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# Creation of bulk elementary excitations in superfluid helium-II by helium atomic beams at low temperatures

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The experimental results of creating bulk elementary excitations (BEEs) in isotopically pure liquid helium-II by helium atomic beams at low temperatures ~60 mK are presented. In the present experiment, BEE signals generated by $^4$He-atomic beams incident on the liquid free surface were detected by a bolometer positioned in the liquid helium-II. Some detected signals were very weak and depended on the heater power. Some examples of BEE detected signals are shown. Also, group velocities of the detected BEEs are evaluated and the threshold velocities of the helium atoms are discussed. The present experimental results demonstrate BEE creation, such as the third non-dispersive Zakharenko waves (supra-thermal phonons), with energies ~17 K (the Cooper pairing phenomenon doubles the supra-thermal phonon energy $E_k \sim 2 \times 17$ K~34 K in order to fulfil the energy conservation law) in the positive roton branch of the BEE energy spectra by helium atomic beams with suitable energies ~35 K, which perturb the liquid surface at incidence points similar to heaters.

## 1. Introduction

The so-called 'quantum evaporation' of $^4$He-atoms by bulk elementary excitations (BEEs) of the liquid helium-II with energies greater than the binding energy $E_B \sim 7.15$ K [1] is now well known owing to, for example, the experimental and theoretical works of A. F. G. Wyatt *et al.* [2, 3]. The quantum evaporation effect occurs in the liquid helium at low temperatures below the $\lambda_0$-point, $T_{\lambda 0} = 2.17$ K, at which the bulk liquid possesses three different types of BEEs in the phonon, negative and positive roton branches of the BEE energy spectra. The BEEs phonon branch represents a mesoscopic scale branch because the wavelengths $\lambda = 2\pi/k$ ($k$ is the wavenumber) are much greater than the line size $a_4$ of a $^4$He-atom, $a_4 \sim 1$Å, at the first boundary of the phonon branch and there is $k \sim 1/a_4$ and $\lambda \sim a_4$ at the second boundary of the branch. Indeed, corresponding surface elementary excitations (SEEs) of the liquid helium-II can participate in the quantum evaporation process in addition to the corresponding BEEs, for example, interacting with incoming BEEs at the liquid–vacuum interface.

This report presents experimental evidence confirming the existence of the 'quantum condensation' process, in which the helium atoms can condense on the $^4$He-liquid surface and

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