FERMILAB-CONF-16-685-AD
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Citation: AIP Conference Proceedings **1812**, 060013 (2017); doi: 10.1063/1.4975880
View online: http://dx.doi.org/10.1063/1.4975880
View Table of Contents: http://aip.scitation.org/toc/apc/1812/1
Published by the American Institute of Physics

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

Advanced, Phase-Locked, 100 kW, 1.3 GHz Magnetron

Michael Read[1,b], R. Lawrence Ives[1,a], Thuc Bui[1], Ralph Pasquinelli,[2] Brian Chase,[2] Chris Walker[3] and Jeff Conant[3]

[1]*Calabazas Creek Research Inc., Palo Alto, CA, USA 94404, USA*
[2]*Fermi National Accelerator Laboratory, Batavia, IL, USA 60510, USA*
[3]*Communications and Power Industries LLC, Beverly, MA, USA 01915, USA*

[a)] rli@calcreek.com
[b)] mike@calcreek.com

Abstract. Calabazas Creek Research, Inc., in collaboration with Fermilab and Communications & Power Industries, LLC, is developing a phase-locked, 100 kW peak, 10 kW average power magnetron-based RF system for driving accelerators. Phase locking will be achieved using an approach originating at Fermilab that includes control of both amplitude and phase on a fast time scale.

The magnetron is a highly efficient and relatively inexpensive source of RF power. Magnetrons providing 100 kW with efficiencies exceeding 85% are available at 915 MHz and are commonly used in industrial RF heating systems. However, these are free-running oscillators and not suitable for systems requiring control of the frequency and phase, including many accelerator systems. While the amplitude can be adjusted by varying the beam current, this cannot be achieved on a sufficiently fast time scale for systems requiring feedback control. Calabazas Creek Research, (CCR), Fermilab, and Communications & Power Industries, LLC (CPI) are developing a phase-locked, 1.3 GHz magnetron-based RF system for accelerator applications with frequency, phase, and amplitude control. The peak power and duty cycle will be 100 kW and 10%, respectively. The magnetron will be phase-locked using a system developed by Fermilab [1]. This approach employs phase modulation of the locking signal to produce sidebands that are rejected by a high Q load, such as a superconducting cavity. The power in the sidebands represents a reduction in the power delivered to the cavity, and forms the basis for amplitude modulation on a very fast time scale.

A block diagram of the system being assembled is shown in Fig. 1. The magnetron is driven through its output via a circulator. The power to the cavity is controlled via probe measuring the field in the cavity and a feedback circuit controlling the modulation of the magnetron locking signal. The experiment will use a 2–5 kW RF driver to explore a range of locking scenarios. For the final system, the goal is to lock the magnetron with less than 1 kW. This can be obtained using a reasonably economical, solid-state source.

The program is developing both a suitable magnetron and the requisite electronics. The magnetron design was scaled from a 100 kW CW, 915 MHz device. Since the average power at 1.3 GHz is only 10 kW, the scaling was relatively simple. The first version of the magnetron is complete and has undergone initial testing. The tube is shown in Fig. 2.

The tube was tested with short pulses and low duty, and operated stably in the design (pi) mode at full power. A plot of cathode voltage versus current is shown in Fig. 3.

Advanced Accelerator Concepts
AIP Conf. Proc. 1812, 060013-1–060013-4; doi: 10.1063/1.4975880
Published by AIP Publishing. 978-0-7354-1480-8/$30.00

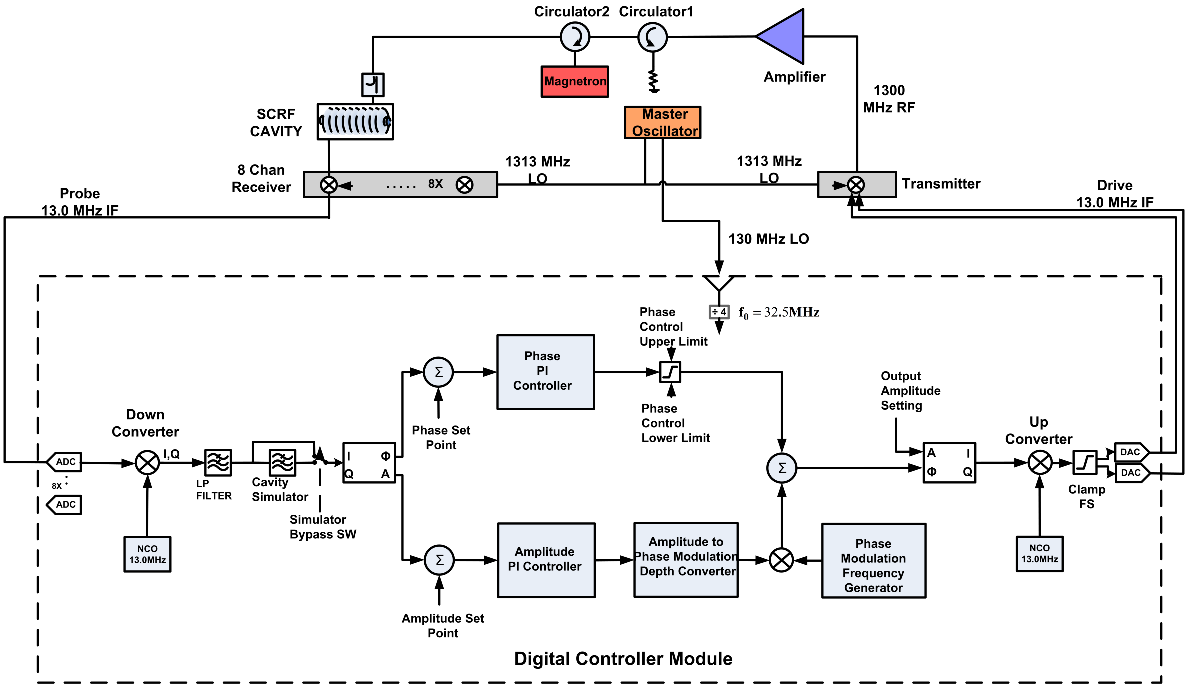

FIGURE 1. Block diagram of the phase-locked magnetron system.

FIGURE 2. 100 kW peak power, 1.3 GHz magnetron.

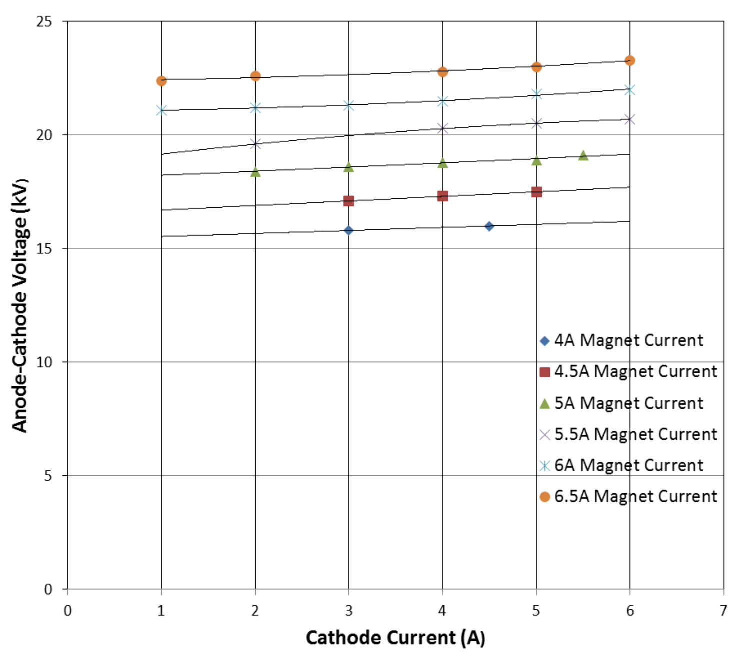

FIGURE 3. V-I Characteristics of magnetron at varying electromagnet current values from initial short pulse tests.

The system was assembled into a portable package, as shown in Figs. 4 and 5. The principal components are the magnetron, a 5 kW klystron amplifier used to lock the magnetron, the power supply for the klystron, a circulator for coupling into the magnetron, and a diagnostics and control package. The circulator is from Ferrite Microwave Technologies, LLC. Two 3-port circulators are tuned as a single unit to provide the 4-port capability required for the system. The klystron will provide more power than required to lock the magnetron, which will allow flexibility in the initial experiments. It is intended that the klystron will be replaced with a lower power, solid-state source for the final package.

The electronics that control the feedback loop and the phase modulation incorporates a Field Programmable Gate Array for stable operation with a superconducting cavity. This is similar to the system developed by Fermilab [1].

The system is scheduled to be tested in the fall of 2016. This will be followed by testing on a superconducting cavity at Fermilab.

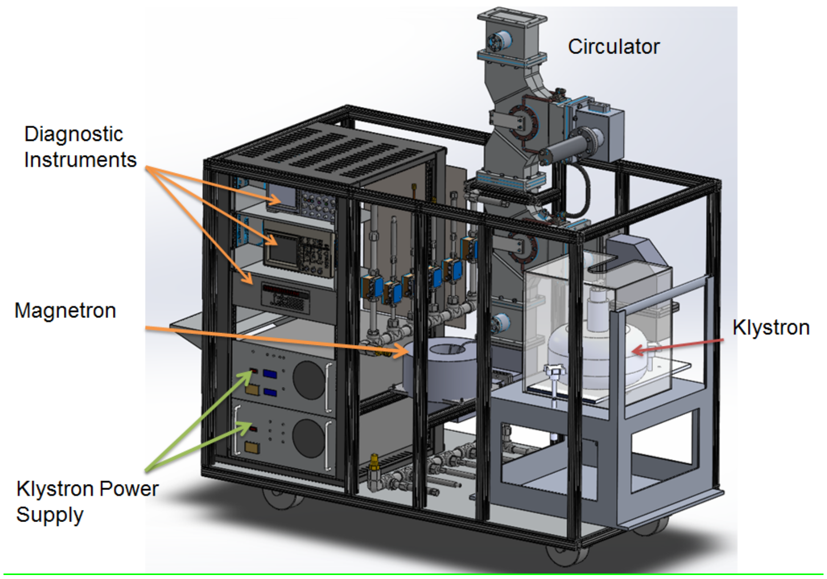

FIGURE 4. Layout of the magnetron system.

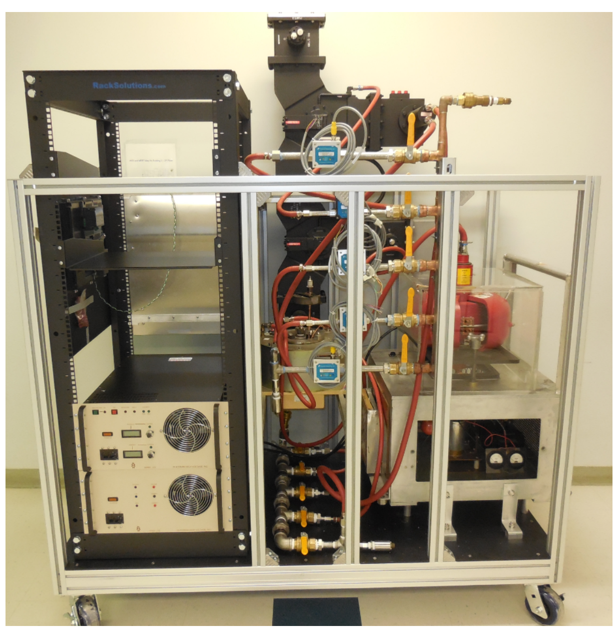

FIGURE 5. Magnetron system prior to installation of diagnostic electronics

ACKNOWLEDGMENTS

This work is funded by the United States Department of Energy under SBIR contract DE-SC0011229.

REFERENCE

1. 1. B. Chase, R. Pasquinelli, E. Cullerton and P. Varghese, "Precision Vector Control of a Superconducting RF Cavity driven by an Injection Locked Magnetron," J. Instrum., **10**, P03007 (March 2015).