

Summary

This thesis reports a substantial body of high-quality experimental work on ultracold helium in optical and magnetic traps. The physics is interesting, and the experiments are challenging. The overall theme is the precision measurement of fundamental physical quantities made viable using atomic helium, which has a relatively straightforward structure that simplifies precision calculations.

The main new results of this thesis can be summarized as follows:

- Frequency measurements of the transitions from the 2^3P_2 state improving the previous measurements by an order of magnitude and a direct measurement of the spin-forbidden transitions $2^3P_2 - 5^1D_2$.
- Determination of the tune-out frequency near 413 nm, providing a precise constraint of the relative transition-rates, with a 20 fold improvement over the first experiment.
- Observations of quantum depletion in an expanding condensate of helium in the far field regime.

This thesis is, in general, well written, and the author does an excellent job of putting his work in context. The author also captures the right amount of detail and background in his experimental chapters.

The work is interesting and has new/novel research for a PhD. It is clear that such precision experiments are challenging: trying to discern such subtle effects will always be hard. The analysis included in the thesis supports the conclusions reached. However, as the author states, further experimental work is required, especially in the quantum depletion experiment, to resolve why there is an excess of particles in the depletion region not accounted for in theory.

Comments and Corrections

Most of the corrections are typographical however, I would like to make a couple of comments about the reference ordering and Chapter 3.

While I understand the references in the overview would be out of order, I don't understand why the references start at [144] in chapter 1, personally I dislike this, as it feels clumsy. I would suggest re-ordering these, unless there is some underlying reason that I've not picked up on.

Personally, I think chapter 3 is not required, as it adds no new science. Instead, it shows that the student worked on another project for some time, which is unnecessary considering the excellent results. I feel it breaks the overall flow of the thesis and could be relegated to an appendix or excluded entirely without harming the outcome of the thesis. Whether to change this or not is left to the author and supervisor.

Throughout the thesis, the author is missing a space between numbers and their associated units, e.g. 50 nm. This should be corrected.

Chapter 1

Page 19, line 8: potential³ have the form → potential³ will have the form.

Page 32, line 24: poalrized in the either → polarized in either

Chapter 2

Page 45 line 6: "molecular pumps³," → remove the full stop.

Page 45 line 12: "faraday cups" → "Faraday cups"

Page 50 figure 2.2: This figure is unclear, other than showing the figure four configuration it is unclear in the context of where the beams come from, go to etc. Better labelling is required.

Page 50 line 5: "forming a a 2D" → "forming a 2D"

Page 53 line 18: "2.3for" \rightarrow 2.3 for

Page 59 line 6: "chapters ?? respectively" \rightarrow correct the ??

Chapter 5

Page 134 line 18: "section 5.3gives an" \rightarrow "5.3 gives an"

Page 149 line 1: "clculations" \rightarrow "calculations"

Page 150 line 2: " f_{TO} we and" \rightarrow " f_{TO} and"

Chapter 6

Page 186 line 26: "intractions" \rightarrow "interactions"

Page 194 line 10: "espeially" \rightarrow "especially"

Page 211 line 5: " n_0 " \rightarrow " n_0 "