Wolf Udo Schröder
(Professor of Chemistry and Physics))**:**

RESEARCH INTERESTS
Basic and applied nuclear science: Nuclear transfer, thermo-nuclear fusion and breakup reactions at low energies, nuclear plasma physics, nuclear thermodynamics. Light-ion reactions in a thermonuclear environment. Physico-chemical transport processes in interactions of tritium with metals.

Udo Schröder's **Nuclear Science Research Group** has continued research in radiation and nuclear science, specifically in light-ion or neutron induced reactions on light nuclei (^{2,3}H, ^{6,7}Li, ^{9}Be). In collaboration with a group at the **L**aboratory for **L**aser **E**nergetics (LLE), we have pursued the project *Laser Ion Acceleration for Nuclear Science* (LIANS) with experimental campaigns at the **M**ulti **T**era **W**att (MTW)laser facility. These preparatory experiments were designed to investigate efficiencies of tritium loading of metallic converter target foils. The latter serve as temporary reservoirs for the particles released and accelerated following irradiation with intense laser flashes. Several target fabrication methods were developed and tested by Physics graduate student Arnold Schwemmlein. In these studies, deuterium functioned as chemical equivalent to tritium, whose radioactivity would have complicated and even precluded corresponding experiments with tritium-loaded targets. To date, these efforts have succeeded in producing the first controlled low-energy (MeV) LIANS deuterium beam at the MTW laser. A series of scaled-up experiments, first with deuterium and then with tritium loaded targets, are under way at the most powerful LLE laser systems Omega/EP. Arnold has presented some of these results at several meetings of the APS and is working on a publication.

The NSRG also collaborated with the LLE-nuclear physics group in experiments studying neutron scattering and neutron-induced breakup with targets of deuterium and the lithium isotopes ^{6}Li and ^{7}Li. Experimental data are not only of technical interest for fusion research. They are relevant also for tests of modern nuclear structure theory and for nuclear astrophysics. The experiments utilized the ultra-bright flashes of up to 10^{14} neutrons released in Omega laser shots. In such a shot, a small deuterium/tritium gas cell is uniformly irradiated by many short-pulsed (*ps-ns*) laser beams leading to *inertial-confinement fusion* (ICF) explosions. Several journal publications and presentations at APS meetings have emerged from this work.

Our previous radio-chemical experimental study of tritium transport in metals has prompted further, specialized experimentation and analysis. Again, the experimental data have practical import for fusion R&D; but they also have more general relevance for industrial use of hydrogen. Recent research by Chemistry graduate students Cody Fagan and Dan Bassler and our LLE collaborators has focused on physio-chemical properties that influence tritium absorption on metal surfaces and the further transfer into the lattice. Stainless-steel samples were coated with films of Al_2O_3 using atomic layer deposition (ALD), before exposure to a tritium gas phase. The ALD method produces thin (~20-40 nm) films that are conformal, at angstrom-level precision, to the actual surface topology. Radio-chemical study of the inventory depth profile of the treated samples showed that most (~ 80%) of the total tritium inventory is confined to the alumina surface layers. Only the smaller remainder seems to diffuse further into the lattice. Here, hydride formation can lead to weakening of the lattice structure. In addition, with ALD "designer" coatings produced at elevated temperatures (~200°C), the total uptake of tritium by metallic samples could be significantly (x1/2) reduced, as compared to untreated metal. These studies have exhibited non-trivial, interesting depth profiles of hydrogen content in metals exposed to hydrogen gas. The findings await theoretical explanation and demand further, specific investigation. This research has been reported in several publications and have been presented by Cody and Dan at national and international conferences. Cody was awarded a Department travel grant to the 12th International Conference on Tritium Science and Technology - April 2019, Busan, South Korea, where he presented his PhD research. He has been extremely busy as a presenter at various topical meetings on tritium technology.

Group Publications

"Nuclear science experiments with a bright neutron source from fusion reactions on the OMEGA Laser System," by C.J. Forrest,, J.P. Knauer, W.U. Schröder , V.Yu. Glebov, P.B. Radha, S.P. Regan, T.C. Sangster, M. Sickles, C. Stoeckl, J. Szczepanski, Nuclear Instruments and Methods in Physics Research A 888, 169–176 (2018)

"A Platform For Nuclear Physics Experiments With Laser Accelerated Light Ions," by C. Stoeckl, C. J Forrest, V. Yu. Glebov, S.P. Regan1, T.C. Sangster, W. U. Schröder, A. Schwemmlein, W. Theobald, Nuclear Instruments and Methods in Physics Research B 453, 41-49 (2019)

"Deuteron breakup induced by 14-MeV neutrons from inertial confinement fusion," by C. J. Forrest, A. Deltuva, W. U. Schröder, A. V. Voinov, J. P. Knauer, E. M. Campbell, G. W. Collins, V. Yu. Glebov, O. M. Mannion, Z. L. Mohamed, P. B. Radha, S. P. Regan, T. C. Sangster, and C. Stoeckl, Physical Review C 100, 034001 (2019)

"The Impact of Acid Treatments and Elec- tropolishing Stainless-Steel Surfaces on Tritium Inventories", by C. Fagan, M. Sharpe, W.T. Shmayda and W.U. Schröder, Fusion Science and Technology, 71:3. 2017

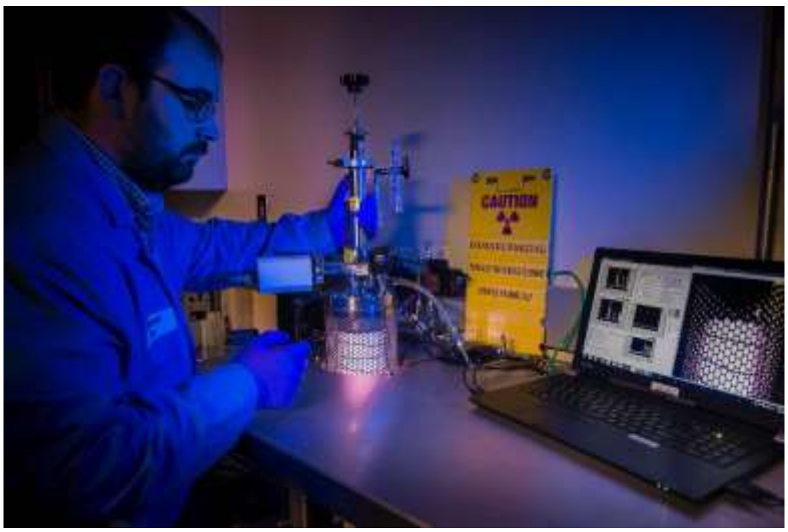
"Partitioning of tritium between surface and bulk of 316 stainless steel Surfaces at room temperature," by M. D. Sharpe, C. Fagan, W.T. Shmayda, and W. U. Schröder, Fusion Engineering and Design, Vol. 130, 76-79 (2018)

Tritium Retention in Hexavalent Chromate-Conversion-Coated Aluminum Alloy," by C. Fagan, M. D. Sharpe, W.T. Shmayda, and W. U. Schröder,
Fusion Science and Technology, DOI:10.1080/15361055.2019.1610308,1, (2019).

”Distribution of tritium in the near surface of stainless-steel 316”, M.D. Sharpe, C. Fagan, W.T. Shmayda, Fusion Science and Technology, 75:8, 1053-1057, 2019.

The most recent Ph.D. graduates from the Nuclear Science Research Group are all doing well: Former student Sheth Nyibule teaches Freshman physics at the Rochester Institute of Technology, Eric Henry is busy developing the next generation of semiconductor computer chips at INTEL, while Matt Sharpe, just promoted to a research associate position at LLE, will continue working there (with our colleague Dr. Walter Shmayda) on the tritium fuel cycle and remain an important resource for our development of a tritium beam for the LIANS platform at the Omega/EP facility.

The junior graduate students Arnold Schwemmlein and Cody Fagan have received



their respective MS degrees in physics or chemistry. Arnold has been working on GEANT simulations of light-ion reactions, with ^{9}Be(d,n)^{10}B as a first test case. His main task is to design and test a LIANS adaptation for unique triton beams. To supplement his training in applied nuclear reactions, Arnold attended a 10-day TRIUMF summer school on astrophysics at Vancouver/Canada. On the radio-chemical side, Cody has embarked on a detailed study of surface effects in tritium absorption, storage, and desorption by metals. He has obtained specialized skills and now enjoys using a host of advanced equipment and methods (ALD for modification, XPS, SEM, AFM for analysis) available on Campus for the study of metallic surfaces. The photograph shows him at his plasma desorption setup, now at LLE. As the most recent addition to the group, Daniel Bassler has finished his teaching assignments in Chemistry. With Cody, he is now busy testing various methods to alter metal surfaces in a controlled fashion.

Results of the group’s research have been reported in journal and book publications, as well as in invited lectures. Udo has published another book (WSPC); this most recent one reports on Nuclear Particle Correlations and Cluster Physics and represents joined efforts by research teams on four continents. He also presented an invited lecture at the International Workshop on Finite System in Nonequilibrium in Natal/Brazil. During a week in summer at the ACS Summer School on Nuclear Chemistry at Brookhaven National Laboratory, he lectured on nuclear structure concepts and applications.

Publications

Book:

W. U. Schröder (Editor): *Nuclear Particle Correlations and Cluster Physics,*
World Scientific Publishing Co, Singapore, 2017, 572 pages

Articles

"'Necklace' Cluster Fragmentation of the Dinuclear System in Dissipative Reactions,"
S. O. Nyibule, M. J. Quinlan, E. Henry, H. Singh, I. Pawelczak, J. Tõke, W. U. Schröder, and the CECIL Collaboration, LNS Catania
Invited article in ***Nuclear Particle Correlations and Cluster Physics,*** (W. U. Schröder, Editor) World Scientific Publishing Co, Singapore, pp. 537-558 (2017)

"The Impact of Acid Treatment and Electropolishing Stainless-Steel Surfaces on Tritium Inventories,"
C. Fagan, M. Sharpe, W.T. Shmayda, and W. U. Schröder,
Fusion Science and Technology, Vol. 71, 275-280 (2017)

"Nuclear science experiments with a bright neutron source from fusion reactions on the OMEGA Laser System,"
C. J. Forrest, J. P. Knauer, W. U. Schroeder, V. Yu. Glebov, P. B. Radha, S. P. Regan, T. C. Sangster, M. Sickles, C. Stoeckl, and J. Szczepanski
Nucl. Inst. and Methods in Physics Research A, 2017, in press

Lectures

"Nuclear structure: Concepts and Applications."
Series of 10 lectures at the ACS Summer School in Nuclear Chemistry, Brookhaven National Laboratory, July, 10-15, 2017.

"Forced Cluster Correlations: Aligned Multiple Cluster Emission in Dissipative Reactions,"
Inv. Talk, Int. Workshop Finite Systems in Non-equilibrium: From quantum quench to the formation of strong correlations." Natal/Brazil, Sept 22, 2017