Fluorescence Imaging of He_2^* Excimers generated by neutron and gamma irradiation of superfluid Helium using a cold neutron beamline at J-PARC / MLF

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Metastable He_2^* molecules (excimers) are a newly developed tracer[1] for visualization of the superfluid ^{4}He velocity distribution used in investigations for the field of quantum turbulence. Due to their relatively long excited state lifetime of 13s they can be repeatedly interrogated by interacting with a laser for fluorescence imaging. One particular excitation scheme uses a near-resonant two-photon process at $\lambda = 905$ nm from the excimer ground state to the excited state $d^3\Sigma^+_u$, after which fluorescence at 640 nm is emitted, giving a near background-free signal if using spectral filtering.

For full 3D flow-field mapping a distributed cloud of localized clusters of the excimer are required, which may be generated via the ^{3}He(n,p)^{3}T neutron absorption reaction. The resulting recoils of the reaction create a short track (100µm) of ionized and excited Helium atoms, which form a cluster of approximately 10^4 excimer molecules via recombination. Electrons ejected by Compton-scattering of gamma-rays may create excimers as well, though with lower density. At the neutron beamline (BL22) of the Materials and Life Science facility (MLF) at J-PARC cold neutrons are produced via proton impact on a target, which results in a neutron beam accompanied by intense gamma radiation. In previous experiments[2,3] fluorescence emitted by the excimers could clearly be detected via use of photomultiplier tubes (PMT). From these results it was however not clear whether the dominant excimer generation process was neutron absorption or Compton scattering. Furthermore, imaging of the fluorescence using a camera system showed only hints of a signal by careful background subtraction.

In a recent experiment at the beginning of this year we obtained new results using an image intensifier enhanced CCD camera. While individual He_2^* clusters could not be seen directly, a clear intensity distribution related to the exciting laser's beam profile was observed during irradiation. To distinguish between the effects of gamma and neutron irradiation, different types and thicknesses of absorbers (Pb, Bi) were placed into the upstream neutron beam. Their respective neutron absorption and gamma ray scattering cross sections were then used to estimate the ratio between the two He_2^* generation processes.

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