NEUTRON CHARACTERIZATION FOR NUCLEAR NON-PROLIFERATION USING 3D OPTICAL MEMORY DETECTORS

J.S. Bogard and T. Vo-Dinh Oak Ridge National Laboratory
M. Moscovitch and G.W. Phillips Georgetown University

Neutrons are emitted by some special nuclear materials (SNM), either as a result of spontaneous fission or by the interaction of alpha particles from radioactive decay with the nearby nuclei of lighter elements in SNM compounds. Neutron fluence rate is a direct function of the amount of SNM present, and the energy spectrum is dependent on the neutron source. Efficient neutron detection, measurement and characterization is a promising strategy for detecting the presence of neutron-emitting fissile materials and for identifying and quantifying the neutron sources. Uses include treaty verification and interdicting covert transport of fissile material. Current techniques for measuring neutron energy spectra are hampered by complicated suites of instrumentation, bulky detector arrays, or extensive chemical processing and analysis of the detector material in a fully equipped laboratory with long delays in obtaining results. No single neutron dosimetry method combines energy response and sensitivity in a small, simple detector, which is the object of this research.

Neutrons impart energy to matter in billiard-ball-like collisions with atomic nuclei. These collisions produce energetic charged particles (the recoil nuclei themselves) that generate heating along their paths through coulombic interactions with orbital electrons. Theoretical analysis predicts[1] that this heating is sufficient to cause a lasting change in the electronic state of certain chromophoric compounds, thereby recording the track of the charged particle. The length, radius and other characteristics of these tracks provide information about the energy and type of charged particle -- and this, in turn, about the energy of the incident neutron. We are developing this patented technique and have observed these changes in small volumes of poly-methylmethacrylate (PMMA) plastic doped with anthracene[2]. The effect, though lasting, is reversible, and the chromophoric changes can be imaged with 20 ：m resolution, as shown in Figure 1, by a 2-photon (crossed-laser) technique[3] that provides the image location in 3 dimensions.

While offering the greatest amount of information, 3-dimensional imaging of particle tracks is also technically challenging. Parallel research using commercially available atomic-force microscopy (AFM) and near-field surface optical microscopy (NSOM) is also being pursued to determine characteristics of surface features produced by neutron exposure of plastic films. The distributions of key parameters from these measurements are also expected to yield useful information for determining neutron spectra, as illustrated in Figure 2.

---

[1] M. Moscovitch and D. Emfietzoglou, *Journal of Applied. Physics*, 1997, **81**, 58-69.
[2] B. M. Cullum, J. Mobley, J. S. Bogard, M. Moscovitch, G. W. Phillips, and T. Vo-Dinh, *Analytical Chemistry*, 2000, **72(22),** 5612-5617.
[3] J. M. Song, B. M. Cullum, J. Mobley, J. S. Bogard, M. Moscovitch, G. W. Phillips, & T. Vo-Dinh, *Review of Scientific Instruments*, 2002, **73(12)**, 4214-4217.

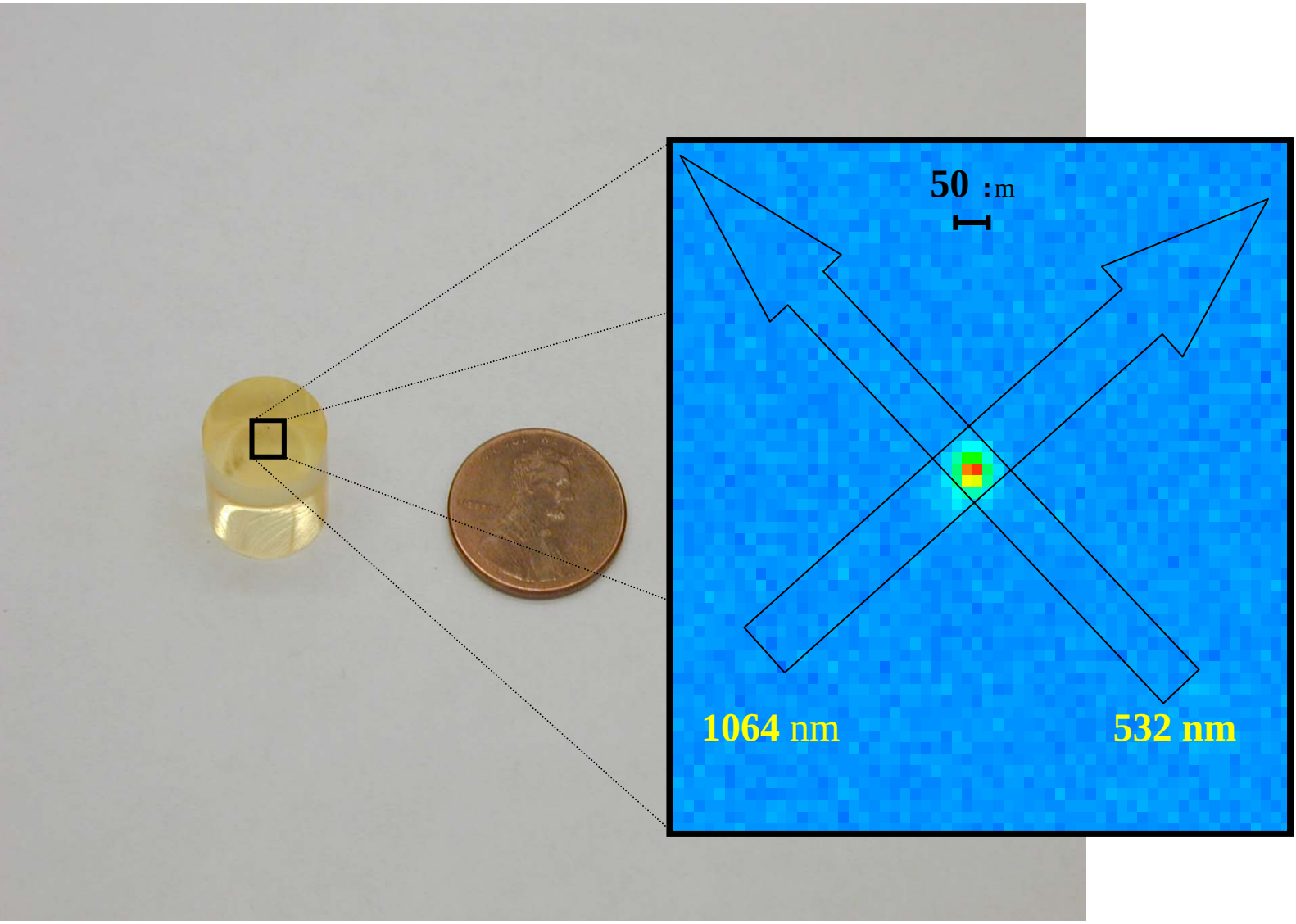

Figure 1. Small volumes of PMMA plastic (left) doped with materials like anthracene that change optical properties in a neutron field are promising new detectors for rapid, convenient detection and characterization of special nuclear materials. Fluorescence is observed with two-photon excitation (532 nm + 1064 nm) from orthogonal lasers. Resolution (FWHM) is about 20 :m.

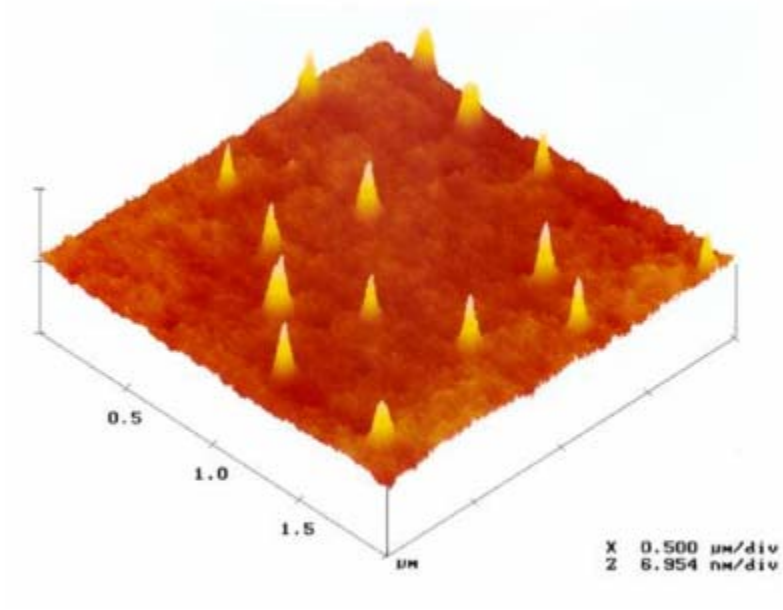

Figure 2. AFM image of the surface of PMMA after irradiation with accelerator-produced $^{12}C^{++}$ ions. Cones projecting above the surface are believed to be extrusions of PMMA melted by high temperatures near the axes of the charged particle tracks. Feature parameters, such as radius and height, should provide information about the charged particles and their energies. (Note that horizontal dimensions are in micrometers, vertical dimensions are in nanometers.)