FIRST RESULTS FROM A HIGH POWER Ka BAND TWT *

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Abstract

In this paper we report first results obtained in a new program to develop high power, high efficiency TWT microwave sources at 35 GHz. In these experiments we use a 30 cm long dielectric (Teflon) amplifier with an 850 kV, 200 A pencil electron beam. The input power is provided from a 250ns long, 10 kW pulse from a magnetron. The experience obtained with this device will guide further development of multistage disk loaded amplifiers. Experimental results indicate output power levels of about 1 MW and a gain of about 18 dB. These results are consistent with expectations from PIC code simulations. Details of the system designs and performance will be presented.

1 INTRODUCTION

Future high gradient accelerators will require the use of high power microwave sources at frequencies in excess of X band. A recent analysis of the requirements of an 5-15TeV accelerator indicates that the operational frequency should probably be in the vicinity of ~35 GHz [1,2]. A source efficiency of order or greater then 40% will be required.

We have initiated a research program to investigate the development of a TWT amplifier at this frequency and we report first results from the program. In other laboratories work is in progress in developing gyroklystron amplifiers at this band [3,4]. In our initial experiments we have used a dielectric amplifier to allow us to obtain experience in the use and measurement of high power Ka band radiation. The dielectric amplifier is probably restricted to output power levels of a few megawatts, but has the advantage of ease of fabrication and matching of the amplifier input and output regions to other waveguide structures. We report a gain of 18 dB from the amplifier and an output power of about 1 MW. A disk loaded amplifier has also been fabricated and initial tests are in progress. This device, which consists of a single stage amplifier, expected to have gain of about 30 dB, an efficiency of close to 15%, and a multimegawatt output power in a 50 ns pulse.

In all of these experiments we use a single shot 900 kV, 200 A, 50 ns electron beam as the primary pulse power source.

In the following sections we describe the dielectric amplifier configuration and show typical data from the amplifier experiments. We also indicate the design of a disk loaded amplifier, which has been constructed and is currently being tested.

2 EXPERIMENTAL CONFIGURATION

The experimental arrangement of the dielectric amplifier is sketched in Figure 1. It uses a Teflon loaded waveguide having a length of 30 cm with 2.5 cm tapers to a uniform cylindrical waveguide at the input end, and to a coaxial guide on the output. The internal diameter of the waveguide is 12.5 mm and the inner diameter of the dielectric is 9.5 mm. The amplifier is terminated with an absorbing load and the output of the amplifier sampled prior to the load. The input rf signal is provided to the amplifier from a Ka band magnetron through pressurized waveguide. Typical input powers injected in the amplifier range from 5-10 kW and the driving beam carries 200-300 A at a beam energy of 850-900 keV. The full width pulse duration is about 50 ns. The electron beam is guided by a 1 Tesla magnetic field, which is carefully aligned with the axis of the experiment. The input coupler design, which is tunable to maximize input to the cylindrical TM_{01} mode, is based on results obtained from the HFSS code. The coupler has two adjustable elements namely an anode stub positioned to suppress coupling to the TE_{11} mode, and the other a rectangular waveguide arm, located directly opposite to the input arm and with a tunable shorting stub which allows us to maximize the deliverable input power from the magnetron. The position of the anode stub is experimentally determined using a network analyzer. A TE_{11} to TE_{10} mode converter and crystal detector is used to minimize the TE_{11} signal. The position of stub in the sidearm is determined by maximizing the power detected by the E field probe located at the output of the amplifier.

We have also assembled a disk loaded amplifier designed to work under identical electron beam and

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microwave parameters. It has up to 100 uniform cells and employs two 10 cell tapered sections at both ends of the uniform section. The tapered sections are used to minimize the reflections at the transitions between the structure and the uniform waveguide sections. The structure has a phase advance per cell of $\pi/2$ at an operating frequency of 35 GHz for an 850 kV beam. With these parameters each cell has length of 2 mm (a 1mm long iris and a 1mm long cavity). The outer radius of the cavities is R_{ext} = 5.0 mm and the inner radius, R_{int} = 3.5 mm. The input structure and the termination are the same as those used for the dielectric amplifier. Gain has been observed for this structure.

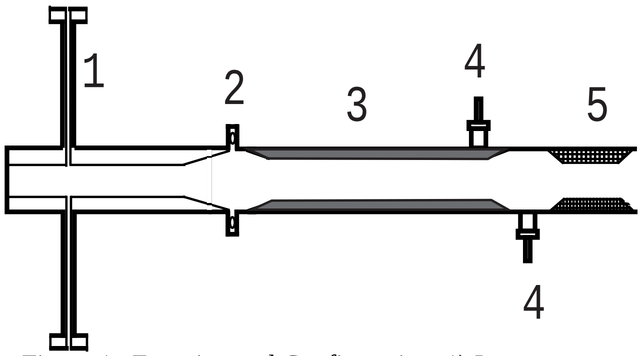

Figure 1. Experimental Configuration. 1) Input structure, 2) Rogowski coil, 3) Dielectric Amplifier 4) Output Wave E Field probes, 5) Microwave absorber

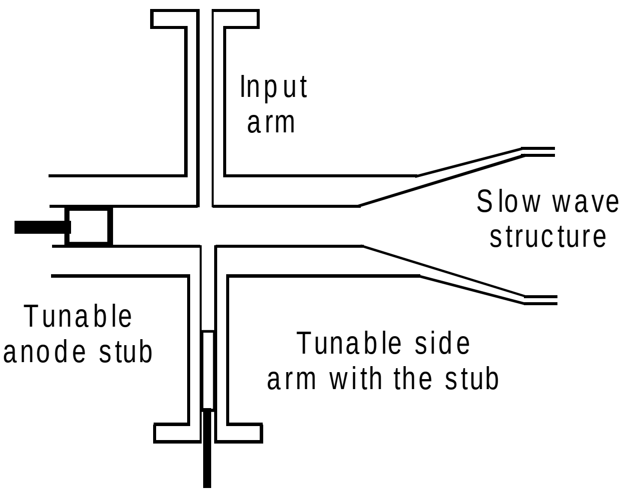

Figure 2. Input coupler.

In typical operation of the amplifier the 250 ns magnetron output pulses are injected via pressurized guide through the input coupler to the amplifier. The coupler tuning elements are adjusted immediately before firing of the beam to maximize the TM_{01} input signal to the amplifier. Although the magnetron source has an output of 40 kW only 10 kW are available at the amplifier input, since the source is kept in the screen room and the waveguide run drops the available power by about 5 dB, limiting the input signal to about 10 kW. The output signal is detected on an electric field probe located in the uniform guide after the output taper. The sampled output is sent to the

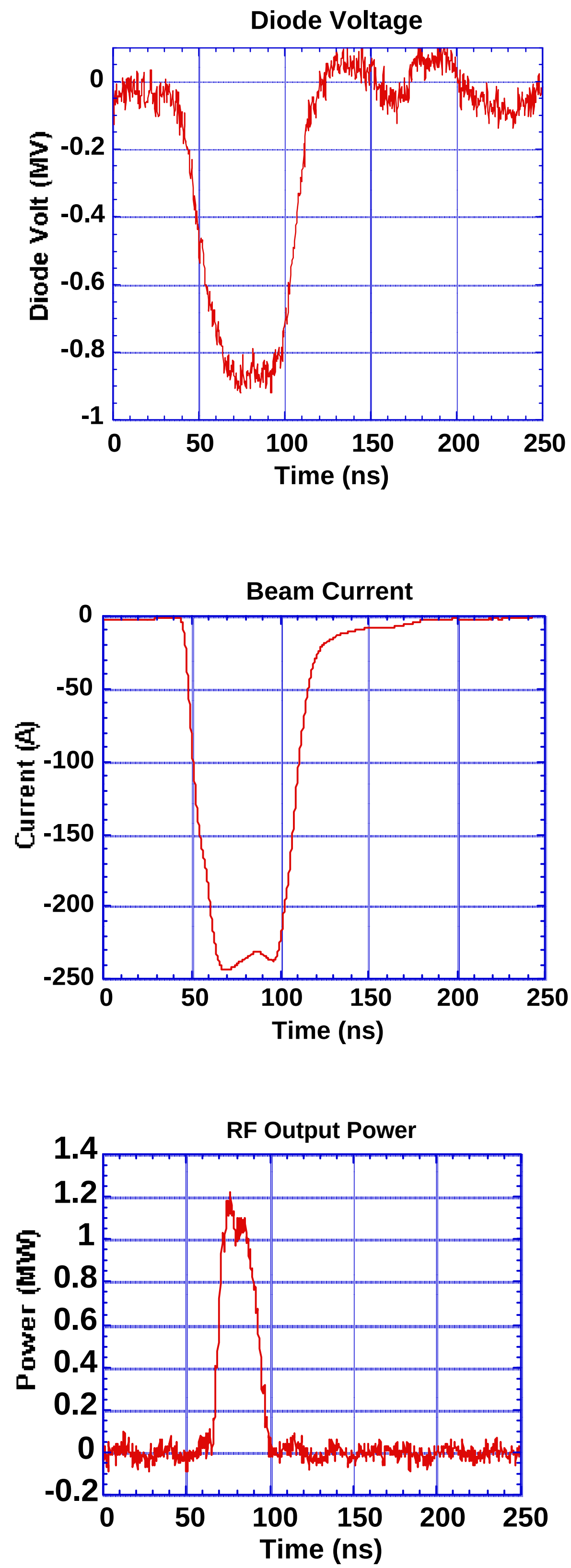

Figure 3. Diode voltage (top trace), Diode current (middle trace), and the RF output signal (bottom)

screen room where the signal is split into two and the envelope detected in one output arm, while the other arm feeds a double balanced mixer with local oscillator input provided by a Gunn diode. The amplifier gain is measured using a substitution technique, comparing the attenuated amplifier signal directly with the input signal measured using the same detector. The attenuation required to reduce the amplifier signal to its input level is a direct measure of the gain.

4 RESULTS

The diode voltage, the diode current and the RF output are shown in Figure 3.

The output signal from the dielectric amplifier as shown in Figure 3 (bottom) has the same length as the "flat" top of the beam current. The output signal is found to track the input frequency and power level for the frequency range available of 34-35.2 GHz and for variations of a factor of 2 in the input power level. Peak output signals of 1.2 MW were obtained with a pulse duration matching that of the pulse power. Typically the data showed a gain of 17.5 ± 2.5 dB.

In Figure 4 we show a heterodyned waveform which illustrates that the amplified output is single frequency. The frequency of the amplified signal matches the frequency of the magnetron input.

We have examined, using a computer calculation the effect of the beam temperature on the gain. For a current of I= 275A at a beam energy of V=0.875MeV, and for an amplifier length of 30cm we find the gain of the

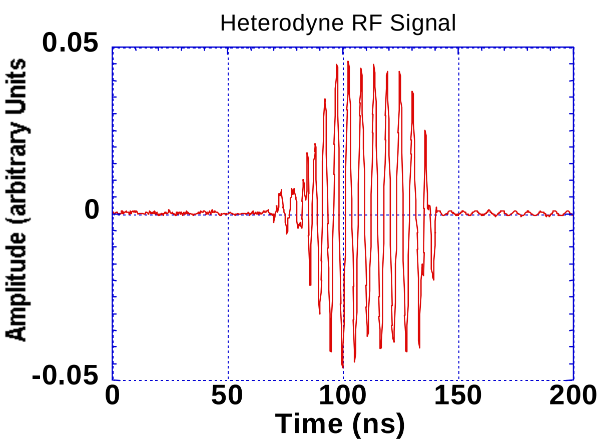

Figure 4. Heterodyne Output Signal. The local Oscillator frequency was 34.6 GHz.

system drops from 22dB to 16dB when the on the energy spread during the 50ns duration of the energy spread at the input increases from 0 to 15%. Based on this calculation we can place an upper limit pulse of 10%. The beam source in these experiments was a field emission tip.

5 CONCLUSIONS

We have successfully tested a 35 GHz dielectric TWT amplifier using a relativistic electron beam as the primary power source. The diode produced an adequate quality electron beam guided by a 1T magnetic field. We have gained experience in using Ka band diagnostics to measure the input and output power from the experiment. The HFSS designed coupler was found to work satisfactory over the frequency (~1 GHz) range available from the magnetron. The full range of the available frequency from the magnetron was amplified by the dielectric amplifier. The output RF power was in the range of one megawatt with a gain of 17.5 ± 2.5 dB in the available frequency range of the magnetron (34-35.2 GHz). The RF output results suggest that the amplifier is sensitive to the current level and its variations. Therefore, special attention will have to be paid to the current beam shape and intensity in the future Ka band experiments

6 ACKNOWLEDGEMENT

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7 REFERENCES

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