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Muons Inc Master CRADA with Annex A for Magnetron Development

Cooperative Research and Development Agreement Final Report

CRADA Number: FRA-2017-0026

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Summary Report
24 July 2019

NOTICE

In accordance with Requirements set forth in Article XII.A(2) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

CRADA number: FRA-2017-0026

CRADA Title: Muons Inc Master CRADA with Annex A for Magnetron Development

Parties to the Agreement: Muons, Inc. and Fermi Research Alliance, LLC

Abstract of CRADA work:

Modern CW or pulsed superconducting accelerators of megawatts beams require efficient RF sources controllable in phase and power. It is desirable to have an individual RF power source with power up to hundreds of kW for each Superconductive RF (SRF) cavity. For pulsed accelerators the pulse duration in millisecond range is required. The efficiency of the traditional RF sources (klystrons, IOTs, solid-state amplifiers) in comparison to magnetrons is lower and the cost of unit of RF power is significantly higher. Typically, the cost of RF sources and their operation is a significant part of the total project cost and operation. The magnetron-based RF sources with a cost of power unit of 1-3 dollars per Watt would significantly reduce the capital and operation costs in comparison with the traditional RF sources. This arouses interest in magnetron RF sources for use in modern accelerators. A recently developed kinetic model describing the principle of magnetron operation and subsequent experiments resulted in an innovative technique producing the "stimulated" generation of magnetrons powered below the self-excitation threshold voltage. The magnetron operation in this regime is stable, low noise, controllable in phase and power, and provides higher efficiency than other types of RF power sources. It allows operation in CW and pulse modes (at large duty factor). For pulsed operation this technique does not require pulse modulators to form RF pulses. It also looks as a promising opportunity to extend magnetron life time.

Summary of Research Results:

An innovative technique was developed, allowing a pulsed RF generation of a magnetron without modulation of the cathode voltage, while the tube is powered below the self-excitation threshold. A pulsed resonant injected signal with power ≥ -11 dB of the magnetron nominal power is required for such operation. The technique was substantiated by the developed kinetic model of the magnetron operation representing the principle of RF coherent generation of the tube. Experiments with a 2.45 GHz magnetron proved the developed technique. The CW magnetron operating in the “stimulated” mode has efficiency higher than for its operation in a “free run” or driven by small (≤ -20 dB) injected signal. The latter cases relate to the traditional regimes when the tube operates above the self-excitation threshold. The magnetrons powered below the self-excitation threshold and driven by the sufficient resonant signal provide higher conversion efficiency, significantly lower (by ≈ 20 dB/Hz) spectral power density of noise and significantly wider (up to hundreds of kHz) the phase control bandwidth. The developed innovative mode of magnetron operation demonstrates properties attractive for superconducting CW and pulsed accelerators with megawatts beams. Performed estimates of the cathode sputtering in high power CW magnetrons support expectations for extended lifetime of the magnetrons applicable for modern accelerator projects.

Related Reports, Publications, and Presentations:

Report: https://arxiv.org/ftp/arxiv/papers/1905/1905.04550.pdf

Subject Inventions listing:

None

Report Date: 7-24-19

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