2006

Reactor Physics Studies for the AFCI Reactor-Accelerator Coupling Experiments (RACE) Project

Denis Beller
University of Nevada, Las Vegas

Task 27
Reactor Physics Studies for the AFCI Reactor-Accelerator Coupling Experiments (RACE) Project

D. Beller

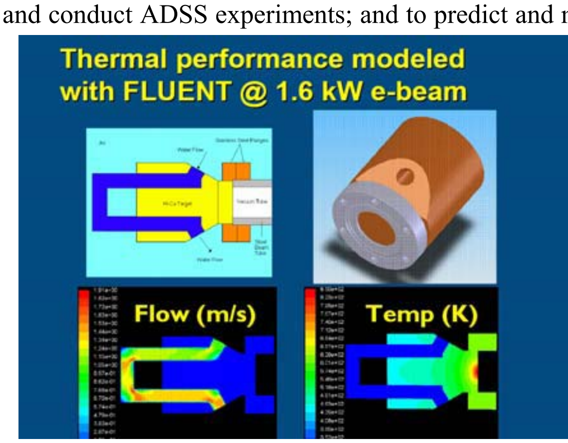
BACKGROUND

In the RACE Project of the Advanced Fuel Cycle Initiative, a series of accelerator-driven subcritical systems (ADSS) experiments were conducted at the Idaho State University's Idaho Accelerator Center (ISU-IAC) and at the University of Texas (UT) at Austin. In these experiments, electron accelerators are used to induce bremsstrahlung photon-neutron reactions in heavy-metal targets. They produce a neutron source of 0.8 to 1.0 x 10^{12} n/s per kW of electron beam, which will then initiate fission reactions in the subcritical systems. These subcritical systems include a compact, transportable assembly at ISU and a TRIGA reactor at UT-Austin. A variety of fuel and assembly geometries are being studied. The use of compact accelerators and a small target allow the target to be placed in various positions in or adjacent to these subcritical assemblies to "map" the coupling of driven neutron sources; measuring core coupling and mapping adjoint flux.

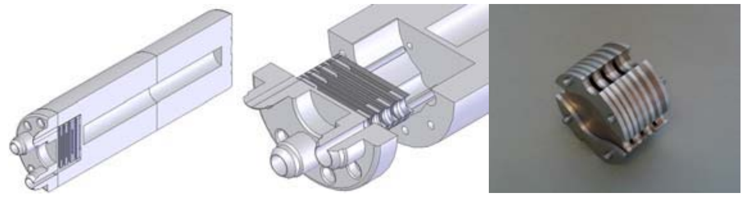
The RACE Project is an important intermediate step between the recent European program MUSE and a future near full-scale demo. For design of full scale ADSS, a complete knowledge of the effects of the driving neutron source is essential. This will ultimately require spectral, temporal, directional, and intensity fidelity in prototype experiments. In the absence of this fidelity, simulated sources should match some of the characteristics of projected driving sources to build confidence in predicting performance of these systems, and codes and methods must be validated. The RACE Project will provide experience in a higher energy range (above 14.1 MeV) and with a stronger and more isotropic source than the MUSE experiments.

RESEARCH OBJECTIVES AND METHODS

The specific research objective of this three-year project is to design and conduct an accelerator driven experiment. This experiment will help demonstrate in the U.S. the ability to design, compute, and conduct ADSS experiments; and to predict and measure source importance, coupling efficiency, sub-critical reactor kinetics and source-driven transients. In addition, databases will be created for both steady state and transient ADSS experiments for the nuclear community to develop and test new computational codes and methods, and the importance of a driving neutron source in various regions of different subcritical assemblies will be mapped. Experiments will be conducted and compared to calculations with radiation transport and thermal-hydraulics codes such as MCNPX and RELAP.



Modeling of the Texas RACE target with FLUENT computational fluid dynamics code.



High-power RACE Target. The left is a cutaway drawing of the full assembly as assembled showing the target, water cooling channels, and electron-to-photon converter plates. The middle picture is a close-up of the plate assembly and water cooling channels. At the right is a photograph of tungsten-copper converter plates and spacer assembly with alignment pins.

RESEARCH ACCOMPLISHMENTS

Modeling for Texas RACE

UNLV examined the thermal performance of the accelerator target for experiments to be conducted at UT-Austin with their TRIGA reactor. A MCNPX (LANL radiation transport code) model was developed to produce energy deposition data for thermal analysis of the Texas RACE target. FLUENT, a computational fluid dynamics code, was then used to predict the thermal performance of the target.

High-power Target Design

A new high-power, uranium-containing water-cooled target for the RACE Project was designed, constructed and tested. The design included a tungsten electron-photon converter, an aluminum cooling shroud, and aluminum-clad natural uranium photon-neutron converter. After analyzing and constructing a prototype of a compact version of the Cooled Electron Target — Optimized for Neutron production (CETON), it was determined that a design change was needed. The new design includes a multiple plate tungsten electron-photon converter, an aluminum cooling shroud, and a cavity for inserting an aluminum-clad natural uranium photon-neutron converter. The CETON was assembled in Nevada and successfully leak tested with high-pressure water. The finished High-Power RACE (CETON) Target was then assembled and tested at the Idaho Accelerator Center with lead beads substituted for the uranium rod. Thermal and neutron production performance with an electron linac were measured.

As a result of their design, acquisition, fabrication, and construction, the students won the UNLV Mechanical Engineering Senior Design Competition for their design of the High-Power RACE Target.

Reactor Physics Studies

A variety of code systems for modeling neutron generation and transport and thermal feedback effects in accelerator-driven TRIGA as well as other reactors were evaluated. Code systems considered were ERANOS, RELAP, PARCS, and APOLLO. Modeling with MCNPX was initiated in support of subcritical experiments at the Idaho Accelerator Center and of target design studies for Texas RACE. Electron beam/target interactions were studied for maximizing and characterizing photoneutron production from high-energy electrons.

Experiments

UNLV collaborated with ISU and CEA in a series of accelerator-driven subcritical (ADS) experiments at the Idaho Accelerator Center. A fuel loading/criticality measurement experiment was conducted in the ISU RACE Subcritical Assembly (SCA). This measurement was followed by a series of ADS experiments using a low-power, 20-MeV electron accelerator coupled to the SCA with a tungsten-copper neutron generating target. Results are being analyzed.

Components of the CETON (Cooled Electron Target — Optimized for Neutron production) excluding tungsten-copper disks for converting electrons to photons. The W-Cu disks fit in the cavity at the upper left. In addition, the body is bored to accept a 10" aluminum-clad uranium photo-neutron generator.

ACADEMIC YEAR HIGHLIGHTS

- D. Beller, F. Harmon, T. Ward, and F. Goldner, "Update on the AFCI Reactor-Accelerator Coupling Experiments (RACE) Project," *Proceedings of the Nuclear Criticality Safety Division 2005 Conference*, Knoxville, TN, Sept 21, 2005.
- D. Beller and J. Knebel, "Phase IV of the RACE Project: European Collaborations," *Transactions of the American Nuclear Society, 93*, Washington, DC, pp. 901-902 (2005).
- D. S. O'Kelly, D. Beller, and W. S. Charlton, "Accelerator Driven Subcritical System Experiments at The University of Texas," *Transactions of the American Nuclear Society, 93*, Washington, DC, p. 903 (2005).
- V. K. Taraknath Woddi, S. OKelly, T. Green, and D. Beller, "Reactor-Accelerator Coupling Experiments (RACE): Heat Generation Rates Using W-Cu and U Targets, W. S. Charlton," *Transactions of the American Nuclear Society, 93*, Washington, DC, pp. 904-906 (2005).
- J. Chen, D. Beller, F. Harmon, and K. Sabourov, "ISU Accelerator-Driven Sub-critical System Characterization," *Transactions of the American Nuclear Society, 93*, Washington, DC, pp. 907-908 (2005).
- D. Beller, Overview of the AFCI Reactor-Accelerator Coupling Experiments (RACE) Project, *Proceedings of the Eighth Information Exchange Meeting on Actinide and Fission Product Partitioning & Transmutation*, OECD/NEA, Paris, France, pp 495-504 (2005).
- D. Beller, A. Hunt, J. Bennion, M. Reda, K. Sabourov, R. Spaulding, and K. Folkman, Initial Results from the AFCI Reactor-Accelerator Coupling Experiments (RACE) Project, *Proceedings of the Eighth Information Exchange Meeting on Actinide and Fission Product Partitioning & Transmutation*, OECD/NEA, Paris, France, pp 699-710 (2005).
- T. Beller, B. Howard, R. LeCounte, and D. Beller, "High-Power Accelerator Target Design for the AFCI RACE Project," *Proceedings of the 2006 International High Level Radioactive Waste Management Conference*, 2006.

FUTURE WORK

UNLV will focus on conducting subcritical experiments at ISU and completing the evaluation of the CETON high-power RACE target. The ADSS experiments will focus on increasing the level of subcriticality of the ISU RACE assembly, evaluation of results, and comparison to Monte Carlo modeling. The target work will include further testing at the Idaho Accelerator Center and analysis of results using MCNPX and FLUENT.

Research Staff

Denis Beller, Principal Investigator, Research Professor, Department of Mechanical Engineering

Students

Evgeny Stankovskiy, Graduate Student, Department of Mechanical Engineering
Shruti Patil, Graduate Student, Department of Electrical and Computer Engineering
Timothy Beller, Brice Howard and Ryan LeCounte, Undergraduate Students, Department of Mechanical Engineering

Collaborators

George Imel, Argonne National Laboratory
John Bennion and Alan Hunt, Idaho State University
William Charlton, Texas A&M University
Sean O'kelly, University of Texas at Austin
John C. Lee, University of Michigan