実験報告書様式（一般利用課題・成果公開利用）

（ ※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。）

# Experimental Report	承認日 Date of Approval 2017/5/28 承認者 Approver Takenao Shinohara 提出日 Date of Report 2017/5/27
課題番号 Project No. 2016B0111 実験課題名 Title of experiment Generation of Helium Excimer Clusters via Neutron-^{3}He Absorption Reaction 実験責任者名 Name of principal investigator Taku Matsushita 所属 Affiliation Department of Physics, Nagoya University	装置責任者 Name of responsible person Dr. Takenao Shinohara 装置名 Name of Instrument/（BL No.） BL-22 実施日 Date of Experiment From 24 March 2017, 9:00AM to 27 March 2017, 9:00AM

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）

Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

Liquid helium-4 (^{4}He), and helium-3 atoms (^{3}He) included in commercial liquid helium-4 as isotopic impurities

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）

Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

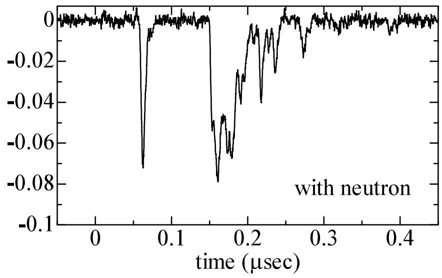
The aim of our project is to prove possibility to generate clusters of excited ^{4}He molecules He_2* (excimers) in liquid He via the neutron-^{3}He absorption reaction, and, if it can do, to perform 3D mappings of normal-component flow in superfluid He by using the excimer clusters with lifetime of 13 sec as tracers, which is critically required for complete understanding of nature in quantum turbulence but has not been performed so far. As the first step of all, in this experiment, we examine whether the excimers are generated when a neutron beam is applied into liquid ^{4}He.

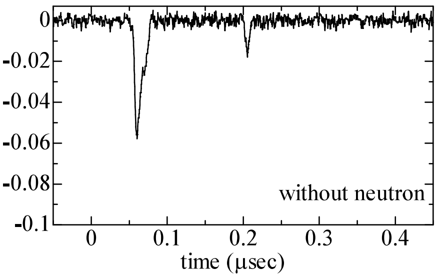
Liquid He was stored in a stainless Dewar with four quartz optical windows at the bottom part. Commercial liquid He usually includes 0.3 ppm of ^{3}He as isotopic impurities. By absorption of a neutron, the ^{3}He atom splits into ^{1}H and ^{3}H with an energy of 764 keV, which will ionize ^{4}He atoms along their track, and lead to a generation of a cluster consisting of typically 10^4 excimers. In the measurements, liquid He temperature was kept around 2.0 K below the superfluid transition temperature by pumping, to avoid disturbance by bubbles. For detection of the excimers, 905 nm laser pulses were applied to excite 640 nm fluorescence of excimers. To

2. 実験方法及び結果（つづき） Experimental method and results (continued)

generate the 905 nm pulses, 532 nm Nd:YAG laser pulses were converted via a resonator using a Ti-sapphire crystal. In addition, a 1085 nm cw repumping laser was also applied to help excimers to return the ground state for a sufficiently short time. In this experiment, a neutron beam with a cross section about 1cm^2 passed through liquid ^{4}He by two optical windows of the Dewar. The 905 nm pulsed laser and 1085 nm repumping laser (cross section ~1 mm^2) were also applied in the center of the neutron beam in parallel. In this condition and for 150 kW neutron beam at J-PARC, a generation rate 2.4 clusters/sec for the excimer cluster is expected in the applied laser volume. And, 640 nm fluorescence from the excimers was observed through an optical window placed in the direction perpendicular to the beam, by a photomultiplier (PMT) with a 640 nm bandpass filter.

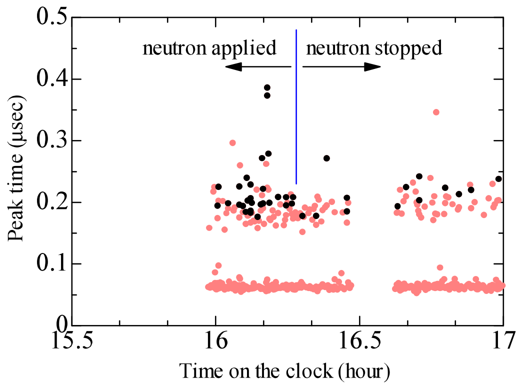
The figures below are examples of PMT signals after a 905 nm laser pulse, with and without neutron beams.





Even when neutrons are not applied (right), two peaks are often observed. They are attributed to photons directly from remaining 532 nm laser pulse and from delayed 905 nm pulse 0.1-0.18 μsec behind it, respectively. Even considering contributions of these direct photons, several peaks were additionally observed in the neutron-applied case as shown in the left figure, which are considered to be fluorescence from the excimers generated by the neutron beam.

To appropriately consider the contribution of additional signals directly from laser pulses, in this experiment, each event after a laser pulse such as the above figures is individually collected by a digital oscilloscope in a random manner, and the cases when the neutron beam is applied and not applied were compared. The typical data which most clearly shows the effect of a neutron beam is below. The vertical axis is times of PMT peaks



observed in each event, and horizontal axis is time on the clock when the event was observed. Here, peaks appearing around 0.06 μsec are caused by photons directly from 532 nm pulse, and peaks after t = 0.1 μsec are direct photons from 905 nm pulse and desired 640 nm fluorescence of the excimers. For the latter, peaks after the second peak are plotted by black dots, to emphasize the multipleness of the peaks. In this case, by an unknown reason, the efficiency of signal acquisition is lower than the case of the above examples, so that numbers of peaks are less than those. However, it can be clearly seen that the number of peaks decreases immediately just when the application of neutron beam was stopped. This successfully proves the effect of neutrons on the excimers showing the multiple peaks in PMT signals. This experiment is thus the first observation of helium excimers generated by neutron beams.

Fortunately, this experiment also clarified several technical problems which should be settled in next steps of our project, for examples, the efficiency of the present laser settings. Their improvements will allow us to observe positions of helium excimers by a high-speed video camera in future experiments.