Contribution ID: **69**   Type: **Poster**

Nuclear Forensics via Machine Learning Laser Based Spectral Analysis and Imaging

Wednesday 9 July 2014 13:00 (1 hour)

The global nuclear renaissance, re-emergence of nuclear security threats and the limitations of classical nuclear forensics methods calls for innovative approaches for detecting the illicit trafficking of nuclear and radiological material. A unique synergy for direct, rapid trace quantitative analysis and imaging is enabled by combining machine learning and laser based spectroscopy and imaging techniques. Imaging spectrometry is spectroscopy pursued in the image domain (especially where the sample material is limited and the maximum amount of information needs to be probed more rapidly in two and three dimensions). The methods are targeted for their versatility, high sensitivity, speed, simple operation and in situ capabilities. These techniques have capacity to investigate nuclear or radiological material for its isotopic and elemental composition, geometry, and microstructure (as each step in the fuel cycle creates and/or modifies these signatures). At Nairobi we are investigating the potential of exploiting laser induced breakdown spectroscopy (LIBS) spectral/imaging and laser Raman spectromicroscopy techniques to noninvasively determine the trace elemental and isotopic composition of nuclear materials and in the assessment of isotopic signatures of nuclear and concomitant elements in the environment. The main attributes targeted are the uranium isotopics (234U, 235U, 236U, 238U) as well as to identify attribution indicators, age (chronometry), intended use, enrichment process used to create the material, method of production, and identity of the reactor in which it was used. We are using these techniques in responding to environmental releases of nuclear (NORM) materials and illicit trafficking activities in our region, which involve both radioactive 'conflict'minerals like coltan and counterfeit materials, and in responding to suspect trafficking activities. We use machine learning for mining (management, analysis and visualization) of the extensive data sets and for extracting relevant information from the complex spectral measurements as it affords multivariate data reduction in a graphical interface which permits visualization of relationships between samples characterized by multiple measured variables and also exploratory analyses. We report on the progress of this new research line at Nairobi. We have found that machine learning LIBS methodology represents a promising tool of nuclear forensics. We reconstructed the isotopic composition of high background radiation area (HBRA) derived uranium ores, analyzed and imaged uranium levels in uranium hexafluoride, and interpreted natural variability between isotopes in uranium ores using machine learning thus advancing towards understanding the mechanisms that cause the differences, and to source apportionment. We have developed advanced machine learning tools for spectral and image processing, which reduce the need for expensive signal to noise reduction in techniques. The prospect of direct analysis for REE determination using LIBS is particularly promising as discriminating characteristics like total actinide content, isotopics, metallic and non-trace elemental data are amenable to the method: origin of uranium deposits may be revealed. REE patterns are also very specific to each uranium deposit type and can thus directly reflect the conditions of its genesis and are therefore efficient tools for constraining the geological models of uranium deposits as well as for genetically discriminating new uranium discoveries, a starting point in the fight against nuclear trafficking. Microstructural features obtained from laser Raman spectromicroscopy are also proving informative: Because of its inherent characteristics, the small sample size and the nondestructive nature of the method, the Raman scattering technique represent a significant spectrometry in making stable isotope ratio measurements. This research line supports our educational efforts under INSEN since 2013 to develop courseware to be incorporated into the Nuclear Security education program to start at Nairobi in the near future.

References

[1] F. E. Stanley, A. M. Stalcup, H. B. Spitz, A brief introduction to analytical methods in nuclear forensics, J Radioanal Nucl Chem, DOI 10.1007/s10967-012-1927-3, 2012.

[2] P. Ko, K. C. Hartig, J. P. M cNutt, R. B. D. Schur, T. W. Jacomb-Hood, I. Jovanovic, Adaptive femtosecond laser-induced breakdown spectroscopy of uranium, Review of Scientific Instruments 84, 13-20, 2013.
[3] Q. Lin, G. Niu, Q.Wang, Q. Yu, Y. Duan, Combined laser-induced breakdown with Raman spectroscopy: historical technology development and recent applications, Applied Spectroscopy Review s, 48:487–508, 2013.
[4] B. Zawisza, K. Pytlakowska, B. Feist, M. Polowniak, A. Kita, R. Sitko, Determination of rare earth elements by spectroscopic techniques: a review, J. Anal. At. Spectrom. 26, 23-73, 2011.
[5] X. Hou, W. Chen, Y. He, T. B. Jones, Analytical atomic spectrometry for nuclear forensics, Applied Spectroscopy Reviews 40: 245 –267, 2005.

Country and/or Institution

Department of Physics, University of Nairobi, Kenya.

Author: Dr KALAMBUKA, H.A. (Kenya)

Co-authors: Dr DEHAYEM-MASSOP, A. (Department of Physics, University of Nairobi, Kenya.); Mrs BHATT, B. (Department of Physics, University of Nairobi, Kenya.)

Presenter: Dr KALAMBUKA, H.A. (Kenya)

Session Classification: Poster Session II