02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: Melinda J Kellogg

Gender: ☐ Male ☒ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☒ White

Disability Status:
(Select one or more)

☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☐

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☐

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 10-1

NSF 10-539 **10/21/10**

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

DUE - ATE-Projects

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				065391526	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)

546001796

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

University of Virginia Main Campus

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

University of Virginia Main Campus
P.O. Box 400195
Charlottesville, VA. 229044195

AWARDEE ORGANIZATION CODE (IF KNOWN)

0037457000

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

University of Virginia's College at Wise

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE

U of VA's College at Wise
P.O. Box 400195
Charlottesville, VA 22904-4195

PERFORMING ORGANIZATION CODE (IF KNOWN)

0037473000

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS
☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS
☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Atom Trapping Teaching Laboratory**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 61,647	24 months	06/01/11	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☒ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________
PHS Animal Welfare Assurance Number ________
☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ________
Exemption Subsection ________ or IRB App. Date ________
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
____
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT

UVa's College at Wise Natural Sciences

PI/PD POSTAL ADDRESS

P.O. Box 400195

Charlottesville, VA 229044195
United States

PI/PD FAX NUMBER

276-376-4603

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME Melinda J Kellogg	DPhil	2005	276-328-0179	mjk6u@uvawise.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, lobbying activities (see below), responsible conduct of research, nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 10-1). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.
The undersigned shall require that the language of this certification be included in any award documents for all subawards at all tiers.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER

* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

NATIONAL SCIENCE FOUNDATION
Division of Undergraduate Education

NSF FORM 1295: PROJECT DATA FORM

The instructions and codes to be used in completing this form are provided in Appendix II.

1. **Program-track** to which the Proposal is submitted: **ATE-Projects**
2. Name of **Principal Investigator/Project Director** (as shown on the Cover Sheet):
   Kellogg, Melinda
3. Name of submitting **Institution** (as shown on Cover Sheet):
   University of Virginia Main Campus
4. **Other Institutions** involved in the project's operation:

Project Data:

A. Major Discipline Code: **13**
B. Academic Focus Level of Project: **LO**
C. Highest Degree Code: **B**
D. Category Code: **K**
E. Business/Industry Participation Code: **NA**
F. Audience Code: __ __ __ __ __ __ __ __
G. Institution Code: **PUBL**
H. Strategic Area Code: _____
I. Project Features: __ __ __ __ __

Estimated number in each of the following categories to be directly affected by the activities of the project during its operation:

J. Undergraduate Students: **10**
K. Pre-college Students: **0**
L. College Faculty: **1**
M. Pre-college Teachers: **0**
N. Graduate Students: **0**

Project Summary

We are applying for an Advanced Technology Education grant for the construction of a low-cost rubidium atom cooling and trapping apparatus to be used in an advanced lab component of a new course to be called *Modern Physics II*. This would give students experience in the cutting-edge field of laser cooling and trapping, as well as exposure to high-tech methodologies relevant to post-graduate studies and employment in high-tech industries.

<u>Intellectual Merit</u>

Laser cooling and trapping is the foundation for creating atomic Bose-Einstein condensates (BECs) which constitute the fastest growing and most stimulating field in modern physics. For a low cost we can build a cooling and trapping apparatus that cools rubidium gas down to microkelvin temperatures (one step away from creating a BEC) and thus expose our students to the technologies and physics of this cutting-edge field. The apparatus, which includes two homemade stabilized diode lasers, will be built by students as summer research projects, following instructions by BEC Nobel laureate Carl Wieman as published in the American Journal of Physics. The students who build the apparatus (as part of a currently existing summer fellowship program) will gain valuable experience in metal machining, ultra high vacuum technology, resistive electromagnets, the utilization of basic optics components such as mirrors, lenses, wave plates, and photodiodes, the building of their own electronics to interface with the apparatus, and data interpretation.

The completed apparatus will then be used to establish a new course in which future students will have the opportunity to use the apparatus in advanced lab experiments in which they will learn about diode lasers and basic atomic physics while gaining hands-on experience with the lasers, basic optics, ultra high vacuum technology, electromagnets, homemade and commercial electronic equipment, and data interpretation. These technologies are found in many experimental physics labs and in high-tech commercial industries, but at the college now, students have no opportunities to gain experience with these types of equipment.

<u>Broader Impact</u>

The University of Virginia's College at Wise is located in the Appalachian Mountains. This region is home to a population that suffers a high poverty rate and low educational attainment rate. Wise County is one of the counties included in the NSF-funded Appalachian Rural Systemic Initiative and the Appalachian Math and Science Partnership both of which recognize the county as an economically and educationally disadvantaged region, particularly lacking in the areas of math and science achievement.

This project would give these local Appalachian students exposure to and training in technologies which are currently not available to them. Additionally, the exciting visual nature of the apparatus should draw students into the new proposed course, possibly increasing the number of local students majoring in the sciences.

The addition of this new course with its advanced lab component will strengthen the physics discipline, bringing us closer to our goal of creating a physics major. Strengthening our physics discipline also improves our pre-engineering program since bringing more motivated students into our physics courses makes the courses more competitive, giving the pre-engineering students a more suitable preparation to transfer to engineering schools such as Virginia Tech.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Project Description

Impact

The University of Virginia's College at Wise (UVa-Wise) is a four-year public liberal arts college located in the Appalachian Mountains in southwest Virginia. The college primarily serves the people of Wise County, as well as some neighboring counties, all of which have high poverty rates (19.2% of the Wise County population lives in poverty [1]) and low educational attainment rates (19.4% of the population over age 25 has less than a 9th grade education, only 62.5% have high school diplomas [2]).

Wise County is one of the counties included in the NSF-funded Appalachian Rural Systemic Initiative and the Appalachian Math and Science Partnership both of which recognize the county as an economically and educationally disadvantaged region, particularly lacking in the areas of math and science achievement. Of special concern, in regards to this proposal, are the local students who show natural aptitudes in physics and engineering, but have little opportunity to develop these gifts because of the lack of opportunities in these fields in Wise and its neighboring counties.

UVa-Wise is a small college with an enrollment of about 1900 students. The sciences are grouped together in one Natural Sciences department which offers some strong programs, especially in biology, but currently has a very weak physics program and a weak pre-engineering program. There is a minor in physics offered, but no physics major and no physics research that the students can get involved with. Local students who come to the college primarily for geographic regions are often disappointed that they cannot major in physics, after having discovered from taking an introductory physics class (required for all science students) that they are quite gifted in this subject and find it very exciting.

Some of the local students who come to the college are extremely intelligent. Recently, we had a 17-year-old college senior from the town of Appalachia with an IQ around 200 (he started taking courses at the college when he was 12). He was one of the students who dearly wished we offered a physics major at the college. He loved physics and took all the minor courses that we offered. He wanted to go to graduate school and pursue a Ph.D. in physics, but without a bachelor's degree in physics (he instead majored in math) he could not get admitted to a physics graduate program. He currently has no academic plans for the future (he does not like math enough to pursue a Ph. D.) – which is a terrible loss to this community as he had tremendous potential as a physicist. He is of course an exceptional case, but there are a surprising number of highly intelligent students here who are capable of achievement in high technology fields if they were given exposure to them and given educational opportunities in these fields.

The funds requested in this grant proposal would help these students by giving them these opportunities. The funds would be used to create summer and academic year research projects for two years and to create a new physics course with an advanced lab component that would provide future students the opportunity to gain real-world lab experience that would prepare them for post-baccalaureate research in physics labs or employment in an industrial lab. Offering a course with an advanced lab will bring the physics program closer to the implementation of a physics major.

The Natural Sciences department already has a successful summer research program, used primarily by biology students, called the Fellowship in the Natural Sciences (FINS) program. Students compete for the fellowship by writing a description of their research project and submitting their grade transcripts and letters of recommendation. The winning students receive a $3,000 stipend to work in one of the department's research labs over the summer. The projects funded by this proposal would allow students interested in physics to also participate in FINS. In addition to providing a paid summer academic job, participation in the fellowship program is prestigious and has proven to be very helpful in gaining admission to graduate programs.

The two years of student projects that this grant will fund include the construction of homemade precision lasers made from inexpensive laser diodes. These lasers will then be used as part of a laser cooling and atom trapping apparatus that students in the second year will assemble. Laser cooling and atom trapping are extremely exciting technologies in physics, and they are crucial for the achievement of atomic Bose-Einstein condensation (BEC), which is the fastest growing field in physics today. Although this apparatus is not capable of atomic BEC, it can cool and trap atoms to temperatures somewhat above the critical temperature. Experience with this apparatus and the manipulation of the trapped atoms however can prepare a student for research in an ultracold atom or BEC lab, and there are many of them in Virginia. There are two groups at the University of Virginia, Charlottesville that work with rubidium (this is the atom we will be trapping): Prof. Cass Sackett's lab performs experiments with rubidium BECs [3], and Prof. Tom Gallagher's lab studies cold Rydberg atoms in magneto-optical traps (like the traps we will be building) [4]. Prof. Mark Havey at Old Dominion University in Norfolk slows and freezes light with cold rubidium atoms [5]. Prof. Charles Sukenik also at Old Dominion University researchs the ultracold production of rubidium-argon molecules [6]. In addition to directly preparing a student to work in a cold atom research lab, the technologies they will be learning about: lasers, ultra-high vacuums, electromagnets and electronics are all generally useful for work in any physics lab or in high-tech industry.

Project Activities and Implementation of New Course

Year One (6/1/2011 – 5/31/2012)

During the first year we will construct the two diode laser systems and locking devices needed for the finished atom trapping apparatus. This will require metal machining, building homemade electronics, working with standard optics components, and working with rubidium vapor cells which will require the learning of basic atomic physics. This is a rich opportunity for motivated students to learn a large set of technological skills currently not obtainable at the college.

Laser diodes are inexpensive lasers that are found in laser pointers, CD players, and grocery store scanners. These lasers are not immediately suitable for most scientific work because the frequency of the laser light output is not stable: the frequency randomly jumps over a relatively broad range. For exacting scientific work, the frequency must be stabilized to a precise value. In year one, we will follow instructions given by Nobel laureate Carl Wieman to turn a standard inexpensive diode laser into a stabilized laser that is locked to a precise frequency [7], tuned to an optical transition in the rubidium-87 atom so that this laser may be used to interact with and trap rubidium-87 atoms. Stabilizing our own laser diodes is much less expensive than purchasing commercial stabilized lasers, which cost from $20,000 to $50,000 apiece.

Carl Wieman's paper [7] gives complete, detailed, easy-to-follow instructions in the building and testing of a narrow-band tunable diode laser made from a low-cost high-power laser diode, along with a saturated absorption spectrometer to lock the laser's output to a specific frequency. The first laser will be built by two students over the first summer. One student will be funded by the department's FINS program and the other will be funded by this grant.

Summer Student Project I

This student (student A) will be funded by the department's FINS program, and will build all components of the first laser except for the electronics, which will be built by the second student (student B).

Student A will first be trained in the safe use of standard machine shop equipment, specifically the drill press, band saw, and milling machine. The student will practice drilling and tapping holes, and cutting various shapes before machining the laser system components following machine drawings provided in Wieman's paper. These components include: a diode laser base plate, a laser diode mounting block, a collimator lens mount, and an alignment jig all machined from solid aluminum blocks.

The laser's frequency will be stabilized by the method of optical feedback, in which a small amount of the laser's output is fed back into the laser. This method both centers the frequency of the output and narrows the laser's linewidth (the width of its optical spectrum). The latter is crucial to the laser cooling of atoms which requires the manipulation of precise transitions between hyperfine sublevels in the atom's energy levels, some of which are less than 100 MHz apart.

The optical feedback is provided by a diffraction grating which the student will epoxy onto a standard mirror mount. When properly positioned near the laser diode output, this creates an external resonant cavity which will determine and stabilize the laser's frequency. A piezoelectric disk mounted behind the diffraction grating mount allows for fine-tuned electronic control of both the cavity length and the grating angle which allows the laser frequency to be automatically scanned, which is necessary for the laser locking mechanism. A piezoelectric disk is a piece of crystal or ceramic which changes its length when a voltage is applied across it. Exposure to even simple technologies such as this is currently unavailable at our college.

The student will then assemble all of these parts, being careful to first properly align the diode with the collimating lens. An infrared (IR) viewer will be necessary at this phase. Even though 780 nm light can be detected visually, it appears much brighter through an IR viewer. Once the collimating lens is aligned, the power output of the laser will be measured as a function of drive current, using at this point a commercial diode laser current controller. This information will be recorded and compared to the laser diode's specifications.

Finally, the diffraction grating will be mounted and aligned. Once aligned, the frequency can be tuned manually with a fine adjustment screw mounted in the laser base plate. A low-resolution spectrometer will be used to assess the tuning characteristics of the laser.

For long term frequency stabilization the temperature of both the laser diode and the laser base plate must also be stable. This requires separate thin film heaters, temperature-sensing thermistors, and feedback electronics for each of these components. These electronics will be assembled by student B, who will also build a current controller and a servo-lock system. Once the electronics are complete, the two students will work together to finish the laser system which will include a saturated absorption spectroscopy locking mechanism.

Summer Student Project II

This student (student B) will be funded by this grant. While student A is constructing and assembling the diode laser components, student B will be assembling the electronics required for feedback and control of the laser system. This student will be required to have taken our 15-week electronics course (Phy 3030) which we offer annually. This course will familiarize the student with most of the elements used in the circuits: resistors, capacitors, switches, diodes, op-amps, and transistors.

This student will build four pieces of electronics: one current controller (Fig. 1), two temperature controllers (Fig. 2), and one servo-lock mechanism (Fig. 3). These circuits, diagrams of which are provided in Wieman's paper, will be soldered onto a circuit board and enclosed in an aluminum box with appropriate input and output connectors, switches, and indicators. Before constructing the circuits, the student will read papers on the principles of current and temperature control circuits [8], and servo-lock circuits [9].

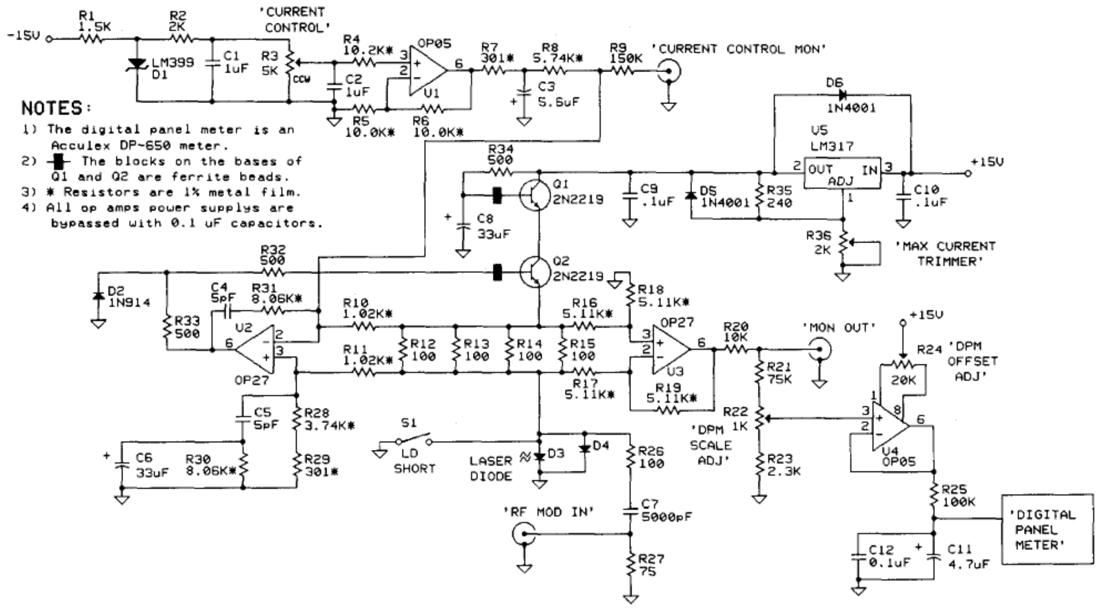

Figure 1. Laser current control circuit, circuit diagram from reference 8.

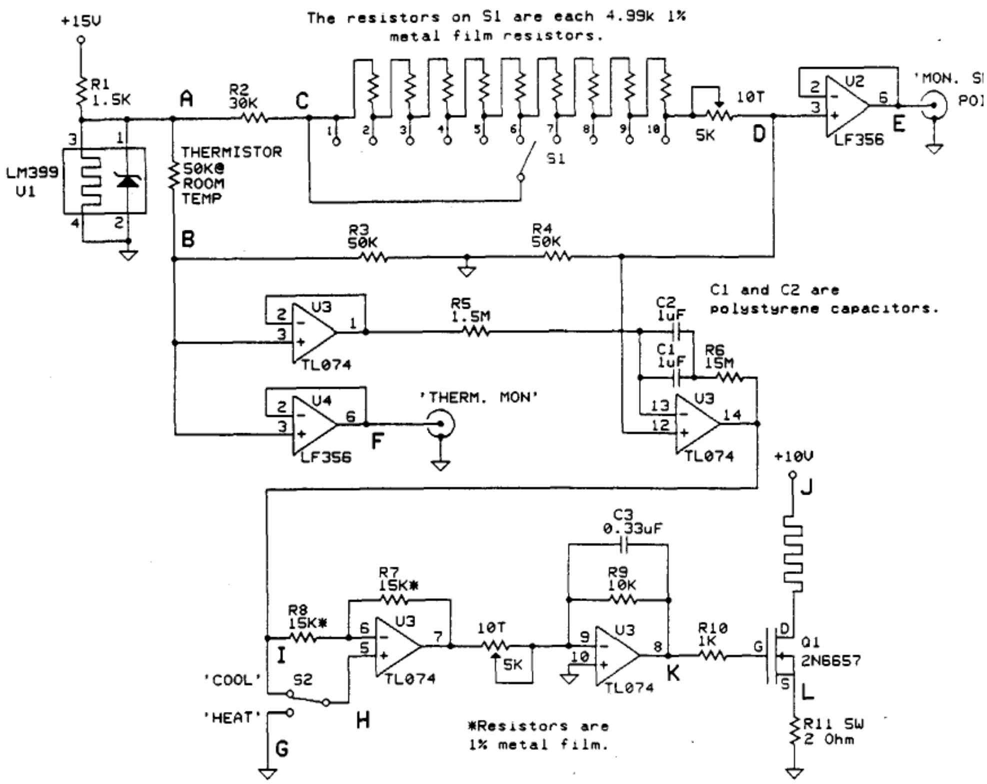

Figure 2. Laser temperature control circuit, circuit diagram from reference 8.

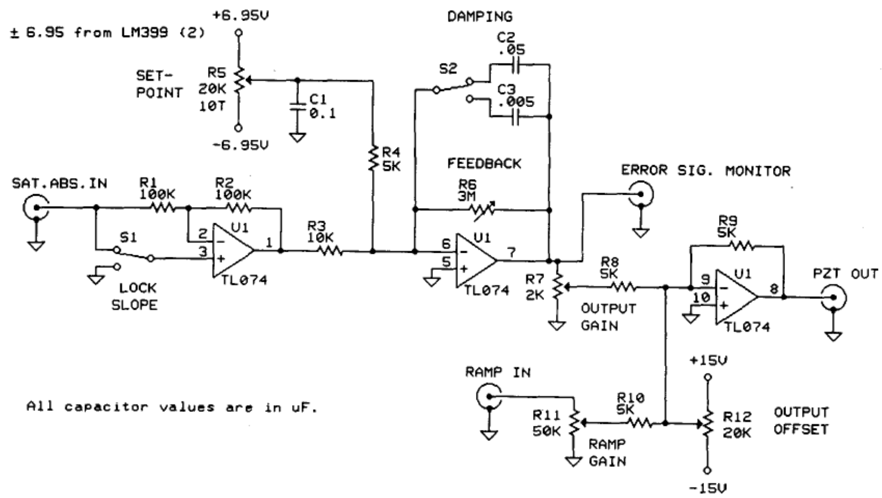

Figure 3. Laser servolock circuit, circuit diagram from reference 8.

This project will give the student advanced electronics experience beyond the fundamentals learned in Phy 3030. The student will be building more complex circuits than we build in class and learn about control voltages, feedback loops, error signals, and proportional-integral controllers, as well as gain valuable practical experience in constructing permanent circuits and working with enclosures.

After student B completes the electronics to the extent possible while working alone, the two students will work together to complete the laser system, adding a saturated absorption spectrometer and completing the locking mechanism.

Summer: Completing Laser System

With student B's current supply replacing the commercial current source, and the temperature control electronics in place stabilizing the temperature of the laser, the students will work together to construct the saturated absorption spectroscope necessary to lock the frequency of the laser to the relevant transition in the rubidium-87 spectrum.

Saturated absorption spectroscopy is a spectroscopic method which eliminates the Doppler broadening of the spectral lines. Doppler broadening results from the thermal motions of the atoms. It is crucial to remove the Doppler broadening from the spectrum because the laser cooling of atoms requires the manipulation of optical transitions between hyperfine sublevels of the $5^2S_{1/2}$ and $5^2P_{3/2}$ states. Many of these sublevels are less than 300 MHz apart, whereas the Doppler broadening FWHM of the 780 nm transition line of rubidium-87 at room temperature is ~ 500 MHz [10].

To achieve this, the laser beam (probe beam 1) will be sent through a glass cell containing room temperature rubidium-87 gas (Fig. 4). As the piezoelectric disk is repeatedly ramped with a triangle wave from a function generator, the laser output will scan back and forth in frequency. By observing changes in the laser's intensity after it emerges from the rubidium cell (using a photodiode) a Doppler broadened spectrum will be observed so long as the frequency is being scanned through one of the optical transitions of the rubidium gas (Fig. 5a).

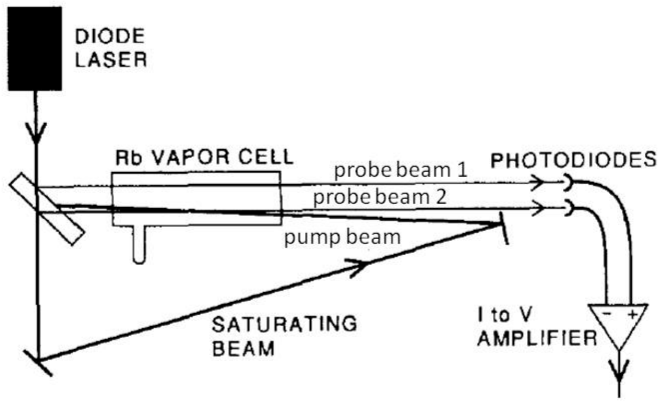

Figure 4. Saturated absorption spectroscopy setup, adapted from reference 8.

The relevant optical transitions for this apparatus is from the $5^2S_{1/2}$, F = 1 hyperfine ground state to the $5^2P_{3/2}$, F′=0, 1, or 2 states; and from the $5^2S_{1/2}$, F = 2 state to the $5^2P_{3/2}$, F′=1, 2, or 3 states (Fig. 6). To initially locate the two main ground state transitions, the frequency of the laser is adjusted by manually turning the fine-adjustment screw which rotates the diffraction grating. When one of these transitions is excited, a bright path of fluorescence will appear in the rubidium cell as seen through the IR viewer. At this point the current will be adjusted to maximize the fluorescence.

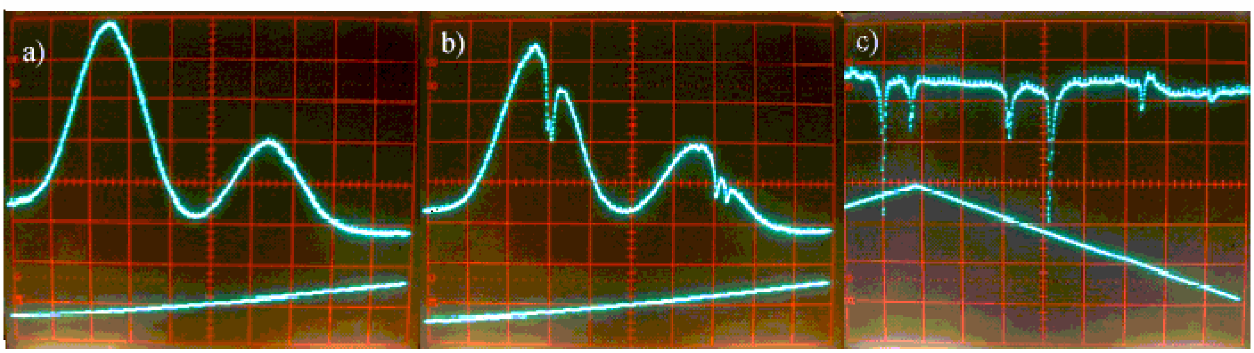

Figure 5. Laser saturation absorption spectroscopy of rubidium as seen on oscilloscope. a) Doppler broadened spectral lines. b) Doppler broadened spectral lines with hyperfine structure. c) Doppler-free saturated absorption spectral lines [11].

If a second laser beam is sent through a beam splitter (a simple glass plate), sending one of the split-off beams through the rubidium cell (probe beam 2) and the second split-off beam (the pump beam) through the rubidium cell but in the opposite direction so that it intersects probe beam 2 (Fig. 4), a single-beam saturated absorption spectrum will result, in which Doppler-free hyperfine spectral features will be resolved. The probe beam will still show the Doppler-broadened spectrum, but during the portion of the frequency scan in which the laser frequency is equal to the Doppler-free transition frequency, the probe beam's absorption will be altered by the pump beam. At this frequency, both the probe and pump beams are interacting with atoms that are more or less at rest relative to the laboratory. Thus, at this frequency, both beams will be interacting with the same population of atoms. The higher intensity pump beam will pump the atoms out of the ground state of the relevant transition, through both hyperfine pumping and saturation, leaving fewer atoms to absorb the probe beam photons, resulting in Doppler-free spectral features on the broader backdrop of the Doppler-broadened absorption line (Fig. 5b).

The probe beam 2 will be unaffected by the pump beam at other frequencies because at frequencies different from the Doppler-free transition frequencies, the atoms can only absorb photons that are Doppler-shifted to the correct transition frequency. If, for example, the laser frequency is below the F = 1 to F′ = 0 transition frequency, only atoms moving toward the laser beams at the appropriate speed can absorb photons. In reference to figure 4, this would mean that only atoms moving to the right could absorb pump beam photons, and only atoms moving to the left could absorb probe beam photons. So the beams will be interacting with two different populations of atoms and so will not affect each other.

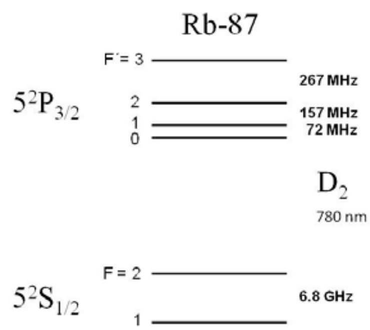

Figure 6. Relevant hyperfine energy levels in rubidium-87.

An exception occurs at frequencies $\nu = (\nu_1 + \nu_2)/2$ for each pair of true transition frequencies ν_1 and ν_2. In this case, an atom, say, moving to the right at the appropriate speed will simultaneously be in resonance with both beams, but for different transitions: one at frequency ν_1 and the other at frequency ν_2. This will create "crossover peaks" in the hyperfine spectrum.

To isolate the Doppler-free spectral features from the broad background, two probe beams are sent through the rubidium vapor cell, only one of which intersects the probe beam (Fig. 4), both terminating on identical photodiodes. Keeping the probe beam intensities similar, the two signals are then subtracted by wiring the two photodiodes in parallel with reverse polarity, leaving the hyperfine features on a relatively flat background (Fig. 5c). By comparing this signal with the known saturated absorption spectra for the relevant transitions in rubidium-87 (Fig. 7), the appropriate transition frequency can be chosen as the reference frequency to which the laser will be locked.

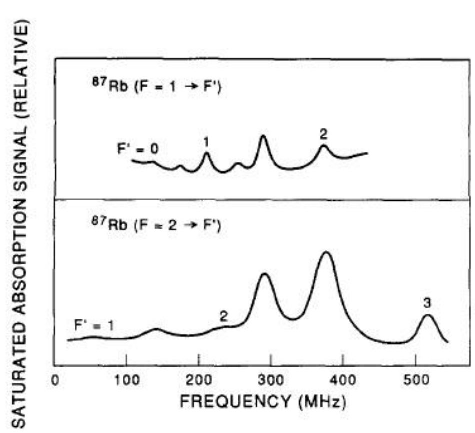

Figure 7. Saturated absorption spectra for the $5^2S_{1/2}$ state to the $5^2P_{3/2}$ state transitions in rubidium-87, adapted from ref. 8.

The laser will be locked using the servo-lock electronics built by student B. The laser will be locked to a frequency just to one side of the relevant transition peak where there is a strong slope in the output signal, which is necessary to produce an error signal. The error signal, which will be modified in the servo-lock electronics by both proportional gain and integration time, will be fed back into the laser's piezoelectric disk, controlling the laser's frequency by adjusting the rotation and position of the diffraction grating. This will stabilize the laser's output to precisely the right frequency for long time periods (1 hour).

At this point the students will test the finished laser to show that it is performing as desired. Both students will be required to give 30-minute long presentations on their portion of the work during the following academic year. These presentations, which are regularly occurring for the FINS students, are historically well attended by students, faculty, and administrative officials. The students may choose to also enter their talks into the annual Student Research Symposium hosted by UVA-Wise and the nearby Emory and Henry College.

Academic Year Projects

During the following academic year, a second laser will be constructed, identical to the first. The second laser is required for the atom trapping device which will be constructed in year two. After successfully building the first laser, this should be a straightforward process. We will upgrade the servo-lock system for this laser so that both the diffraction grating position and the laser current will be included in the feedback loop – this will make the locking system more robust, which will be important for the trapping laser. Circuit diagrams for this more complex servo-lock design are available in reference 9.

The second laser will be built by one or two students over one or both semesters for which the students will receive college credit (Independent Study, Phy 4970). This will give additional students the opportunity to learn about and gain practical experience in: metal machining, the use of standard optics equipment, the detailed workings of lasers, advanced electronics, and atomic physics.

Year Two (6/1/2012 – 5/31/2013)

During the summer of the second year we will construct a laser cooling and atom trapping apparatus which will then be incorporated into a new course offering at the college. This course will be first offered during the academic year of year two. This course will allow students for years to come to gain experience with lasers and the exciting field of atom trapping.

The atom trapping apparatus we will build was designed to be as inexpensive as possible, while still providing a high number of trapped atoms (4×10^7) with a long trap lifetime (3.5 s). The clever use of mirrors and beam alignment eliminate the need for expensive items such as beam-splitting cubes and optical isolators, but mainly it is the homemade stabilized lasers built in year one which keep the price of the apparatus low. We will again follow step-by-step, detailed instructions by Carl Wieman [12] in the construction of the apparatus. The apparatus will be built by a FINS student during the summer.

Summer Student Project

This student will be funded by the FINS program and will construct the atom trapping apparatus from standard vacuum parts and equipment, fashioning an inexpensive glass trapping cell from pyrex glass plates. After pumping down the completed apparatus, the student will use lenses and mirrors to direct six circularly polarized laser beams, each split off from just one of the lasers, orthogonally into the glass cell. These beams will trap the atoms when a magnetic field is also applied. The second laser will provide hyperfine pumping of the atoms. The student will learn how to characterize the trapped atoms through fluorescence measurements. This will give the student valuable experience in ultra high vacuum technologies, resistive electromagnets, the use of basic optics components, atomic physics, and data analysis.

Lasers can be used to cool atoms because an atom moving toward a laser beam that is slightly detuned to the red from an optical transition in the atom will be slowed by the Doppler effect. Atoms moving toward the beam will "see" the beam as being Doppler-shifted to the blue, and (depending on the precise detuning and the atom's speed) the laser light will then be in resonance with an atomic transition in the atom and the atom will begin absorbing photons from the beam. As the atom de-excites it re-emits the photon in a random direction. Since the atom absorbs photons primarily from the direction of the incoming laser beam, but emits photons in random directions, conservation of momentum requires that the atom must slow its velocity as it moves toward the beam.

The trapping laser beam will be slightly red-detuned from the F=2 → F′=3 cycling transition (Fig. 8). To keep the atoms in the F=2 hyperfine ground state a second laser will be locked to the F=1 → F′=2 transition. A single expanded beam from this laser (the pumping laser beam) sent into the glass cell will pump atoms out of the F=1 state into the F=2 state so that they will be in the proper hyperfine ground state for interacting with the trapping beam.

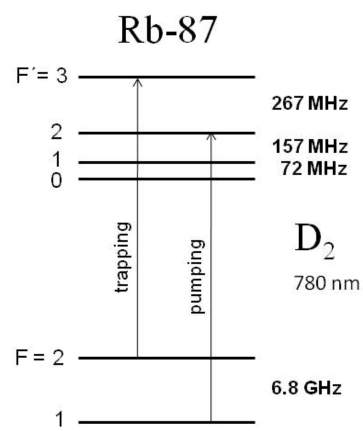

Figure 8. Trapping beam and hyperfine pumping beam transitions in rubidium-87.

Trapping beams sent into the cell from six more-or-less orthogonal directions will slow the atoms regardless of their direction of motion, since the atoms will always be moving towards one or more of the red-detuned laser beams. This will cool the gas of atoms.

In order to trap the atoms, a similar Doppler effect mechanism must be created that is position-dependent rather than velocity-dependent. This is done by applying a magnetic field within the cell and circularly polarizing the trapping beams. The magnetic field will Zeeman split the hyperfine energy levels of the rubidium atoms so that there will be multiple transition frequencies for the F=2 → F′=3 transition, each associated with a specific change in magnetic quantum number, Δm. The new transition frequencies will depend on the magnetic field strength, thus the spatial dependence of the applied magnetic field produces a spatial dependence in the resonant transition frequencies.

The photons in right circularly polarized light (σ^+) can only excite transitions where $\Delta m = +1$; those in a left circularly polarized beam (σ^-) excite only $\Delta m = -1$ transitions. If a $\Delta m = +1$ (-1) transition becomes resonant with the laser beam at a location between the trap's center and the direction of an incoming σ^+ (σ^-) trapping beam, the atom will absorb photons from that beam (predominantly) and be pushed back towards the center of the trap. Such a spatial dependence in the transition frequencies is easily produced by a pair of anti-Helmholtz coils positioned on either side of the glass trapping cell.

The first order of business for this student will be to build the trapping cell apparatus: a glass cell evacuated as well as possible of all substances, but containing a controllable supply of rubidium-87 atoms. For this, the student will first attach to a 5-way ConFlat stainless steel cross (Fig. 9) a 20 liter/s ion pump which can pump the apparatus to ultra high vacuum levels (after it has first been rough pumped). This ion pump will also serve as a pressure indicator.

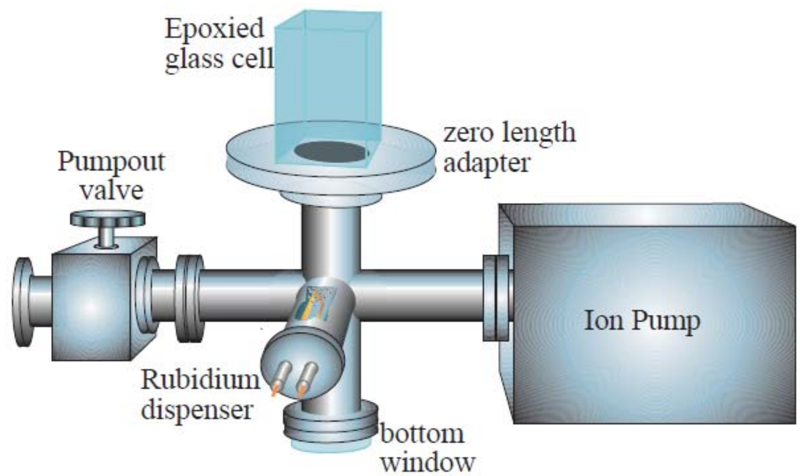

Figure 9. Trapping cell apparatus, from reference 13. Length of cross arms are exaggerated for clarity.

To the opposite arm an all-metal bakeable valve will be attached, which will allow for a cryogenic sorption pump to be connected to the apparatus during the initial rough pumping phase of the evacuation. Another arm will hold the homemade glass trapping cell which will be epoxied onto a ConFlat adapter. Opposite to that will be a commercial glass viewport to allow optical access to the glass cell from the sixth direction.

On the fifth arm will be attached a commercial rubidium-87 getter. A current run through the getter releases rubidium vapor in proportion to the current, allowing for excellent and near-immediate control of the rubidium vapor pressure in the apparatus (which is also affected by adsorption of the rubidium onto the interior walls of the apparatus). For optimum performance of the apparatus, the rubidium vapor pressure must be kept low enough so that collisions with background atoms do not reduce the trap lifetime too much, but high enough to provide a sufficient number of atoms from the low-tail end of the Maxwell distribution to load the trap in a reasonable time. This optimum rubidium pressure is 10^{-8} Torr.

After assembly, the apparatus will be pumped out and baked in a 100˚C oven (the temperature will be increased slowly over several hours), until the pressure is below 10^{-8} Torr when the system is cooled back down.

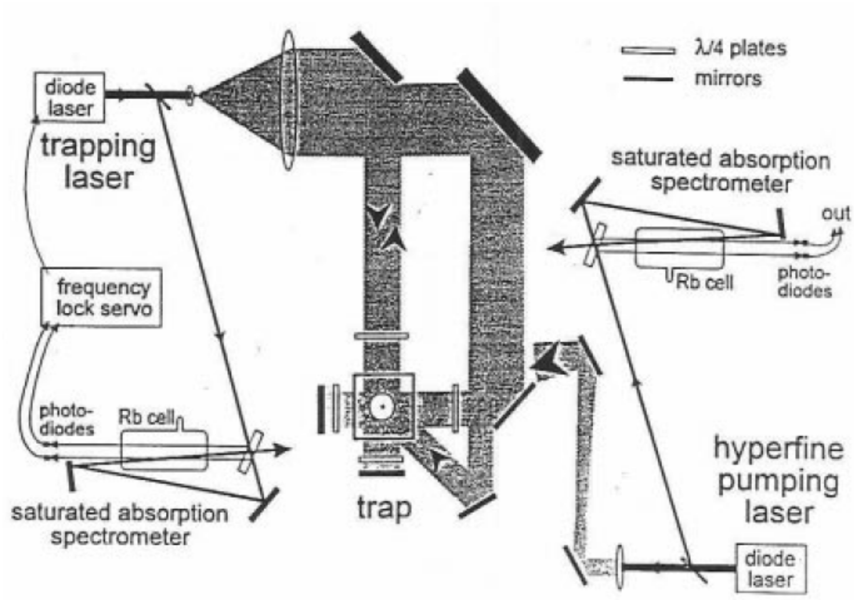

Figure 10. Optics setup for atom trap. One of the trapping beams is being directed under the glass cell, and then reflected upward through it. From reference 14.

The student will then begin to set up the laser beam optics (Fig. 10). One of the two lasers built in year one will be used as the trapping laser, the other as the hyperfine pumping laser. The trapping laser beam will be expanded and clipped off into three separate beams with the judicious use of mirrors. Each beam will be appropriately circularly polarized by sending it through a quarter-wave plate prior to entry into the cell. Each beam will then be retroreflected back through the cell, passing through another quarter-wave plate just before and after its reflection, this will give the retroreflected beam the opposite circular polarization to the incoming beam.

The three incoming beams and three retroreflected beams comprise the six more-or-less orthogonal beams required for the slowing and trapping. After these beams are aligned, the vapor cell will be put in place, and simple anti-Helmholtz coils will be attached to two opposite sides of the glass cell. A single expanded beam from the pumping laser directed into the cell will be sufficient to pump the atoms into the F=2 hyperfine sublevel.

With the apparatus completed and the optics ready to go, the first task will be to establish a sufficient rubidium pressure in the glass cell. The pressure will be monitored initially by the absorption of a weak probe beam tuned to the $F=2 \rightarrow F'= 1, 2$, or 3 transition. An absorption of 1% per centimeter of travel through the cell's vapor has been found [12] to indicate a good pressure for trapping. The absorption will be measured by terminating the probe beam on a photodiode. The getter current that produces this pressure will be noted and used to reproduce the pressure from this point on.

With sufficient rubidium pressure in the cell, the six trapping beams will be sent into the cell and a current applied to the two anti-Helmholtz coils, this should produce a visible cloud of trapped atoms, visible due to the fluorescence caused by the trapping beams. The fluorescence can be seen with the naked eye, if the room is dark enough, or with the aid of an IR viewer or an inexpensive security CCD camera and monitor.

The luminosity of the fluorescence produced by the cloud of trapped atoms is proportional to the number of atoms trapped and can be measured with a photodiode placed near the trap (with care to subtract off the signal due to fluorescence of background atoms and reflections of the lasers off of the glass cell), or better yet: a combination of a lens plus a photodiode. At this point trap parameters can be tweaked to maximize the trapped atoms' fluorescence, and thus their numbers. Parameters to be adjusted include: getter current (thus background pressure), beam frequencies, beam alignment, coil positions, and beam polarization.

With the apparatus optimized, the student will then measure the total number of atoms in the trap and the trap lifetime. To measure the total number of trapped atoms, the total luminosity of their fluorescence is determined by converting the photodiode current to luminosity using the photodiode's calibration information. Dividing that number by the fractional solid angle subtended by the photodiode (or lens, if used) gives the total luminosity. Then the number of atoms fluorescing is equal to that total luminosity divided by the rate R at which an individual atom scatters a photon times the energy per photon. This rate is given by [12]:

$$R = \frac{(I/I_s)\pi\Gamma}{1+(I/I_s)+4(\Delta/\Gamma)^2} \tag{1}$$

Where I is the sum of the intensities in all six trapping beams, I_s is the 4.1 mW/cm^2 saturation intensity, Γ is the natural linewidth of the transition, 6 MHz, and Δ is the detuning of the laser frequency from resonance (roughly 10 to 20 MHz) which can be measured from the saturated absorption spectrometer apparatus.

The trap lifetime will be measured by recording the fluorescence intensity as a function of time as the trap is being filled (the filling can be initiated by turning on the current to the anti-Helmholtz coils). The number of trapped atoms will increase with time according to the following formula [12]:

$$N(t) = N_0\left(1 - e^{-\frac{t}{\tau}}\right) \tag{2}$$

Where N is the number of atoms in the trap at time t, N_0 is the maximum number of atoms in the trap, and τ is the time constant for the trap filling, but also represents the average lifetime of an atom in the trap before it is knocked out of the trap by a collision with a background atom. A simple fit to the experimental curve, even without an absolute determination of N or N_0 will yield the trap lifetime.

This student will then prepare a 30-minute talk on the construction of, and theory behind, the atom trapping device to be delivered during the following academic year as part of the annual FINS presentations.

The completed atom trapping apparatus will then gain a new life as a lab experiment to be used in a new course offering. This course will be offered for the first time in the spring semester of the following academic year.

Academic Year: First Run of New Course

The new course will be a continuation of a popular course we currently teach called Modern Physics. The current course will be renamed Modern Physics I and the new course will be called Modern Physics II.

Modern Physics is a sophomore level course in which students learn special relativity and introductory level quantum mechanics up through solving the Schrödinger equation for the hydrogen atom. The textbook used for this course is "Modern Physics," 5^{th} ed., by Tipler and Llewellyn [15] and we make it about 40% of the way through this book during the semester long course. The students attracted to this course are intelligent and extremely curious about physics but have weak physics and math backgrounds (i.e., no physics courses prior to college and perfunctory calculus skills below those encountered in students at higher-ranked colleges). Because of this, extra care is put into the lectures to assure that the students are being reached at their current levels of understanding. So, we go a little more slowly through the material, but the end results are worth it. The students taking Modern Physics last fall semester were very unhappy when we stopped midway through the text, they wanted to learn more. The funding of this proposal will allow us to offer an especially exciting version of the second half of this class.

The lab component to our Modern Physics course did not exist last fall semester, but has since been funded by the state of Virginia's Higher Education Equipment Trust Fund and is being offered this fall (2010). Over $13,000 was given to the college for self-contained modern physics experiments such as: the photoelectric effect experiment, the Millikan oil drop experiment, and a blackbody radiation experiment. This will provide a wonderful introduction to more advanced physics experiments, apparatus, and data interpretation, but the "canned" nature of these experiments will not provide them with real-world physics lab experience.

The new course will be a four unit, four hour a week, lecture/lab course. This course structure is unique to our college and allows for classes that contain lab components but require more flexible scheduling as to when the labs occur. Lab work may comprise between 20 to 50% of the class meetings, in the case of Modern Physics II, the lab will comprise 20% of the course. The course will incorporate most of the material remaining in the Tipler and Llewellyn textbook. We will not cover the chapter on astrophysics, as the material in that chapter is covered in our comprehensive year-long astronomy course. We will also not cover the chapters on nuclear and particle physics, as those can be made into separate courses in the future as our physics program grows. We will cover everything else: atomic physics, statistical physics, lasers, and solid state physics. However, these lessons will be structured around the theme of lasers, laser cooling, atom trapping, and Bose-Einstein condensation. This will provide an exciting narrative to the course and supply motivation for each lesson learned. The lasers and atom trapping apparatus will then serve the purpose of illustrating the concepts learned in the textbook, while providing a coherent semester-long lab experience.

Because of the nature of the homemade lasers and the atom trapping apparatus, the lab component will provide students with their first real-world physics lab experience. This apparatus, like those in working physics labs, consists of dozens of individual components (laser diodes, lenses, diffraction gratings, mirrors, quarter-wave plates, photodiodes, commercial electronics, homemade electronics, cameras, etc.) that must be set up and interfaced by the student. The labs will familiarize the students with each of the components separately, and then guide them on how to set up the components for the experiment. They will essentially gain research skills that would directly prepare them to join a physics research lab doing atomic Bose-Einstein condensation, but the skills in general would be useful in any physics or industrial research lab setting.

Below is an outline for the new course. Some of the material will supplement the Tipler and Llewellyn text when greater detail is needed than the text provides. Resources for the supplementary materials will come from books by Siegman [16], Metcalf and van der Straten [17], Budker *et al*. [18], and Foot [19], among others. The labs will be based on advanced optics labs [11, 13, and 20] used in courses at the University of Colorado, Boulder which utilize lasers and an atom trapping apparatus identical to the ones in this proposal. These labs are written by Carl Wieman with at least one co-written by Daryl Preston and are designed to be used by schools and lab instructors without pre-existing laser spectroscopy expertise.

Modern Physics II Course Outline

Week	Topics (relevant sections of Tipler & Llewellyn text in parentheses)
1	classical statistics (8-1), Fermi statistics (8-2, 8-5), solid state physics (10-1, 10-2)
2	solid state physics (10-3, 10-4, 10-6, 10-7, 10-8)
3	lasers (9-5, 9-6), supplemental material: diode lasers, transverse modes, resonant cavities, mode hopping, spectral linewidth
4	LASER LAB [ref. 20]
5	Exam I; spin/magnetic moment (7-4), total angular momentum/fine structure (7-5). Note: 7-1 thru 7-3 is covered in Modern Physics I.
6	multi-electron atoms (7-6, 7-7), atomic spectra (7-8), supplemental material: hyperfine structure, Zeeman effect, selection rules
7	supplemental material: Doppler broadening, hyperfine pumping, saturation intensity, Doppler-free saturated absorption spectroscopy
8	DOPPLER-FREE SATURATED ABSORPTION SPECTROSCOPY LAB [ref. 11]
9	Exam II; supplemental material: laser cooling and trapping, scattering force, cycling transitions
10	supplemental material: optical molasses, circularly polarized light, quarter wave plates
11	supplemental material: magneto-optical traps
12	LASER COOLING AND TRAPPING LAB [ref. 13]
13	Exam III; Bose-Einstein statistics (8-2)
14	Bose-Einstein condensation (8-3), supplemental material: magnetic traps, evaporative cooling
final exam week	Comprehensive Final Exam

Facilities and Maintenance Costs

The optical table and equipment required for the two years of student projects and the lab component of the new course will be housed in a 28' × 18' room that was recently constructed as part of a $13 million state-funded renovation of the science building at UVa-Wise. The room was constructed for use by the physics faculty and is currently empty. The room is outfitted with a large array of 110 V and 220 V, 3-phase and single phase outlets, as well as high amperage (30 and 60 A) electrical outlets should we in the future wish to operate larger electromagnets. Unistrut bars are installed in the ceiling above the anticipated location of the optical table so that we can construct a Unistrut framework over the table for holding controllers and other instruments. The lab has double doors which open out into the hallway and the hallway has double doors with a removable center bar where the hallway leads to the outside of the building: this will allow problem-free delivery of the large optical table into the lab. Laser safety signs are already in place outside the lab doors. Although temperature stability of the room will not be highly critical in the cold atom trap we will be building, the heating/cooling system for the room was designed to be stable to within +/- 1 F°. The window in the lab will be outfitted with total blackout shades.

Also included in the state-funded renovation is a 200 square foot room located in the basement which will serve as a machine shop. This room was recently completed and will soon house: a lathe, drill press, band saw, milling machine, grinder, workbench, as well as the various tools one would expect in a machine shop. The items in the machine shop will be paid for by the Higher Education Equipment Trust Fund which is subsidized by the state of Virginia. The purchase of these items is expected to be approved in the early part of 2011, and will be ordered immediately thereafter.

After the lasers and atom trap are completed and are incorporated into the new course, maintenance costs will be limited to replacement or repair of broken components and costs for consumables. This apparatus requires very few consumables for its maintenance. Consumables would include optics cleaning supplies, and the replacement of the rubidium getter. Cleaning supplies such as acetone, methanol and lens tissues can be purchased with department funds. The rubidium getter should have a very long lifetime if used properly. Should the getter need to be replaced, FINS funds are available for such purchases. For each FINS student that works in a professor's lab, $500 is allocated from that same fund for supplies for the lab. These funds can also be used to replace the most fragile component of the apparatus which are the laser diodes. However, laser diodes are quite inexpensive, costing less than $100 apiece, and can easily be covered by the FINS funds. The remaining components should be quite robust. Should an expensive item (such as a rubidium vapor cell or the IR viewer) be accidentally broken, replacement funds would be requested from the Higher Education Equipment Trust Fund which is what the Natural Sciences department relies on for the purchasing of expensive items.

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Biographical sketch for Melinda Kellogg (aka Mindy Kellogg)

Professional preparation:

- Massachusetts Institute of Technology, postdoctoral training (Sep. 2004 – Dec. 2004).
- California Institute of Technology, PhD in Physics, finished Aug. 2004, awarded June 2005.
- California Institute of Technology, MS in Physics, June 2000.
- California Institute of Technology, MS in Astronomy, June 1999.
- University of Hawaii, Institute for Astronomy (1994-1995, no degree).
- University of California, Santa Barbara, College of Creative Studies, BS in Physics (summa cum laude), June 1993.

Honors:

- Caltech Everhart Lecturer, 2004.
- Caltech Physics Stemple Prize, 2002.
- National Science Foundation Graduate Fellow, 1996-1999.
- UCSB Physics Outstanding Senior Award, 1993.
- University of California Regent's Scholar, 1989-1991.

Appointments:

- **The University of Virginia's College at Wise**, Wise, Virginia USA (Aug. 2005 – present), Assistant Professor of Physics.
- **MIT-Harvard Center for Ultracold Atoms**, Cambridge, Massachusetts, USA (Sep. 2004 – Dec. 2004),
  Postdoctoral Research Associate, Atomic, Molecular and Optical Physics.
- **California Institute of Technology**, Pasadena, California USA (April 1999 – Aug. 2004), Graduate Research Assistant, Experimental Condensed Matter Physics.
- **California Institute of Technology**, Pasadena, California USA (Jan. 1998 – June 1998), Teaching Assistant, Astronomy.
- **California Institute of Technology**, Pasadena, California USA (June 1996 – July 1998), Graduate Research Assistant, Extra-Galactic Observational Astronomy.
- **Institute for Astronomy**, University of Hawaii, Honolulu, Hawaii USA (Aug. 1994 – May 1996),
  Research Assistant, Extra-Galactic Observational Astronomy.
- **University of California, Santa Barbara**, Santa Barbara, California USA (June 1993 – Aug. 1993),
  Summer Research Fellow: built laser pulse compressor for pulsed Ti:sapphire laser.
- **Center for Quantized Electronic Structures**, University of California, Santa Barbara, Santa Barbara, California USA (June 1992 – Aug. 1992),
  Intern: designed and constructed filters for Free Electron Laser.
- **Quantum Institute**, University of California, Santa Barbara, Santa Barbara, California USA (June 1991 – Aug. 1991),
  Research Assistant: built high-vacuum chamber for Free Electron Laser experiments.

Selected Publications:

- M. Kellogg, J. P. Eisenstein, L. N. Pfeiffer, and K. W. West, "Observations of nascent superfluidity in a bilayer two-dimensional electron system at $\nu_T = 1$,"
  Physica E **34 (1-2)**, 6 (2006).
- I. B. Spielman, M. Kellogg, J. P. Eisenstein, L. N. Pfeiffer, and K. W. West, "Onset of interlayer phase coherence in a bilayer two-dimensional electron system: effect of layer density imbalance,"
  Phys. Rev. B **70**, 081303 (2004).

- M. Kellogg, J. P. Eisenstein, L. N. Pfeiffer, and K. W. West, "Vanishing Hall resistance at high magnetic field in a double layer two-dimensional electron system," Phys. Rev. Lett. **93**, 036801 (2004).
- M. Kellogg, J. P. Eisenstein, L. N. Pfeiffer, and K. W. West, "Bilayer quantum Hall systems at $\nu_T = 1$: Coulomb drag and the transition from weak to strong interlayer coupling," Phys. Rev. Lett. **90**, 246801 (2003).
- M. Kellogg, J. P. Eisenstein, L. N. Pfeiffer, and K. W. West, "Evidence for $2k_F$ electron-electron scattering processes in Coulomb drag," Solid State Commun. **123**, 515 (2002).
- M. Kellogg, I. B. Spielman, J. P. Eisenstein, L. N. Pfeiffer, and K. W. West, "Obvservation of quantized Hall drag in a strongly correlated bilayer electron system," Phys. Rev. Lett. **88**, 126804 (2002).
- M. Pettini, M. Kellogg, C. C. Steidel, M. Dickinson, K. L. Adelberger, and M. Giavalisco, "Infrared observations of nebular emission lines from galaxies at $z \sim 3$," Astrophys. J. **508**, 539 (1998).
- C. C. Steidel, K. L. Adelberger, M. Dickinson, M. Pettini, and M. Kellogg, "A large structure of galaxies at redshift $z \sim 3$ and its cosmological implications," Astrophys. J. **492**, 428 (1998).
- A. Stockton, M. Kellogg, and S. E. Ridgway, "The nature of the stellar continuum in the radio galaxy 3C 65," Astrophys. J. **443**, L69 (1995).

Synergistic Activities:

Bringing MIT-level physics to local students who because of geography or poverty never had the opportunity to go to MIT (or some comparable institution) is a personal passion of the PI. The PI grew up in poverty in a rural environment and never expected to receive a college education. In an effort to share the education the PI ultimately did receive, she has offered an MIT sophomore-level physics course called "Black Holes: An Introduction to General Relativity" at UVa-Wise in the Fall of 2007. The PI taught the same material as in the MIT course, although more slowly and with more explication, and the students did the same homework problems. The students performed excellently, proving they are capable of learning difficult subjects if given the opportunity. The top student was born and raised in Wise County.

Collaborators:

- Max Pettini, currently at Cambridge University, Cambridge, England.

Thesis Advisor and Postgraduate-Scholar Sponsor:

- Thesis advisor: Jim Eisenstein, currently at the California Institute of Technology, Pasadena, California USA.
- Postdoc sponsors: Wolfgang Ketterle and David Pritchard, currently at the Massachusetts Institute of Technology, Cambridge, Massachusetts USA.

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **University of Virginia Main Campus**			FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Melinda J Kellogg**			AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Melinda J Kellogg - none**	0.00	0.00	0.00	$ **0**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	**0**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**1**) UNDERGRADUATE STUDENTS				**3,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**3,000**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**201**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**3,201**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **Atom Trapping Device, portion assembled year one** $ **17,910** **Optical Table, including shipping** **15,811**					
TOTAL EQUIPMENT				**33,721**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**0**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**6,554**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**6,554**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**43,476**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Fringes (Rate: 26.0000, Base: 201) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**2,536**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**46,012**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **46,012**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $			
PI/PD NAME **Melinda J Kellogg**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION			
ORG. REP. NAME*		Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

**** I- Indirect Costs**
Materials and Supplies (Rate: 26.0000, Base 6554)
Other Personnel (Rate: 26.0000, Base 3000)

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY					
ORGANIZATION: University of Virginia Main Campus	PROPOSAL NO.	DURATION (months) Proposed	Granted		
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Melinda J Kellogg	AWARD NO.				

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Melinda J Kellogg - none	0.00	0.00	0.00	$ 0	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				0	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				0	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) Atom Trapping Device portion assembled year 2 $ 11,773					
TOTAL EQUIPMENT				11,773	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,628	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1,437	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				1,437	
H. TOTAL DIRECT COSTS (A THROUGH G)				14,838	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Materials and Supplies (Rate: 26.0000, Base: 1437) (Cont. on Comments Page)					
TOTAL INDIRECT COSTS (F&A)				797	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				15,635	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 15,635	$
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME: Melinda J Kellogg	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 2

**** I- Indirect Costs**
Travel (Rate: 26.0000, Base 1628)

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **University of Virginia Main Campus**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	Granted	
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Melinda J Kellogg**	AWARD NO.			

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Melinda J Kellogg - none	0.00	0.00	0.00	$ 0	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (1) UNDERGRADUATE STUDENTS				3,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				3,000	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				201	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				3,201	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 45,494					
TOTAL EQUIPMENT				45,494	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,628	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				7,991	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				7,991	
H. TOTAL DIRECT COSTS (A THROUGH G)				58,314	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				3,333	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				61,647	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 61,647	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME **Melinda J Kellogg**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Equipment, Materials, and Supplies (shaded items will be used to create Atom Trapping Device)

qty	description	company	$ ea	$ total	quote date
1	RS4000-58-18 optical table 5'x8'x18"(w/304SS top)	Newport Corporation	9057.00	9057.00	7/13/2010
1	Four 16" optical table legs I-2000-416tc	"	3950.00	3950.00	9/2/2007
1	optical table setup kit	"	500.00	500.00	7/15/2010
1	tie bar/casters	"	604.00	604.00	9/2/2007
1	shipping for above items	"	1700.00	1700.00	9/2/2007
2	AJS100-0.5 high precision fine adjustment screw	"	24.99	49.98	7/15/2010
1	3PN1210B-MOD 120V 1 phase variac 12 A	ISE, Inc.	332.00	332.00	10/19/2007
6	Sanyo DL7140-201S 80mW laser diodes	Thorlabs, Inc.	39.50	237.00	7/15/2010
5	DET36A high speed Si detectors	"	107.10	535.50	7/15/2010
2	VRC5 infrared viewing card 700 - 1400 nm	"	113.00	226.00	7/15/2010
1	LDC205C laser diode current controller	"	950.00	950.00	7/15/2010
6	WPQ10M-780 Zero order Quarter Waveplate	"	500.00	3000.00	7/16/2010
6	PRM1 high precision rotation mounts	"	255.00	1530.00	7/16/2010
1	SPW602 spanner wrench for 1" rotation mount	"	29.00	29.00	7/16/2010
1	PCB-2.5-NIR linear polarizer module, 750-870nm	"	270.30	270.30	7/15/2010
2	L200 mini lab jack	"	397.80	795.60	7/15/2010
50	BA1S mounting base	"	5.20	260.00	7/15/2010
50	PH3 post holder 3"	"	8.27	413.50	7/15/2010
50	TR2, TR3, TR4 posts	"	5.87	293.50	7/15/2010
4	GR13-1205 ruled diffraction grating 1/2"x1/2"	"	61.20	244.80	7/15/2010
9	BB1-E03-01" broadband dielectric mirror 750-1100nm	"	75.10	675.90	7/15/2010
15	PF10-03-M01 1" gold mirrors	"	54.10	811.50	7/15/2010
1	PFSQ20-03-M01 - 2" x 2" Protected Gold Mirror	"	110.00	110.00	7/16/2010
24	KM100 1" two-adjuster kinematic mirror mounts	"	39.90	957.60	7/15/2010
3	KMS kinematic compact mirror mount	"	33.50	100.50	7/16/2010
1	KM100B 2" x 2" kinematic platform mount	"	52.00	52.00	7/16/2010
4	LMR1 lens mounts for 1" optics	"	15.70	62.80	7/16/2010
2	LMR2 (comes w/SM2RR) lens mounts	"	23.50	47.00	7/16/2010
1	LSC01-B 2" AR-coated plano-convex Lens Kit	"	443.30	443.30	7/16/2010
1	LSB02-B 1" AR-coated bi-convex Lens Kit	"	457.30	457.30	7/16/2010
1	SPW604 spanner wrenches for 2" mounts	"	49.00	49.00	9/14/2007
3	NE10A-B mounted AR neutral density filter OD=1.0	"	68.20	204.60	7/15/2010
3	LG9 laser safety glasses (or LG5 or LG4)	"	188.70	566.10	7/15/2010
1	CCS175 compact spectrometer 500-1000nm	"	1950.00	1950.00	7/15/2010
2	CQ19075-RB87 87-Rb quartz reference cells	"	970.60	1941.20	7/15/2010
2	reference cell mounts	"	125.00	250.00	
2	ID25 iris diaphragm	"	51.50	103.00	7/15/2010
7	RA90 right-angle post clamp	"	9.93	69.51	7/16/2010
1	S19909 9 drawer storage cabinets	"	110.20	110.20	7/16/2010
1	BX01 lens/mirror boxes 1" 10 pack	"	16.40	16.40	7/16/2010
1	TZ1 optics tweezers	"	42.00	42.00	7/16/2010
1	MC6 cotton optics gloves (12 pr)	"	13.40	13.40	7/16/2010
1	FCP forceps	"	18.70	18.70	7/16/2010
1	JEL10 jeweler's magnifier	"	20.36	20.36	7/16/2010
1	CTA10 cotton tipped applicators	"	4.20	4.20	7/16/2010
1	MC-5 lens tissues	"	8.90	8.90	7/16/2010
1	CA3 Can-of-air duster	"	10.10	10.10	7/16/2010
3	LB1 beam block	"	45.20	135.60	7/15/2010
1	PM10-10 (or -3) optical power meter	"	922.00	922.00	7/15/2010
1	Q-See QSVOSB Security Observation System	Amazon.com	89.99	89.99	7/16/2010
1	3037000 sorbothane pad	Edmund Scientific	19.95	19.95	7/15/2010
2	G311328000 collimating lens	qioptiq.com	50.00	100.00	7/15/2010
1	Tektronix TPS2024 digital oscilloscope	Allied Electronics	3750.00	3750.00	7/15/2010
1	find-r-scope 84499A infrared hand-held viewer	FJW Optical Systems	1495.00	1495.00	7/15/2010
1	80385 wrist strap for above	"	25.00	25.00	7/15/2010
1	Tektronix AFG3011 20V_pp function generator	Mouser Electronics	3690.00	3690.00	7/15/2010
1	563-DR-8092 double rack (equipment rack) 19" x 77"	"	570.99	570.99	8/1/2010

1	563-SH-8096 rack shelf	"	92.35	92.35	8/1/2010
1	615-1627A-NIST 30V DC power supply	"	322.55	322.55	7/16/2010
1	electronic components: op amps, resistors, switches, boxes, dpm, diodes, pzt, bnc cables	"	500.00	500.00	
1	unitstrut	Unistrut Corp.	200.00	200.00	
1	Rb metal getter Rb/NF/3.4/12/FT 10+10	SAES Getters	350.00	350.00	
1	EFT0024032 Power feedthrough Moly 8A/pin 2 pins	Lurt J. Lesker Co.	118.00	118.00	7/18/2010
6	Q720125 pyrex plate windows	Esco Products, Inc.	20.00	120.00	7/18/2010
1	Q-11-T transmissive IR viewing card	Lumitek International	130.00	130.00	7/18/2010
5	HK5207R12.5L12A(B!) kapton heater	Minco	35.00	175.00	
1	LK-120 magnetic shielding lab kit	Magnetic Shield Corp.	149.50	149.50	9/16/2007
6	8975K562 aluminum bars 6"x3"x2"	McMaster-Carr	25.79	154.74	7/16/2010
1	VAR-9530001 (2?) torr seal epoxy	Varian, Inc.	41.25	41.25	7/16/2010
1	9290191 MiniVac controller	"	1225.00	1225.00	7/16/2010
1	FVG0075 zero length glass viewports	"	98.00	98.00	7/16/2010
1	VacIon Plus 20, diode Ion Pump w/magnets	"	1934.00	1934.00	7/16/2010
1	FG0133C1 copper gaskets for 1.33" flanges (10)	"	16.00	16.00	7/16/2010
2	FB0133CS silver plated bolts/nuts (25)	"	24.00	48.00	7/16/2010
1	L9580501 stainless steel inline block valve, CF 1.33"	"	423.00	423.00	7/18/2010
1	406000 five-way crosses, 1.33" flanges	MDC Vacuum Products	165.00	165.00	7/16/2010
1	150001 reducing flange 2.75" to 1.33"	"	61.00	61.00	7/16/2010
1	500000 (SP-150) cryogenic sorption pump (single)	"	660.00	660.00	7/16/2010
1	F.W. Bell 5180 gauss meter	Allied Electronics	1437.62	1437.62	7/15/2010
6	121-503JAJ-Q01 thermistor	Newark	31.92	191.52	7/15/2010
			Total:	**53484.81**	

Total for equipment: **45493.49**

TRAVEL TO ATI PI CONFERENCE

roundtrip mileage Wise to D.C. (842mi) × $0.42/mile			353.64
4 nights hotel at $211/night			844
per diem: 2 days travel, 3 days conf. @$71/day			355
3 days parking			75
		Total:	**1627.64**

STUDENT WAGE

See Project Description; $3,000 is standard stipend for summer students.
6.7% fringes charged for student not enrolled in summer classes.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: 28' x 18' room along same hallway as physics labs and classrooms. Has its own separate air intake and exhaust. Double doors to allow for delivery of optical table. Laser warning sign outside of doors. Unistrut framework in ceiling for creating shelving above the tables. Electrical outlets in

Clinical:

Animal:

Computer:

Office: P.I. has 12' x 12' office.

Other: 200 square foot machine shop in basement of science building.

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

FACILITIES, EQUIPMENT & OTHER RESOURCES

Continuation Page:

LABORATORY FACILITIES (continued):

overhead beam above anticipated optical table location.