YALE Ka-BAND FACILITY FOR HIGH-GRADIENT ACCELERATOR R&D: STATUS REPORT*

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Abstract

Development of a future multi-TEV warm collider demands new technological solutions and new accelerator structure materials. The Ka-Band test facility being put into operation at Yale University that centers on the Yale/Omega-P 34 GHz magnicon allows users to carry out high gradient experiments on RF breakdown, pulse fatigue, tests of new high power pulse manipulation systems, and RF components. Prior to installation of the barrier windows on the output the magnicon was conditioned for a pulse width up to 1 μsec, and an output of 25 MW, high enough for basic studies of electric and magnetic RF field limits at surfaces of conductors and dielectrics. The high power waveguide transmission system for the facility was assembled and installed in February 2007. The system includes RF windows, phase shifters, 13 mm diameter TE_{11} waveguides, mode converters, and high-power vacuum loads. Recently the assembled system has undergone conditioning in preparation for carrying out the first user experiments.

Ka-BAND TEST FACILITY

The Ka-Band test facility consists of the Yale/Omega-P 34 GHz magnicon and the recently installed high power transmission system.

Yale/Omega-P 34 GHz Magnicon

The heart of the test facility is the Yale/Omega-P 34 GHz magnicon shown surrounded by blue shielding bricks in Figure 1. Details of the magnicon and its operation have been published elsewhere [1]. In February 2007 the magnicon was opened to allow the installation of barrier windows and other transmission line components described in the next section, necessary in order to configure the magnicon into a test facility.

Prior to opening, the magnicon reliably produced in excess of 25 MW at 34.3 GHz with pulse widths of 500 nsec or more [2]. This represents over 6 MW per arm on the magnicon output.

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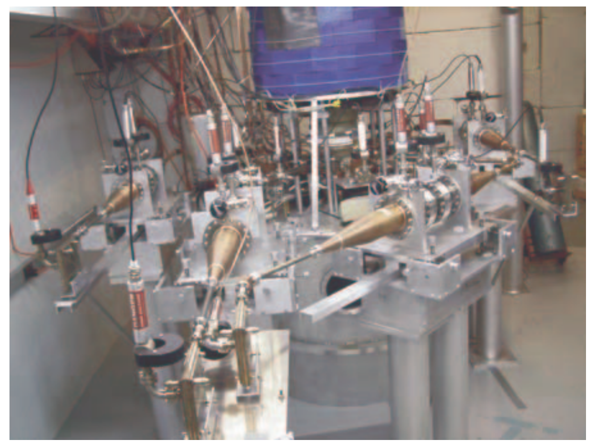

Figure 1: The Ka-Band test facility is shown installed in the Beam Physics Lab at Yale University. The magnicon is in the background below the blue shielding and the four output arms are shown connected to their respective transmission lines.

After opening, re-conditioning the magnicon together with conditioning of the transmission line system started and continues as of this writing. As the initial planned experiments require no more than 1.5 MW, the conditioning was centered around achieving this power level. Shown in Figure 2 is an output pulse with a peak power of 1.5 MW in a 500 nsec pulse from one of the four output arms. Also shown are the gun voltage and current in the collector for this case. All waveforms are an average over 16 shots. Conditioning continues to recover the >25 MW output that was achieved prior to installation of the barrier windows.

The pulse width for a stable flat pulse is currently limited by the modulator voltage waveform, which varies by approximately ± 1% over the flat top region. Later this year an all solid state Marx bank is to be delivered from Diversified Technologies Inc. (DTI) to replace the line-type modulator currently in operation. The specification

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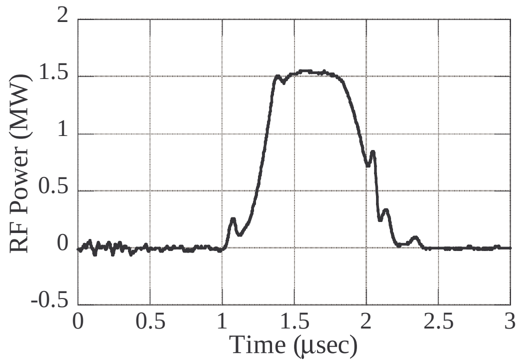
for the voltage uniformity over the flat top region of the pulse in the DTI unit is less than ±0.5%.



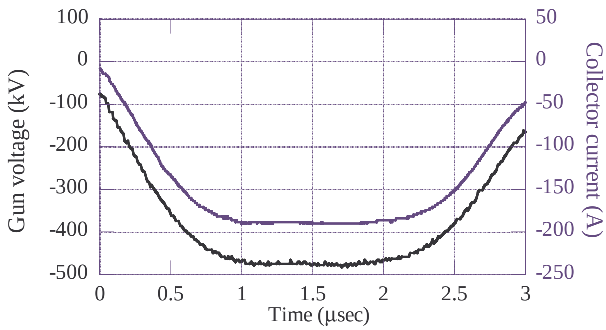


Figure 2. Magnicon power from one of the four outputs (top trace); and gun voltage and collector current (bottom trace).

High Power Transmission System

The transmission line system, shown in Figure 1, consists of a dual directional coupler and a phase shifter in WR-28 followed by a mode converter from WR-28 to TE_{11} circular 13 mm waveguide. Straight 13 mm waveguides and bends bring the output power to a 63.5 mm barrier window which consists of an up-taper from 13 mm to 63.5 mm waveguide, a pumping port, the barrier window, another pumping port, then followed by a 63.5 mm to 13 mm down-taper. Additional 13 mm waveguide and bends are followed at present by a 13 mm circular to WR-28 taper and the WR-28 high power vacuum loads. The vacuum loads will be replaced by user's experiments as these are scheduled for running.

Some care was taken prior to installation of the barrier windows, since the tapers had internal reflections that caused standing waves in the assemblies. The lengths of the assemblies were adjusted using spacers between the components to move any standing wave resonances out of the operating band of the magnicon. Insertion losses in the transmission line system over the operating band of the magnicon were measured to be less than 1 dB.

FIRST USER EXPERIMENTS

There are three experiments currently in line to use the test facility and each is briefly described below.

Pulsed Heating and Fatigue

An experiment to study pulsed heating and surface fatigue due to magnetic stresses in a variety of materials has been designed and will be the first experiment utilizing the Ka-band test facility [3]. The device, pictured in Figure 3, consists of a TM_{011} cavity with a protrusion designed to maximize the magnetic stress on the tip. Initial experiments will be with copper to compare results of this experiment with prior work. Other metals and alloys are to be studied as well.

Figure 3: Picture of the pulsed heating cavity awaiting installation.

Breakdown Tests of Materials

An experiment designed to study the breakdown of materials due to electric stresses has been built and is shown in Figure 4. The experiment [2] consists of a cavity operating in the TM_{020} mode with two pin protrusions facing one another in the center of the cavity. The design is such that the electric field is greater on the surface of the protrusions compared with elsewhere by a factor of 3:1. As with the pulsed heating cavity, various metals, alloys, coatings and surface preparations are to be studied.

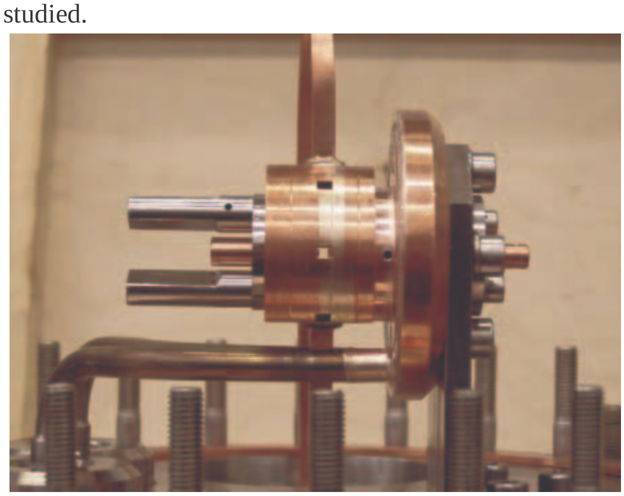


Figure 4: The breakdown test cavity is shown with the vacuum jacket removed. RF power is fed from the WR-28 waveguide entering vertically at the bottom of the picture. A diagnostic WR-28 line is shown at the top.

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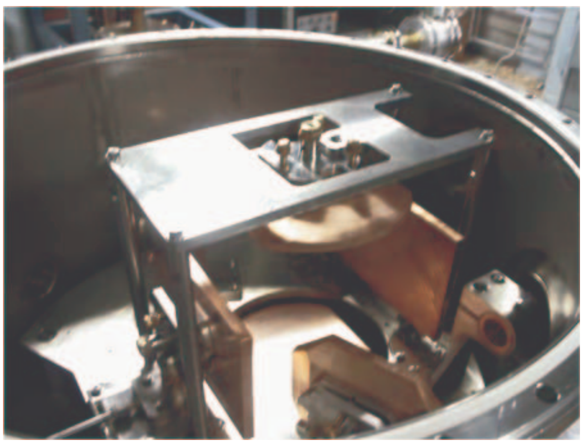
Quasi-optical Pulse Compression

A quasi-optical pulse compressor [4] has been built and is awaiting installation. There are two systems to be studied, a three mirror system and a four mirror system. The latter is pictured in Figure 5. Both systems utilize a Gaussian beam and a mirror cavity resonator. Coupling to the resonator is via a diffraction grating. Both the three mirror and four mirror systems are initially to be passive compressors with power gains in the range 2.5 – 3. An active compressor is also planned where the diffraction grating has nitrogen filled tubes inserted in the grating. When switched the tubes create plasma which changes the diffraction properties of the grating and allows the stored energy to be rapidly discharged. Cold tests of this active system show power gains of 10:1.



SUMMARY

The Yale/Omega-P magnicon in the Beam Physics Lab at Yale University has had barrier windows and transmission lines installed. Conditioning of the new setup has progressed to a point that initial experiments utilizing the 34 GHz RF power can be scheduled and installed. A planned upgrade to a solid state modulator will allow for wider pulses and more reliable operation.

REFERENCES

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