

KA-BAND TEST FACILITY FOR HIGH GRADIENT ACCELERATOR R&D*

M.A. LaPointe¹, A.A. Bogdashov⁵, A.B. Chirkov⁵, G.G. Denisov⁵, A.S. Fix⁵, J. L. Hirshfield^{1,2},
E.V. Kozyrev^{1,3}, S.V. Kuzikov^{1,5}, A.G. Litvak^{2,5}, D.A. Lukovnikov⁵, V.I. Malygin⁵,
O.A. Nezhevenko, Yu.V. Rodin⁵, G.V. Serdobintsev³, S.V. Shchelkunov⁴, M.Y. Shmelyov⁵,
M.I. Petelin^{2,5}, A.L. Vikharev^{2,5}, V.P. Yakovlev²

¹Yale University, 272 Whitney Ave, New Haven, CT, USA,

²Omega-P, Inc., 199 Whitney Ave, New Haven, CT, USA,

³BINP SB RAS, Novosibirsk, Russia,

⁴Columbia University, New York, NY, USA,

⁵IAP/RAS Nizhny Novgorod, Russia

Abstract

Achievement of high acceleration gradients in room-temperature structures requires basic studies of electrical and magnetic RF field limits at surfaces of conductors and dielectrics. Facilities for such studies at 11.4 GHz have been in use at KEK and SLAC; facilities for studies at 17.1 GHz are being developed at MIT and UMD; and studies at 30 GHz are being conducted at CERN using the CLIC drive beam to generate short intense RF pulses. Longer pulse studies at 34 GHz are to be carried out at a new test facility being established at the Yale Beam Physics Laboratory, built around the Yale/Omega-P 34 GHz magnicon. This high power amplifier, together with an available ensemble of components, should enable tests to be carried out at up to 9 MW in 1 μ sec wide pulses at up to four output stations or, using a power combiner, at up to 35 MW in 1 μ sec wide pulses at a single station. RF pulse compression is planned to be used to produce 100-200 MW, 100 nsec pulses or GW level 1 μ sec wide pulses in a resonant ring. A number of experiments have been prepared to utilize multi-MW 34 GHz power for accelerator R&D, and users for future experiments are encouraged to express their interest.

THE KA-BAND TEST FACILITY

The Ka-band test facility in the Yale Beam Physics Lab is centered around the Yale/Omega-P 34 GHz magnicon [1]. Ka-band transmission lines and windows from the four outputs allow the mm-wave power to be transported to up to four experimental areas or to be combined for higher power experiments at a single location.

The Yale/Omega-P 34 GHz Magnicon

The Yale/Omega-P magnicon will provide up to 35 MW of RF power at 34.299 GHz. The magnicon [1,2], shown in Fig. 1, is a frequency tripling amplifier consisting of an 11.433 GHz TM₁₁₀ drive cavity, five TM₁₁₀ gain cavities and a TM₃₁₀ output cavity. There are

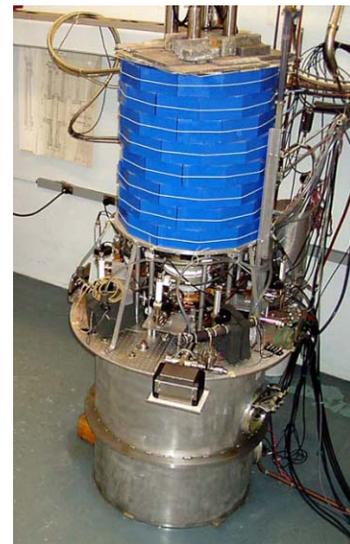


Figure 1. The Yale/Omega-P, 34 GHz magnicon as installed in the Yale Beam Physics Lab

four output arms emanating from the output cavity which will allow up to four independent experiments to be operated at up to 9 MW of RF power each. Current parameters of the magnicon are shown in Table 1.

Table 1: Achieved Magnicon parameters

| | |
|------------------|------------|
| Output Frequency | 34.296 GHz |
| Drive Frequency | 11.432 GHz |
| Power | 26 MW |
| Gain | 57 dB |
| Beam Voltage | 475 kV |
| Beam Current | 200 A |

A set of transverse correction coils was installed across the cathode so as to gently steer the beam to correct for any misalignment in the beam optics. After installation the magnicon produced very stable, repeatable output pulses shown in Fig. 2. There are two regimes found for

*Work supported by U.S. DoE High Energy Physics
#slava@omega-p.com

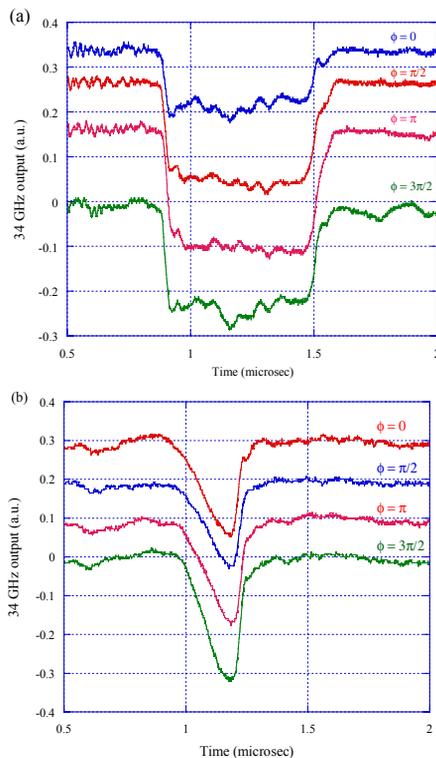


Figure 2. Output power traces showing all four output arms of the magnicon for both long pulse (a) and short pulse (b) operation

the magnicon. First was a long pulse, 500+ nsec, with a maximum output power of 26 MW and second was a short pulse regime, 150 nsec, with a maximum output power of 30 MW. It should be noted that at this time these measurements have yet to be confirmed with calorimetric measurements. Modifications have been made to the magnicon modulator in order to increase the RF pulse width to 1 μ sec. Once this is accomplished, and with an increase in pulse repetition rate to 5 Hz or more, reliable calorimetric measurements can be performed on the magnicon output.

Transmission Line Components

In order to distribute the RF power from the magnicon to the various planned experiments a transmission line system [3] is being installed. Dual directional couplers and high power matched loads in WR-28 waveguide were assembled onto the magnicon when first installed and operated. Phase shifters in WR-28 are to be installed so that when the four arms are combined into a single output any phase difference can be adjusted to maximize the combined power. After the phase shifter is a mode converter from WR-28 to TE₁₁ 13 mm circular waveguide. H-bends, straight sections and pumping ports in 13 mm are to be used to transport the RF power to the experimental stations. Barrier window assemblies which consist of 13 mm to 63.5 mm up/down tapers, 63.5 mm pumping ports and a 63.5 mm alumina window are used to isolate the magnicon vacuum from the experiment

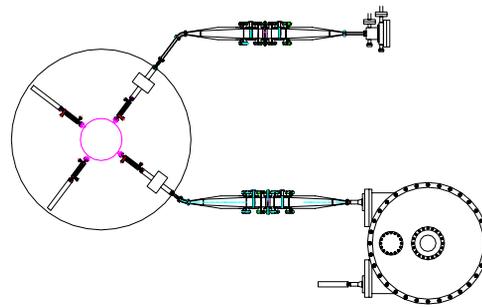


Figure 3. Schematic of Ka-band facility layout showing magnicon on left and two experiments, the pulsed heating at the top and the quasi-optical pulse compressor below.

vacuum system. This allows different experiments to be installed without the need to recondition the magnicon.

The window assemblies are scheduled to be installed in late summer 2006 and are to be operated into matched calorimetric loads for conditioning. In late fall 2006 initial experiments are to be installed on two of the arms as shown in Fig. 3. After the initial experiments which involved only one arm of the magnicon, the four outputs will be combined in order to perform experiments with the full power output from the magnicon sometime in early 2007.

Initial and Future Experiments

There are two initial experiments which are ready to begin and will be connected each to one arm of the magnicon. The first is a pulsed heating experiment [4] which is to study the effects of pulsed heating and surface fatigue near high field regions of accelerating structures. The experiment consists of a cavity designed to maximize the magnetic stress around a nose region. The power requirement to achieve the desired 0.82 MA/m is 1.5 MW. The estimated temperature rise at the surface is 650 °C. This power is already available from a single arm of the magnicon and the experiment, pictured in Fig 4, is awaiting the installation of the barrier windows.



Figure 4. Pictured is the pulsed heating cavity which is awaiting installation onto one arm of the magnicon.



Figure 5. Pictured is one version of the quasi-optical pulse compressor which utilizes a four mirror configuration.

The second experiment is a passive quasi-optical pulse compressor [5] which is to provide a power gain of 2.5 and a pulse compression of four as demonstrated during cold tests. The pulse compressor, pictured in Fig. 5, will be tested initially with one arm and up to 9MW, 0.25 μ sec of input power and provide 22MW, 60 nsec at the output.

An experiment has been designed to bond various materials (Pt, Pd, Ir, Au,...) to copper in order to increase the work function of the resulting surface in an attempt to suppress both primary and secondary electron emission as well as dark current buildup from high field regions in an accelerator. A TM_{030} cavity, shown as a model in Fig. 6, will have capacitive stubs inserted along the axis to induce breakdown on the prepared stubs rather than elsewhere in the cavity. Field enhancement at the stubs is calculated to be 3:1 larger than anywhere else in the cavity. The prepared stubs are to be exposed to increasing levels of RF until a set breakdown rate occurs at which time the stubs will be removed and analyzed.

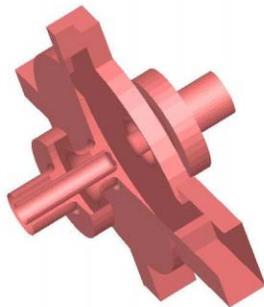


Figure 6. A three dimensional picture of the breakdown cavity is shown which was used to model the cavity and place the maximum electric field on the test stubs.

Other experiments planned include the installation of a resonant ring [6] for testing low loss Ka-band components such as windows, converters, high power bends, etc. at circulating power levels from 200 MW up to 1 GW. Also planned is a diamond lined test accelerator section [7] whose purpose is to find the dielectric surface electric field breakdown limit at 34 GHz.

SUMMARY

A Ka-band test facility is near commissioning in the Yale Beam Physics Lab. The Yale/Omega-P 34 GHz magnicon has achieved parameters which allow the installation of the output windows and transmission line assemblies in mid to late summer 2006. After a conditioning period, pulsed heating and quasi-optical pulse compression experiments will begin late 2006. Material breakdown studies will be performed in early to mid 2007 after which the four outputs of the magnicon will be combined for full power experiments sometime in mid 2007.

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