COUPLER STUDIES FOR CLIC ACCELERATING STRUCTURES

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Abstract

Due to the high input power required to feed the accelerating structures of the Compact Linear Collider, the RF input and output couplers are critical components. Four different types of double-feed cavity-based couplers as well as a mode launcher have been investigated. Three of them are based on magnetic coupling between the input waveguides and the cavity while the fourth is based on electric coupling. The different designs have been optimized to minimize surface electric field as well as field asymmetry and to reduce the pulse surface heating and the sensitivity to mechanical errors.

1 INTRODUCTION

The input/output couplers of the accelerating structures for any future linear collider are very important components that require particular attention at the design stage to ensure a good matching of the waveguide feeder to the structure, to minimise field asymmetries which can kick the beam, and to limit the maximum surface electric and magnetic fields to acceptable values. Much emphasis in the past has been placed on matching [1-5]. Other studies have focused on the field asymmetry problem [7]. More recently, after discovering at CERN [6] and SLAC that input couplers of accelerating structures are damaged during conditioning by local RF breakdown at the position of maximum surface electric field, design changes have been implemented by both the CLIC and NLC study groups [8-9] to lower peak surface field levels. High surface magnetic fields create local surface heating which in turn can lead to surface damage by fatigue. This paper discusses the various approaches undertaken by the CLIC Study Group in the framework of the 30 GHz structure development programme to find solutions to these various problems.

2 DOUBLE-FEED COUPLERS

The Double-Feed Coupler (DFC) is one of the most commonly used coupler designs, which substantially reduces the field asymmetry. The residual field asymmetry, which causes electric field enhancement on the coupler surface, can be compensated by suitable shaping of the outer coupler wall (racetrack [7] or similar geometries). In fact this asymmetry is a strong function of the structure beam aperture (group velocity). For moderate group velocity (below 5% *c*), the electric field enhancement is less than 2-3% of that in the regular cell. An accelerating structure with 4.6% *c* group velocity is now under consideration as a possible candidate for CLIC. A few DFC configurations were recently studied to develop an appropriate coupler design for this structure. Exotic concepts, like a four-feed coupler and an E_{02} mode coupler were also examined [11].

Three DFC types which magnetically couple the cavity to the waveguide feed through small holes (see Fig.1.) will be discussed first.

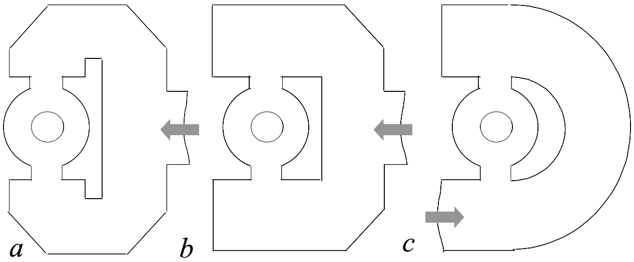

Figure1. Three types of DFC couplers: *a*-standard [1], *b* – SBLC DESY, [2], *c* – J-type, JLC, KEK [4].

Maximal electric surface field for all three DFC versions appeared to be the same - about 2% higher than that in a regular cell. To minimize the surface magnetic field, two parameters were adjusted – the coupling aperture and the iris thickness. The iris rounding diameter was chosen to be equal to the iris thickness. Profiles of the surface magnetic field along a path around the coupling irises for all three cases are shown in Fig. 2. The normalization was done with respect to the maximal surface magnetic field in a regular cell.

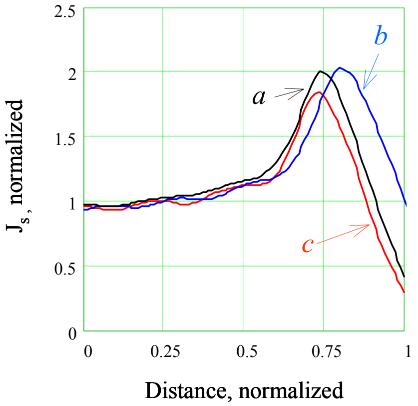

Figure 2. Surface magnetic field profiles for three DFC versions.

From this data, one can see that a strong concentration of the magnetic field in this kind of coupler is unavoidable and is about twice that in a regular cell. As a consequence the pulsed temperature rise in the area around the coupling holes is about four times higher.

To avoid the prohibitive levels of the magnetic field inherent to the couplers mentioned above, a DFC with electric coupling between the feeding waveguide and the accelerating structure has been investigated. In this configuration (see Fig. 3), the waveguide crosses the structure resulting in an on-axis coupling iris between the waveguide and the first cell of the structure [13]. The matching is done by varying the radius of the coupling iris and the diameter of the first cell. The iris thickness and cell length are the same as for the regular cell.

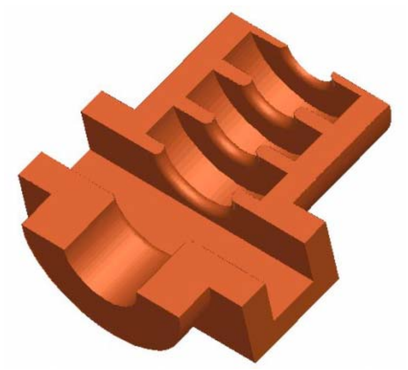

Figure 3. Artistic view of the coupler.

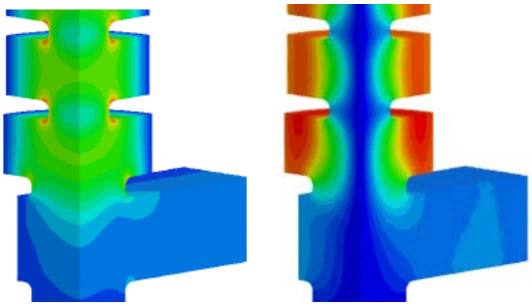

Figure 4. Electric (left) and magnetic (right) field plots in a coupler (only one quarter is shown).

In this coupler, the maximum surface electric field on the coupling iris is about 80 % of that in regular cell (see Fig. 4). The magnetic field in the matching cell is 5 % higher than in regular cell.

3 MODE LAUNCHER

A mode-launcher-type coupler has been proposed as an alternative to the usual cavity-based coupler [12, 10]. The idea is to split the coupler functionality into two distinct parts. The first part of the coupler converts the H_{10} mode of the standard rectangular waveguide into the symmetric E_{01} mode of the circular waveguide. This is a broadband device that launches a wave pattern in the circular waveguide which is similar to that in the accelerating structure. The second part consists of a special transformer cell that provides the matching between the circular guide and the structure. This mode-launcher (ML) coupler is compact, has an excellent field symmetry, and much reduced surface electric fields and local surface heating.

Five different designs have been studied [11]. Two designs, one with a double feed and one with a single feed, have been selected for further development (see Fig. 5). Measured and calculated matching data for the single-feed ML is given in Fig. 6.

Figure 5. General view of the double (1) and single-feed (2) mode launchers together with matching (3) and regular (4) cells.

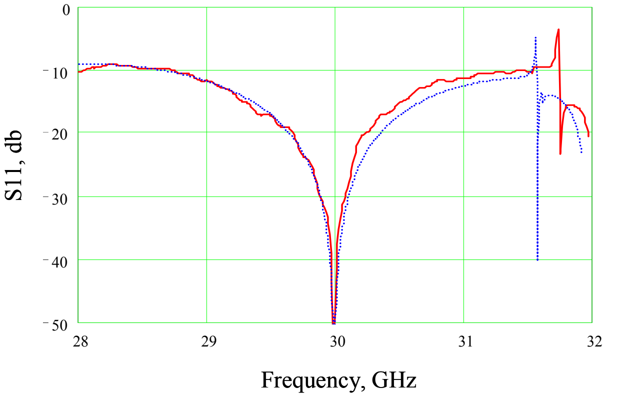

Figure 6. Measured (solid) and calculated (dotted) matching of the single-feed ML's pair.

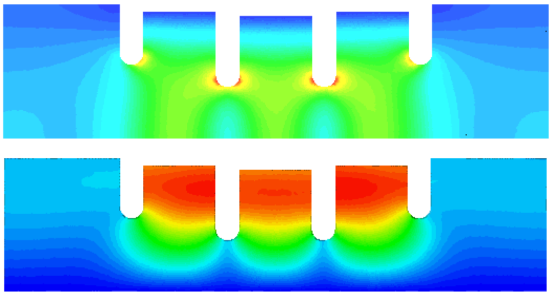

Figure 7. Electric field (up) and magnetic field (down) plots in two transformers plus a regular cell.

Matching of a low-impedance circular waveguide to a high-impedance accelerating structure would normally require a series of special cells, but since the bandwidth of the structure is quite narrow it was possible to do the matching with a single transformer cell (see Fig. 7).

The maximum electric surface field in the transformer cell is about 15% lower than that in the regular accelerating cells for this particular design, see Fig. 8. A further reduction could be achieved simply by increasing the thickness of the first iris. The maximum magnetic field is, however, 5 % higher. In the ML part of the coupler, the maximum values of both electric and magnetic field are 30% lower than in the regular cells

A 12-cell copper test structure has been equipped with single-feed ML-type input and output couplers. Fig. 9 compares the measured S-parameters of this structure with those calculated by HFSS. Agreement is very good.

A general purpose single-feed ML coupler has been fabricated for routine high-gradient testing of prototype 30 GHz structures in CTF2.

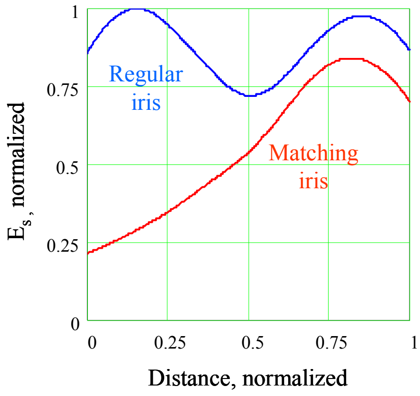

Figure 8. Electric field amplitudes along the irises of matching and regular irises.

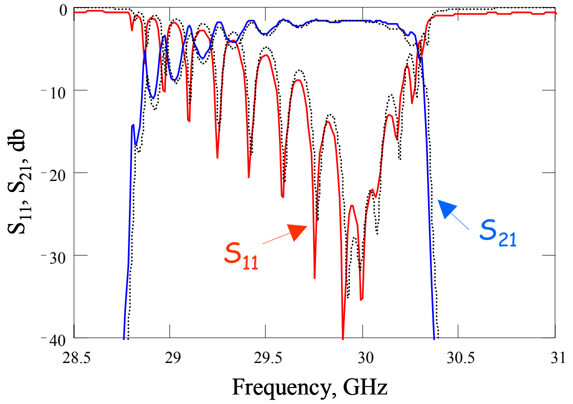

Figure 9. Measured (solid) and calculated (dotted) S-parameters of the CLIC test structure (12 regular cells) plus matching cells and two single-feed ML's.

A large-beam-aperture version (MLB) of ML coupler has been fabricated for use with CLIC prototype 30 GHz power-extraction structures. One of these structures will be used in CTF3 to produce 30 GHz power for high-gradient testing. For this application it was necessary to incorporate a resonant choke to prevent the propagation of the backward wave in the circular waveguide. The 30 GHz MLB high-power version (shown in Fig. 10) has been tested up to 100 MW in CTF2.

Figure 10. The assembly of the high power version of the MLB.

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