Stopping of ions in and extraction from superfluid helium*

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A variety of scientific disciplines makes use of radioactive isotopes in the form of a low-energy ion beam or an ion or atom cloud in a trap. In order to allow such research, in-flight radioactive ion beam facilities are equipped with an ion catcher device transforming high-energy ions into low-energy ones. After slowing down in solid degraders and possibly range bunching, the ions are typically stopped in helium gas and extracted using electric fields. These devices have specific problems for relativistic light ions: (1) the large aereal weight of stopping gas required to cover the broad stopping range distribution; (2) light ions cannot be separated from the much more abundant helium ions by radio-frequency electrode structures, causing space charge problems. Superfluid (SF) helium is an attractive alternative stopping medium: (1) the much higher density combined with high ion mobility allows efficient stopping and fast extraction of ions; (2) the very fast recombination of helium ions may alleviate space charge problems.

We are investigating the survival of positive ions introduced at high energy in SF helium, their transport to the surface by electric field and subsequent extraction from the liquid. We earlier showed the extraction across the SF surface to be a major critical issue [1]. New results shed more light on the relevant mechanisms: thermal excitation across a barrier (dominant above about 1.3 K) and an as yet unknown temperature independent mechanism. The second sound-induced evaporation of the SF surface does not effect the survival of ions, but has a negative effect on the extraction mechanisms, possibly related to the trapping of ions by vortex tangles.

An overview of the use of SF helium for the manipulation of radioactive ions will be given. The focus will be on the use in an ion catcher device; some comments on the study of radioactive ions inside the SF helium medium will be added. New results will be presented based on which one can now state a combined efficiency for ion survival in and extraction out of SF helium of between 1 and 10 percent; about an order of magnitude higher than previously reported [1] and high enough to consider practical application.

[1] W.X. Huang *et al.*, Europhys. Lett. 63, 052001 (2003)
[2] S. Purushothaman *et al.*, J. Phys.: Conf. Series (to be published) (2009)

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* This work has been performed as part of the research program of the ``Stichting voor Fundamenteel Onderzoek der Materie" (FOM), which is financially supported by the ``Nederlandse Organisatie voor Wetenschappelijk Onderzoek"; (NWO).

この論文は Proceedings of the 10th International Workshop on Stopping and Manupulation of Ions, Stanford University, March 21-24, 2010 に収録