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RF DESIGN OF THE WAVEGUIDE NETWORK FOR THE KLYSTRON-BASED CLIC MODULE

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Abstract

A new RF module has been designed for the Klystron-based CLIC main linac. The module deploys two X-band klystrons to feed eight CLIC-K accelerating structures, giving a beam energy increase of 138 MeV. This module uses a double-height waveguide distribution network, which reduces the RF power loss in the network by about 40%. All the RF components have been redesigned to meet the double-height requirement, including the 3-dB hybrid, the choke mode flange, the bending waveguide, correction cavities and the BOC pulse compressor. A CLIC-K accelerating structure with bent damping waveguides has also been designed. The summary of RF designs for the klystron-based CLIC module is provided.

INTRODUCTION

The Compact Linear Collider (CLIC) project uses a two-beam acceleration scheme for three stages at centre-of-mass energies of 380 GeV, 1.5 TeV and 3 TeV [1]. A klystron-based CLIC with an initial stage with energy of 380 GeV has also been proposed [1]. At this low-energy stage, the two powering shemes, klystron-based and two-beam, have been compared for the CLIC main linac. The Klystron-based scheme is an affordable option, whereas beyond this energy level, the two-beam scheme is the only possibility. In the klystron-based scheme, klystrons are used to power the accelerating structures and an accelerating structure named CLIC-K as well as a pulse compression system based on individual cavities have been designed [2, 3]. The distance between the klystrons and the accelerating structures is much larger than between the Power Extraction and Transfer Structures (PETs) and accelerating structures, resulting in a larger RF power loss. To reduce the RF loss and increase the stability of the RF system, RF components with double height of the standard WR-90 waveguide has been studied, which have the advantages of lower RF loss and surface fields compared to standard RF components. The alignment requirements of the klystron-based CLIC is also different from the two-beam case. A special RF component is necessary to enable the movement of the accelerating structures for beam-based alignment.

This paper presents two schemes that utilize RF components with double-height waveguides for the beam-based alignment: Choke Mode Flange (CMF) and L-shape waveguide (LSW). Additionally, we discuss the wakefield calculations of the accelerating structure, which require a HOMagic-T to damp the wakefield from the input coupler [4]. Without the HOMagic-T, the wakefield generated in the input coupler cannot be well damped resulting in significant electron beam deflections. To enable efficient transmission, a compact H-bend was designed for the accelerating structure that can transmit the working mode at 12 GHz and the wakefield at 17 GHz was designed for the accelerating structure.

SCHEMATIC LAYOUT AND BASIC RF COMPONENTS OF THE RF MODULE

Figure 1 shows the schematic layout of the RF module for the klystron-based CLIC. It comprises two klystrons with a peak power of 50 MW, a pulse compression system that increases peak power by a factor of 3.81, and eight accelerating structures with average loaded accelerating gradient of 75 MV/m. For beam-based alignment, the girder with eight accelerating structures must be moved. The CMF between the pulse compression system and the power splitters is designed to accommodate this movement with no effect on the RF power transmission. Another method is using of an LSW with bending that also allows movement of the accelerating structures.

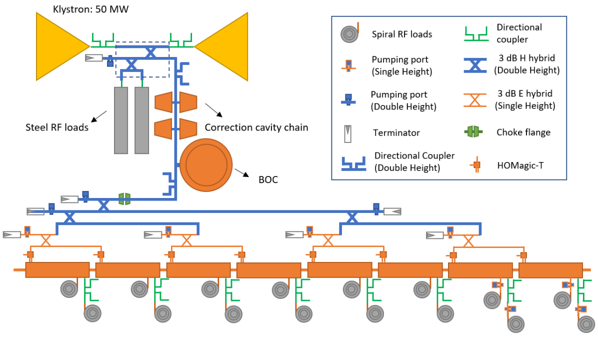

Figure 1: Schematic layout of the RF module for the klystron-based CLIC.

The spiral load, steel RF load and terminator are well-researched among the RF components in the schematic layout. Figure 2 shows the other basic RF components in the RF network between the klystrons and the accelerating structures. All RF components are optimized for minimual reflection and surface fields. The double height pumping port, 3-dB hybrid and H-bend can be obtained by increasing their heights.

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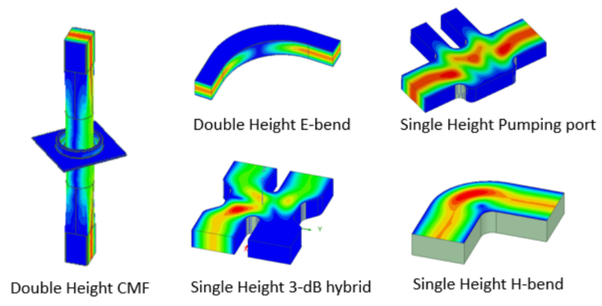

Figure 2: New RF components for the RF network from klystrons to the accelerating strucutres.

RF NETWORK FROM KLSTRONS TO ACCELERATING STRUCTURES

The RF combiner is shown in the Fig. 3, mainly comprising a double-height 3-dB hybrid, a double-height pumping port, and a double-height splitter. A double height waveguide (DH WG) with length of 3 m is present between the RF combiner and the pulse compression system. The pulse compression system comprises a correction cavity chain (CCC) and a BOC pulse compressor. Details of the pulse compression system can be found in Ref. [3].

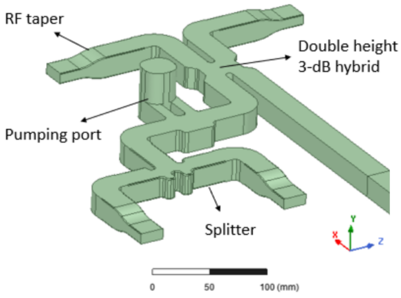

Figure 3: RF combiner for combining the RF power from two klystrons.

The RF networks based on the CMF and the LSW are shown in the Figs. 4 and 5. After the pulse compression system, the RF power enters the accelerating structures through three 3-dB hybrids. The input power for each accelerating structure is 40.6 MW.

Table 1 summarizes the calculated RF losses of the two RF networks for comparison. The overall RF losses amount to 10.66% and 12.25% for the CMF-based and LSW-based RF networks, respectively. The LSW-based RF network employs standard waveguides, providing maximum flexibility and a wide range of movement, resulting in higher RF loss for this RF network. Table 2 summarizes the surface fields of the two RF networks. Before the BOC pulse compressor, the pulse length is 2500 ns and then the pulse length is 334 ns.

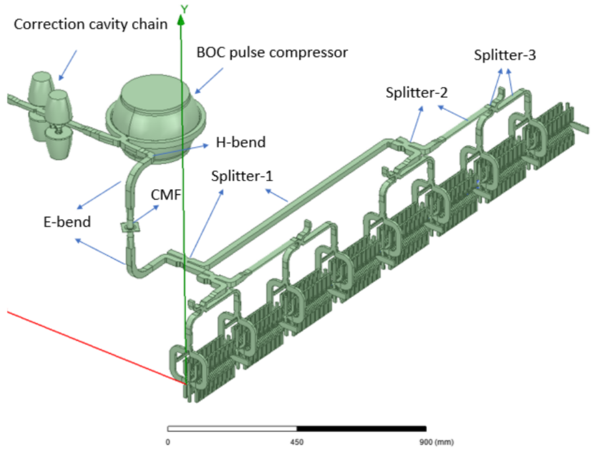

Figure 4: RF network based on CMF.

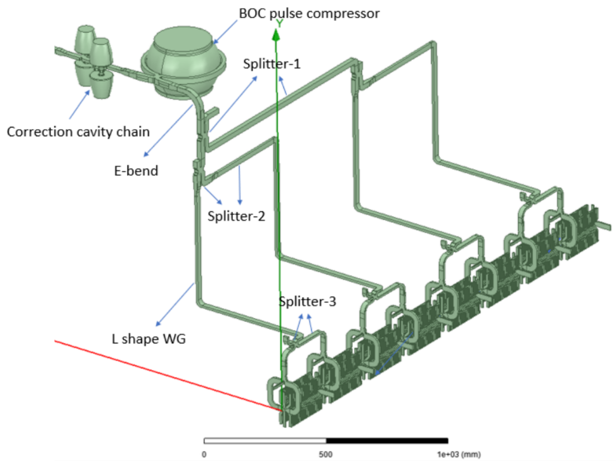

Figure 5: RF network based on L shape waveguide.

Table 1: RF Loss of the RF Networks

Components	RF loss (CMF)	RF loss (LSW)
Combiner	0.66%	0.66%
DH WG	4.01%	4.01%
CCC	1.29%	1.29%
BOC	2.01%	2.01%
H-bend	0.074%	0.0%
E-bend	0.28%	0.28%
CMF	0.29%	0.0%
E-bend	0.28%	0.0%
Splitter-1	0.98%	0.98%
Splitter-2	0.65%	0.85%
Splitter-3	0.62%	0.82%
LSW	0.0%	2.22%
Overall	10.66%	12.25%

ACCELERATING STRUCTURE

Figure 6 shows the RF design of the accelerating structure with higher-order mode damping loads and the definition of three areas for wakefield simulation. Details of the RF design can be found in [2]. The accelerating structure comprises bent damping waveguides, a special H-bend for 12 GHz and 17 GHz and a HOMagic-T to damp wakefields from the input

Table 2: Surface Fields of the RF Networks

Components	**Emax [MV/m]**	**Sc [MW/m^2]**	**Power [MW]**
Combiner	25.9	5.5×10^5	100
DH-WG	19.7	4.3×10^5	100
CCC	53.2	1.9×10^6	95
BOC	47.3	2.0×10^6	350
H-bend	45.9	2.0×10^6	350
E-bend	52.8	3.6×10^6	350
CMF	38.0	1.8×10^6	350
Splitter-1	48.4	1.9×10^6	350
Splitter-2	34.2	9.6×10^5	175

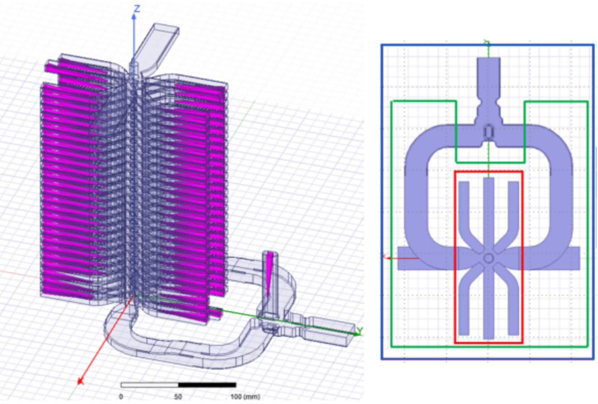

Figure 6: Accelerating structure with HOM dampingloads and bended damping waveguides and the definitions of three areas for the wakefield calculation.

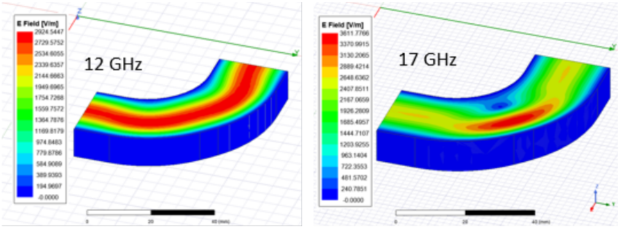

Figure 7: Compact H-bend for 12 GHz and 17 GHz.

coupler. The application of the bent damping waveguide benefits the compactness of the accelerating structure.

The specially designed H-bend is shown in Fig. 7 with reflections below −50 dB for both 12 GHz and 17 GHz. At 12 GHz, the RF power of the working mode can pass through the special H-bends and enter the input coupler. At 17 GHz, the wakefields can also pass through the special H-bends and are absorbed by the HOMagic-T.

Figure 8 shows the wakefields and impedances for three cases, all of which use HOM loads in the damping waveguides but treat the input coupler differently. In case of shorted bends of the input coupler (SFIC), as defined in the green box in Fig. 6, a wakefield reflection from the short faces is observed, resulting in unacceptable F parameters as defined in Ref. [5]. The other two cases has similar wakefields

Table 3: F Parameters in X Direction for Three Cases

Input coupler settings	**Fc**	**Frms**	**Fworst**
PIC-LDw-x	1.0021	1.1623	3.0745
SFIC-LDw-x	1.004 44	1.2392	**64.366**
MTIC-LDw-x	1.0011	1.0692	2.2577

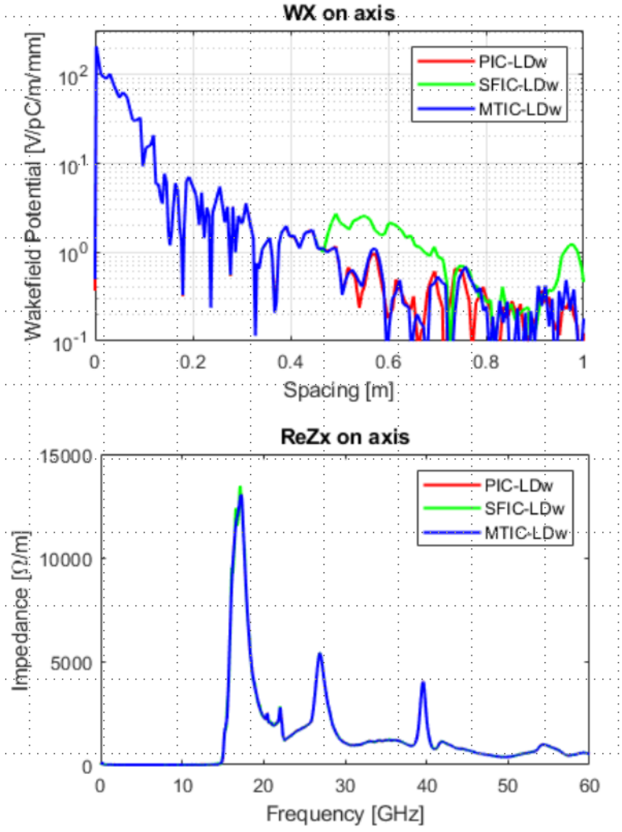

Figure 8: Wakefields and impedances of the accelerating strucutre for 3 cases. PIC: PML for input coupler, SFIC: Short face for input coupler, MTIC: HOMagicT for input coupler, LDw: HOM loads for damping waveguides.

and acceptable F parameters as listed in Table 3. Based on these results, the HOMagic-T is found to be necessary for the accelerating structure.

CONCLUSION

We present the RF module design for the klystron-based CLIC, discussing scenarios based on CMF and LSW. We provide a budget for RF power and the maximum surface field values for each component. Wakefield simulations with different settings for the input coupler indicate that the HOMagic-T is necessary to damp the wakefields from the input coupler. The mechanical design is in progress based on the works in this paper.

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