Phase IV of the RACE Project—European Collaborations

Denis E. Beller

RACE Project Director
Idaho Accelerator Center, Idaho State University, 1500 Alvin Ricken Dr., Pocatello, ID 83209
beller@egr.unlv.edu

and

Joachim U. Knebel

Co-ordinator of Integrated Project EUROTRANS
Forschungszentrum Karlsruhe, Hermann von Helmholtz Platz 1, 76344 Eggenstein-Leopoldshafen
ipeurotrans.knebel@nuklear.fzk.de

INTRODUCTION

Accelerator-driven subcritical systems (ADSS) research is being conducted as one component of transmutation engineering research in the U.S. Department of Energy's Advanced Fuel Cycle Initiative (AFCI).[1] The only ADSS experiments program in the U.S. is the Reactor-Accelerator Coupling Experiments (RACE) Project, which is centered at the Idaho Accelerator Center of Idaho State University (ISU-IAC), and is a well-known university transmutation research project. RACE Project experiments will be conducted in 2005 and 2006 at ISU-IAC (Phase I), at the University of Texas (UT) at Austin (Phase II), and at Texas A&M University (Phase III).[2, 3, 4]. In these experiments, source neutrons are generated by using electron accelerators to produce bremsstrahlung photons that then induce photon-neutron reactions in heavy-metal targets. These compact, transportable accelerator/target systems produce a source of ~10^{12} n/s, which then initiate fission reactions in the subcritical systems. In RACE the ADSS will include a compact, transportable subcritical assembly at ISU and TRIGA reactors at UT-Austin and Texas A&M. Recent changes in international programs as well as the potential to increase beam power, neutron generation, fission power, and thermal feedback effects have resulted in a new phase of the RACE Project, a collaboration with European programs.

Unique features of the RACE Project:

- Only U.S. experimental research with subcritical accelerator-driven assemblies.
- Neutron source from compact, reliable, transportable electron linear accelerators.
- Wide variety of accelerator/reactor configurations:
  - up to five target/core/reflector configurations,
  - different fuels (20% and 70% enrichment, rods and plates, U-Al and U-ZrH),
  - a range of fuel exposure histories, from fresh cores to spent cores, and
  - different accelerator beam targets.
- Ability to examine three-dimensional effects of source location, to map source importance, and to study ADSS with multiple accelerators and/or targets.
- Ability to examine start-up and shut-down procedures with thermal feedback.
- Ability to examine near-critical reactor dynamics, e.g. $k_{eff} = 1-\beta$ to $1+\beta$, with a short-pulse neutron source.
- Five U.S. universities lead this effort for the nation: ISU, Texas A&M, UT-Austin, UNLV, and Michigan

RACE Phase IV: High-power RACE with EUROTRANS-ECATS Collaboration

The purpose of accelerator coupling studies is to demonstrate ADSS concepts and to develop as complete as possible an understanding of source terms and their coupling to subcritical reactors. This understanding is necessary for the construction of demonstration and prototype transmutation facilities, such as the European XT-ADS (eXperimental demonstration of the technological feasibility of Transmutation in an ADS) and EFIT (European Facility for Industrial Transmutation), which are investigated in the Integrated Project EUROTRANS (EUROpean Research Programme for the TRANSmutation of High Level Nuclear Waste in an ADS) of the EURATOM 6th Framework Programme (FP6).[5] Additionally, ADSS experiments are used to validate and benchmark computer codes for use in designing safe and reliable ADS systems for transmutation purposes. To validate these computer codes and demonstrate that they are applicable to a variety of reactor configurations, a wide array of coupling experiments must be performed. The objective of Domain 2 ECATS (Experimental activities on the Coupling of an Accelerator, a spallation Target and a Sub-critical blanket) of the Integrated Project EUROTRANS is to provide validated experimental input from relevant experiments at sufficient power (20-100 kW) on the coupling of an accelerator, a spallation target and a sub-critical blanket. These experiments should provide design input on the dynamics and experimental techniques of such a coupled system with feedback effects, together with shielding, safety and licensing issues.

In the U.S. RACE Project, we initially planned a limited number of experiments with each configuration, along with limited instrumentation and measurements, at low beam and reactor powers. However, following cancellation of the proton-spallation phase of the TRADE Project,[6] ECATS participants are now available to expand the benefits of the RACE Project by participating in design, planning, and execution of experiments in the U.S.

RACE collaborations with ECATS engineers will permit a much broader range of experiments including more detailed measurements with a wider range of instruments. ECATS-RACE collaborators can contribute expertise in target design and analysis (neutronics, thermalhydraulic performance, and reduction of residual radiation/doses), planning of reactor experiments (both critical and driven subcritical), and analysis (using MCNPX, KTAR, and other codes). In addition, equipment that was previously used for MUSE and TRADE (e.g. fission chambers, EM shielding, Piccolo micromegas, and data acquisition systems) may be available to enhance the RACE instrumentation and data acquisition. Thus, contributions that the ECATS group will make toward the RACE Project will enhance our technical success, will advance the significance of our project in the overall advanced nuclear energy arena, and will promote academic involvement and education and training, which is one ultimate goal of both the RACE and EUROTRANS Projects. The exchange of staff between Europe and the U.S., especially the exchange of Ph.D. students and post-doctoral staff, is a major component of the joint R&D and training activities.

In addition, with the participation of ECATS we will investigate the potential to increase neutron generation by one to two orders of magnitude, which may allow us to drive high-average-power experiments with significant, and easily measured, thermal feedback. In a separate effort the IAC is investigating connecting a high-power modulator and klystrons to existing 20 and 25-MeV linacs. This new configuration, which will be tested during 2005-2006, would provide 20 to 30 MW of electron current, compared to 1 to 2 MW with the existing ISU RACE and Texas RACE accelerators. In addition, we are investigating incorporating depleted or natural uranium into existing heavy metal targets to increase the photon-neutron yield. The combination of these two enhancements, if successful, will generate 5×10^{13} to 10^{14} n/s in the center of the Texas TRIGAs. With this new source strength, we will be able to perform studies in the range of 100-150 MW_{th}, which will provide very reliable thermal feedback information as well as start-up and shut-down experience.

Thus, the RACE-ECATS collaboration can yield a much broader set of data for code verification, which will greatly benefit both the U.S. and European transmutation research programs. This project will help attract students to nuclear science and technology, provide them a diverse nuclear science education, including experience in international collaborations, and train them in operation and modeling of accelerator-driven systems as well as in measuring reactivity of subcritical systems.

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