DESIGN OF RF FEED SYSTEM FOR STANDING-WAVE ACCELERATOR STRUCTURES

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Abstract

We are investigating a standing wave accelerator structure that uses a rf feed to each individual cell. This approach minimizes rf power flow and electromagnetic energy absorbed by an rf breakdown. The objective of this work is a robust high-gradient (above 100 MV/m) X-band accelerator structure.

INTRODUCTION

Typical surface damage in travelling wave accelerator structures occurs on the high electric field region of the iris. As the damage accumulates the phase shift between cells is changed. This damage issue can be reduced by use of standing wave (SW) cells that are fed in parallel. RF breakdown is contained to the cell where it originates and the available electromagnetic energy absorbed by the breakdown is minimized by the parallel feed. An additional benefit to this type of structure is improved vacuum pumping conductance.

There are a few drawbacks to the parallel fed SW accelerator structure approach. In order to minimize power transfer between cavities during a breakdown the iris aperture must be relatively small. This can lead to increased short-range wakefields. The design complexity is increased as both rf power coupling and wakefield damping must be carefully implemented to prevent excessive pulse heating.

Several schemes [1] have been proposed for parallel fed SW structures. The proposed designs feed several cells from each coupling waveguide, which reduces the advantage of localizing a rf breakdown to an individual cavity. We are proposing a somewhat more complex approach using a directional coupler on each cell [2]. This design approach isolates the cells and should improve operational robustness of the accelerator structure. We are also proposing four feed arms spaced uniformly around the cavity azimuth to suppress rf drive induced dipole and quadrapole modes. The feed arms will also be used suppress long range wakefields. Our prototype design will be for π mode cavities separated by a half-wavelength at a design frequency of 11.424 GHz.

RF FEED STRUCTURE

A conceptual drawing of the feed structure is shown in Fig. 1. A group of N accelerator cavities is fed by a waveguide running along the length of the structure. From this waveguide each cavity in the group is fed by a directional coupler that extracts some of the rf power

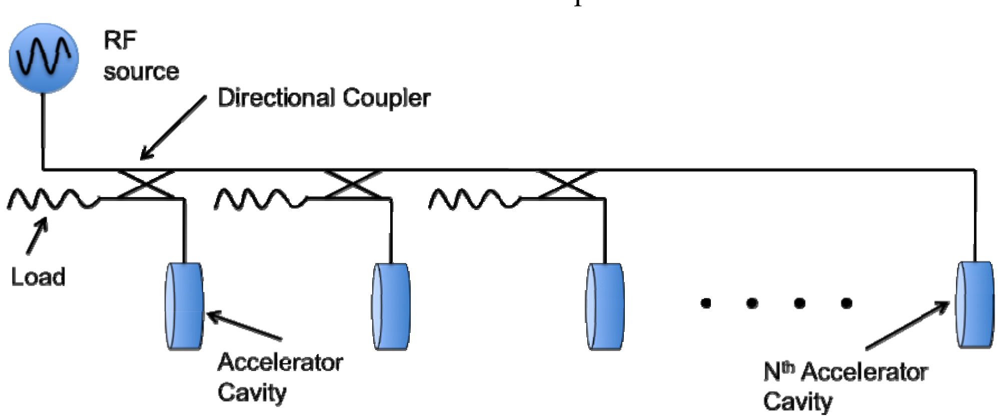

Figure 1: Conceptual schematic of rf feed system for a set of SW cavities.

flowing in the feed waveguide. The coupling factor of each coupler is designed to provide equal power to each cell. The coupling coefficient for the ith coupler that provides this equal power division is given by

$$C = \frac{1}{\sqrt{1 - i + N}}$$

For our prototype design we chose each cavity group to consist of 18 cavities for a total structure length of 18 X 1.31 cm = 23.58 cm. This arrangement will require 17 couplers with the directional coupling factors ranging from -12.4 dB (first coupler) to -3 dB (last coupler). The rf waveguide feed arm is terminated in the last cavity.

A reflected signal from an individual accelerator cavity is partially absorbed by the load in the directional coupler attached to the cavity. The remaining reflected power will be absorbed in the other loads and reflected back to the source. Proper combination of the reflected power from one cavity group with other cavity groups can be used to cancel the total reflected power to the source [2] and eliminate the need for a circulator to protect the source.

The typical waveguide directional coupler uses a series of coupling holes between two parallel adjacent waveguides. The coupling section length for these type of couplers is larger than the λ/2 spacing between cavity centers thereby precluding the use of this coupler type. Conventional crossguide couplers [3] are sufficiently compact to fit in the λ/2 cavity spacing but would require reduction of the waveguide coupling arm height to less than half of the cavity spacing. The combination of this reduced waveguide height and coupling slots used in for this type of coupler would have prohibitively high surface fields.

A directional coupler type called the biplanar coupler [3] (Fig. 2) provides a nearly ideal solution for the feed system. Since the coupler waveguide height can be close to the cavity spacing and does not use coupling slots, field enhancement is minimized. The 2D planar structure is also easier to manufacture than the crossguide type coupler.

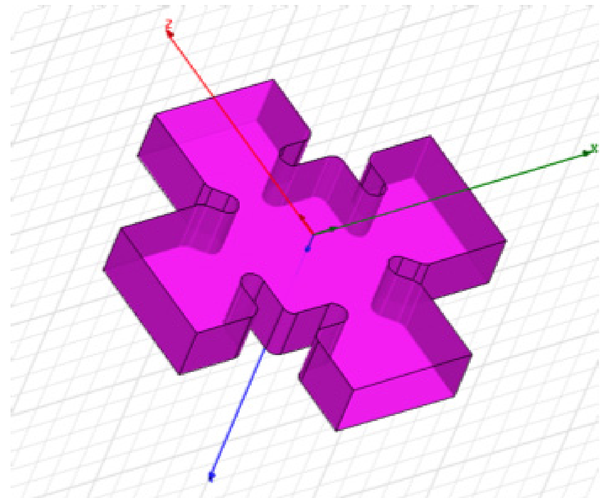

Figure 2: Internal structure of biplanar coupler.

We have generated biplanar coupler designs for the required range of coupling factors. The return loss for the designs is greater than 40 dB and the directivity ranges from 37 dB and 62 dB respectively for the -12.4 dB and -3 dB designs. For a given input power, the peak electric field in the coupler is only 1.5 times that of rectangular waveguide of the same dimension. With this modest field enhancement the coupler should be capable of transmitting 130 MW using the standard WR90 waveguide dimensions. This is considerably higher than the rf power required to drive the cavity group for a gradient of 100 MV/m. There are four drive ports per cavity so the power in each arm is one quarter of the total input drive power.

The couplers are designed to provide equal power to each cavity. Since there will be some variation in the coupling factors due to manufacturing tolerances, some cells will have higher fields which may reduce the peak achievable acceleration gradient for the cavity group. The sensitivity of the coupler designs was tested using a Monte-Carlo type analysis. This analysis was performed by running multiple coupling calculations while simultaneously varying each dimension randomly about the design value. The -12.4 dB coupler showed the greatest sensitivity to dimensional variation. The sensitivity of the coupling factor for a dimensional tolerance of +/- 0.012 mm (tolerance achievable with

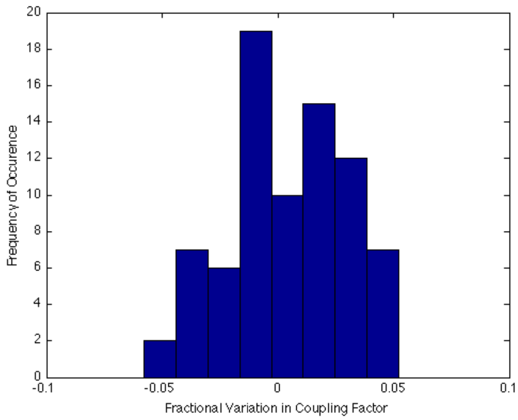

Figure 3: Fractional variation of coupling for +/- .012mm tolerance.

numerical controlled machine) is shown in Fig. 3. The variation of the coupling factor is sufficiently low that it will cause minimal limitation on the achievable acceleration gradient.

A conceptual view of the rf feed system consisting of the couplers and connecting arms that connect each successive coupler is shown in Fig. 4. With a λ/2 cavity spacing the rf drive phase difference between successive cavities is 180 degrees. Obtaining the correct phase shift will be achieved by adjustment of the waveguide length connecting successive couplers between the cavities. As can be seen in Fig. 4, the use of X-band components results in a fairly compact accelerator structure.

CONCLUSIONS

A prototype design of a rf feed system for a group of standing wave accelerator cavities has been developed. This design isolates the cells and should provide the basis for a robust high-gradient accelerator structure.

ACKNOWLEDGMENTS

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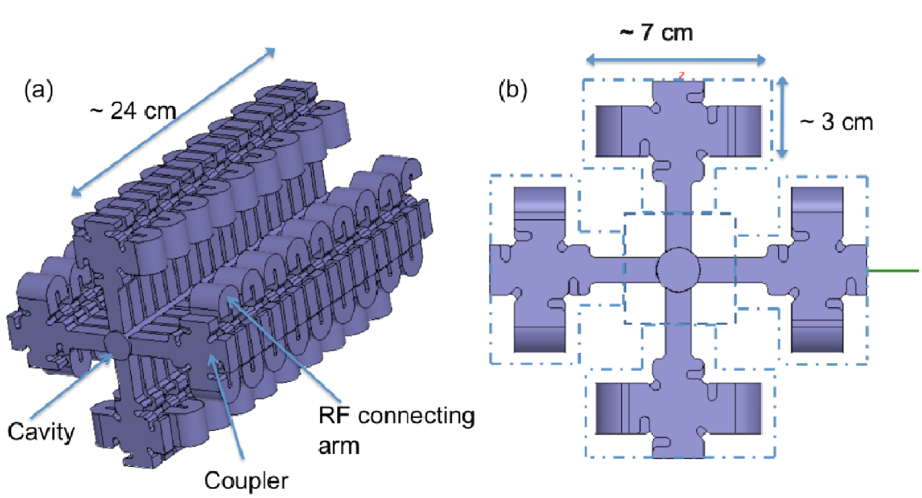

Figure 4: Conceptual schematic of rf feed system for a set of SW cavities.