QUASI-OPTICAL COMPONENTS FOR FUTURE LINEAR COLLIDERS

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Abstract

This paper presents a concept of the quasi-optical RF system for future Ka-band electron-positron linear collider. According to this concept a quasi-optical Delay Line Distribution System (DLDS) is considered. The DLDS is based on oversized waveguides. In such waveguides the so-called image multiplication phenomena are used for power launching, extracting, combining, and splitting of waves. Recent low power tests of mode launchers and other DLDS components are discussed.

INTRODUCTION

The DLDS concept is considered as one of prospect solutions for feeding of high-gradient accelerators at 11.424 GHz [1-2]. According to the projected schemes the DLDS is based on relatively oversized delay lines operated with one or several modes and mode launchers completely or partially constructed on the base of single-mode waveguides. Scaling of the mentioned projects to Ka-band seems to be not acceptable because of higher Ohmic attenuation as well as bigger RF power density, which causes a threat of breakdown. More natural way is to use pure quasi-optical solutions in the design of each DLDS component.

MODE LAUNCHERS

A key component of any DLDS project is a mode launcher, which allows feeding consequently different acceleration sections by means of proper setting the phases of RF pulses from different amplifiers. In the scheme, shown in Fig. 1, the mode launcher has four input channels and the same number of output channels providing four times power gaining. The delay lines behind the mode launcher are assumed to be oversized circular cross-section waveguides operated with axis-symmetrical TE_{01} mode.

We considered two possible versions of the mode launcher both based on image multiplication phenomena in an oversized waveguide [3-6].

Mode Launcher Based on Rectangular Cross-Section Waveguide

In this version (Fig. 2) the mode launcher is shaped of a smooth oversized (waveguide size is a) rectangular waveguide, where image multiplication occurs at one coordinate only. Four TE_{01} modes at the input of rectangular waveguide are combined into one of four output channels. The position of the resulted channel depends on the mutual phases at the input. The required length of the waveguide equals to a^2/λ.

The mode launcher was calculated using Kirhgof's approach, and results were published in paper [3]. According to these results the wider waveguide the higher efficiency of the launcher. For example, at 34 GHz, width a=120 mm, and length L=1600 mm provide 99% efficiency of the power summarizing.

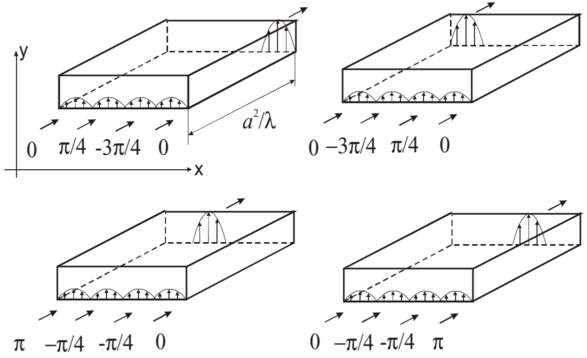

Figure 1: Mode launcher based on rectangular cross-section waveguide (principal scheme).

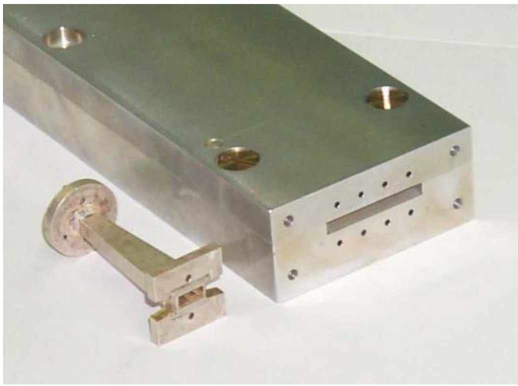

Figure 2: Mode launcher based on rectangular cross-section waveguide (photograph of the prototype).

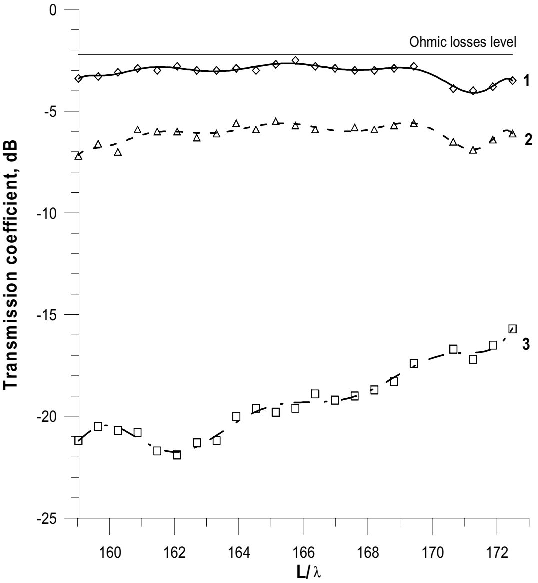

Figure 3: Measurements of mode launcher efficienc when incident wave is launched into a channel near the wall.

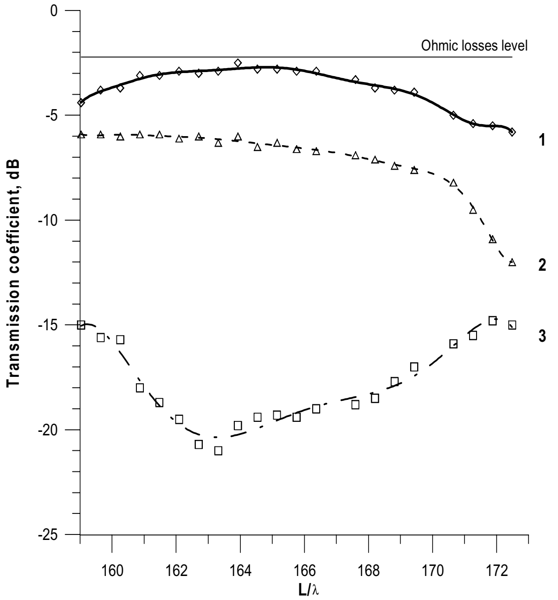

Figure 4: Measurements of mode launcher efficiency when incident wave is launched into a channel near the center of waveguide.

Preliminary tests were performed with the launcher prototype (Fig. 2) scaled to 4-times higher frequency in order to minimize launcher sizes and simplify its fabrication. This resulted in higher Ohmic losses (about two times) and more critical alignment of parts. The launcher was fed by one wave and the output field structure and reflection coefficient from specially shaped mirrors at the launcher output were measured.

The results of the measurements, carried out for two regimes, are shown in Figs. 3-4, where reflection is plotted as a function of launcher length normalized on a wavelength. The first used mirror provided phases of four reflected waves at the output end so, that the reflected waves were combined again in the input waveguide where the initial wave was radiated. The curves marked by *1* in both Fig 3 and Fig. 4 show the reflection in this case. This reflection was actually the squared efficiency of the launcher, because all other channels were opened and the scattered radiation was free to go away. The measured difference between the reflection and Ohmic losses level is rather small: 0.5 dB.

The curves marked by *2* correspond just to the flat mirror reflectors. In such a case according to image multiplication effect the reflected waves formed two identical waves at input cross-section. One of them came back into the feeding channel, but the second wave was radiated away. So, -3 dB extra losses, measured in this scheme, are agreed well with a theory.

The curves marked with *3* correspond to the case when reflected radiation was combined all power in another channel (not in the feeding channel). In this case we could measure the scattered radiation only. Its level appeared about –15-20 dB.

Mode Launcher Based on Square Cross-Section Waveguide

The second version of a mode launcher is based on image multiplication in square cross-section waveguide with the impedance corrugation of walls (Fig. 5). The infinite impedance allows combining TE_{01} modes of a circular waveguide, and thus, any mode converters, in order to match such mode launcher with TE_{01} delay lines, are not needed. The length of the launcher equals $2a^2/\lambda$.

For tests we used four-times higher frequency and selected sizes of mode launcher (Fig. 6), which provided 93% efficiency.

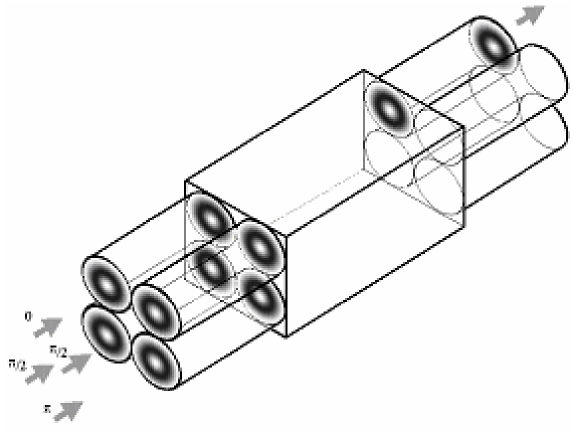

Figure 5: Mode launcher based on square cross-section waveguide (principal scheme).

The scheme of efficiency measurements coincides with the scheme chosen for the rectangular mode launcher described above. with mode purity at operating frequency estimated as 96-97%. In our tests we found out that the efficiency of such a mode launcher is very sensible to the accuracy of manufacturing. In particular, difference in sizes of the walls results in an essential drop of the efficiency in comparison with the ideal case. That was the main reason, why we measured rather high power losses (Fig. 7). Nevertheless, taking into account the actual accuracy of fabrication and purity of the incident TE_{01} mode, one concludes that the efficiency of such a component at 34 GHz is able to be high enough.

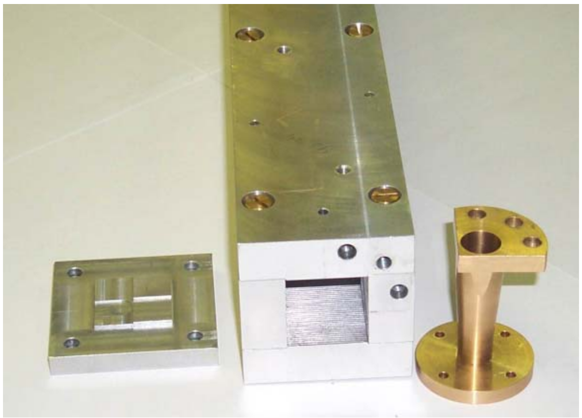

Figure 6: Mode launcher based on square cross-section waveguide (photograph of the tested prototype).

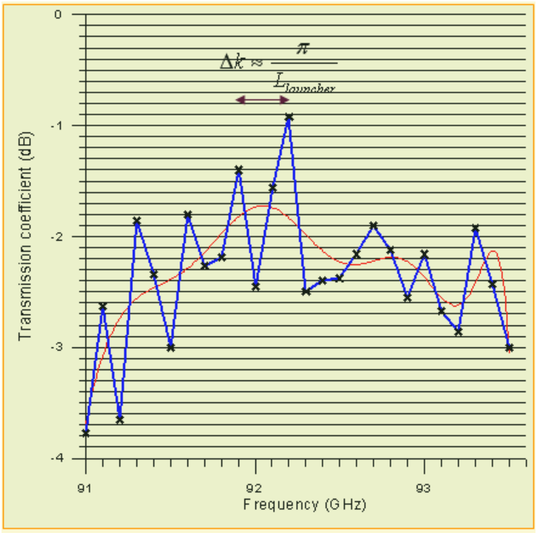

Figure 7: Measurement of efficiency of the TE_{01} mode launcher based on square cross-section waveguide.

CONCLUSION

The main components of Ka-band transmission line for future accelerator system were designed, fabricated and tested at low power experiments. The test results agree well with the design parameters. Therefore, the Ka-band DLDS seems to be feasible.

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