EMSL Research and Capability Development Proposals

Nonlinear Radiation Response and Transport Properties in Scintillating Materials

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Scintillation response has wide applications in the field of astronomy, medical physics, high-energy nuclear physics, non-destructive evaluation, non-proliferation, and national security. Stringent requirements involving nuclear proliferation, national security, and defense have prompted urgent needs for new radiation detector materials with excellent energy resolution (<2%) at room temperature, which has attracted attention toward accelerated materials discovery. Due to a general lack of fundamental understanding of the underlying scintillation physics, the field of radiation detection has reached an impasse.

The objective of this proposed work is to develop fundamental understanding of nonlinear radiation response to ionization/excitation and transport properties in advanced scintillating materials. The novelties in the proposed work were single-ion excitation and electronic ionization, as well as controllable ion-crystal interactions so the scintillation response can be quantitatively studied with additional control and separation of mechanisms over a continuous energy region. The ultimate goal was taking advantage of better-understood ion-solid interactions to determine nonlinear radiation response, energy partitioning, and transport mechanisms of scintillation physics. This knowledge will provide a pathway for predicting relationships between material properties and performance and for optimizing advanced scintillators. The single-ion excitation technique, as well as the ion beam induced luminescence and electron beam induced luminescence methods developed as part of this project, allows examination of material response to external energy excitation in both single crystalline materials and nanoparticles. A few benchmark scintillating materials, where dramatically different behaviors are observed under gamma irradiation, were studied using the single-ion excitation technique, as shown in Figure 1. The light yield, nonlinearity, and energy resolution were measured over a wide energy region of interest. Emission spectra of CdSe/ZnS core/shell quantum dot composites were also studied to develop a fundamental understanding of the scintillation physics of ion- and photon-nanoparticle interactions in the composite structures.

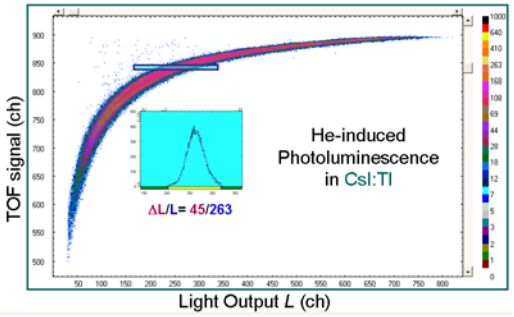

Figure 1. *Time-of-Flight (TOF) versus light output (L) of CsI:Tl to He^+ ions. The inset is an example where L=263 is determined for particles with certainty energy (TOF=840). The energy resolution can be determined by ΔL/L = 45/263. The light-energy dependence and energy resolution can be observed as the difference in curvature and dispersive of the data.*

Products and Output

New Capability for EMSL Users

The results from this project provide a pathway to understand the underlying scintillation physics and to aid in the development of new materials for radiation detection applications. The research also produced a *new capability—Ion Beam Induced* and *Electron Beam Induced Luminescence*.

We designed and constructed an optical analysis system for measuring both ion beam induced luminescence and electron beam induced luminescence, as shown in Figure 2, where photons produced from ion-solid or electron-solid interactions are collected into fiber optics and guided into a spectrograph and a matching charge coupled device (CCD).

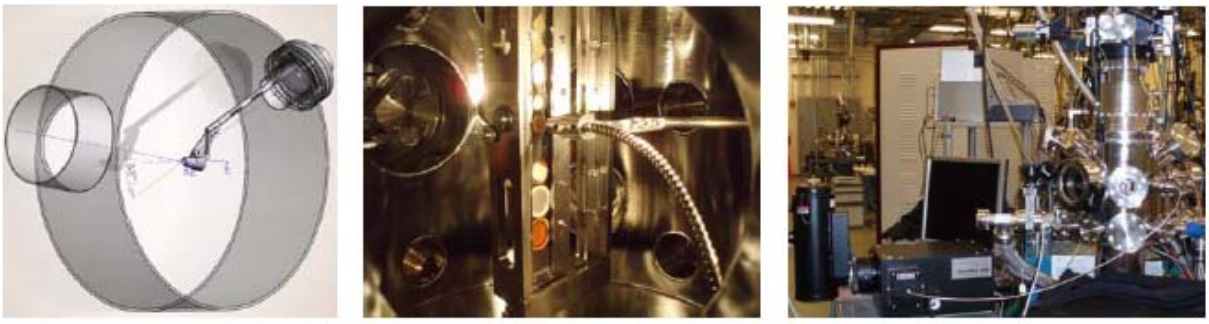

Figure 2. The optical analysis system: schematic drawing (left), sample holder and fiber optics inside chamber (middle), and optical measurement setup outside the chamber (right).

Publications

Zhang Y. and W.J. Weber. 2009. "Response of materials to single ion events." *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 267(8-9):1705-1712. DOI: 10.1016/j.nimb.2009.01.104.

Zhang Y., X. Xiang, J.L. Rausch, X. Zu, and W.J Weber. 2009. "Ion Technique for Identifying Gamma Detector Candidates." *IEEE Transactions on Nuclear Science* 56(3):920-925. ISSN: 00189499.

Presentations[1]

Zhang Y. 2009. "Ion-beam techniques to study signal generation mechanisms in radiation detector materials." presented at the *19th International Conference on Ion Beam Analysis (IBA-2009)*, September 7-11, 2009, Cambridge, United Kingdom.

Shutthanandan V. 2009. "Synthesis and characterization of Ga doped ZnO films for scintillation applications." presented at the *19th International Conference on Ion Beam Analysis (IBA-2009)*, September 7-11, 2009, Cambridge, United Kingdom.

Zhang Y. 2009. "Ion-induced and Photon-induced Scintillation in CdSe/ZnS Core/shell Nanoparticles." presented at the *19th International Conference on Ion Beam Analysis (IBA-2009)*, September 7-11, 2009, Cambridge, United Kingdom.

[1] Since there were presentations supported by other projects presented at the same conferences, no fees for corresponding travel and labor were charged to this Intramural Project.

Zhang W.[2] 2009. "Ion-, electron- and Photon-induced Scintillation in MgO." presented at the *19th International Conference on Ion Beam Analysis (IBA-2009)*, September 7-11, 2009, Cambridge, United Kingdom.

Zhang Y. 2009. "Ion Methods for Material Research at the EMSL Accelerator Lab." presented at a *Université Paris-Sud 11 Seminar*, April 21, 2009, Orsay, France.

Shutthanandan V., Y. Zhang, T.C. Kaspar, B. Arey, Z. Zihua, Z. Wang, W. Zhang, and M.H. Engelhard. 2008. "Synthesis and characterization of Ga doped ZnO films for scintillation applications." presented at the *20th International Conference on the Application of Accelerators in Research and Industry*, August 10-15, 2008, Fort Worth, Texas.

Zhang W., G. Li, R. Linares, S. Sangyuenyongpipat, M.G. Warner, B.W. Arey, V. Shutthanandan, and Y. Zhang. 2008. "Ion Beam-Nanoparticle Interactions for Radiation Detection." presented at the *Pacific Northwest Chapter-AVS Symposium 2008*, September 18-19, 2008.

Zhang Y., F. Gao, and Y. Xie. 2008. "Scintillation Response and Transport Properties in CsI:Tl." presented at *COSIRES2008: The 9th International Conference on Computer Simulation of Radiation Effects in Solids*, October 12-17, 2008, Beijing, China.

Zhang Y., F. Gao, and Y. Xie. 2007. "Scintillation Response and Transport Properties in CsI:Tl." presented at the *Materials Research Society (MRS) Fall Meeting*, November 26-30, 2007, Boston, Massachusetts.

[2] Ph.D. student and EMSL user.