quarter wave choke.

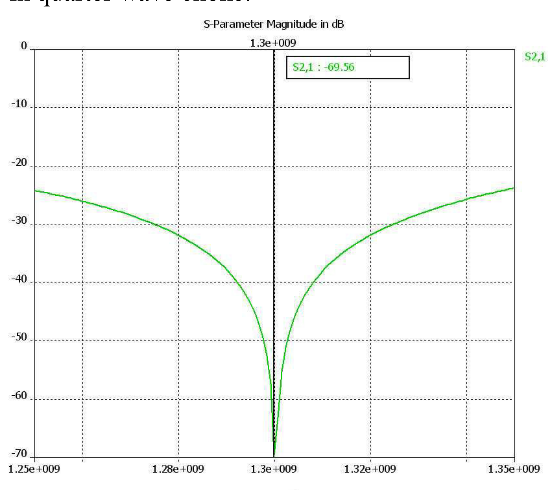

Figure 4: S_{21}-parameter of quarter length coaxial choke.

BNL profound investigations of such chokes indicate that the designers must solve significant problems by quarter wave coaxial chokes implementation [2]. Additionally, the tuning procedure of such chokes during operation is not straightforward.

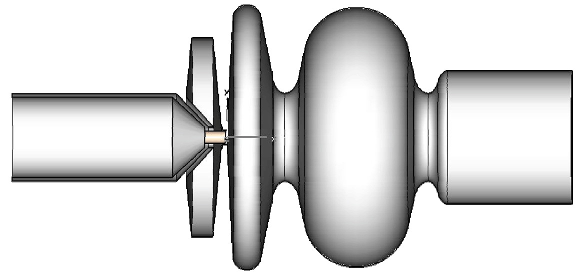

Figure 5: Simulation model of 1.4-cell HZB SRF gun cavity with resonance choke-cell.

GUN CAVITY WITH CHOKE-CELL STRUCTURE

Forschungszentrum Dresden-Rossendorf (FZDR) SRF gun [3] consists of three acceleration cells with TESLA shape and a half-cell with the normal conducting cathode mounted at the center of the half-cell. To prevent leaking out of the RF energy from the gun cell to the cathode housing an additional resonance choke-cell is implemented. A similar choke-cell is used in the HZB gun cavity (Fig. 5).

The operation of the choke-cell is the same like quarter wave choke with similar S_{21}-parameter distribution. An advantage of choke-cell is better possibilities of the cleaning and less probable and less stable multipactor discharge in the choke-cell. Also the tuning procedure is simpler and can be realized with well-developed SRF cell tuners. In HZDR and HZB projects the SRF gun cavity frequency tuning is designed for the choke cell, half-cell and TESLA cells. Since the half-cell and TESLA cells differ in their mechanical properties it was decided to use two separate tuning systems.

The notch filter frequency shift under working conditions is bigger than its bandwidth. Therefore a filter tuning during assembly only in the warm stage seems insufficient [4] and requires also fine-tuning during operation.

GUN CAVITY WITH COMBINED CHOKE STRUCTURES

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 (Figs. 6-7).

The notch filter consisted of quarter wave choke and choke-cell represents two coupled resonant circuits [5]. The main advantage of the coupled circuits is its resonance wide bandwidth (Fig. 7).

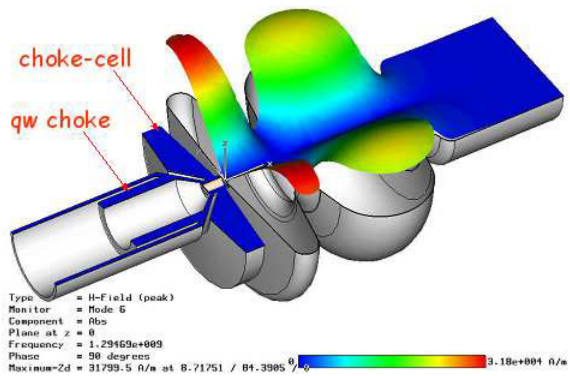

Figure 6: HZB gun option with combined internal quarter wave choke and choke-cell (also magnetic field distribution is shown).

The choke-cell and quarter wave choke parameters can be adjusted independently to tune to the required frequency in the warm stage. Fig. 7 shows the possibility to adjust such notch filter with an attenuation of around –50 dB in the frequency range of 250 MHz. This allows simplifying the gun cavity mechanical design avoiding using notch filter tuner. The tolerances of choke-cell and quarter wave coaxial choke are quite relaxed.

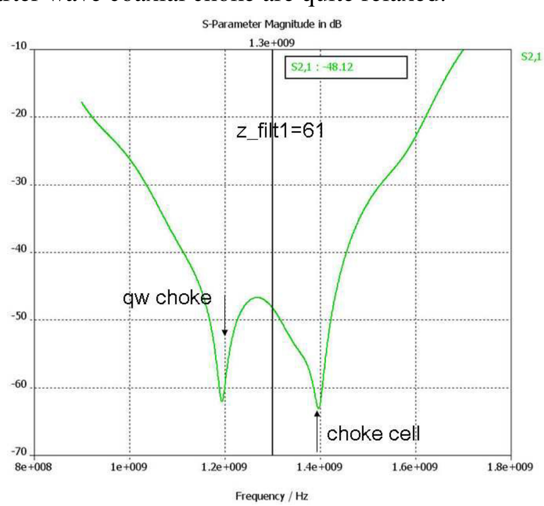

Figure 7: S_{21}-parameter of the combined notch filter.

Simulations of a simple provisional two choke-cell concept (Fig. 8-9) confirm that it can be more favourable in terms of the notch filter cleaning and multipactor discharge minimization providing the same RF power leakage attenuation to the cathode housing. A cavity geometry shown on Fig. 8 is used only for an idea demonstration and the real design of the double choke-cell filter need to be worked out. A further double choke-cell notch filter optimisation will result in a simpler design and manufacturing securing more stable cavity operation. This also results in the simpler helium vessel mechanical design.

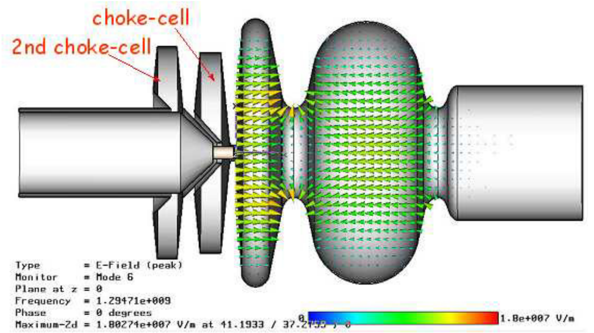

Figure 8: HZB gun option with double choke-cell notch filter.

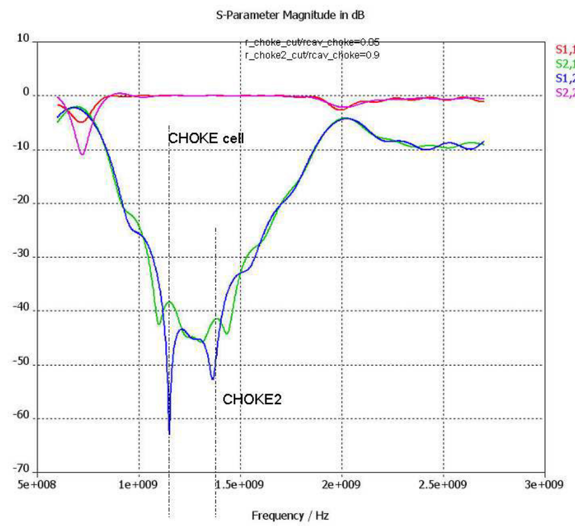

Figure 9: S-parameters of the double choke-cell notch filter.

CONCLUSIONS

Quarter wave coaxial choke and resonance choke-cells are essentially two resonant cavities playing the same role as filter circuits for RF power attenuation.

Provided simulation did not detect multipactors (MP) in both chokes but worse cleaning conditions could cause MP in quarter wave coaxial choke.

A double choke-cell concept looks more favorable in terms of MP minimization and helium vessel mechanical design providing a much more effective RF power attenuation.

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ISBN 978-3-95450-142-7