Field Ionization and Field Emission with Intense, Single-cycle THz Pulses Need to replace with my own title

by

© Yunxiao Wang

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Chapter 1

Introduction

1.1 Overview of Recent Target Development

Nuclear-polarized noble gases have been proven to be very useful in various applications, such as polarized targets for electron scattering experiments [?], magnetic resonance imaging [?] and neutron scattering experiments [?]. ^{3}He has been particularly useful for studying spin-dependent interactions involving neutrons because, to first order approximation, a ^{3}He nucleus has a pair of protons with paired spins and a single neutron that contributes the most of the nuclear spin. Free neutrons are not used as targets because they decay with a lifetime of roughly 15 minutes.

The latest experiments run in JLAB prior to the 12GeV upgrade have been using cells polarized with Spin-Exchange Optical Pumping (SEOP). Fig. 1.1 shows what a typical target cell looks like. These cells were made of the GE180 glass and use a two-chambered design. The top chamber, known as the pumping chamber, is where ^{3}He is polarized through SEOP. The bottom chamber, known as the target chamber, is where electron scattering occurs. Great effort has been made in our lab to develop this generation of cells. Alkali-hybrid SEOP together with narrowband laser diode arrays have increased the ^{3}He polarization from 37% to 70%. Among other things, we also carefully studied an additional spin relaxation mechanism that limits the maximum achievable ^{3}He polarization, which is referred to as the "X Factor". Analysis of data accumulated through developing this generation of target cells were thoroughly discussed in Ref. [?], part of which will be presented in chapter 4.

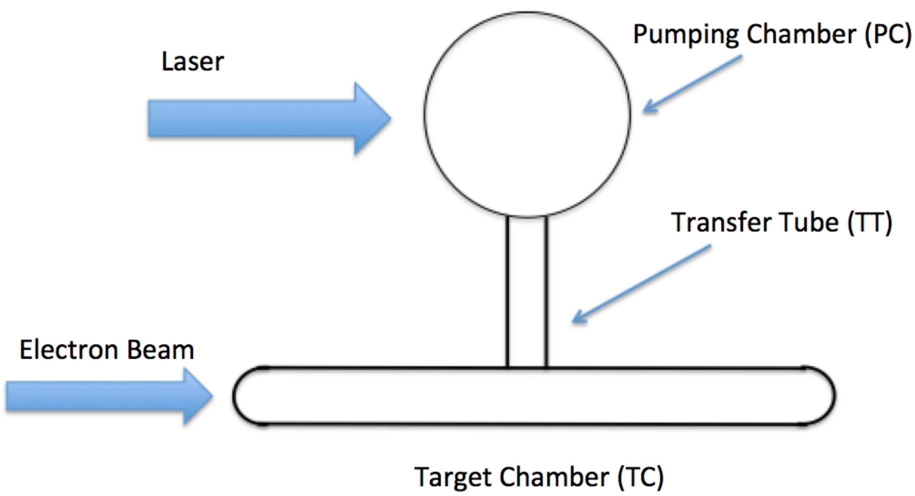

Figure 1.1: A target cell. The dimensions of different parts of the cell are not to scale.

1.2 New Generation Target Cells

The future experiments planned during the 12GeV era after the upgrade will be much more demanding in terms of target cell performance. One challenge it brings is the high relaxation due to electron beam. We have designed and tested a new style cell that utilizes convection instead of diffusion to increase the rate at which the polarization in the target chamber is replenished by polarized gas from pumping chamber [**?**]. We have obtained over 50% polarization with controllable convection speed so far. Fig. **??** shows a picture of the prototype cell.

An additional problem that comes with higher beam current is that the glass end windows of traditional design are not likely to survive the experiments. Our group started exploring the option of using metal end windows from a decade ago. Fig [**?**] shows an example configuration of such a cell. The first problem to solve is to find out the correct material and the proper technique to incorporate metal without introducing significant spin relaxation and still being able to hold high pressure gas (12 atm) inside. This is a brand new technique that may have a profound impact of future cell designs once fully developed. Although no metal end windows have been tested so far, multiple glass cells with different kinds metal tubes (much larger in area compared to the end windows that will be used in JLAB experiments) attached were examined and were enough to convince us the extra spin relaxation is not likely to cause significant problems. The metals tubes were connected to Pyrex glass with knife-edge (houskeeper) seals and stayed intact through high pressure tests. After exploring options such as pure copper, gold coated copper, titanium, stainless steel, gold coated titanium, we have established that electroplating gold on copper substrate

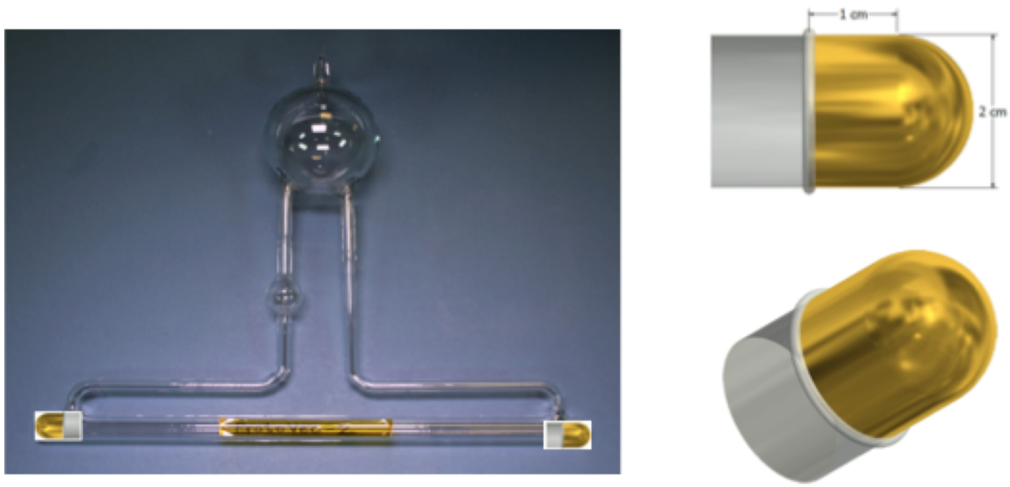

Figure 1.2: A diagram of target cell with metal end windows.

yields the best result so far, we have achieved a 15.6 h relaxation time with a Pyrex cell that had a 5” long by 1” gold coated copper tube attached horizontally. By extrapolating the relaxation rate due to gold surface from this result, we believe the relaxation rate introduced by small metal windows in a target cell will be less than $1/135\ \mathrm{hr}^{-1}$. To the best of our knowledge, our group was the first to have proved the potential of incorporating metal to target cells in the presence of alkali vapor.

1.3 Structure of This Thesis

This thesis focuses on both discussion on the development of high-performance polarized 3He targets that utilize spin-exchange optical pumping (SEOP) and the development of future target cells that incorporate metal end windows. Chapter 2 gives a general description of SEOP. Chapter 3 introduces polarimetry techniques used in our lab for target cell characterization. Chapter 4 discusses the result collected in our lab from the over-a-decade development of ^{3}He target cells, in which the spin-exchange rate constant for K and ^{3}He is calculated and the so-called "X Factor" is studied. Chapter 5 presents the development process of target cells with metal parts that aims to incorporate metal end windows to future cells for the 12 GeV era experiments. Chapter 6 summarizes this thesis and suggests future directions.

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Appendix A

Appendix title

This is Appendix A.

You can have additional appendices too (*e.g.*, `apdxb.tex`, `apdxc.tex`, *etc.*). If you don't need any appendices, delete the appendix related lines from `thesis.tex` and the file names from `Makefile`.