AN ALL-METAL HIGH POWER CIRCULARLY POLARIZED X-BAND RF LOAD*

W. R. Fowkes, E. N. Jongewaard, R. J. Loewen, S. G.Tantawi and A. E. Vlieks
Stanford Linear Accelerator Center, Stanford University, Stanford CA 94309 USA

Abstract

A compact rf load has been designed using a cascaded array of lossy radial rf chokes to dissipate 100 MW peak and 8 kW average power uniformly along the length of the load. Operation in the circularly polarized TE_{11} mode assures uniform dissipation azimuthally as well.

INTRODUCTION

The usual high power termination used for klystron testing at SLAC is the so-called SLAC "grapefruit load" because of its compact size and shape. Both X and S band versions have been designed [1]. These designs consist basically of a circular quarter wave ceramic window separating a water chamber from the waveguide vacuum. A circular to rectangular transition and an inductive post provide a sufficiently broadband match. The X band design uses a circular taper as well.

The accelerator community has always steered clear of any components where there is even the remotest possibility of water entering the accelerator vacuum due to the failure of a non-metal seal such as the ceramic window in the grapefruit load. All-metal loads with lossy conducting surfaces such as Kanthal have been used in both the long taper and disk loaded waveguide form. Kanthal coated surfaces are usually rough and can absorb large amounts of gas and water vapor when exposed to air resulting in prolonged outgassing and lengthy rf conditioning. Field emmission and multipactor can impede operation. Loads using lossy ceramic tiles have been used successfully at some laboratories but they also have outgassing problems and there are difficulties bonding the ceramics to a metal substrate, usually copper, for thermal conductivity reasons.

Tapered X-band loads made from type 430 magnetic stainless steel have been used at SLAC with limited success because of the inherent low pumping speed of the small cross-section taper and the ever-present liklihood of multipactor in a tapered structure.

ALL-METAL RADIAL CHOKE LOAD

Design

The theoretical design of the load described in this paper appears in an earlier paper [2]. It was designed with the following requirements in mind:

1. All-metal, ultra-clean, high vacuum
2. Uniform power dissipation both axially and azimuthally.
3. Resistant to RF breakdown and multipactor
4. Good heat transfer to water cooling passages.
5. No weld or braze joints separating water cooling passages and the internal vacuum.

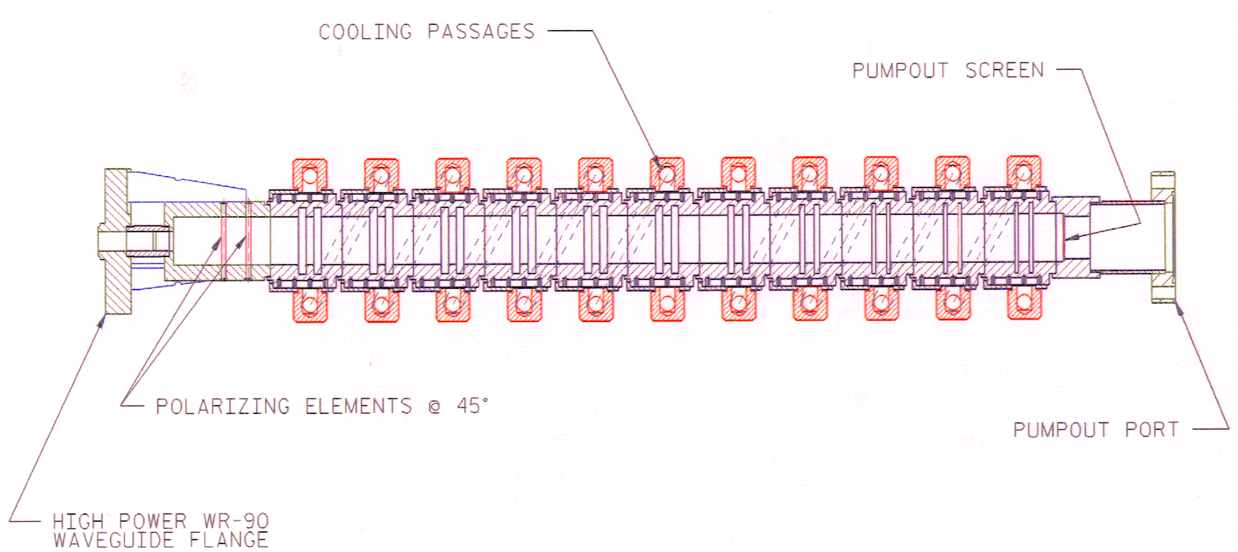

Fig. 1. 11 cell Radial Choke load operating in circularly polarized TE11 mode at 11.424 Ghz

* Work supported by Department of Energy contract DE-AC03-76SF00515

The first version of this type of load consisted of five lossy modules, each absorbing 20% of the input power thereby requiring the attenuation in each successive module to increase in the direction of power flow. The rf fields and the heat load per module is this design turned out to be excessive for most of the needed applications.

An improved version is being built that will handle twice the power of the unit described above. It contains 11 cells with approximately 10% of the input power being dissipated in each of the first 9 cells and the remainder in the final 2 cells at the design frequency. The two way attenualtion is about 32 dB.

The load operates in a circularly polarized TE_{11} mode in 25.4 mm diameter magnetic stainless steel waveguide. The circular polarization offers two advantages over the normal TE_{11} mode operation. First, the power dissipation is approximately uniform azimuthally. Second, the peak rf electric field is lower by the square root of 2. The polarizer, to be described later, is at the front end of the load following a rectangular to circular waveguide transition.

Each module or cell consists of a pair of self-matching radial chokes made from type 430 magnetic stainless steel. The radial extent and axial length of the choke slots determine the loss. The spacing between choke slots is critical for a good match. All of these dimensions are dependent upon frequency. The design of the choke slots was done using MLEGO which was developed at SLAC for accurately computing the scattering coefficients of circularly symmetric elements in circular waveguide. The details of the choke pair design is described in reference [2]. To discourage breakdown, the edges of the choke slots are radiused, the effect of which cannot be modeled accurately using MLEGO and had to be determined experimentally. The effect of the radius is to raise the frequency at which the maximum loss occurs. A cutaway view of one of the choke-pair cells is shown in figure 4.

Cooling Design

The load material, 430 stainless steel was chosen for its high RF loss characteristics at x-band. Unfortunately this material also exhibits poor thermal conductivity, limiting the average power handling capability of loads fabricated from this material. To allow operation at reasonable average power levels, cooling channels are placed as close as possible to the lossy surfaces of the load to minimize the conductive path through the stainless steel load material. These cooling channels are formed by circumferential grooves machined into the outer diameter of each load subassembly and an outer sleeve brazed over the load subassembly. This construction method provides cooling close to the load choke surfaces while eliminating any potential leak paths from water to vacuum joints. With this design we see a maximum temperature in the inner web between chokes of approximately 150 °C at an average power of 600 W per choke pair (6 kW total load power). The peak surface temperature at the end of an RF pulse may reach 500°C or more depending on the peak RF power and pulse length.

Circular Polarizer

The polarizer section consists of a pair of inductive posts, each having a normalized susceptance of -j2.0, and are spaced 3/8 λ_g apart. The 2.3 mm diameter posts are oriented at an angle of 45˚ with respect to incident rf electric polarization in the TE_{11} mode. This incident wave can be considered as the superposition of two orthogonal, in-phase, TE_{11} waves, one of which is normal to the posts and is relatively unaffected by their presence. The other component undergoes a phase shift that differs by 90˚ from its partner. The two components, orthogonal to one another and 90˚ apart in time, recombine as a circularly polarized wave emerging from the post pair region. The result is a rotating vector at any cross section beyond the polarizing section.

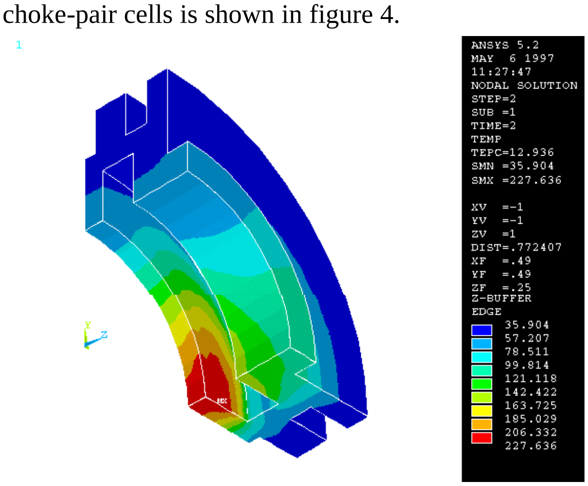

Fig 3a. Plot of surface temperature of load choke **without** circular polarization. The temperature at the "hot spot" reaches 227 ˚C with 600 watts dissipated in each cell.

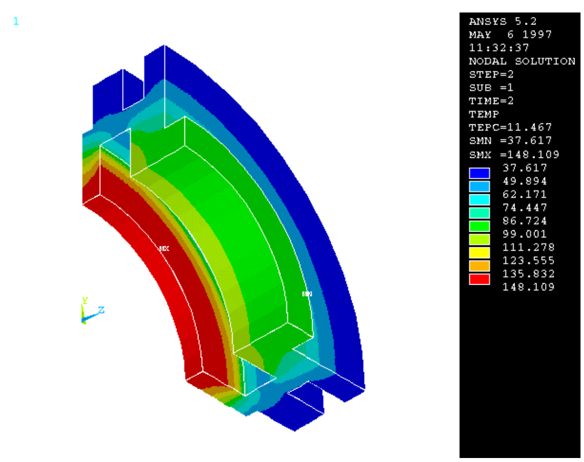

Fig 3b. Plot of surface temperature of load choke **with** circular polarization. At the same power level as Fig. 3a, the maximum surface temperature is 148 ˚C.

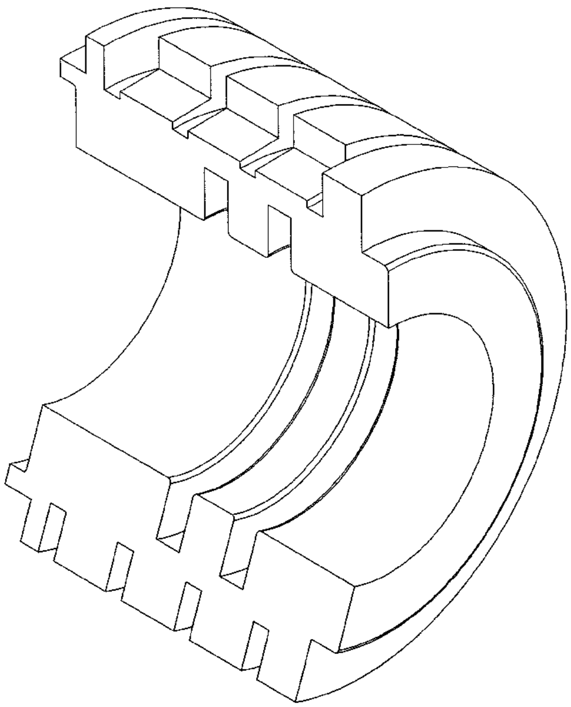

Fig. 4 Choke-pair cell in position 8.

SUMMARY

Although the 11 cell load has not yet been high power tested, it is expected perform comfortably up to 150 MW peak and 6 KW average power based on design calculations.

REFERENCES

[1] W. R. Fowkes, R. S. Callin, A. E. Vlieks: "High Power RF Window and Waveguide Component Development and Testing above 100 MW at X-band". Proc. 1992 Linac Conf., vol. 1, pp 184-186.

[2] S. G. Tantawi and A. E. Vlieks, "Compact X-band High Power Load Using Magnetic Stainless Steel", Proc. 1995 Particle Accelerator Conf., p. 2132.