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**Characterization of the Oxidation State of $^{229}$Th Recoils Implanted in $MgF_2$ for the Search of the Low-lying $^{229}$Th Isomeric State**
BEAU BARKER, EDMUND MEYER, MIKE SCHACHT, LEE COLLINS, MARIANNE WILKERSON, XINXIN ZHAO, Los Alamos National Laboratory — The low-lying (7.8 eV) isomeric state in $^{229}$Th has the potential to become a nuclear frequency standard. $^{229}$Th recoils from $^{233}$U decays have been collected in $MgF_2$ for use in the direct search of the transition. Of interest is the oxidation state of the implanted $^{229}$Th atoms as this can have an influence on the decay mechanisms and photon emission rate. Too determine the oxidation state of the implanted $^{229}$Th recoils we have employed laser induced florescence (LIF), and plan-wave pseudopotential DFT calculations to search for emission from thorium ions in oxidation states less than +4. Our search focused on detecting emission from $Th^{3+}$ ions. The DFT calculations predicted the $Th^{3+}$ state to be the most likely to be present in the crystal after $Th^{4+}$. We also calculated the band structure for the $Th^{3+}$ doped $MgF_2$ crystal. For LIF spectra a number of excitation wavelengths were employed, emission spectra in the visible to near-IR were recorded along with time-resolved emission spectra. We have found no evidence for $Th^{3+}$ in the $MgF_2$ plates. We also analyzed the detection limit of our apprentice and found that the minimum number of $Th^{3+}$ atoms that we could detect is quite small compared to the number of implanted $^{229}$Th recoils. The number of implanted $^{229}$Th recoils was derived from a $\gamma$-ray spectrum by monitoring emission from the daughters of $^{228}$Th. These were present in the $MgF_2$ plates due to a $^{232}$U impurity, which decays to $^{228}$Th, in the source.
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