

RECOMBINATION X-RAY LASER USING COHERENCE

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A DISSERTATION
PRESENTED TO THE FACULTY
OF PRINCETON UNIVERSITY
IN CANDIDACY FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

RECOMMENDED FOR ACCEPTANCE
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Abstract

iiiiiii HEAD A strong femto-second laser pulse ($800nm$, $10^{15}W/cm^2$, $100fs$ pulse width) was directed to Helium gas (atom density: $10^{18}cm^{-3}$). The atoms are fully ionized in this optical field ($E: 10^8V/m$), and plasma is created. Due to collisions, ionized electrons repopulate all the energy levels of Helium in nanosecond time scale. Then with beams from OPA directed to the gas, whose wavelength matches the energy difference of levels interested, the coherence in the atoms are created. With the presence of coherence, the lasing without inversion scheme is created. Finally a transient lasing gain without population inversion between 2^1P and 2^1S was expected, whose wavelength is $58nm$. ===== This is a L^AT_EX template and document class for Ph.D. dissertations at Princeton University. It was created in 2010 by Jeffrey Dwoskin, and adapted from a template provided by the math department. Their original version is available at: <http://www.math.princeton.edu/graduate/tex/puthesis.html>

This is **NOT** an official document. Please verify the current Mudd Library dissertation requirements [?] and any department-specific requirements before using this template or document class.

Your abstract can be any length, but should be a maximum of 350 words for a Dissertation for ProQuest's print indices (or 150 words for a Master's Thesis); otherwise it will be truncated for those uses [?].

Dwoskin Ph.D. Dissertation Template — version 1.0, 5/19/2010 llllllll parent of e75694e... Template only

Acknowledgements

I would like to thank the Math department for providing the original documentclass file that this class is based upon. I would like to thank my parents, without whom my life would not be possible. I would also like to thank my advisor, my dissertation committee, and my research collaborators because every graduate student needs to do so. And finally, I thank the members of my research group, to whom I leave this template to save you some of the trouble I had to go through getting my dissertation to compile in L^AT_EX.

Don't forget to ask your advisor if your work was sponsored by a grant that needs to be acknowledged in this section.

To my parents.

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Chapter 1

Introduction

Introduction - X-Ray - LWI - Various particles after laser passes. Helium Experiment
- Setup + Laser system - KML System - Tarlas system – Weifeng’s Thesis + Image
system + Synchronization - Theory - Simulation - Experiment - Linebroanding analysis
Boron and Carbon

This document serves as a template to demonstrate how to use the `puthesis` documentclass for a Princeton University Ph.D. Disseration. Some of the requirements for a master’s thesis or an undergraduate thesis are different, especially the text on the title page, so you will need to make some modifications to use this template for those purposes.

This template is setup to easily make a few different versions of your dissertation. The version you will print and have bound should generally be single spaced (and single-sided), and not contain any hyperlinks. The electronic version that you submit to your readers to review and to be published by ProQuest will be double spaced, and will contain PDF features such as bookmarks for each section and internal links to citations, footnotes, and other internal references.

During the writing process, you may want to disable some of the frontmatter (list of tables, list of figures, acknowledgements, and maybe even the table of contents.

I have not tested this template with equations or a list of symbols, but those are available.

Chapter 2

Related Work

Everyone needs a chapter about related work, so here is a placeholder.

2.1 Tables

Tables are also quite important. Any table that can fit entirely on one page can be a floating table. If a table is longer and will span multiple pages, a long table can be inserted in-line with the text. This is demonstrated in Table 3.1, and explained in Appendix A.

Tables that fit on one page use normal floating figures. Keep the 'p' placement option (in addition to 'h' and 't') so that if the float cannot fit in-line with the document text, it can be on a separate page by itself immediately after it is placed. Without the 'p' option, the float may get pushed to the end of the chapter, along with all other floats in the chapter that follow it.

Table 2.1 lists the various options for publishing your dissertation, with costs, as of 2010. You will have to bring a check for the appropriate amount, made out to “Princeton University Library”, when you submit your bound dissertation copies to Mudd Library, along with the appropriate forms and the electronic copy of your dissertation burned to a CD (not a DVD) as a single PDF file. (See [?].)

Traditional publishing is cheaper initially and lets you earn royalties if the publisher sells many copies of your dissertation. However, most of us won't have a best-seller dissertation and most likely won't earn royalties anyway. Instead, by choosing open access publishing, your dissertation will be available online for free to anyone who is interested. I strongly advocate for open access, to maximize the impact of your research.

Your dissertation is protected by copyright regardless of whether or not you have the copyright registered. However, registration establishes a public record of your copyright claim [?]. ProQuest will submit the copyright registration for an extra fee (about \$55). Alternatively, you can register it yourself at the Copyright Office's website for only \$35: <http://www.copyright.gov/eco/>.

Table 2.1: Thesis publishing options [?], as of May 2010.

Publishing Method	Publishing Fee	Diploma Fee	Copyright Registration Fee	Total
Traditional Publishing				
Traditional without copyright registration	65	15	–	80
Traditional with copyright registration	65	15	55	135
Open Access				
Open access without copyright registration	160	15	–	175
Open access with copyright registration	160	15	55	230

2.2 Figures

Everyone needs floating figures in their dissertation.

As shown in Figure 2.1, the Mudd Library dissertation requirements [?] specify additional options for formatting the title page. For example, if your thesis has multiple volumes, or to indicate the proper formatting for a master's thesis.

Appendix B

TITLE OF DOCTORAL DISSERTATION [OR MASTER'S THESIS]

Volume (if more than one bound volume)

Legal Name of Author

A DISSERTATION [OR THESIS]
PRESENTED TO THE FACULTY
OF PRINCETON UNIVERSITY
IN CANDIDACY FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY [OR MASTER OF ARTS]

RECOMMENDED FOR ACCEPTANCE
BY THE DEPARTMENT OF [OR PROGRAM IN]
[NAME OF DEPARTMENT OR PROGRAM]
[Adviser: John Doe]

Month* Year

*(The month must be the one when the degree will be granted by the Board of Trustees.
Usually, the only acceptable months are January, April, June, September and November)

Figure 2.1: Sample title page layout [?]

Chapter 3

Usage

* Introduction ** X-Ray Laser To make an X-ray laser at 58nm. ionization-recombination

The ion-electron recombination occurs on a time scale faster than 1 ps which creates Li^{2+} (He-like) ions in highly excited states (large principle quantum number n). By collisions atoms are transferred to states with smaller n on a few ps time scale. For proper density population inversion between the level $n = 2$ and the ground state ($n = 1$) is created for 10–100 ps. This results in lasing on the wavelength of the $n = 2$ to $n = 1$ transition (13.5nm) which is measured by a spectrometer.

- XUV ** Plasma cold plasma 1-2ev

** Helium ** LWI *** Principle Usually, the gain medium of a laser works on the basis of a population inversion. In the 1990s, however, it was shown that optical amplification and consequently lasing without inversion are possible by using an additional optical or microwave field which induces a quantum coherence in the atoms of the gain medium. The basic idea is to provide two different pathways for atoms to get from the ground state to the excited state – a direct one and another one via a third energy level –, and to induce a quantum coherence, so that the quantum-mechanical probability amplitudes for both processes cancel. In effect, this suppresses the reab-

sorption and thus makes it possible to obtain gain even with a small population in the upper state.

In principle, lasing without inversion could help, e.g., in realizing lasers operating on very short wavelengths, where a population inversion is difficult to achieve. *** Dark State The idea: Pump atoms into dark state, then emission from $-1j$ can exceed absorption from ground states.

*** :TODO: *** Atomic Coherence :Question: In physics, atomic coherence is the induced coherence between levels of a multi-level atomic system sometimes observed when it interacts with a coherent electromagnetic field.

**** , dark state *** Rabi frequency :Question: The Rabi frequency for a given atomic transition in a given light field gives the strength of the coupling between the light and the transition. Rabi flopping between the levels of a 2-level system illuminated with resonant light, will occur at the Rabi frequency. The Rabi frequency is a semiclassical concept as it is based on a quantum atomic transition and a classical light field.

*** Helium The brightness of an Atomic spectral line emitted by atoms in a gas (or plasma) can be proportional to the gas's temperature, pressure or a weighted sum of both.

*** Electron density *** Power density *** Inversion or No inversion
 ** EIT * Setup ** Lasers and OPAs **** Powers **** Lens a low power 2 Hz Nd/YAG laser (100 mJ, 5ns) was focused with an f/6 lens.

After a few hundred nsec delay (varied between 300 and 1000 ns), the Ti:sapphire 250 fs laser was fired, whose energy is 50–60 mJ in a repetition rate 2 Hz. This femto-second laser was tightly focused with the same f/6 lens onto the plasma at the entrance of the microcapillary providing a power density close to 21017 W/cm^2 .

was directed to the microcapillary by a near 100% reflectivity mirror, M1, and the femto-second laser beam was directed by directed by a mirror, M2 which is transparent

for the 1.06 m wavelength of the Nd/YAG laser. From the output spectra, we could see the soft X-ray lasing. **** The power of focused beam to create Plasma. ** Optical Path Sketch ** Photos *** Helium *** Optical Path * Preliminary Results and Discussion Purpose: Verify ** Absorption Spectrum ** FWHM vs Pressure, Delay *** Different broadening Gaussian broadening refers to broadening effects in spectral lines, these can be produced by Doppler broadening and natural broadening. - Natural - Doppler - Collision *** Absorption coefficient Verify population on 2 S^3 *** Dynamic Process of Recombination ** Helium ionize spectra

To start, in your main .tex file, use this class as your main documentclass instead of ‘report’ or ‘book’. For example:

```
\documentclass[12pt,lot,lof]{puthesis}
```

In this example, we setup our document to use the PU Thesis style, with 12pt font for body text, and to include a List of Tables and List of Figures in the front matter. You could instead set an 11 point or 10 point font by changing the first option. You can also add ‘los’ to include a list of symbols.

To use single spacing, add the option ‘singlespace’. This is a special option for the `puthesis` documentclass, which sets single spacing for both the front matter and for the document itself. Additional parameters should be set in your main .tex file, and are described in detail in Section 3.1.

The template itself declares two other options, to be set immediately after the `documentclass` command. First is ‘printmode’, declared with the command:

```
\newcommand{\printmode}{}{}%
```

This command, used later in the thesis.tex file, turns off the `hyperref` package and all internal links in the PDF file. This removes any colored links and highlighting that would not be appropriate in a printed and bound thesis. Instead the `url` package is loaded, so that

url commands in your document will continue to work and urls will break properly across multiple lines.

When ‘printmode’ is not specified, the hyperref package is included. It creates colored links for citations, footnotes, and internal references, which can be used to navigate the PDF document more easily. It also adds bookmarks to the PDF file, mirroring the table of contents. By default, it is set to use colored links. For the PDF file that you will submit electronically to ProQuest, this may not be desirable since some copies may be printed, while others will be used electronically. Thus another option, ‘proquestmode’, is defined that keeps hyperref but disables colored links:

$$\backslash newcommand{\backslash proquestmode}\{\}$$

This mode has no effect when used in combination with ‘printmode’.

3.1 Options

In this section, we describe the options you can set when using this thesis class.

Table 3.1: List of options for the puthesis document class and template

Option	Description
12pt	Specify the font size for body text as a parameter to documentclass . The Mudd Library requirements [?] state that 12pt is preferred for serif fonts (e.g., Times New Roman) and 10pt for sans-serif fonts (e.g., Arial).
letterpaper	If your document is coming out in a4paper, your LaTeX defaults may be wrong. Set this option as a parameter to documentclass to have the correct 8.5”x11” paper size.
lot	Set this option as a parameter to documentclass to insert a List of Tables after the Table of Contents.
lof	Set this option as a parameter to documentclass to insert a List of Figures after the Table of Contents and the List of Figures.

(Continued on next page)

Table 3.1: (continued)

Option	Description
<code>los</code>	Set this option as a parameter to <code>documentclass</code> to insert a List of Symbols after the Table of Contents and the other lists.
<code>singlespace</code>	Set this option as a parameter to <code>documentclass</code> to single space your document. Double spacing is the default otherwise, and is required for the electronic copy you submit to ProQuest. Single spacing is permitted for the printed and bound copies for Mudd Library.
<code>draft</code>	Set this option as a parameter to <code>documentclass</code> to have L ^A T _E Xmark sections of your document that have formatting errors (e.g., overfull hboxes).
<code>\newcommand {\printmode}{}</code>	Insert this command after the <code>documentclass</code> command to turn off the hyperref package to produce a PDF suitable for printing.
<code>\newcommand {\proquestmode}{}</code>	Insert this command after the <code>documentclass</code> command to turn off the ‘colorlinks’ option to the hyperref package. Links in the pdf document will then be outlined in color instead of having the text itself be colored. This is more suitable when the PDF may be viewed online or printed by the reader.
<code>\makefrontmatter</code>	Insert this command after the <code>\begin{document}</code> command, but before including your chapters to insert the Table of Contents and other front matter.
<code>\title</code>	Set the title of your dissertation. Used on the title page and in the PDF properties.
<code>\submitted</code>	Set the submission date of your dissertation. Used on the title page. This should be the month and year when your degree will be conferred, generally only January, April, June, September, or November. Check the Mudd Library rules [?] for the appropriate deadlines.
<code>\copyrightyear</code>	Set the submission year of your dissertation. Used on the copyright page.
<code>\author</code>	Your full name. Used on the title page, copyright page, and the PDF properties.
<code>\adviser</code>	Your adviser’s full name. Used on the title page.

(Continued on next page)

Table 3.1: (continued)

Option	Description
<code>\departmentprefix</code>	The wording that precedes your department or program name. Used on the title page. The default is “Department of”, since most people list their department and can leave this out (e.g., Department of Electrical Engineering), however if yours is a program, set <code>\departmentprefix{Programin}</code>
<code>\department</code>	The name of your department or program. Used on the title page.
<code>\renewcommand{\maketitlepage}{}{}</code>	Disable the insertion of the title page in the front matter. This is useful for early drafts of your dissertation.
<code>\renewcommand*{\makecopyrightpage}{}{}{}</code>	Disable the insertion of the copyright page in the front matter. This is useful for early drafts of your dissertation.
<code>\renewcommand*{\makeabstract}{}{}{}</code>	Disable the insertion of the abstract in the front matter. This is useful for early drafts of your dissertation.

I’ve seen other people print their dissertations using `\pagestyle{headings}`, which places running headings on the top of each page with the chapter number, chapter name, and page number. This documentclass is not currently compatible with this option – the margins are setup to be correct with page numbers in the footer, placing them 3/4” from the edge of the paper, as required. If you wish to use headings, you will need to adjust the margins accordingly.

Chapter 4

Conclusion

In this work, we explain how to use the puthesis.cls class file and the accompanying template.

4.1 Future Work

Future work should include options in the template for a masters thesis or an undergraduate senior thesis. It should also support running headings in the headers using the ‘headings’ pagestyle. The print mode and proquest mode included in the template might also be candidates to include in the class itself.

Appendix A

Implementation Details

Appendices are just chapters, included after the `\appendix` command.

A.1 Switching Formats

When switching `printmode` on and off (see Section 3.1), you may need to delete the output `.aux` files to get the document code to compile correctly. This is because the `hyperref` package is switched off for `printmode`, but this package inserts extra tags into the contents lines in the auxiliary files for PDF links, and these can cause errors when the package is not used.

A.2 Long Tables

Long tables span multiple pages. By default they are treated like body text, but we want them to be single spaced all the time. The class therefore defines a new command, `\tablespacing`, that is placed before a long table to switch to single spacing when the rest of the document is in double spacing mode. Another command, `\bodyspacing`, is placed after the long table to switch back to double spacing. Normal

tables using `tabular` automatically use single spacing and do not require the extra commands.

When the documentclass is defined with the ‘`singlespace`’ option, these commands are automatically adjusted to stay in single spacing after the long table.

Make sure there is always at least one blank line after the `\bodyspacing` command before the end of the file.

Some times long tables do not format correctly on the first pass. If the column widths are wrong, try running the \LaTeX compiler one or two extra times to allow it to better calculate the column widths.

If you want your long table to break pages at a specific point, you can insert the command `\pagebreak[4]`, to tell \LaTeX that it really should put a page break there. `\pagebreak[2]` gives it a hint that this is a good place for a page break, if needed. If there’s a row that really should not be broken across a page, use `*`, which will usually prevent a pagebreak.

A.3 Booktabs

The booktabs package is included to print nicer tables. See the package documentation [?] for more details and motivation. Generally, all vertical lines are removed from the tables for a better visual appearance (so don’t put them in), and better spacing and line thicknesses are used for the horizontal rules. The rules are defined as `\toprule` at the top of the table, `\midrule` in between the heading and the body of the table (or between sections of the table), and `\bottomrule` at the end of the table. `\cmidrule` can be used with the appropriate options to have a rule that spans only certain columns of the table.

A.4 Bibliography and Footnotes

The bibliography and any footnotes can also be single spaced, even for the electronic copy. The template is already setup to do this.

Bibliography entries go in the .bib file. As usual, be sure to compile the \LaTeX code, then run BibTeX, and then run \LaTeX again.

To cite websites and other electronically accessed materials, you can use the ‘@electronic’ type of BibTeX entry, and use the ‘howpublished’ field to include the URL of the source material.

The formatting of bibliography entries will be done automatically. Usually the titles are changed to have only the first word capitalized. If you’d prefer to have your original formatting preserved, place the title in an extra set of curly braces, i.e., “title = {{My title has an AcroNyM that should stay unchanged}},”.

A.5 Figures and Tables

The captions of figures and tables take an optional parameter in square brackets, specifying the caption text to be used in the Table of Contents. The regular caption in curly braces is used for the table itself.

Generally captions for tables are placed above the table, while captions for figures are placed below the figure.

Appendix B

Printing and Binding

B.1 Printing

For the library copies of your dissertation, you must use archival quality printing and binding. This means acid-free paper, containing at least 25% cotton fiber. Triangle Repocenter on Nassau Street in Princeton offers both 25% cotton paper and 100% cotton paper. Most people choose the 25% cotton paper, and this is generally recommended by the binders. The 100% copy paper is somewhat thicker and the extra expense is unnecessary.

Triangle offers online submission of your printing and binding order at: <http://triangleprinceton.com/collegiatebinding/thesis/>. If you request binding from them, they will deliver the paper copies to Smith-Shattuck Bookbinding for you and allow you to pick up the completed copies at their store on Nassau Street. The whole process takes 2-3 business days, but check with them in advance during the busy thesis-printing season in April and May.

Currently, your printed and bound dissertation copies can be single spaced. Only the electronic copy submitted to ProQuest must be double spaced. All copies must be printed single-sided, with specific margins.

B.2 Binding

An archival-quality sewn binding is required for the library copies of your dissertation. Smith-Shattuck Bookbinding is highly recommended, and is used by most students. Triangle Repocenter will send your copies there for you, greatly simplifying the process, but you can call Smith-Shattuck with special requests.

The “library standard” sewn binding is sufficient for the copies to be sent to Mudd Library. It uses a black buckram cloth cover, which is the most popular option. For extra copies for yourself and your family members, you can choose “buckram roundback binding”, which adds decorative lines on the spine, and printing of the title and author on the front cover. For a small additional fee, you can include the Princeton University shield on the front cover and a ribbon bookmark. Leather covers are also available. See Smith-Shattuck’s website for more details at: <http://www.thesisbookbinding.com/>.

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