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Studying creation of bulk elementary excitation by heaters in superfluid helium-II at low temperatures

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Abstract: In this paper, the obtained experimental results concerning creation of bulk elementary excitations (BEEs) in isotopically pure liquid ^{4}He at low temperatures ~60 mK are discussed. Positive rotons' (R^+-rotons) creation by a pulsed heater was studied. Signals were recorded for the following quantum processes: quantum evaporation of ^{4}He-atoms from the free liquid-helium surface by the BEEs of the liquid helium-II, and BEEs reflection from the free surface back into the bulk liquid. Typical signals are shown, and ratios of signal amplitudes are evaluated. For long heater pulses from 5 to 10 μs, appearance of the second atomic cloud consisting of evaporated ^{4}He-atoms was observed in addition to the first atomic cloud. It is thought that the first atomic cloud of the evaporated helium atoms consists of very fast ^{4}He-atoms with energies ~35 K evaporated by positive rotons with the special energies ~17 K (~$2E_R$~2×8.6 K with E_R representing the roton minimum energy) corresponding to the third non-dispersive Zakharenko wave. The second cloud of slower ^{4}He-atoms was created by surface elementary excitations (SEEs or ripplons) possessing the special energies ~7.15 K representing the binding energy. It was assumed that such SEEs can be created by phonons incoming to the liquid surface with special energies ~6.2 K corresponding to the first non-dispersive Zakharenko wave, which can interact at the liquid surface with the same phonons already reflected from the surface for long heater pulses. Also, some pulsed-heater characteristics were studied in order to better understand the features of such heaters in low temperature experiments.

Key words: Superfluid helium-II, Bulk elementary excitations (BEEs), Low temperatures, Cooper pairing phenomenon, Non-dispersive Zakharenko waves
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INTRODUCTION

It would be extremely useful to completely understand how the heaters used in low temperature experiments behave, in order to improve their features or to make other heaters with properties optimised for the creation of phonon or roton excitations (in particular, R^+-rotons). For example, it should be possible to answer the question: are the rotons created directly by a heater in liquid helium or are they created by phonons that are initially injected by a heater (Brown, 1990). The question is very interesting, because it asks about physical processes that occur at the solid-liquid helium boundary, and one can try to answer it by studying and analysing the properties of a heater pulse in the liquid helium at low temperatures far from those of the heater. In addition, it is useful to have a boundary far from the heater, at which the excitations can reflect, or cause evaporation, in order to gain additional information about properties of the generated excitations. The interface between vacuum and the liquid helium is the simplest possible boundary that is apparent. At this interface, the bulk elementary excitations (BEEs) can be reflected back to a bolometer in the liquid or liberate ^{4}He-atoms in the so-called quantum evaporation process (Wyatt and Brown, 1990; Tucker and Wyatt, 1990; Forbes and Wyatt, 1990).

Probably, isotopically pure liquid helium is the most popular condensed state matter, which can be