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RF POWER GENERATION AND COUPLING MEASUREMENTS FOR THE DIELECTRIC WAKEFIELD STEP-UP TRANSFORMER

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Abstract. The dielectric wakefield transformer (DWT) is one route to practical high energy wakefield-based accelerators. Progress has been made in a number of areas relevant to the demonstration of this device. In this article we describe recent bench measurements and beam experiments using 7.8 and 15.6 GHz structures and discuss some remaining technical challenges in the development of the DWT.

INTRODUCTION

Dielectric loaded structures driven by the wakefields of a high current electron beam have been under study for some time as high frequency high gradient accelerators [1]. The simplicity of this method, as well as the relative ease with which parasitic higher order modes can be damped [2] compared to conventional structures operating at a comparable frequency makes this technology an attractive option for future high energy e^+e^- linear colliders.

A simple collinear drive-witness beam geometry suffers from inefficiencies due to the single bunch beam breakup instability of the drive beam unless unrealistic injection tolerances are imposed. Collinear devices are also limited to transformer ratios < 2, and beam staging is difficult. To circumvent these problems, a transformer geometry is used [3], where the drive and witness beams pass through separate structures (figure 1). The rf pulse generated by the drive beam is transferred via waveguide to a second structure which is adjusted to have the same fundamental frequency but smaller group velocity and transverse dimensions, thus providing an accelerating field step up by compressing the rf pulse. A drive structure can be designed with sufficiently low transverse impedance [4] to avoid beam breakup problems. Multiple drive bunches are used, spaced by an integral multiple of the rf period, to provide a long accelerating pulse.

Initially it was useful to operate with a collinear drive and witness beam geometry in order to probe directly the fields generated in the drive structure. Measurement

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structures. With optimized coupling, the 7.8 GHz structure has a transformer ratio of 2.5, while that of the 15.6 GHz device is 3.6.

BENCH MEASUREMENTS AND RF COUPLING OPTIMIZATION

In the original concept for the DWT [3], the coupling between structures was accomplished by smoothly deforming the dielectric tubes and coupling the rf through a short unloaded section of waveguide which acted as a quarter wave transformer. This scheme involves no mode conversions and was found to be very efficient based on 2D numerical simulations [8]. The difficulty of deforming the ceramic tubes used as dielectrics led to an alternative method of rf coupling, using a section of rectangular waveguide as shown in figure 1.

The coupling of rf from the drive tube into the accelerating tube involves obtaining efficient broadband ($\Delta f/f \simeq 5 - 10\%$) power transfer with two mode conversions, from cylindrical TM_{01} to rectangular TE_{10} and back again. The problem of coupling optimization in the DWT was found to involve considerably more effort than a few hours work by a "halfway decent electrical engineer" as anticipated [5]. A lengthy trial and error procedure of coupling slot adjustments and network analyzer measurements was necessary to obtain reasonable coupling between the structures.

Figure 2 shows the bench measurement setup. A tapered launcher in combination with a tapered dielectric is used to achieve good coaxial to cylindrical waveguide coupling. A waveguide to coax adapter is located at the end of the rectangular waveguide. S_{21} is measured from the tapered launcher to the coaxial coupler output.

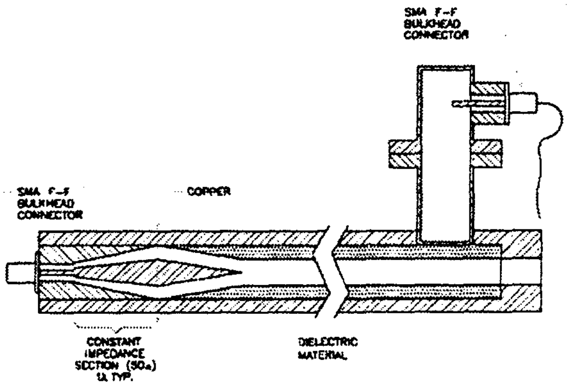

FIGURE 2. Bench measurement setup for dielectric structure to waveguide coupling measurements.

The coupling slot is located about $\lambda_{wake}/4$ from the end of the dielectric waveguide and is longer in the azimuthal direction than in the axial. The slot allows the

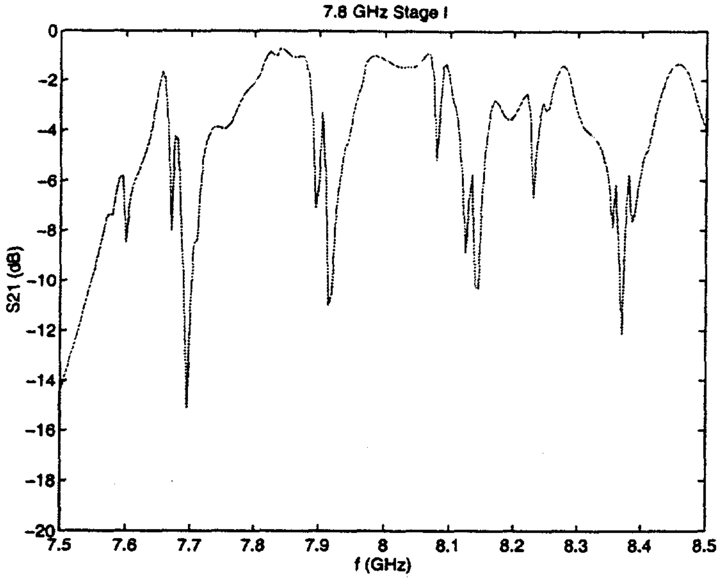

FIGURE 3. Measured S_{21} for stage I of the 7.8 GHz DWT structure.

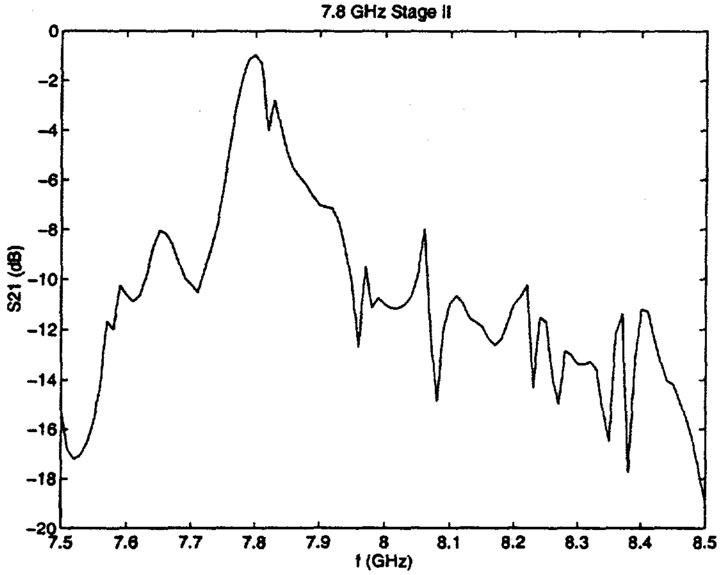

FIGURE 4. S_{21} for stage II of the 7.8 GHz DWT structure.

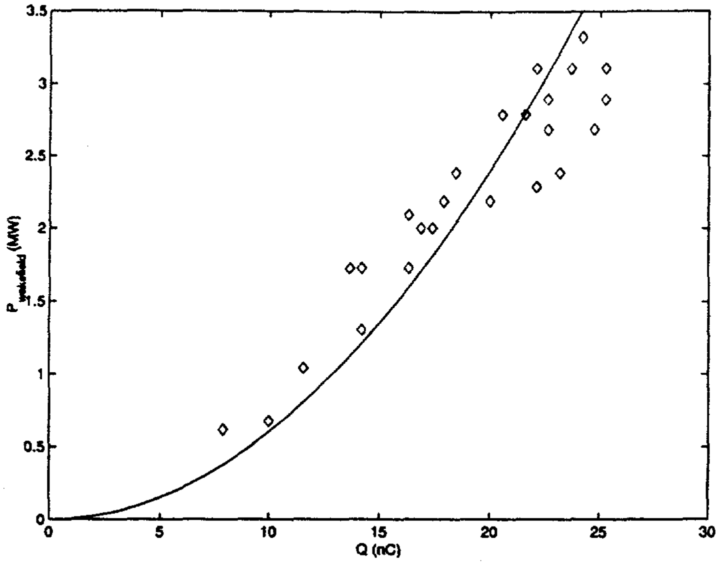

FIGURE 6. Rf power vs drive bunch charge, 7.8 GHz dielectric structure. The scatter in the data is due to bunch length fluctuations.

SUMMARY

Considerable progress has been made towards a demonstration of the dielectric wakefield transformer. Some of the major steps on the way– optimizing the rf coupling from dielectric to transfer structure, multiple drive bunch generation in the AWA linac, and direct measurement of the rf generated by the beam– have been successfully achieved. We have some confidence that the remaining tasks can be accomplished without any major difficulties.

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