Pre-Proposal for the Master's Thesis

Creating and Maintaining a Subsurface Electron Pool in Superfluid Helium for an Ultraslow Muonium Beam

Luc Schnell
D-PHYS, ETH Zürich
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1 Introduction

A high-quality ultraslow muonium ($\mu^+ + e^-$) beam is required for several important experiments, chief among them the MAGE experiment at PSI aiming at a direct measurement of antimatter gravity [1, 2, 3]. The beam must have a very low transverse momentum and a small spread in kinetic energy, this cannot be satisfied by employing existing muonium beam generation techniques [1]. Therefore, a new technique proposed by D. Taqqu [1] is currently investigated at PSI (see Figure 1). It employs a thin layer of superfluid helium (SFHe) that stops an incoming antimuon (μ^+) beam. An electric field applied inside the layer moves the μ^+ to the upper surface, where they combine with electrons trapped in a subsurface pool. Being created close to the surface, most of the resulting muonium atoms are expelled from the SFHe layer due to negative affinity, uniformly having a kinetic energy of 23 meV. The subsurface electron pool needs to be replenished periodically to allow for continuous muonium formation [1].

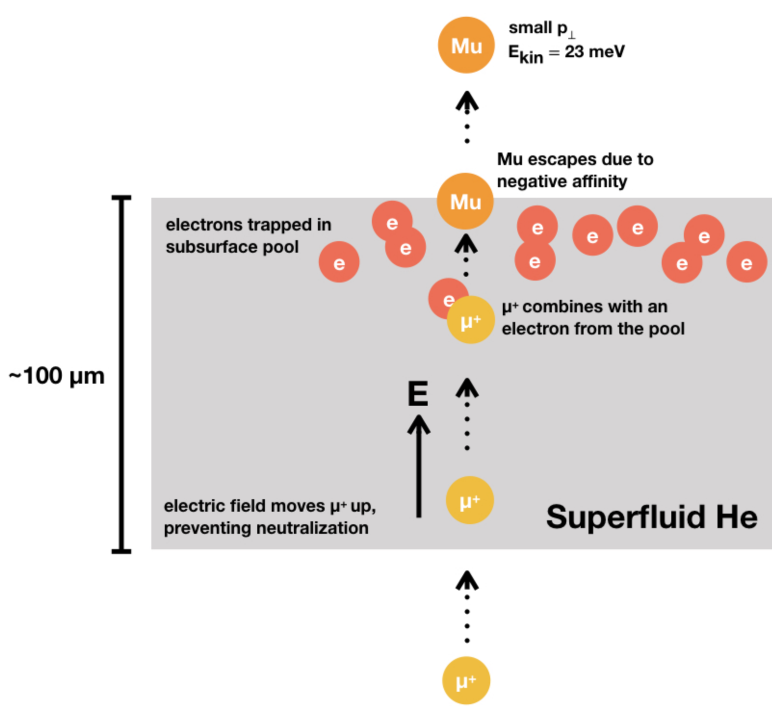


Figure 1: Basic setup of a novel muonium generation technique proposed in [1].

2 Objectives

This project aims at building a setup that creates and maintains the subsurface electron pool. This involves two tasks:

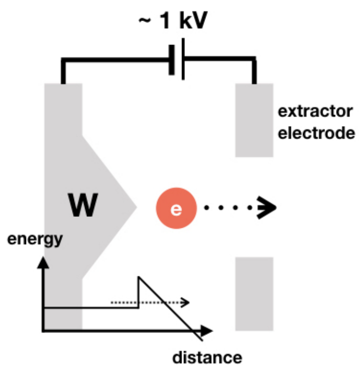
(T1) Creating free electrons in SFHe to replenish the subsurface pool.

(T2) Trapping the electrons close to the surface without interfering with the muonium beam generation.

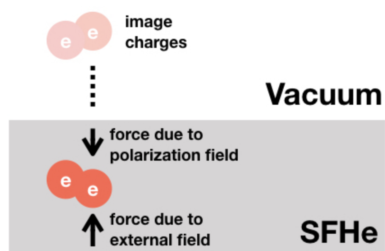
3 Methods

(T1) The idea is to use field emission from a tungsten tip (see Figure 2)[1]. By generating an electric field of approximately 1-5 GV/m at a tungsten nanotip, electrons start to overcome the binding potential barrier via quantum tunneling, thereby being released [4, 5].

(T2) The electrons are trapped by applying an external field that attracts them from the liquid to the surface [1]. They are repelled from the surface by the polarization field of the SFHe (often modeled as the field of an image charge) [6, 7]. The external field needs to be reduced whenever a μ^+ pulse arrives for muonium formation to take place [1].



(T1)



(T2)

Figure 2: Methods (figures inspired by [4, 5]).

4 Prior Work

(T1) The creation of metallic nanotips has been investigated intensively [4]. Nowadays, the Laboratory for Micro and Nanotechnology (LMN) at PSI is able to create whole arrays of metallic nanoemitters [8]. This project will rely on LMN's resources and experience to create a tungsten field emission tip that releases free electrons at a high enough rate to replenish the pool.

(T2) The basic technique to trap electrons in a subsurface pool in SFHe is well established [6]. However, adaptations are necessary to avoid its interference with the muonium beam generation: the beam line must not be obstructed and the applied electric field needs to be reduced periodically, still keeping the pool of electrons trapped.

5 Timetable

The tasks for the respective months (1-6) are:

1. Build field emission tip
2. Test field emission in SFHe
3. Build electron trap
4. Test electron trap
5. Implement periodic reduction of external electric field, test muonium beam generation
6. Complete the project, finalize thesis building upon drafts written along the 6 months

References

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