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Imaging of Individual Barium Atoms in Solid Xenon for the nEXO Neutrinoless Double Beta Decay Experiment

Bill Fairbank

Colorado State University

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Abstract

Individual barium atoms in solid xenon have been detected and imaged with high signal-to background fluctuation ratio by scanning a focused laser across the solid xenon matrix deposited on a cold sapphire window. By fixing the laser position on a single Ba atom, it is found that the fluorescence suddenly drops to background level after times of as short as 30 s. In some cases, it persists for >600 s. The sudden drop to background is a clear confirmation of single atoms. A remarkable result is that heating the matrix to 100 K "erases" all signal from a previous Ba deposit.

To our knowledge, this is the first time that single atoms have been imaged in solid noble gas and represents significant progress towards a practical barium tagging technique for the proposed nEXO neutrinoless double beta decay experiment. The identification, or "tagging" of the Ba-136 daughter atom that results from double beta decay of Xe-136 could be used to eliminate all false radioactive backgrounds in nEXO that do not produce a Ba-136 daughter. The proposed Ba tagging scheme utilizes a cryogenic probe to trap the barium daughter atom in solid xenon and extract it from the time projection chamber. The observation of a single barium atom in the laser scan of the solid xenon matrix on the widow at the end of the probe would be a positive confirmation of a true double beta decay event.

Observation of neutrinoless double beta decay would represent a discovery of new physics beyond the Standard Model of elementary particles. This would include confirmation of the Majorana character for neutrinos, i.e., that the neutrino is its own antiparticle, and violation of lepton number conservation. This also could contribute to an understanding of the mystery of the missing anti-matter in our universe from the Big Bang.

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Biography

Dr. Fairbank is a Professor of Physics at Colorado State University. He received a B.A. degree from Pomona College and a Ph. D. degree from Stanford University and is a Fellow of the American Physical Society. He is a member of the EXO-200 and nEXO double beta decay collaborations and has been working on double beta decay research for more than two decades.