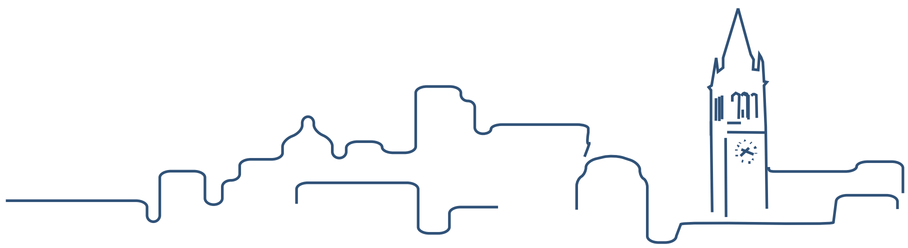

1st Workshop on Special Topics in Homeland Nuclear Security

July 22 -24, 2009

International House, University of California, Berkeley

Berkeley, CA

WEDNESDAY, July 22nd, 2009

9:00 – 12:00

Plenary Opening Session

Talks are 30 minutes.

LTC Nicholas Prins, US Department of Homeland Security
Mission of the Transformational and Applied Research Directorate

Prof. Edward C. Morse, University of California at Berkeley
DoNuTS activities in NRF and Machine Vision

Prof. Dorit S. Hochbaum, University of California at Berkeley
The Role of Data Cluster Analysis in Homeland Nuclear Security

10:30 – 11:00

Break

Prof. William Bertozzi, Passport Systems
Review of Nuclear Resonance Fluorescence Fundamentals

Dr. Dennis P. McNabb, Lawrence Livermore National Laboratory
Searching for illicit materials using nuclear resonance fluorescence simulated by narrow-band photon sources

12:00 – 1:30

Lunch*

1:30 – 3:15

Machine Vision I

All session talks are 20 minutes long plus 5 minutes allotted for questions.

Prof. Vikas Singh, University of Wisconsin-Madison
An efficient algorithm for Co-segmentation

Dr. Daniel Chivers, University of California at Berkeley
Machine Vision Radiation Detection System: The Multiple Object Problem

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*Please note that lunch is *not* catered. For a list of restaurants in the area please refer to the page located at the front of this binder.

Dr. Nils Krahnstoever, GE Global Research
Video Analytics Applications in Security and Homeland Protection

Dr. Barak Fishbain, *University of California at Berkeley*
Nuclear Threat Detection with Mobile Distributed Sensor Networks

3:15 – 3:45
Break

3:45 – 5:00
NRF I:
Data and Applications

Dr. Glen Warren, Pacific Northwest National Laboratory
Applications of Nuclear Resonance Fluorescence

Prof. Hugon Karwowski, University of North Carolina, Chapel Hill
Dipole states in ^{235}U and ^{238}U

Dr. Chris Angell, University of California at Berkeley
Preliminary results from Nuclear Resonance Fluorescence Measurements on ^{237}Np

5:30 – 6:30
Reception and Poster Session

THURSDAY, July 23nd, 2009

9:00 – 10:15

NRF II: Accelerators

Dr. Chris P. J. Barty*, Lawrence Livermore National Laboratory*
Efforts and future plans at the LLNL related to MEGa-ray source development.

Dr. Felicie Albert, Lawrence Livermore National Laboratory
Isotope specific detection with T-REX : LLNL's Bright, tunable, laser-based Mono-energetic gamma-ray (MEGa-ray) source

Prof. Donald Umstadter, University of Nebraska-Lincoln
Development of a Laser-Based, Tunable, Monoenergetic, MeV X-Ray Source

10:15 – 10:45

Break

10:45 – 12:30

Machine Vision II

Mr. Matt Wu*, California Institute of Technology*
Combinations of Mobile and Static Sensors for Detecting Nuclear Radiation

Dr. Ofer Hadar, Ben-Gurion University
Compression of infrared imagery sequences containing a slow moving point target

Dr. Tom Karnowski*, Oak Ridge National Laboratory*
Fusion of visible light and gamma ray imaging for portable portal monitoring

Dr. Kevin Wood*, Naval Postgraduate School*
Network Interdiction Models for Detecting Smuggled Nuclear Materials

12:30 – 2:00

Lunch

2:00 – 3:15
NRF III
Data and Applications

Dr. **Christian Hagmann**, Lawrence Livermore National Laboratory
Detector Backgrounds in NRF cargo interrogation systems

Mr. **Curtis Hicks**, Passport Systems
Nuclear Resonance Fluorescence: Applications, Capabilities and New Frontiers

Mr. **Brian Quiter**, University of California at Berkeley
Modeling of NRF Applications in Nuclear Safeguards

3:15 – 3:45
Break

3:45 – 5:00
NRF IV:
Accelerators

Dr. **James Hall**, Lawrence Livermore National Laboratory
Monte-Carlo Based Simulations of proposed MEGa-ray (NRF) applications

Dr. **Miro Shverdin**, Lawrence Livermore National Laboratory
Status and Plans for Mono-Energetic Gamma-ray (MEGa-ray) Source Development and Applications at LLNL

Dr. **Scott Anderson**, Lawrence Livermore National Laboratory
Inverse Free-Electron Laser Accelerators of Compact, High Flux Compton-scattering based light sources

7:30
Dinner

Please find the menu included.

FRIDAY, July 24th, 2009

9:00 – 10:15
NRF V:
Accelerators

Dr. Tsahi Gozani, Rapiscan Systems
Old but useful concept of accelerator based neutron generator for HS inspection

Dr. Gil Travish, UCLA
Particle Beam Based Gamma Ray Sources for Stand-off Detection of SNM

Dr. Charles Yeamans, University of California at Berkeley
Development of Experimental Physics Capabilities at UC Berkeley for National Security-Related Research

10:15 – 10:45
Break

10:45 – 12:00
NRF VI

Dr. Tsahi Gozani, Rapiscan Systems
Delayed Gamma Rays as a Fission Signature from Photofission

Dr. Dan Chivers, University of California at Berkeley
Electron-track Compton Imaging using High Resolution CCD Detectors

Dr. Bethany Goldblum, University of California at Berkeley
The Role of Surrogate Reactions in the Search for New NRF States

12:00 – 2:00
Lunch

2:00 – 3:00
Tours

Dr. **Charles Yeamans**, University of California at Berkeley
UC Berkeley DoNuTS project NRF Laboratory

Dr. **Dan Chivers**, University of California at Berkeley
UC Berkeley DoNuTS project MV Laboratory

Abstracts

Wednesday, July 22nd, 2009

LTC Nicholas Prins, US Department of Homeland Security

Mission of the Transformational and Applied Research Directorate

The Transformational and Applied Research Directorate (TAR) was established within DNDO to conduct, support, coordinate, and encourage an aggressive transformational program of Research and Development (R&D) that will dramatically improve national capabilities to detect and report attempts to import or transport a nuclear device, Special Nuclear Material (SNM), or radiological materials intended for illicit use.
TAR seeks to identify, explore, develop, and demonstrate scientific and technological approaches that address gaps in the Global Nuclear Detection Architecture (GNDA), dramatically improve the performance of nuclear detection components and systems, or significantly reduce the operational burden of radiological/nuclear detection. Transformational R&D is carried out within three major programs: Advanced Technology Demonstrations (ATD), Exploratory Research (ER) and Academic Research Initiative (ARI). This talk will discuss the mission of TAR; as well as topics of interest for this workshop.

Prof. Edward C. Morse, University of California at Berkeley

DoNuTS activities in NRF and Machine Vision

The Domestic Nuclear Security Technology (DoNuTS) project at UC Berkeley is a four-pronged effort with research programs in advanced materials for radiation detection, data mining and pattern recognition techniques for detection, nuclear data, and signal processing and networks for radiation detection. All of these areas contribute in some way to the two topics of this conference. Specifically this talk will highlight the group's participation in NRF data for special nuclear material isotopes, image segmentation techniques for video-assisted radiation imaging, and investigation of novel photon production methods for NRF active interrogation sources. We will describe our current activities as well as future experimental plans, including the utilization of a 3.5 MeV/7.0 MeV tandem pelletron accelerator for projects in the areas described above.

Prof. Dorit S. Hochbaum, University of California at Berkeley

The Role of Data Cluster Analysis in Homeland Nuclear Security

We present in this talk several clustering and image segmentation algorithms. These algorithms, recently discovered, are the first known efficient algorithms for these clustering/segmentation problem. It is demonstrated that the capabilities of these algorithm permit pattern recognition and the identification of pathologies in real time. The concepts have potential application in Homeland Security applications in general, and domestic nuclear threat detection in particular.

Prof. William Bertozzi, Passport Systems, Inc.

Review of Nuclear Resonance Fluorescence Fundamentals

The fundamental physics underlying nuclear resonance fluorescence (NRF) will be discussed and related to the phenomenology of the process. The topics elaborated include cross sections, angular distributions, radiative widths, Doppler broadening, zero point motion, temperature effects, molecular and crystalline binding, recoil shifts, absorption spectroscopy and other aspects that make NRF a powerful tool for research in physics and a fundamental tool for material identification. The relation to some nuclear properties such as magnetism, charge polarization, spins and collectivity will be presented. Advantages and limitations of bremsstrahlung as a photon source and the usefulness of monochromatic sources will be discussed along with important backgrounds and their dependence on specific sources. Detector parameters and choices are related to specific NRF techniques, scattering and absorption. Examples of promising applications will be discussed in areas such as forensics, product verification, material analysis and detection of special nuclear materials.

Dr. Dennis P. McNabb, Lawrence Livermore National Laboratory

Searching for illicit materials using nuclear resonance fluorescence simulated by narrow-band photon sources

We study the sensitivity of two distinct classes of systems that exploit nuclear resonance fluorescence to search for illicit materials. One class of systems infers the presence of a particular isotope by observing the preferential attenuation of photons that excite a nuclear resonance. A separate class of systems detects resonantly scattered photons. We have performed benchmark experiments of both approaches for a variety of different scenarios at Duke University's High Intensity Gamma Source and developed an analytic model that reproduces our results. The model is limited to systems based on photon sources with an energy spread $< \sim 10\%$ and an angular spread $< \sim 10$ mrad. We estimate the performance of conceivable future systems for certifying containers as free of illicit materials and for detecting the presence of those same materials.

Dr. Vikas Singh, University of Wisconsin-Madison

An efficient algorithm for Co-segmentation

The Co-segmentation problem - where the objective is to segment a similar object from a pair of images. The background in the two images may be arbitrary; therefore, simultaneous segmentation of both images must be performed with a requirement that the appearance of the two sets of foreground pixels in the respective images are mutually consistent. Existing approaches cast this problem as a Markov Random Field (MRF) based segmentation of the image pair with a regularized difference of the two histograms – assuming either a Gaussian prior on the foreground appearance or by calculating their sum of squared differences. Both are interesting formulations but lead to difficult optimization problems, due to the presence of the second (histogram difference) term. The model presented here bypasses measurement of the histogram differences in a direct fashion, we show that this enables obtaining efficient solutions to the underlying optimization task. Our new algorithm is similar to the existing approaches in spirit, but differs substantially in that it can be solved to optimality in polynomial time using a maximum flow (graph-cuts) procedure on an appropriately constructed graph. We discuss our ideas and present promising experimental results which include an application to an important medical imaging problem.

Dr. Daniel Chivers, University of California at Berkeley

Machine Vision Radiation Detection System: The Multiple Object Problem

Machine vision is the ability to recognize object patterns within video streams in order to ascertain information that may be vital to a specific problem. For the development of a machine vision application for radiation detection, the information gained from object recognition will be a 3D position and time that can be merged with data from gamma-ray imaging detectors. The correlation of the movement of objects and changes in the gamma-ray imaging detectors can be used to improve detection sensitivity or give more information to users once a threat is detected. The DoNuTS ARI group is currently testing a number of techniques of combining video streams with a large number of sodium iodide detectors that can be tested in a number of configurations. The primary focus of this work is to quantify the impact of various gamma-ray imaging detection schemes ranging from simple one over R-squared response, passive and active coded masks, and Compton imaging within machine vision applications. The results of this study will produce trade-off relationships between gamma-ray imaging efficiency, angular resolution, object speed and complexity, and detection efficiency for various implementations.

Dr. Nils Krahnstoever, GE Global Research

Video Analytics Applications in Security and Homeland Protection

The GE Intelligent Video system has been developed to enable a wide range of security and homeland protection applications. It is a flexible system that combines computer vision components from the areas of biometrics, person and vehicle detection, site-wide tracking, object recognition and many others.

We will provide a general overview of our computer vision technologies and discuss several homeland security focused applications and deployments and integration with non-video sensor modalities.

In addition we will specifically discuss our current work on Target Linked Radiation Imaging (TLRI), which combines video with Intelligent Personal Radiation Locators (IPRL) to enable the detection and tracking of vehicles and people that may carry nuclear materials. The TLRI system under development will consist of one or more small-sized CZT Compton cameras for radiation detection and multiple CCTV security cameras for target tracking. The combined system will detect moving radiation sources under conditions where traditional Compton effect based localization fails due to an insufficient number of detected gamma events.

Dr. Barak Fishbain, University of California at Berkeley

Nuclear Threat Detection with Mobile Distributed Sensor Networks

The ability to track illicit radioactive source in an urban environment is critical in national security applications. To this end, two modes of operation are common: positioning individual portal monitors, and deploying a network of distributed sensors. We address here the use of multiple detectors, mounted on moving vehicles, for the purpose of detecting nuclear threats. An example scenario is that of multiple taxi cabs each carrying a detector. The detectors' positions are known in real-time as these are continuously reported from GPS data. The level of detected risk is then reported from each detector at each position. The problem is to delineate the presence of a potentially dangerous source and its approximate location by identifying a small area that has an elevated concentration of reported risk. This problem of using spatially deployed mobile detector networks to identify and locate risks is modeled and formulated. The problem is shown to be solvable in polynomial time and with a combinatorial network flow algorithm. The efficiency of the algorithm enable its use in real time, and in areas containing a large number of deployed detectors. A simulation study, that takes into account false-positive and false-negatives reports from individual sensors, demonstrates the effectiveness of the algorithm in using the sensor network's detection capabilities.

Dr. Glen Warren, Pacific Northwest National Laboratory

Applications of Nuclear Resonance Fluorescence

Nuclear resonance fluorescence (NRF) is a photon-based active interrogation approach that provides isotope-specific signatures that can be used to detect and characterize samples. Photon energies are in the range of a few MeV, so that penetration through significant material is possible. Unlike other active interrogation techniques that are based on inducing fission, NRF is sensitive to a wide range of isotopes: for example 11B, 12C, 13C, 14N, 16O, 27Al, 208Pb, 235U, 238U and 239Pu just to name a few. NRF is most likely to outperform existing technologies for applications requiring isotopic information of sealed samples. Pacific Northwest National Laboratory is conducting a review of potential applications that could be addressed by NRF techniques. These applications cover a wide range of topics, from geo-location, to material assay, to safeguarding the nuclear fuel cycle. The objective of the project is to search for potential applications, define technical requirements, identify physical limitations, conduct an initial assessment of the technique and design a research approach for developing the applications. In this talk, our current results for several of the applications will be presented.

Prof. Hugon Karwowski, University of North Carolina, Chapel Hill

Dipole states in ^{235}U and ^{238}U

The presence of a particular isotope can be inferred by observing de-excitations of nuclear levels of gamma-ray transitions characteristic for the isotope of interest using nuclear resonance fluorescence (NRF) techniques. Nearly mono-energetic, high-intensity and 100% polarized gamma-ray beams from the HIGS facility at Triangle Universities Nuclear Laboratory were used to search for low-spin states in ^{235}U *and* ^{238}U*.*We used NRF to measure the widths and multipolarities of 20 newly observed states at excitation energies between 3 and 5 MeV. In my talk I will describe the accelerator facility, the detector system and show the data on the distribution of dipole strength below particle emission threshold. I will also discuss nuclear structure aspects of the presented data.

Dr. Chris Angell, University of California at Berkeley

Preliminary results from Nuclear Resonance Fluorescence Measurements on ^{237}Np

Nuclear resonance fluorescence can be an effective tool to identify specific isotopes for security and safeguards applications. It is ultimately limited by the availability of data for each isotope. Existing NRF data is currently limited to only five actinide nuclei. The nuclear database needs to be expanded to make NRF a practical tool. In particular, ^{237}Np presents significant safeguard challenges; it is fissile yet currently has fewer safeguard restrictions. NRF measurements on ^{237}Np will expand the nuclear database and will permit designing active interrogation systems.

Measurements were made using the bremsstrahlung beam at the HVRL at MIT on a 7 g target of ^{237}Np with two incident electron energies of 2.8 and 3.1 MeV. Preliminary results of the analysis will be presented.

Thursday, July 23nd, 2009

Dr. Chris P. J. Barty, Lawrence Livermore National Laboratory

Efforts and future plans at the LLNL related to MEGa-ray source development.

Optimally-designed, laser-based, inverse Compton sources produce highly-directional, polarized, mono-energetic gamma-ray (MEGa-ray) beams that can have peak photon brilliance at 1 MeV 15 orders of magnitude beyond that of the world s brightest synchrotrons. This revolutionary leap in source brightness enables a host of new nuclear applications in which the photon interacts primarily with the protons of the nucleus and not the valence electrons. Nuclear resonance fluorescence (NRF) is efficiently excited by MEGa-rays and enables isotope-specific detection, assay and imaging of concealed objects and materials.

This presentation will review the past decade's efforts and future plans at the Lawrence Livermore National Laboratory related to MEGa-ray source development and specific optimization for NRF-based, isotope-specific detection, assay and imaging applications. Currently LLNL is constructing the first 3rd generation MEGa-ray machine: a compact, high flux source that will simultaneously increase MEGa-ray source flux by 5 orders of magnitude from previous machines and decrease MEGa-ray source size by nearly 2 orders. This new machine will utilize high power, diode pumped laser technology and high gradient x-band accelerator technology developed by the Stanford Linear Accelerator Center. The aim of the new machine is to both provide the laboratory photons necessary to validate the efficacy of NRF-based detection, assay and imaging systems and to provide the technical path forward for construction of field-deployable, mobile MEGa-ray sources for homeland security, nuclear waste management, stockpile surveillance etc.

Dr. Felicie Albert, Lawrence Livermore National Laboratory

Isotope specific detection with T-REX : LLNL's Bright, tunable, laser-based Monoenergetic gamma-ray (MEGa-ray) source

We present the experimental characterization and applications of T-REX (Thomson-Radiated Extreme X-rays), a bright, tunable, laser-based mono-energetic gamma-ray (MEGa-ray) source commissioned at LLNL. The gamma-rays are produced by Compton scattering of laser photons off relativistic electrons accelerated by a linac. Because the source is narrow band and potentially brighter than any other existing light source above 0.5 MeV, it has a lot of potential applications in homeland security and special nuclear materials assay and detection. We have investigated such applications by detecting the nuclear resonance fluorescence line of 7Li at 0.478 MeV.
The experimentally measured properties (beam profile and spectrum) of the source are those of a Compton scattering source, it is collimated (with the lower divergence along the laser horizontal polarization), and the peak energy of the spectrum varies with 4g2EL, where g is the electron relativistic factor and EL the laser energy. Furthermore, the spectra recorded on a germanium detector agree well with Monte-Carlo simulations performed with the MCNP5 code and with a

relative spectral width of 12 %.

We have used the source to detect the 0.478 MeV nuclear resonance fluorescence (NRF) line of 7Li in a LiH target with two different techniques. First, a 8 cm long LiH sample with a 0.36 g/cm3 density was placed in the beam path, 20 m away from the interaction region, and the NRF scattered photons were detected by another germanium detector 15 cm away from the target and oriented at 90o with respect to the incident beam axis. This direct detection has allowed us to detect the NRF line with a confidence superior to 99%. Having detected NRF from 7Li, we investigated another method to ascertain the presence or absence of a given isotope that has the potential to yield lower false positive and negative rates. In this method, first proposed by Bertozzi, gamma-rays are transmitted through the material under interrogation to a reference sample containing the isotope of interest. If NRF is detected from the reference, one can conclude that the interrogated material did not contain the isotope. If no NRF is observed, either the resonant photons have been scattered by the isotope in the interrogated sample, or the material is optically too thick; the latter case can be ruled out by a simple transmission measurement. Since this method relies on the creation of a notch in the transmitted spectrum at the NRF energy by the isotope of interest, the advantages of narrow-band, highly collimated light sources are clear.

Prof. Donald Umstadter, University of Nebraska-Lincoln

Development of a Laser-Based, Tunable, Monoenergetic, MeV X-Ray Source

The results of experiments and numerical modeling will be presented on a project to develop a tunable, monochromatic MeV-energy x-ray source by means of all-laser-driven Compton scattering. X-rays are generated when one laser pulse accelerates an energetic electron beam, from which a second synchronized laser pulse scatters.

The first laser pulse (peak power < 100 TW) is focused on a supersonic helium nozzle to drive a relativistic plasma wave. Electron beams with energies of > 600 MeV are accelerated by means of laser wakefield acceleration. The electron beam is measured to have an angular spread of < 5 mrad. Remarkably, the acceleration region is < 5 mm in length. High electron beam stability and reproducibility result from the use of a stable and well-characterized laser system, in conjunction with high laser contrast and adaptive optical phase correction.

When a second laser pulse from the same laser system is focused onto the laser-driven electron beam, 1-eV energy photons are Doppler-shifted in energy to > 1 MeV. It is predicted that Compton-scattered x-ray photons can be produced in a well-collimated beam, with up to 2.6 x 10^8 photons per laser shot (operating at 10-Hz repetition rate).

A source of tunable, collimated, monochromatic, MeV-energy photons may provide important advantages for active interrogation of containers and vehicles, particularly those where dose limits are an issue. Nuclear resonance fluorescence spectroscopy and photofission activation analysis can both benefit from the large reduction of wasted radiation dosage and undesired background noise predicted from the use of monochromatic x-rays instead of polychromatic bremsstrahlung.

Mr. Matt Wu, California Institute of Technology

Combinations of Mobile and Static Sensors for Detecting Nuclear Radiation

A team of computer scientists and physicists at Caltech, in cooperation with LLNL, has been studying systems for detecting static and mobile sources of radiation. There are three aspects to our research:
1. Algorithms
2. Simulation and laboratory experiments
3. An interactive "gaming" laboratory to evaluate strategies.

The algorithms use Bayesian decision theory to estimate the probability of a radiation source at a given location given the number of photons striking sensors, and the photon energy recorded by the sensors. The algorithms then determine the optimum k-step movement of mobile agents to locate sources (Computation is exponential in k).

We study tradeoffs between static sensors, and slow and fast mobile sensors. We show the significant benefits of even slow-moving sensors. We show how to use the energy spectrum. We have developed a simulation environment that allows for the rapid analysis of different strategies for placing and moving sensors. The simulator models absorption of photons by different types of material. We show how the simulation environment can be used to study the effect of directionality of sensors – more directionality and fewer photons versus less directionality and more photons per unit time.

The interactive game allows players to take the roles of terrorists with radiation material and security officers trying to apprehend them. The physics of radiation is incorporated into a multiplayer game called Half Life 2. We show how the game can be used by security officers to try out different avoidance and interdiction strategies.

Dr. Ofer Hadar, Ben-Gurion University

Compression of infrared imagery sequences containing a slow moving point target

Infrared imagery sequences are used for detection of moving targets in the presence of evolving cloud clutter or background noise. In this work, we consider slow moving point targets, which are one pixel size, such as long range aircraft. These sequences are captured by ground sensors. These infrared imagery sequences contain enormous amount of data, which transmission to a base unit or storage is very time and resource consuming. Thus, a compression method which maintains the point target detection capabilities is desired. Such a compression was not investigated publicly until now. For this purpose, we developed a temporal compression method which preserves the temporal profile properties of the point target. We evaluate the proposed compression method using a SNR-based measure for point target detection, and show that the compression may improve the SNR results compared to the original movie.

Dr. Tom Karnowski, Oak Ridge National Laboratory

Fusion of visible light and gamma ray imaging for portable portal monitoring

The use of radiation sensors as portal monitors is increasing due to heightened concerns over the smuggling of fissile material. Portable systems that can detect significant quantities of fissile material that might be present in vehicular traffic are of particular interest, especially if they can be rapidly deployed to different locations. To serve this application, we have constructed a prototype, rapid-deployment portal monitor that uses visible-light and gamma-ray imaging to allow simultaneous monitoring of multiple lanes of traffic from the side of a roadway. The portal monitor uses machine vision methods to identify and track vehicles in visible light images. We have built two prototypes of the instrument with increased capabilities. The basic operation of both versions is identical: The field of view of the visible camera system overlaps with and is calibrated to that of a one-dimensional gamma-ray imager. Then the machine vision system detects vehicles as they enter and exit the field of view, and estimates their position in each frame. The position is used to estimate the times for crossing gamma-ray pixel boundaries. Based on this information, the gamma-ray imager "harvests" the gamma-ray data specific to each vehicle, integrating its radiation signature for the entire time that it is in the system field of view. In this fashion we are able to generate vehicle-specific radiation signatures and avoid source confusion problems that plague non-imaging approaches to the same problem. Our initial proof-of-concept instrument used a single imaging system for one side of the road, along with a monocular camera mounted on a 24-foot mast [Ziock et. al, "The Use of Gamma-Ray Imaging to Improve Portal Monitor Performance", IEEE Trans Nuclear Science, V. 55, pp 3654-3664]. Our current prototype (still under development) features two imaging systems (one for each side of the road), 50-foot masts, and stereo cameras along with a third "alignment camera" to estimate and correct for the motion of the mast. This second system is designed for use at highway speeds with up to five lanes of traffic and features more precise measurement capabilities, increased automation, and better user interfaces. We report on the design considerations for the machine vision system, the algorithms used for vehicle detection and position estimates, and the overall architecture of the system. We also discuss system calibration for rapid deployment. Finally we illustrate the performance of the system under test conditions.

Dr. Kevin Wood, Naval Postgraduate School

Network Interdiction Models for Detecting Smuggled Nuclear Materials

Network interdiction models have been applied, by other researchers, to create a “last line of defense” for detecting stolen nuclear materials being smuggled out of a country. This talk reviews that application and describes other interdiction models that may be useful in the general area of nuclear security. Importantly, the models apply to materials being smuggled into an area for the purpose of attack. For instance, we describe a model for applying a limited number of mobile sensors to maximize detection probability: a Cournot (simultaneous-play) game results, in contrast to the Stackelberg game of the “last line of defense.” Other models combine the Cournot and Stackelberg paradigms. All the above models make worst-case assumptions, for us, about a smuggler's intentions and knowledge. If we have solid intelligence about those intentions, and/or are willing to model a smuggler's "true" view of the world, more sophisticated models can be created, involving traps and decoys. We are leery to promote the use of such models, but they are fun to explore.

Dr. Christian Hagmann, Lawrence Livermore National Laboratory

Detector Backgrounds in NRF cargo interrogation systems

We'll discuss the various backgrounds encountered in NRF-based detection systems. The 2 broad categories are (1) elastic scattering comprised of Rayleigh, Nuclear Thomson, and Delbrueck and (2) inelastic processes such as bremsstrahlung. Their dependence on Z and E is reviewed. Possible NRF detector systems are touched upon, e.g. spectrometer arrays and gas Cherenkov detectors.

Mr. Curtis Hicks, Passport Systems, Inc.

Nuclear Resonance Fluorescence: Applications, Capabilities and New Frontiers

Nuclear Resonance Fluorescence (NRF) provides an isotope-specific signature that could be used for the identification and characterization of materials. The applications of NRF include contraband detection, detection of conventional and chemical weapons, special nuclear materials (SNM) as well as forensics applications. A discussion of the experiments that Passport Systems, Inc. have performed in order to demonstrate the utility of NRF to these applications will be provided. The discussion will cover the measurements performed on drug simulants, explosives, certain SNM materials and various other materials of interest to contraband detection. Finally, an overview of NRF utilization in Passport's commercial scanning system and new concepts for use of NRF will be discussed.

Mr. Brian Quiter, University of California at Berkeley

Modeling of NRF Applications in Nuclear Safeguards

Non-destructive isotopic assay of materials has numerous applications in nuclear safeguards, including quantifying Pu content in spent fuel and measuring U enrichments UF_6 and MOX fuel. To facilitate studying these problems, the ability to simulate NRF has been added to MCNPX for known U and Pu NRF lines. It has also been observed that MCNPX does not properly simulate the photon physics that contribute the majority of the background photon fluence. The effects of this limitation on studies of safeguards applications as well as a proposed solution and simulation results will be discussed.

Dr. James Hall, Lawrence Livermore National Laboratory

Monte-Carlo Based Simulations of proposed MEGa-ray (NRF) applications

LLNL is currently engaged in the development of intense gamma-ray sources with very narrow bandwidths (10's of keV) for use in isotope-specific imaging and nuclear assay applications. One example is the planned Mono-Energetic Gamma-ray ("MEGa-ray") facility which, when it comes on line in the 2012 time frame, is expected to be capable of generating tunable photon beams with energies of ~ 0.5 – 2.5 MeV and spectral intensities many orders of magnitude beyond current (3rd generation) synchrotron light sources. MEGa-ray will exploit a physical process known as nuclear resonance fluorescence (NRF). Essentially analogous to atomic fluorescence, NRF occurs when an energetic photon is absorbed by a nuclear isotope, which then decays to its ground state by emitting one or more characteristic gamma rays.

Dr. Miro Shverdin, Lawrence Livermore National Laboratory

Status and Plans for Mono-Energetic Gamma-ray (MEGa-ray) Source Development and Applications at LLNL

A primary obstacle to generating a high brightness gamma-ray flux in Compton scattering based sources is the relatively small Thomson scattering cross-section. As a result, high brightness Compton sources require high power Joule-class lasers which are costly and have a large footprint. Since only a small fraction ($\sim 10^{-10}$) of the incident laser photons is converted to gamma-rays, recirculation of the laser pulse would increase both the gamma-ray flux and the efficiency of the Compton light source. We have recently demonstrated a novel pulse recirculation scheme for high energy, ultrashort laser pulses. This scheme termed RING (Recirculation Injection by Nonlinear Gating) relies on nonlinear conversion inside a cavity for pulse trapping. To date, we achieved 14 times average power enhancement of a 180 mJ, 20 ps pulse at 532 nm, incident at 10 Hz repetition rate. While other pulse recirculation schemes exist, none are compatible with high energy picosecond laser pulses.

In the simplest implementation of RING technique, the incident laser pulse at the fundamental frequency enters the resonator and is efficiently frequency doubled. The resonator mirrors are dichroic, coated to transmit the 1? light and reflect its 2nd harmonic. The upconverted 2-gamma pulse becomes trapped inside the cavity. After many roundtrips, the laser pulse decays primarily due to Fresnel losses at the crystal faces and cavity mirrors. The major advantage of the outlined recirculation scheme compared to active (electro-optic or acousto-optic) pulse switching is that the pulse traverses through an order of magnitude thinner optical material. For short, high peak power pulses, this reduces pulse dispersion and nonlinear phase accumulation that ultimately lead to beam break-up. In contrast to resonant cavity coupling techniques, RING does not require inteferometric cavity stabilization and can operate with low duty cycle pulse trains.

The nonlinear frequency conversion based beam trapping and recirculation concept can be extended to a variety of potential applications including the proposed gamma-gamma collider at the International Linear Collider (ILC), enhancement of high harmonic generation in a gas jet, and improvement of frequency tripling efficiency.

RING could eventually provide up to 2 orders of magnitude improvement in average brightness of Compton-scattering gamma-ray light sources currently being developed at LLNL.

Dr. Scott Anderson, Lawrence Livermore National Laboratory

Inverse Free-Electron Laser Accelerators of Compact, High Flux Compton-scattering based light sources

Compton scattering of intense laser pulses with relativistic electron beams has recently been demonstrated to be a viable source of narrow bandwidth gamma-rays suitable for NRF-based detection missions. The accelerators required for this application must produce both high peak brightness and high average current for efficient gamma-ray production in a compact footprint. The Inverse Free-Electron Laser (IFEL) acceleration scheme is a promising potential solution to this challenge. IFELs can produce > 300 MeV/m accelerating gradients using TW lasers and magnetic undulators, and will scale naturally to higher repetition rates with the continuing advancement of high power lasers. We describe the proposed LLNL IFEL experiment and outline the potential development path toward deployable machines for NRF detection of illicit materials.

Dr. Tsahi Gozani, Rapiscan Systems

Old but useful concept of accelerator based neutron generator for HS inspection

The generation of intense neutron beams through the photoneutron and photofission processes was common in the Sixties through early Eighties as sources for neutron cross sections measurements. The frequent use of relatively compact, intense and reliable electron linear accelerators with energies above a few MeV for x-ray radiography inspection, suggests the possible use of such linac also as neutron generators for neutron based inspection systems.
In this presentation we will describe a new study to optimize the spectra and intensity of pulsed linac based photonuclear neutron sources for cargo inspection employing a host of fission based detection techniques.

Dr. Gil Travish, UCLA

Particle Beam Based Gamma Ray Sources for Stand-off Detection of SNM

Stand-off detection of Special Nuclear Materials by active interrogation with gamma rays (> 6 MeV) through photofission shows promise. For long-range detection (~1 km), an intense beam of gamma rays (~10^{14} per second) is required, and the production of such fluxes and in the pulse formats useful for detection, presents many technical challenges. Novel approaches to the accelerator and laser technology are demanded. Improvements in the photoinjector, linac, final focus, and laser system are necessary. These enhanced sub-systems are being studied and developed in parallel work being performed at RadiaBeam, UCLA and elsewhere. The proposed system will be a transportable source of high-flux, high-energy quasi-monochromatic gamma rays.

Dr. Charles Yeamans, University of California at Berkeley

Development of Experimental Physics Capabilities at UC Berkeley for National Security-Related Research

In 2008, the UC Berkeley Department of Nuclear Engineering acquired a Pelletron particle accelerator from the Department of Homeland Security through the Domestic Nuclear Threat Security Initiative. Delivery of the major components was completed in January 2009, with the final shipments arriving in April 2009. Since then, work has focused on installation and retrofitting. Originally a 7 MeV tandem deuteron accelerator, replacement of the beam tube and ion source will re-commission the machine as a 3.5 MeV electron accelerator. Current activities include installation and adjustment of charging chains; wiring of charging power supplies; design and construction of appropriate safety interlock systems, instrumentation, and peripheral systems; and redesigning of the interior high-voltage terminal to accommodate an electron source. Upon completion, the Pelletron will be used for both basic NRF measurements and novel "hair of the dog" photon beam generation technology development. The accelerator will be designed and operated to allow for future source replacement in support of positron annihilation materials characterization experiments and high-energy proton and deuteron physics experiments in addition to maintaining electron-beam capabilities.

Dr. Tsahi Gozani, Rapiscan Systems

Delayed Gamma Rays as a Fission Signature from Photofission

It has been amply shown that delayed gamma rays are a very useful signature of nuclear materials when fissioned by neutrons. We will show in this presentation that delayed gamma rays can provide a very positive indication for the presence of fissionable materials when cargo is interrogated by high energy x-rays.

Dr. Dan Chivers, University of California at Berkeley

Electron-track Compton Imaging using High Resolution CCD Detectors

The Compton gamma-ray imaging method utilizes advanced detectors designed to acquire information on the position and energy deposition of individual gamma-ray interactions within the detection volume. Given this information of individual interactions, the trajectory and energy of the incident gamma-rays can be constrained to a distribution of possibilities. It has been shown that the source position and emission energy can be reconstructed using iterative approaches given a large number of interaction sequences within the detector. Without the knowledge of the momentum vector of scattered Compton electrons, a symmetry exists which spreads the incident trajectory distribution about the surface of a number of cones. By measuring Compton electron trajectories, the number of cones along with the number of possible trajectories along the cone(s) will be reduced. This will allow for a greater efficiency and precision of iterative Compton imaging algorithms given a smaller number of interaction sequences. This talk will outline the effort to quantify the impact of measuring electron tracks in silicon detectors using 10 micron spatial resolution and introduce a new effort to produce a practical implementation using a *hybrid CCD-strip silicon detector.*

Dr. Bethany Goldblum, University of California at Berkeley

The Role of Surrogate Reactions in the Search for New NRF States

The Surrogate Method is a technique for the indirect determination of neutron-induced reaction cross sections on radioactive isotopes, where a "surrogate", or light-ion induced direct reaction, is performed using a stable target and beam, to access the compound nucleus of interest in the neutron-induced reaction. Similarly, surrogate reactions can be performed to search for new NRF states in various isotopes of proliferation concern using significantly less target material than is required for photon interrogation. For example, inelastic scattering of alpha particles can be used of populate collective states in 239Pu using milligram-scale targets. By examining a fixed excitation energy window in the residual nucleus (as determined by the energy of the ejectile), gamma-rays can be identified that decay directly to the ground state. By identifying parallel decay paths, gamma-gamma coincidences can provide the branching ratios of these states. To ascertain the suitability of these states for NRF imaging, precision lifetime measurements can be obtained using the Doppler shift attenuation method.