DEVELOPMENT OF AN HIGH GRADIENT, S-BAND, ACCELERATING STRUCTURE FOR THE FERMI LINAC

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Abstract

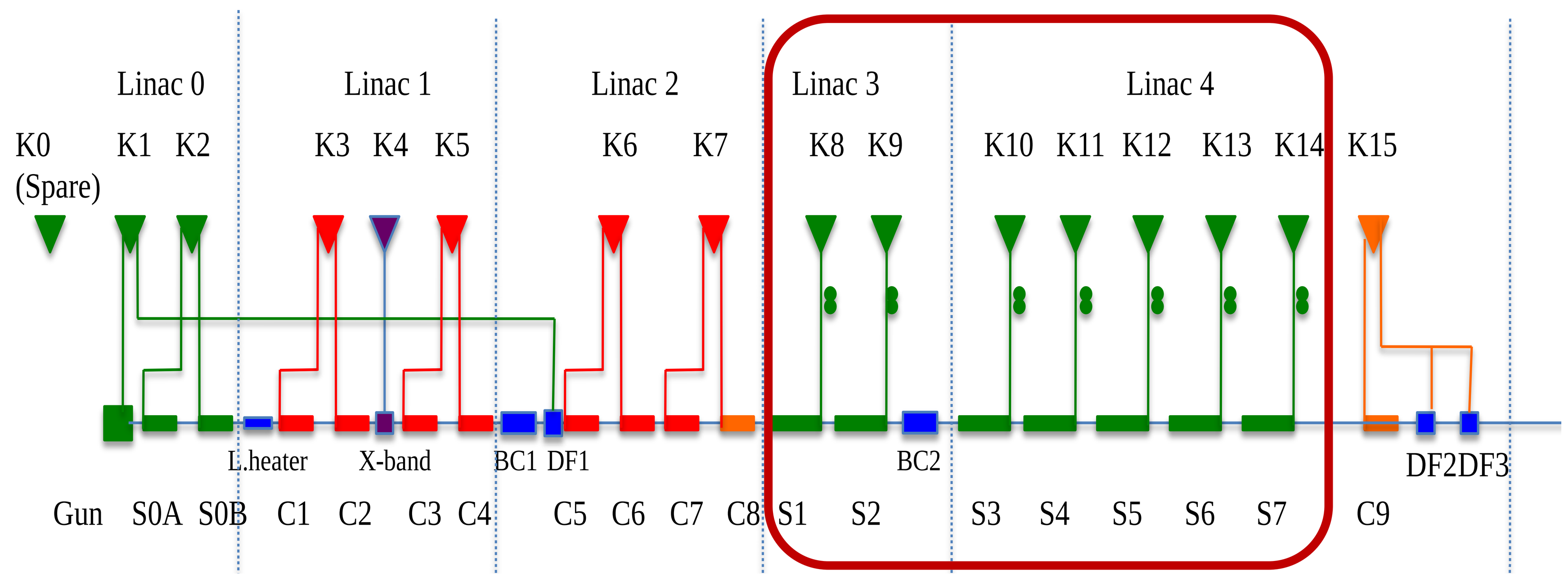
The FERMI seeded free-electron laser (FEL), located at the Elettra laboratory in Trieste, is driven by a 200 meter long, S-band linac routinely operated at nearly 1.5 GeV and 10 Hz repetition rate. The high energy part of the Linac is equipped with seven, 6 meter long Backward Traveling Wave (BTW) structures: those structures have small iris radius and a nose cone geometry which allows for high gradient operation. Nonetheless a possible development of high-gradient, S-band accelerating structures for the replacement of the actual BTW structures is under consideration. This paper investigates a possible solution for RF couplers that could be suitable for linac driven FEL where reduced wakefields effects, high operating gradient and very high reliability are required.

Introduction

The high energy part of the Linac is equipped with seven Backward Traveling Wave (BTW) structures. Small beam apertures and nose cone geometries allow for high gradient operation.
Each structure is powered by a 45 MW, Thales klystron. BTWs have been found to suffer from increased breakdown activity when operated at 25-26 MV/m and 50 Hz repetition rate.
Therefore, a development of new, low wakefields, high gradient and high reliability S-band accelerating structures for the replacement of the existing BTWs is under consideration.
A design of an RF coupler that could be suitable for linac driven FELs is here presented.

Breakdowns on inner surfaces

Linac Layout



Limitations to the attainable energy at 50 Hz come essentially from the reliability of operating the BTW structures at full gradient

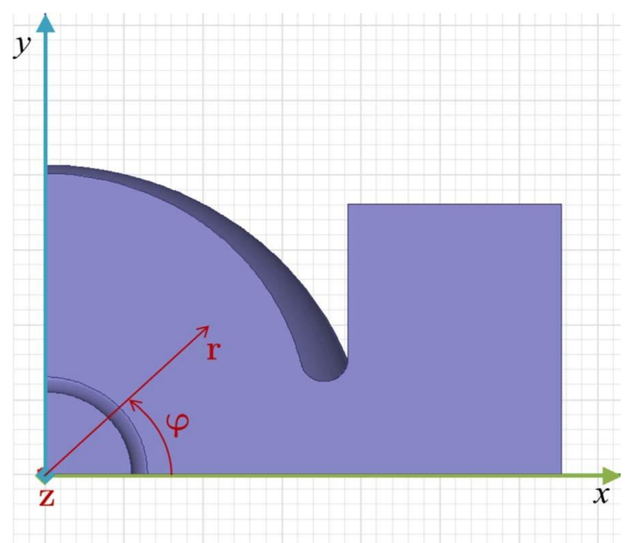
Field Asymmetry Analysis

The impact on the electron beam dynamics produced by field asymmetries in the coupler region can be studied by analyzing the transverse momentum change.

So, the function $F_\varphi(z)$ is introduced and then integrated along a line of length L contained in the coupler region. This yields to the quantity k_q: minimizing the value of k_q will reduce the residual quadrupole kick in the coupler.

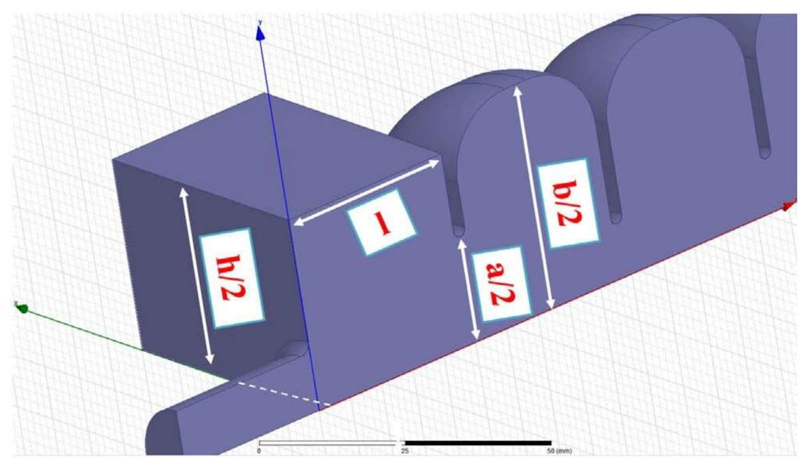
$$F_\varphi(z) = [F_x(r_0, \varphi = 45°, z) - F_y(r_0, \varphi = 45°, z)]$$

$$k_q = \frac{1}{qr}\left|\int_0^L F_\varphi(z) e^{j\frac{\omega}{c}z} dz\right|$$



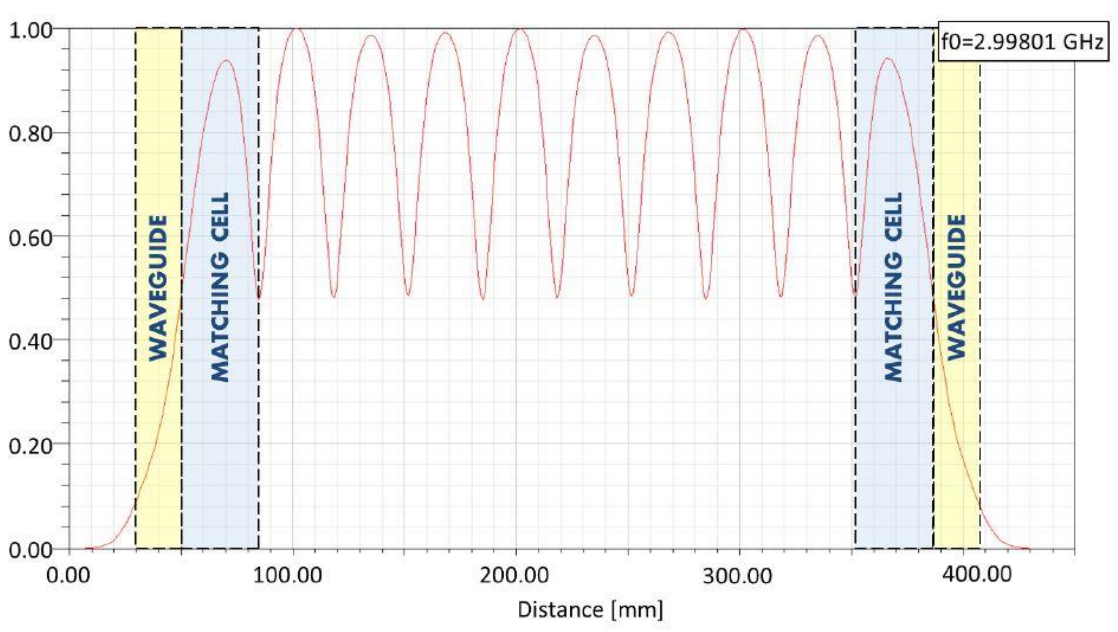
Electric-Coupled RF Coupler

In the development of high gradient accelerating structures, the high electromagnetic fields arising in magnetic-coupled couplers, where the power is transferred to the accelerating structure through a slot aperture between the wall of the waveguide and the coupling cell, could represent a bottleneck.
To remove possible limitations to the achievable operating gradients, changes in the couplers' design have been introduced: the input power coming from the source is directly coupled to the accelerator through a circular iris in the broad wall of the WR284 waveguide. The electric coupling requires a matching cell to match the input waveguide to the periodic structure .

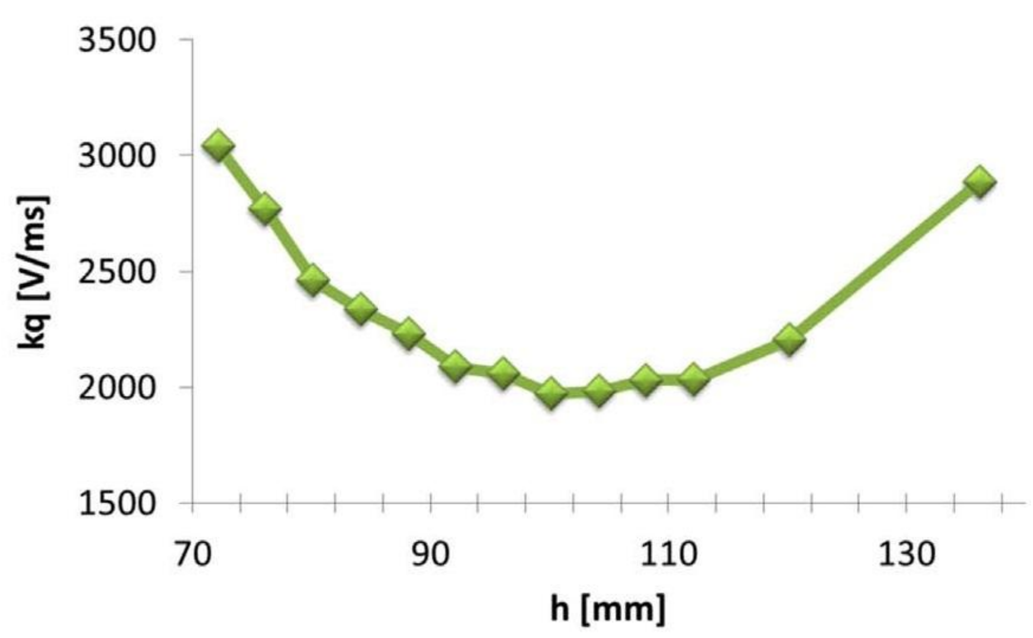


Layout of an electric-coupled RF coupler

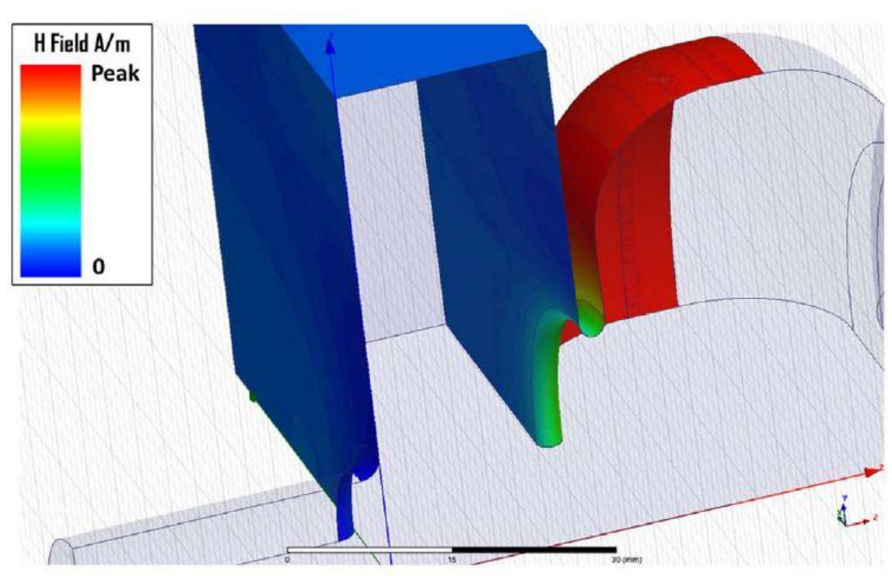
The electric-coupled solution sacrifices some acceleration efficiency. This has been partially recovered by stepping down the narrow size of the input rectangular waveguide.



Residual quadrupole components have been minimized adjusting the geometric parameters of the coupler.



For an input power of 65 MW (needed to get 30 MV/m) the maximum surface electric field is 81 MV/m. The surface magnetic field is 78 kA/m.



Conclusion

The high energy part of the FERMI Linac is equipped with seven BTW structures. Small beam apertures and nose cone geometries allow for high gradient operation. Nonetheless, BTWs have been found to suffer from increased breakdown activity even when operated at 25-26 MV/m and 50 Hz repetition rate. Therefore, the development of low wakefields, high gradient and high reliability structures is under consideration. To remove possible limitations to the achievable operating gradients, a dual-feed, electric-coupled RF coupler has been adopted.
Because of lower field in both input waveguide and coupling cell, a drawback of electric-coupled RF couplers is in general a reduction of the acceleration efficiency. Nonetheless, stepping down the narrow size of the input rectangular waveguide, the loss in efficiency results to be negligible.
High frequency simulations showed that the residual quadrupole field is not as low as in magnetic-coupled solutions: this makes the electric-coupled ones more suitable for use in the high energy part of a linear accelerator.
Since the new accelerating structures are foreseen to replace the existing BTWs, actually installed in the high energy part of the machine, and given the low surface fields which make the EC couplers suitable for high gradient operation, the electric-coupled RF couplers revealed to be the most appropriate choice in the development of the new structures.

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