Single Barium Tagging in Solid Xenon for the nEXO Experiment

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Extending the Sensitivity of Neutrinoless Double Beta Decay in the nEXO Detector

$^{136}Xe \rightarrow ^{136}Ba^{++} + 2e^-$

0νββ decay discovery would demonstrate:
- Neutrinos are Majorana Particles
- Lepton Number Violation
- Input on Neutrino Mass and Hierarchy

Apparatus
1. Cool sapphire window to 50K
2. Begin Xe gas flow
3. Pulse Ba$^{+}$ beam onto window
4. Stop Xe gas flow
5. Cool window to 10K

Deposition
- Cool sapphire window to 50K
- Xe gas flow begins
- Pulse Ba$^{+}$ beam onto window
- Xe gas flow stops
- Cool window to 10K

Observation
- Excite with dye laser at 572 nm
- Observe fluorescence at 619 nm
- Image with LN-cooled CCD
- Scan laser with piezo-electric translation stages
- Evaporate sample at 100K

Background Bleaching
- 532 nm laser rastered across sample (90μm × 90μm)
- Reduces surface background by a factor of 30

Fixed Laser Images
- Sample images:
  - Fluorescence signal is linear with # of ions deposited: not Ba$_n$ molecule!
  - Best fit of 409±10 counts/mWs/ion

Scanned Laser: successive CCD images
- Moving laser in x in 4 μm steps

Composite scan image
- (each pixel is integral of counts in 3x3 laser region of CCD image)

Summary: First detection of single atoms in solid rare gas, a major step for Ba tagging in nEXO

Key features:
- Single Ba atoms can be counted with S/σ ≈ 70.
- Ba deposit can be “erased” by evaporating and re-freezing the solid Xe coating.
- No sensitivity to any stray Ba atoms on window surface.