

DESIGN OF SLED SYSTEM WITH DUAL SIDE-WALL COUPLING IRISES AND BIPLANAR POWER SPLITTER FOR PAL XFEL

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Abstract

The SLED system of the PAL XFEL is required to be operated with the RF input power of 80 MW and the pulse width of 4 us. The high RF dose from the RF breakdown at the coupling holes and power splitter prohibits that the original design of the SLED serve this operation condition. To reduce the gradient at the cavity coupling structure, the concept of dual side-wall coupling irises is introduced. In addition, the 3dB splitter is modified with the concept of biplanar coupler structure.

INTRODUCTION

The RF pulse compression system, called SLED (Stanford Linear Accelerator Energy Doubler), was first developed in the 1970's [1-3]. A 3-dB sidewall waveguide power coupler is inserted into a waveguide between the klystron and the accelerating section as shown in Fig. 1. Two identical over-coupled cavities, resonant at the SLAC RF frequency, are connected to the remaining power coupler ports. A fast-acting triggered PIN diode π -phase-shifter which reverses the phase of the klystron output power is inserted into the klystron drive line. At first, the cavities store klystron output power during a large fraction of each pulse. Then the phase of the klystron output is reversed, and the cavities emit stored power rapidly into the accelerating section adding to the given klystron output power during the remaining of the pulse. By this means, peak power is enhanced at the expense of pulse width without increasing the average input power consumption simultaneously.

At the time of the first SLED development, there was no problem with RF breakdown because the available klystron output power was only around 30 MW. However, the output peak power of klystron has been increased, and therefore, the maximum power from SLED is limited by the RF breakdown due to the high electric field. The RF system of PAL X-FEL project provisionally requires the klystron RF output peak power of about 80 MW and the

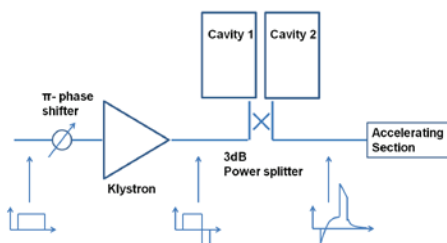


Figure 1: A schematic diagram of the SLED system in the accelerator.

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repetition rate of 120 Hz. Consequently, it is important to design the new SLED system with low electric field and surface current even in the high power operation.

In this study, we designed a new SLED system using a biplanar 3-dB power coupler and the dual side-wall coupling irises using a finite-difference time-domain (FDTD) simulation. The new SLED system proved to be a good method to help alleviate the RF breakdown in the high power operation.

DESIGN OF BIPLANAR 3-DB POWER COUPLER

A full three-dimensional FDTD simulation, Microwave Studio (MWS) [4], is carried out to estimate the characteristics of the original 3-dB power coupler. The simulation result of the magnitude of S parameter is shown in Fig. 2(a), and the phase of S parameter is shown in Fig. 2(b), respectively.

The simulation model with mesh description and the port number is shown in the inset. The $|S_{21}|$ and $|S_{11}|$ are both about -30 dB at the frequency of 2856 MHz. The magnitudes of the divided waves ($|S_{31}|$ and $|S_{41}|$) are both about -3 dB. In addition, the phase of the divided wave crossing the power coupler ($\arg(S_{41})$) has a phase difference of 90 degrees from that of the other divided wave ($\arg(S_{31})$). These results are well matched with test result, and therefore, the MWS simulation is verified to be a design tool. The simulated distribution of electric field

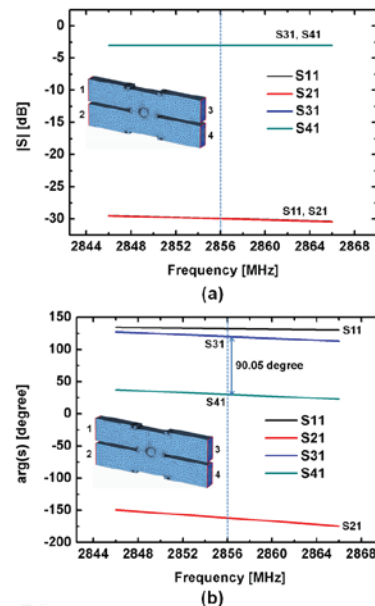


Figure 2: (a) The simulated amplitude of S parameters and (b) the phase of S parameters for the original 3-dB power coupler. The MWS simulation model with mesh description is shown in the inset.

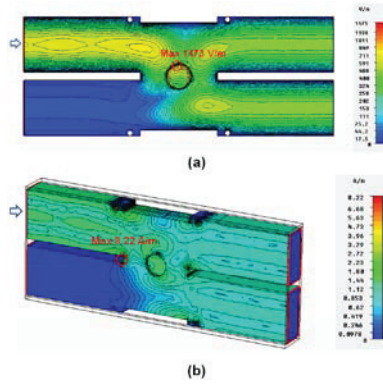


Figure 3: (a) The simulated distribution of electric field, and (b) the surface current of the original 3-dB power coupler.

and surface current is also shown in Fig. 3(a) and Fig. 3(b), respectively. The electric field has the maximum value of about 1470 MV/m at the edge of the center rods, and the surface current has the maximum value of about 8 A/m at the sharp edge.

Here, the concept of biplanar coupler [5,6] can reduce the peak electric field and surface current. The inner shape and the structure parameters of the new biplanar 3-dB power coupler are shown in Fig. 4. The structural parameters are determined by the MWS simulation optimization process in order that the power split ratio is 1:1.

The simulation result of S parameter's magnitude is shown in Fig. 5(a), and the phase of S parameter is shown in Fig. 5(b) while the simulation model with mesh description and the port number is shown in the inset. The $|S_{21}|$ and $|S_{11}|$ are both about -50 dB at the frequency of 2856 MHz. The magnitudes of divided waves ($|S_{31}|$ and $|S_{41}|$) are both about -3 dB. In addition, the phase of the divided wave crossing the power coupler ($\arg(S_{31})$) is delayed by 90 degrees from that of the other divided wave ($\arg(S_{41})$). The simulated distribution of electric field and surface current is also shown in Figs. 6(a) and 6(b). The maximum peak electric field is about 700 V/m, which is a half of that of the original structure. The maximum surface current is about 2.9 A/m, which is one third of that of the original structure. These results prove that the biplanar 3-dB power coupler is capable of supporting the high power operation.

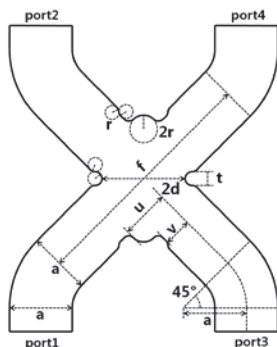


Figure 4: The shape and the structure parameters of the new 3-dB power coupler.

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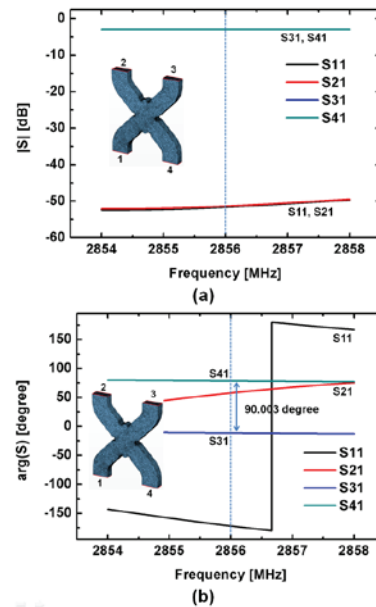


Figure 5: (a) The simulated amplitude of S parameters and (b) the phase of S parameters for the new 3-dB power coupler. The MWS simulation model with mesh description is shown in the inset.

DESIGN OF DUAL SIDE-WALL COUPLING IRISES STRUCTURE

Above the high field gradient inside the 3-dB power coupler, an excessive field at the coupling iris between waveguide and cavity may lead to serious breakdown and radiation safety hazards. This is the problem that limits the maximum power from SLED in practice. It has been reported that the concept of two port side-wall coupling

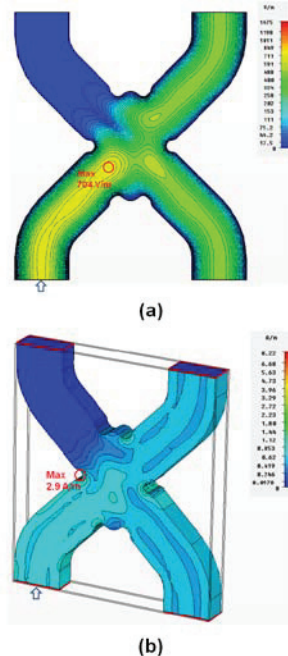


Figure 6: (a) The simulated distribution of electric field and (b) surface current of the new 3-dB power coupler.

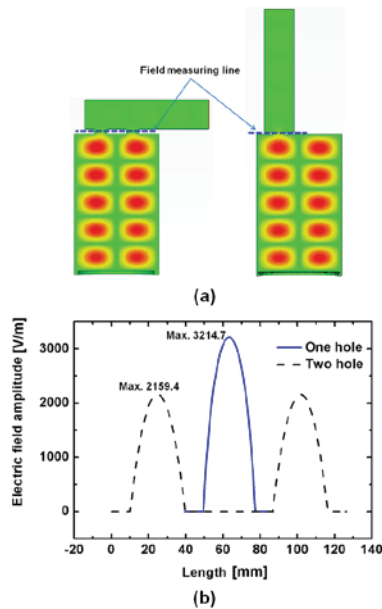


Figure 7: (a) The simulated electric field distribution of dual side-wall coupling irises and single iris waveguide-cavity and (b) The electric field amplitude along the line crossing the center of coupling iris.

irises may be a good solution [7]. The electric field at the coupling iris is decreased by making two irises for RF coupling. The electric field at the coupling iris can be further reduced by building irises on the side wall of the waveguide rather than having them on the end wall.

The distribution of electric field of the cavity with the dual side-wall coupling irises is compared with that of the cavity with the single-iris coupling iris as shown in Fig. 7(a). Here, the dimension of the dual side-wall coupling structure is determined so that the coupling coefficient would be the same as that of single-iris coupling structure. To directly compare the electric field amplitude at coupling iris in the cases of different coupling structures, the line crossing the center of the coupling iris is drawn as shown in Fig. 7(a). Then, the electric field along the line is simulated and plotted in Fig. 7(b). The maximum electric field strength of the dual side-wall coupling irises is just two thirds of that of the single-iris cavity. This result is well matched with the experience that the electric field is reduced by 20-30 % when the dual side-wall irises are adopted [8].

An MWS simulation was performed to find the Q-factors and coupling coefficient. The simulated S11 graph is shown in Fig. 8. The S11 value at the resonance is about 0.66 and the coupling coefficient is calculated as about 4.93. The half maximum frequency difference is about 0.16 MHz, which means that the ohmic Q factor is about 106000. These results of coupling coefficient and Q factors are similar to those of the original SLED cavity [3].

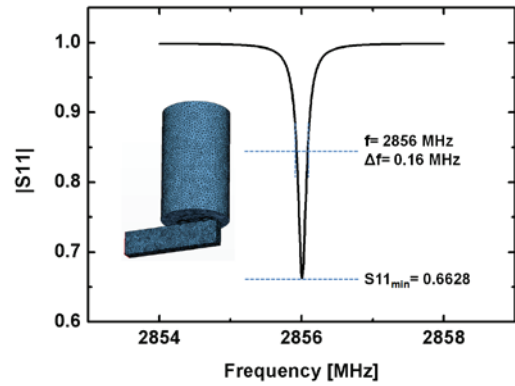


Figure 8: The simulated S parameter of the cavity with dual side-wall coupling irises. The MWS simulation model with the mesh description is shown in the inset.

INTEGRATION OF THE SLED SYSTEM

The TE015 mode cavities with the dual side-wall coupling irises and biplanar 3-dB power coupler are integrated to the new SLED system.

CONCLUSION

We designed a new SLED system with the biplanar 3-dB power coupler and the dual side-wall coupling irises using FDTD simulation. The new SLED system proved to be a good method to overcome the RF breakdown in the high power operation. The maximum electric field in the biplanar 3-dB power coupler is reduced to one half of the original one. The maximum electric field at the coupling irises is also reduced to two thirds of that of the original one.

REFERENCES

- [1] P. B. Wilson, SLAC-TN-73-15 (1973)
- [2] Z. D. Farkas, H. A. Hogg, G. A. Loew and P. B. Wilson, SLAC-PUB-1453 (1974)
- [3] Z. D. Farka, H. A. Hogg, G. A. Loew and P. B. Wilson, IEEE Trans. Nucl. Sci., NS-22, 1299 (1975)
- [4] CST Microwave Studio User's Manual, available on website <http://www.hep.ph.ic.ac.uk/uknfc/fets/docs/mws/Getting%20Started.pdf>.
- [5] C. G. Montgomery, R. H. Dicke and E. M. Purcell, Principles of Microwave Circuits, New York, McGraw-Hill, 1948.
- [6] J. Neilson, S. Tantawi and V. Dolgashev, Proceedings of Linear Accelerator Conference, MOP077 (2010)
- [7] A. Fiebig, R. Honbach, P. Marchand and J. Pearce, CERN/PS 87-45 (1987)
- [8] H. Matsumoto, H. Baba and S. Yamaguchi, Nucl. Inst. Meth. Phys. A, A330, 1 (1993)