DESIGN AND CONSTRUCTION OF A 7MW HIGH POWER CIRCULATOR

X. Wang, G. Su, Y. Sun, Y. Ma and Sh. Bu
China Institute of Atomic Energy, Beijing 102413, China

Abstract

The operation theory and experimental results of ferrite material and a 7MW circulator are presented in this paper. By selecting suitable ferrite material, designing ferrite slabs and electrical and magnetic structure of the circulator, and tuning the circulator under high power for finding the operating point, the 7MW circulator has been successfully constructed. It operates at 2856MHz handling 7MW peak and 5kW average power and offering 25dB isolation and VSWR of 1.1:1. It is designed for application in S-band high energy radiation system.

1 INTRODUCTION

In electron linac, we tend to use higher and higher power sources at 2856MHz. In particular, in standing-wave electron linac, a circulator is indispensable to protect the high power source from damage or the unstable operation caused by power reflected from the accelerating tube. This protection is usually provided by a ferrite circulator, which transmits power to the accelerating tube with minimum transmission loss and diverts reflected power to a matched dummy load capable of safely dissipating that power.

Usually, There are two types of waveguide circulators used for high power source protection, a differential phase shift type and a Y-Junction type. At S-band, the Y-Junction circulator is inferior in power handling capability. Therefore, We selected a four-port differential phase shift circulator. To reduce the power level received by the ferrite material, we use a 3-dB hybrid coupler.

2 DESIGN AND CONSTRUCTION OF A HIGH POWER CIRCULATOR

The high power circulator consists of a folded magic tee, nonreciprocal ferrite phase shifter and a 3-dB coupler. It is shown in Fig.1.

For nonreciprocal ferrite phase-shifter the differential phase shift of each port is $\pm 90^{o}$[1]. In this approach, each ferrite slab receives half of the incident power. In order to reduce weight, the circulator was designed with only two ferrite slabs per waveguide and bar shape of permanent magnet. This calls for thicker ferrite slabs (4.0 to 5.0cm) to maintain the same phase shift for a given length of the guide. Therefore, it raises the possibility of overheated ferries, and calls for tighter tolerances in the insertion loss of the ferrite.

In our high power test, we noticed isolation from port2 to port1 rapidly decreased for some ferrite materials when RF average power exceeded 3kW. Isolation of port2 to port 1 decreased with the power rise. Therefore, the performance of the circulator is affected by the temperature rise of the ferrite due to the power loss in it and the critical magnetic field of it. The ferrite material should be with high critical magnetic field, low loss and good temperature properties.[2] In addition, the magnetic operating point of the ferrite is also very important.[3]

We chose a LiTiMg ferrite. The ferrite slab size is 245×23.5×4.5mm. The ferrite slabs are located symmetrically on the broad walls. Each slab is halfway between the bread wall centerline and the narrow wall of the guide. The RF power absorbed in the ferrite can be removed by conduction to the guide broad wall, which is then water-coded. For magic tee, we calculated the intermediate zone dimension so that only the fundamental TE_{10} mode passed through without a higher mode. Its performance at low level is VSWR on the sum and different ports are less than 1.1. The isolation between these two ports is 36dB. The performance of hybrid 3-dB coupler at low level is VSWR is 1.08 and isolation is 25dB.

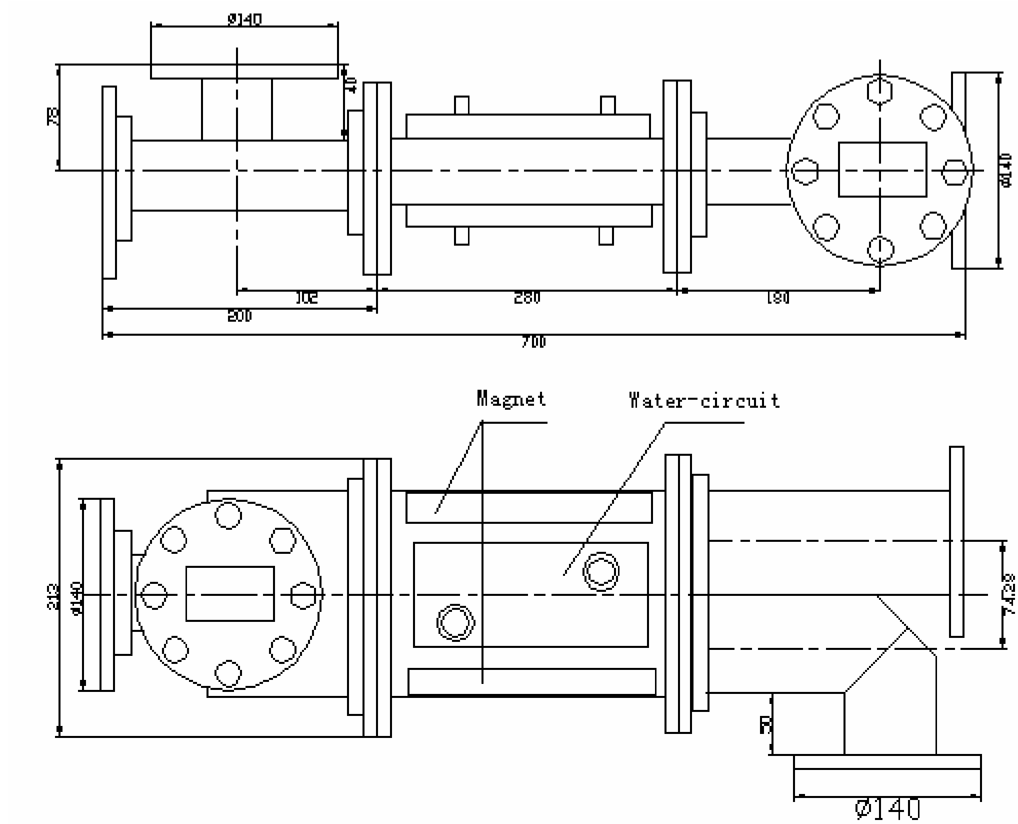

Fig.1 Differential phase-shift circulator

To reduce the insertion losses and achieve higher power ratings, we have taken the following precautions.

1) All waveguide components are silvered inside.
2) All metallic corners are rounded.
3) All electric contacts keep good.
4) Matching is realized by inductance posts.
5) The ferrite phase shifter is cooled by flowing water (6l/min).

3 PERFORMANCES OF THE HIGH POWERCIRCULATOR

We use water calorimeters for measuring the high-level circulator performances. The VSWR is the same as at low level (1.08) when the circulator is terminated in a matched load. The insertion loss from port1 to por2 increases with the power to equal 0.54dB. The Isolation of port2 to port1 increases with power to equal 38.5dB, then decreases with the power to equal 25.6dB. It is shown in Fig.2.

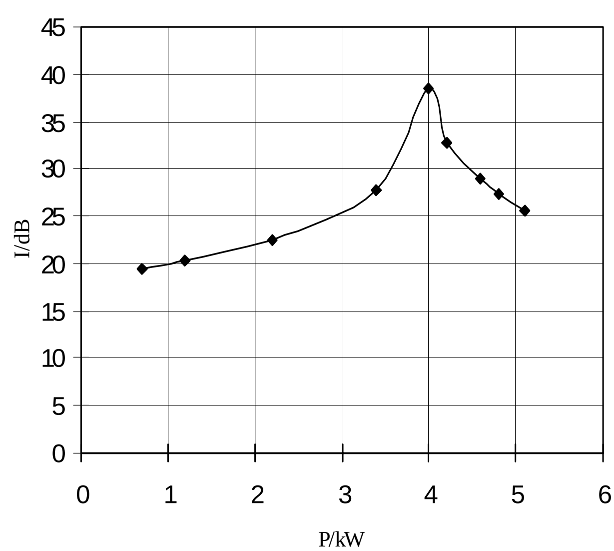

Fig.2 Isolation versus average power at F=2856MHz

The main electrical and mechanical performances of the circulator are:

Frequency	2856MHz
Peak power	7MW
Average power	5kW
VSWR	1.08
Insertion loss	0.54dB
Isolation	25.6dB
Length	0.7m
Width	0.25m
Height	0.15m
Weight	<25kg

4 CONCLUSION

We have constructed the circulator successfully with the power handling capability of up to 7MW peak and 5kW average power. It can be applied to electron linear accelerator and protect high power sources from damage.

REFERENCES

[1] Lax, B., Microwave ferrites and ferrimagnetics, New York: McGraw-Hill, 1962.

[2] Journal of Magnetism and Magnetic Materials, No.9, 1978, PP. 299-317.

[3] Cristian Fournet-Fayas, “A 50-kW CW Ferrite Circulator in S Band”, IEEE Vol. MTT-26, No.5, PP. 360-363.