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.B. 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.)

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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 08-1		FOR NSF USE ONLY
NSF 08-503	01/24/08	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) PHY - MAJOR RESEARCH INSTRUMENTATION		

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546001796	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of Virginia's College at Wise	P.O. Box 400195 Charlottesville, VA 22904-4195
AWARDEE ORGANIZATION CODE (IF KNOWN) 0037473000	
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE
PERFORMING ORGANIZATION CODE (IF KNOWN)	

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 **MRI: Acquisition of Rb Bose-Einstein condensate machine**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 509,423	36 months	06/01/09	

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)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.5) IACUC App. Date ________
PHS Animal Welfare Assurance Number ________
☐ HUMAN SUBJECTS (GPG II.D.6) 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	PI/PD POSTAL ADDRESS
Natural Sciences	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	434-924-4270	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, and lobbying activities (see below), 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 08-1). 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 dislosed 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.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

Project Summary

The University of Virginia's College at Wise in an effort to meet the educational and intellectual needs of the people in the Appalachian Mountains where the college resides, proposes the construction of a rubidium Bose-Einstein condensate (BEC) machine which, if funded, will establish the first physics research lab in the college's fifty-three year history.

Broader Impact

The Appalachian Mountains are home to a population that suffers a high poverty rate and low educational attainment rate. Bright young students have fewer opportunities here than young people in other parts of the country, particularly in the areas of science and technology.

This research lab would give local students exposure to technologies which are currently not available to them. The machine utilizes many different exciting technologies: lasers, ultra-high vacuum, resistive electromagnets, and infrared cameras. 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 learn about these types of equipment. If this proposal is funded, the construction of this machine – an anticipated three year endeavor – will provide practical experience for undergraduate students which will prepare them for graduate studies in physics or for jobs in high tech companies or government research labs.

Additionally, this lab will provide a base for the establishment of a physics major program at the college (currently there is only a physics minor program). The greatest impact of the funding of this proposal will be that it will lead to the development of a physics major and a 3-2 engineering program at the college, filling a large gap in the educational opportunities available to students in this community. Without a robust physics or engineering program at the local college, the local community suffers because nobody in the community is receiving any physics training, even those who want it.

Local students who come to the college often do so because they want to stay in the area, by training these students in physics and engineering, this knowledge will tend to remain in the community and increase the overall intellectual well-being of this region.

Intellectual Merit

The successful condensation of a dilute gas of alkali atoms first occurred in 1995 by groups in Colorado and at MIT, beginning a whole new field of experimental physics research. Bose-Einstein condensation has been known of theoretically for several decades, but never before was there such a good experimental realization of a BEC on which these theories could be tested (superfluid ^{4}He has strong interactions and so is not an ideal BEC). Research on atomic BECs is one of the most exhilarating, rapidly advancing, fields in physics today.

Once construction of the apparatus is complete, there will be a working physics research lab at the college. The research to be conducted will be in the field of quantum computing – by loading the BEC into an optical lattice, one atom per lattice site, the atoms can serve as qubits in a quantum computer. This is a very new field of study, with only a handful of groups at the moment pursuing it; however their excellent experimental progress indicates that this will be a fruitful area of research in times to come.

Even though this research lab will be at a small college, the PI looks forward to making meaningful contributions to the field once the machine is completed.

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

*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, and the 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 areas 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 no 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; there is currently a 16-year-old junior from the town of Appalachia who has a 200 IQ (he started taking courses at the college when he was 12). He is one of the students who dearly wishes there was a physics major at the college. 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 start the first physics research lab in the college's history – which will also be the only physics research lab in more than a hundred mile radius (Virginia Tech, Berea College in Kentucky, the University of North Carolina at Asheville, and the University of Tennessee, Knoxville – each approximately 150 miles from Wise– are the current locations of the nearest physics research labs).

The instrument proposed to be acquired is a rubidium (Rb) Bose-Einstein condensate (BEC) machine. This is a very exciting piece of avant-garde technology; utilizing lasers, ultra-high vacuum technology, and powerful electromagnets. Prospective students in the local community would be exposed to the Rb BEC lab during the college's tri-annual "open house" weekends. Students enrolled in the college would have the opportunity to work with the machine through the college's Fellowship in the Natural Sciences (FINS) program which offers students a $3,000 stipend to work in one of the department's research labs over the summer.

The FINS program funded six students in the summer of 2007, primarily for research in biology. It can be relied on to fund at least one student for full-time work in the Rb BEC lab, funding for additional summer student workers is being requested in this grant proposal. The goal is to eventually have two students working with the PI every summer full time in the lab. During the academic year, students will continue to gain exposure to the lab through smaller projects for which the students will obtain "independent study" course credits. The PI would oversee two to three independent study students each semester.

The impact of this lab would extend beyond those who actually see and work in the lab. With the opportunity for students to engage in physics research, a physics major program can be established that will be on par with the other majors offered in the Natural Sciences department. With the funding of the Rb BEC apparatus, and college commitment to hire an additional physics professor (for a total of three), a physics major can be established at the college. This means that even students who do not directly work in the lab, will benefit from the lab. Students like the 16-year-old junior, whose predilection is for theoretical, not experimental, physics would then have challenging upper division physics courses to take which currently do not exist.

Once there is a comprehensive physics curriculum in place, it is a very short step to offering a 3-2 engineering program. 3-2 engineering programs are common in small schools that wish to offer opportunities for local students to have engineering careers, but because of the size of the college a full-fledged engineering department is not possible. The student spends three years at the small college, taking two years of preparatory engineering courses – these are similar to the courses that physics students also take in their first two years – and then one year of upper division courses in either mathematics, chemistry, or physics. After completing three years at the small college, the student then transfers to a larger partner school that offers engineering degrees, where the upper division engineering courses are taken over the final two years of the program. At the end of the period the student is awarded a Bachelor of Arts degree from the small college (in either mathematics, chemistry, or physics depending on the upper division coursework done) and a Bachelor of Science degree in engineering from the larger school.

UVa-Wise's parent school, the University of Virginia, has already indicated a willingness to participate in a 3-2 engineering program. Both the physics major and the 3-2 engineering program are goals the PI is pursuing determinedly, and will do the work to establish these programs during the nearly one year between approval of this funding (should that occur) and the beginning of the funding period.

Research Instrumentation and Activities

The proposed research apparatus is an 87-rubidium Bose-Einstein condensate (^{87}Rb BEC) machine identical to one the PI worked on as a postdoctoral researcher in Wolfgang Ketterle's group at the MIT-Harvard Center for Ultracold Atoms. This is a proven machine – designed similarly to the successful ^{23}Na BEC machines in the Ketterle lab – that routinely produces BECs containing > 20×10^6 ^{87}Rb atoms [3]. Their ^{87}Rb BEC machine has been used successfully in highly competitive research, especially involving optical lattices [4-9].

The PI will oversee the building of the apparatus, which will be done by the PI and undergraduate students over a three year period, primarily during the summer months but also during the school year as much as possible.

Year One (6/1/2009 – 5/31/2010)

The first year will be devoted to setting up the laser table (Fig. 1b) on which the laser beams used to cool, trap, and probe the atoms are prepared. The rubidium atoms are manipulated by laser light through absorption and emission of photons between the ground electronic state $5^2S_{1/2}$ and the first excited state $5^2P_{3/2}$ (the D2 transition, resonant with 780 nm light). The ground state has two hyperfine levels, labeled F=1 and F=2 in Fig. 1a, which are separated by a frequency of 6.8 GHz. The $5^2P_{3/2}$ state has four hyperfine levels, labeled F'=0, 1, 2, and 3 with separations of 72 MHz, 157 MHz, and 267 MHz. The laser's spectral width is sufficiently narrow ($\lesssim$ 1MHz) that it can be tuned to precisely excite a transition from a specific ground state hyperfine level to a particular excited state hyperfine level.

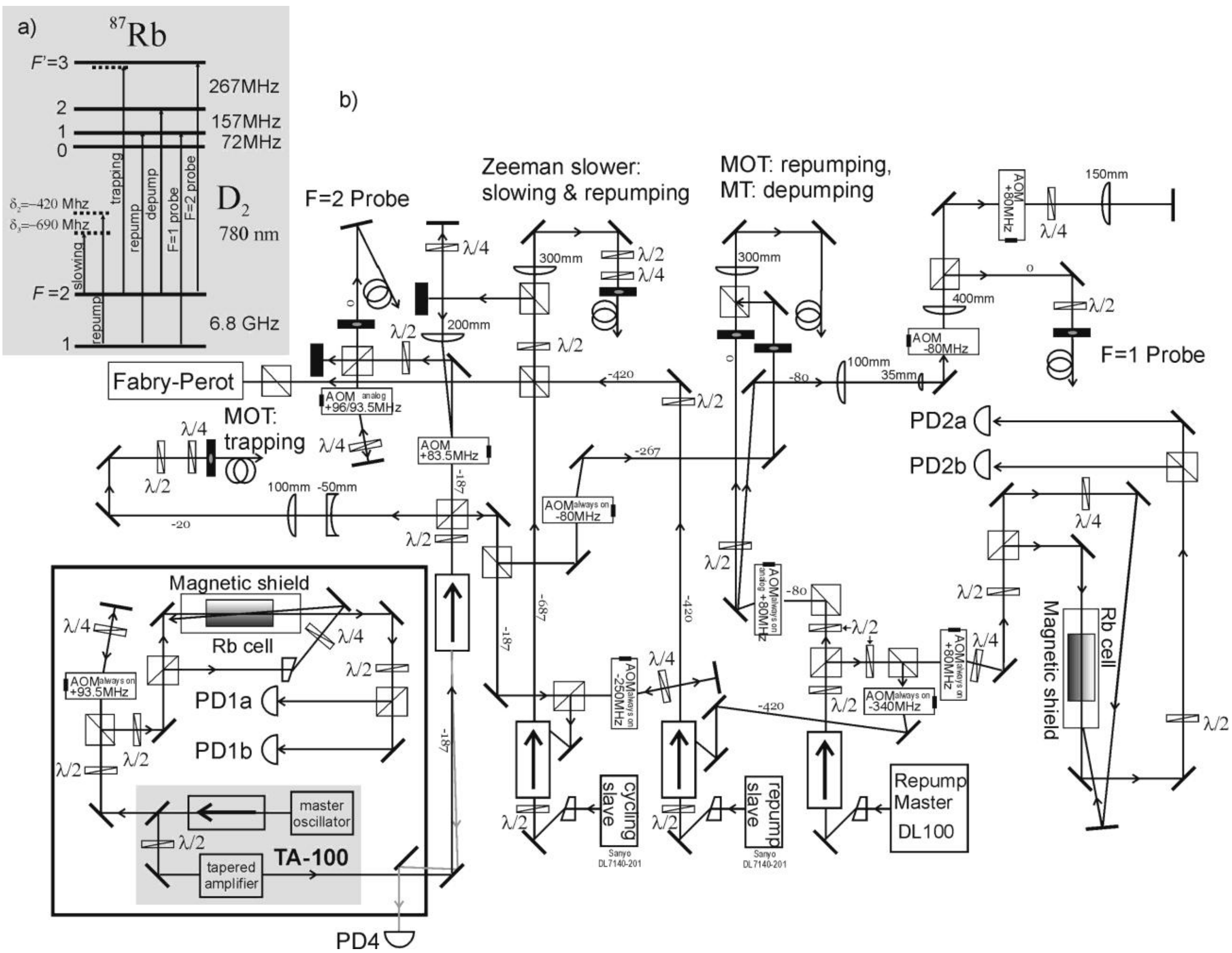

Figure 1. a) The relevant hyperfine energy levels of the ^{87}Rb atom utilized for atom manipulation, b) the layout of the laser table: boxes with arrows represent optical isolators (Optics For Research, IO-5-780-HP), the acousto-optic modulators (AOMs) will be from IntraAction (ATM-801A2, -901A2, -2501A2, -3401A2). The half-circles labeled PD# will be Thorlabs high-speed detectors (DET36A). The Rb cells will be Thorlabs CQ19075-RB87 87-Rb quartz reference cells used for locking the lasers. The dark rectangles with ovals in the center will be LS6ZM2 uniblitz mechanical shutters from Vincent Associates.

For this apparatus seven different beams of laser light are needed, each tuned to excite a precise transition. Two beams are needed to slow the ^{87}Rb atoms from thermal velocities to speeds suitable for loading the magneto-optical trap (MOT). Thermal ^{87}Rb atoms are sent down a Zeeman slowing tube in which their speeds are slowed from ~ 330 m/s to ~ 20 m/s by a counter-propagating laser beam detuned from the cycling transition F=2→F'=3 by -690 MHz. In the frame of the atoms, the laser light will be blue-shifted by the Doppler effect and the atoms moving towards the light at the appropriate speed will be in resonance with the laser light. Through momentum transfer between the laser beam and the atoms, the atoms will be slowed.

Since the speed of the atoms (and thus the Doppler shift) depends on the position of the atoms in the Zeeman slower, an increasing magnetic field is applied inside the slower tube which by the Zeeman effect brings the two levels (now specifically: F=2, m_F = -2 → F'=3, $m_{F'}$ = -3; the light will be σ^- polarized to excite this specific transition) closer together as the atoms move down the tube. This shift is synchronized with the changing Doppler shift, keeping the atoms in resonance with the slowing beam throughout their entire trip through the slower, thus maximizing their deceleration. To ensure that the atoms entering the slower are in the F=2 ground state, a repumping beam is also sent up the slower tube detuned from the F=1→F'=1 transition by -420 MHz.

Two more beams are needed to trap these atoms in the MOT. A quadrupole magnetic field provides position- and polarization-dependent Zeeman shifts for the F=2→F'=3 transition in the atoms in the trap region. Six independent circularly polarized beams detuned from the transition by ~ -20 MHz intersect perpendicularly in the trap and selectively push atoms at the edges of the trap towards the center while simultaneously cooling them. A single trapping MOT beam will be produced on the laser table, to be split into six beams after being delivered to the experiment table. These beams are also used for the optical molasses stage. To keep the atoms in the F=2 ground state, repumping light resonant with the F=1→F'=1 transition is also delivered to the MOT.

Prior to loading the atoms into the cloverleaf Ioffe-Pritchard magnetic trap, they must be transferred to the F=1 ground state. This requires a "depumping" beam tuned to the F=2→F'=2 transition. The remaining two beams needed are for probing and imaging the atoms for analysis: an F=1→F'=1 beam probes atoms in the F=1 state (or pumps them into the F=2 state for F=2 imaging), and an F=2→F'=3 beam is used for imaging atoms in the F=2 state.

Summer Student Project:

The first summer student will be funded by the department's FINS program. This student will focus on the portion of the laser table outlined in the lower left corner of Fig. 1b. In this region, the frequency of the primary laser (Toptica Photonics TA-100) used for slowing and trapping the atoms is stabilized near the F=2→F'=3 transition using the method of Doppler-free polarization spectroscopy [10]. This method produces a derivative of the Doppler-free hyperfine spectrum F=2→F'=1, 2, 3 (plus crossover peaks) by artificially inducing birefringence into the Rb vapor cell with a counter-propagating circularly polarized pump beam at the same frequency. This type of spectra is best for locking the laser because the center of the transition line is not a peak but a zero, making it immune to fluctuations in the laser intensity, and it is flanked by a steeply sloped line which makes the proportional-integral gain servo loop feedback control more effective.

The optics will be set up on a 5' x 8' Newport optics table (RS400-58-18 w/304SS top) with isolating legs (I-2000-416tc). An infrared viewing scope (find-r-scope model 84499A) will be used to detect the fluorescence of the Rb vapor. A digital oscilloscope will be needed to capture images of the Rb spectrum for analysis and the student's presentation on his/her project. The student will become acquainted with diode lasers, basic optical components (mirrors, wave plates, beam splitting cubes) and their alignment, acousto-optic modulators (AOMs), photodetectors, and proportional-integral gain controllers.

Academic Year Projects:

With the successful completion of the first summer project, it should be straight forward to assemble the second master laser (Toptica Photonics DL100) as shown in the lower right hand corner of Fig. 1b. This laser will be locked near the F=1→F'=1 transition to provide the slower and MOT repumping beams and the F=1 probe beam. The remainder of the laser table will also be completed during the academic year.

The slower's cycling and repumping beam will be heavily attenuated by the large frequency shifts they will undergo from the AOMs and will need to be amplified. The powers of these beams will be boosted by injecting them into slave lasers (Sanyo DL7140-201S). The injected light from the master lasers force the slave lasers to emit at the same frequency [11]. Both of these beams will be monitored in a single Fabry-Perot (Toptica FPI-100-0750-1) spectrometer. When the injection locking is successful the beams will become spectrally narrow and will respond linearly to changes in the master laser's frequency.

Once each of the beams has been shifted to its appropriate frequency it will be coupled into a fiber optic for delivery to the experiment table, the construction of which will begin in year two.

Year Two (6/1/2010 – 5/31/2011)

The second year will be devoted to setting up the second optics table (another Newport RS400-58-18 w/304SS top) on which the main chamber for the BEC will be located. The second optics table and the custom-made main experiment chamber (which will be built by Sharon Vacuum in Brockton, Massachusetts) will be ordered in advance. The goal of year two will be to get the Zeeman slower and oven built and the entire chamber assembled as shown in Fig. 2. Then the apparatus will be baked out and pumped down to $\lesssim 10^{-11}$ torr and tested.

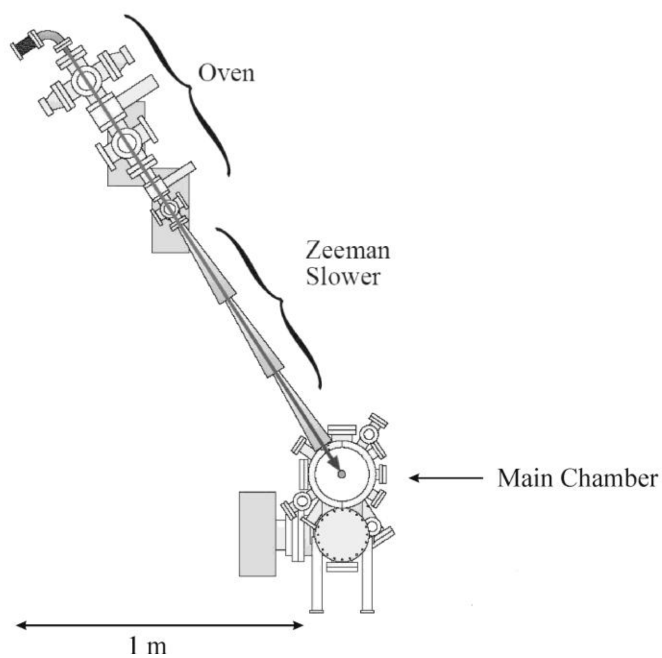

Figure 2. The oven, Zeeman slower, and main chamber after assembly. The rubidium source is located in the bellows attached to the lower left end of the elbow in the top left of the figure, this region is heated to 110°C. In the remainder of the oven the hot atomic vapor is collimated and directed down the Zeeman slower tube. Electromagnet coils are wound around the outside of the Zeeman slowing tube in three sections (shown as three adjacent cones in the figure). Each section will carry a progressively larger current to create a continuously increasing magnetic field inside the slower tube. A σ^- polarized red-detuned slowing beam directed up the Zeeman slower tube from the opposite side of the main chamber works in concert with the changing Zeeman shifts in the tube to provide continuous deceleration of the atoms as they travel down the tube. When the atoms enter the main chamber, their speeds will be low enough to be trapped by the MOT (not shown) in the center of the main chamber. Figure adapted from ref. 12.

Summer Student Project I:

This student will be funded by the department's FINS program, and will build the Rb oven. The oven supplies a high-flux (~ 10^{11} ^{87}Rb atoms/s [3]) beam of thermal Rb atoms to the Zeeman slower (which will be built by the second summer student). Fig. 3 shows a schematic of the oven, which will be constructed primarily from pre-fabricated ultra-high vacuum components (e.g., six-way crosses, elbows, bellows, gate valves) purchased from Varian and MDC Vacuum, but also includes some parts (e.g., the nozzle and cold cup) that must be custom-machined.

When in operation, the elbow and bellows at the far right end of the figure are heated to 110°C by judiciously placed tape and band heaters which are then covered with insulation and aluminum foil. At this temperature the vapor pressure of Rb is ~ 0.5×10^{-3} torr and the atoms have characteristic velocities of ~ 330 m/s [12]. The purpose of the remaining sections of the oven is to collimate these thermal atoms into a narrow beam which is then sent to the slower, while keeping the pressure as low as possible in each stage of the oven.

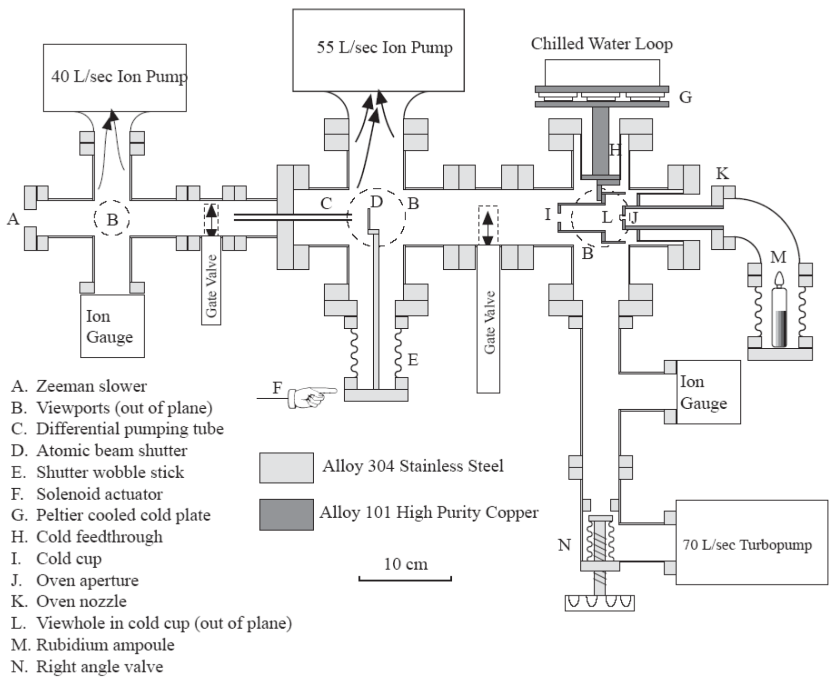

Figure 3. Rb oven schematic. Rb atoms heated in the rightmost elbow and bellows enter the rest of the chamber through a hole at the end of the oven nozzle (J) and are collimated by passing through a second hole at the end of the cold cup (I). All other atoms will stick to the walls of the cold cup which are kept at -30°C by six Ferrotec 9520/185/065BS thermoelectric coolers (TECs). The chilled water loop is cooling the hot sides of the TECs. The pumps will be Varian VacIon Plus 40/55 Noble diode ion pumps, and a Turbo V 81 backed by a DS-102 rotary-vane roughing pump. The gauges will be a UHV-24p nude tungsten ion gauge and a 563 Bayard-Alpert ion gauge both from Varian. The gate valves will be MDC Vacuum GV-1500M-P and GV-2500M-P. Figure from ref. 12.

Atoms will exit the heated region through a small 5 mm diameter opening at the end of the oven nozzle (J in the diagram). A cold cup (I) chilled to -30°C by six thermoelectric coolers (TECs), water-cooled on their hot sides, will capture any Rb atoms leaving the oven nozzle that are not aligned with the small 7.1 mm diameter opening at the end of the cold cup; this creates a high-flux collimated beam of Rb atoms while keeping the pressures in the remainder of the oven very low. The beam can be turned on and off via a beam shutter (D) controlled by a solenoid actuator (F).

The differential pumping tube, the Zeeman slower (connected at A) and the two ion pumps shown isolate the higher pressures in the oven from the $\lesssim 10^{-11}$ torr needed in the main chamber. Gate valves protect the vacuum in the main chamber when the rubidium ampule is replaced and the cold cup cleaned – which must be done approximately every six months when the machine is operating regularly (there are two gate valves incase one fails). The student will learn about ultra-high vacuum environments, outgassing, ConFlat seals, ion and turbo pumps, ion gauges, and thermoelectric coolers.

Summer Student Project II:

This student will be funded by this grant, and will construct the Zeeman slower. The Zeeman slower reduces the speeds of the atoms emanating from the oven (having characteristic velocities of ~ 330 m/s), to speeds which allow the atoms to be trapped by the MOT: ~ 20 m/s.

This slowing is achieved by sending the atom beam down a meter long stainless steel tube (also custom built by Sharon Vacuum) while simultaneously sending a laser beam detuned -690 MHz from the cycling transition F=2→F'=3 up the tube. The light will be blue-shifted into resonance with the cycling transition in the frame of the speeding atoms, which will absorb the light and be slowed. To keep the atoms in resonance with the laser light during their entire trip down the tube, an electromagnet is wound around the outside of the tube to produce an increasing magnetic field inside the tube parallel to its central axis (changing by ~ 270 G along the length of the slower). This magnetic field shifts the energies via the Zeeman effect specifically of the F=2, $m_F = -2$ and the F'=3, $m_{F'} = -3$ states reducing the energy spacing between these two levels as the field increases (the laser light will be σ^- polarized so that it will excite only this specific transition). As the atoms travel down the tube the reduced Doppler shift will match the reduced energy spacing and the atoms will remain in resonance with the laser beam during the entire trip.

The student will wind the magnet around the Zeeman slower tube in three conical sections (see Fig. 2) using square hollow core insulated copper tubing (Small Tube Products will provide the copper tubing; Essex Group, Inc. the insulation). The coils will be secured with Hysol Epoxi-Patch 1C White which can withstand temperatures up to 170°C (important for the bake-out). Pressurized water will be sent through the hollow core to keep the magnet cool. Power supplies will send 10A, 20A, and 30A through the three progressively more powerful sections. An additional coil along the entire length of the slower (underneath the conical sections) will be wound to produce an ~ 200 G bias field, this will additionally shift the slowing light from the zero-field resonance so that the slowing beam will not interfere with the MOT atoms. The student will measure the axial field with a Hall probe (F.W. Bell 5180) and compare this to the ideal theoretical values. The student will learn about resistive electromagnets, water cooling, and the physics of current-induced magnetic fields.

Academic Year Projects:

During the academic year the oven, Zeeman slower, and main chamber will be connected together and platforms will be constructed to hold the assembly in place on the second optics table. The main chamber will be a custom-made 10"-diameter electropolished 304 stainless steel ConFlat cylinder with 12 ports emanating from the cylindrical sides for optical and pumping access. The open ends of the cylinder will be closed off with bucket windows: a type of recessed port that allows the magnet trap coils to be external to the vacuum chamber yet still be very close to the condensate. A small window in the center of these recessed ports allows for additional optical access.

Before sealing the entire chamber assembly, radio frequency (RF) coils with a feedthrough to the outside will be put into the main chamber. The RF antenna is necessary for the evaporative cooling stage. Three pumps will be connected off one of the main chamber's ports: a Varian Starcell VacIon Plus 75 and two titanium sublimation pumps. The pressure will be monitored with UHV-24p nude tungsten ion gauges also from Varian. Unlike the MIT Rb BEC machine, there will be no optical tweezer translation stage or secondary experiment chamber on this machine.

During the bake-out and pumping down of the chamber a residual gas analyzer will be used to monitor the levels of different gas species inside the chamber. The goal will be to reach the extreme ultra-high vacuum pressures of $\lesssim 10^{-11}$ torr necessary for maintaining a reasonably long lifetime for the condensate. After the pump-down, the Zeeman slower will be tested using Doppler-sensitive fluorescence, whereby a probe beam 45° to the atomic beam is scanned in frequency while the beam's fluorescence is monitored with a photodiode placed 90° to the atomic beam, this technique indicates the speed of the atoms as they leave the slower [13,14].

Year Three (6/1/2011 – 5/31/2012)

Finally, in year three the magnetic trap and MOT magnet coils will be constructed and placed inside the bucket windows. The fast-switching electronics will be assembled, the camera and imaging optics will be set up, a master computer program which will control the experiment will be written, and an ^{87}Rb BEC will be pursued.

Summer Student Project I:

This student will be funded by the department's FINS program and will construct the magnetic trap and MOT coils.

A pair of anti-Helmholtz coils carrying a modest current (~15 A) will produce the quadrupole field required for the MOT. The MOT will spatially confine and further cool the atoms after they have exited the slower, slowing them to < 1 cm/s [3] and cooling them to ~150 μK, which is still far above the temperature needed to condense the atoms. To cool the atoms further they must be loaded into a magnetic trap where they can be evaporatively cooled to the BEC transition temperature (~500 nK). A MOT compression stage facilitates the loading of the atoms into the magnetic trap: first the MOT is compressed and then the atoms further cooled by a brief optical molasses stage, the MOT beams doing double duty as optical molasses beams.

The magnetic trap is produced by a cloverleaf-style Ioffe-Pritchard coil (see Fig. 4) [15,16]. The atoms are first depumped into the F=1 ground state. Those having magnetic quantum number $m_F = -1$ are weak-field seeking atoms and can be confined in a magnetic field that has a localized minimum. The Ioffe-Pritchard trap produces such a field with harmonic confinement in the axial direction (along the z-axis in Fig. 4), and a tighter harmonic (at low energies, at higher energies the trap is linear) confinement in the radial directions. This holds the atoms in an elongated cigar-shaped geometry as shown in Fig. 4.

The trap will first be softened (in this case the radial confinement is similar to the axial) to mode-match the MOT [17] in order to maximize the loading efficiency, and then the trap will be adiabatically compressed into its final cigar shape. Once in the magnetic trap, the atoms are evaporatively cooled using

RF radiation [18-20] emitted by the simple RF antenna wound of kapton-insulated 22 gauge copper wire inside the main chamber.

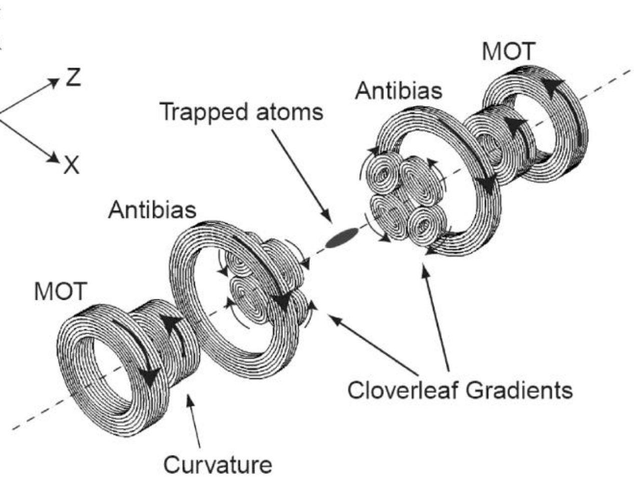

Figure 4. Cloverleaf-style Ioffe-Pritchard magnetic trap coils, shown expanded out for clarity. Arrows indicate current direction. The curvature and antibias coils produce the axial confinement field; the cloverleaf gradients essentially produce a 2D radial quadrupole field that confines the atoms in the transverse directions. Figure from ref. 12.

The RF radiation spin-flips atoms located at specific values of the magnetic field from trapped to non-trapped states and so expels these atoms from the trap. With the RF at relatively high frequency, atoms located at relatively high magnetic field values will be removed. Since it is the high-energy atoms that will probe regions farther from the trap center, thus regions of higher magnetic field, removing these atoms will cool the condensate. The RF is slowly swept to lower frequencies, giving time for the atoms to rethermalize, continuously removing the most energetic of the remaining atoms until the point where the atoms have cooled sufficiently to undergo Bose-Einstein condensation.

The coils shown in Fig. 4 will be wound by hand using the same hollow copper tubing, insulation, and epoxy used for the Zeeman slower. High pressure (~ 230 psi) water will be sent through the tubes to cool the coils when the magnet is operating. These coils will carry high currents of up to 470 A delivered by one Lambda ESS 30-500 and two EMS 20-250 power supplies. The student will run a bench test on the electromagnet, using a Hall probe to measure the magnetic field produced by the coils and comparing it to the theoretical field expected near the trap center as given by:

$$\mathbf{B} = B_0 \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} + B' \begin{pmatrix} x \\ -y \\ 0 \end{pmatrix} + \frac{B''}{2} \begin{pmatrix} -xz \\ -yz \\ z^2 - \frac{1}{2} \; x^2 + y^2 \end{pmatrix}, \tag{1}$$

where B_0 is the Ioffe bias, B' is the radial gradient, and B'' is the axial curvature [12].

The student will learn about current-induced magnetic fields, high current power supplies, I^2R heating, and water cooling systems.

Summer Student Project II:

This student will be funded by this grant. Since the high currents in the magnetic trap need to be switched on and off rapidly – on to transfer the atoms from the MOT to the magnetic trap, and off to free the BEC so it can expand prior to imaging – special transistor circuitry must be custom-assembled for this fast switching. This student will construct this circuitry in rack mount electronics boxes using high current insulated-gate bipolar transistors (IGBTs) as shown in Fig. 5. These circuits not only enable fast switching times, but protect the magnet coils and electronics from voltage spikes.

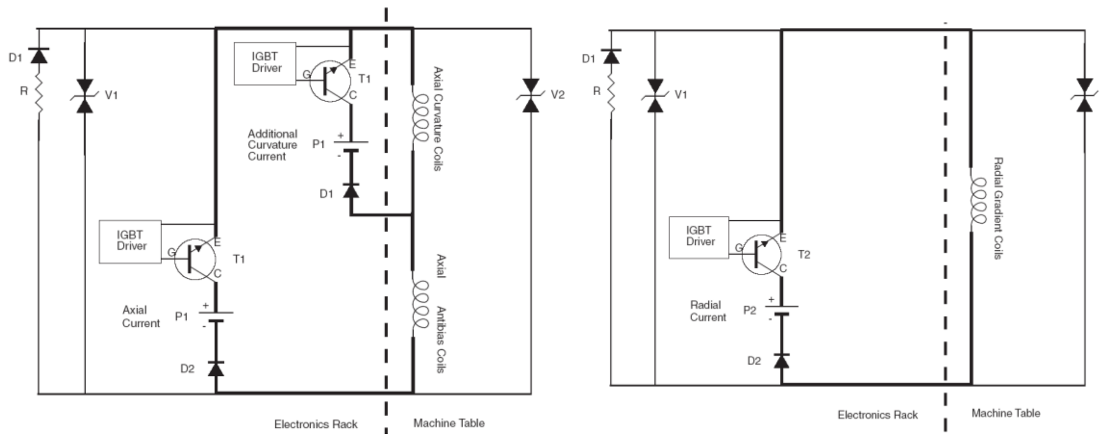

Figure 5. Fast-switching circuitry for magnetic trap. P1 is the EMS 20-250, P2 is the ESS 30-500. Heavy line is 0000 gauge stranded copper wire. T1 and T2 will be Powerex CM600HA-24H and CM1000HA-24H IGBTs respectively. D1 and D2 will be high current, high breakdown voltage diodes to protect the power supplies from reverse current. V1and V2 will be varistors rated for 130V and 30V respectively. The IGBTs dissipate large amounts of heat (up to 1 kW) and so will be water-cooled. Figure from ref. 12.

Since this student can not test the circuitry until the first summer student completes the magnet, this student will in the mean time set up the electronics for controlling the RF antenna inside the main chamber. The RF antenna will be driven by an Agilent 33250A function generator and amplified with a Mini-circuits ZHL-5W-1 amplifier. This student will also be responsible for interfacing the magnet and RF control electronics to the computer.

Academic Year Projects:

During the remainder of the year a number of small projects will be performed to complete the apparatus with the goal of achieving a Rb BEC in the main chamber. First, the magnet trap will be installed in the bucket windows and additional Helmholtz bias coils will be wound outside of the main chamber using 16 gauge stranded wire insulated with high temperature silicone-rubber along each of the three axes (two horizontal, one vertical) to compensate for stray bias fields (such as the earth's). Once the magnet coils are in place, the MOT beams will be aligned and a successful MOT will be pursued. To test and analyze the MOT a portion of the scattered MOT fluorescence will be captured and focused onto a photodiode, this can be used to determine the number of atoms in the MOT [21]. After the imaging system is set up, absorption imaging will allow a more precise characterization of the atoms in the MOT.

Absorption imaging will be the main tool for analyzing both thermal atoms and the condensate. In absorption imaging a large diameter collimated laser beam is sent through the atoms from the direction opposite to the camera location (the camera will be a PIXIS 1024BR from Princeton Instruments). Some of the photons will be scattered out of the beam path by the atoms, creating a shadow in the beam path, as shown in Fig. 6. This shadow is imaged onto the CCD array.

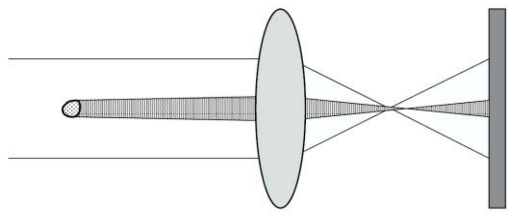

Figure 6. Absorption imaging. The shadow cast by the atoms in a beam of imaging light (coming in from the left) is focused onto a CCD array. The darkness of the shadow gives information on the column density of atoms in the atom cloud. Figure from ref. 22.

Three pictures will be taken to produce a single final image of the shadow: a picture of the illuminated atoms, a picture of the illumination without the atoms, and a picture with no illumination (the bias frame). The bias frame will be subtracted from both the illuminated images, this removes the dark current and hot pixels from the illuminated data, and then the illuminated picture with the atoms will be divided by the one without. The darkness of the shadow then indicates the number of photons removed from the beam by the atoms. From this information the column density of the atoms can be determined on a pixel-by-pixel basis [23].

In general, these images will be taken after the atoms are released from the magnetic trap and allowed to fall and expand for several to tens of milliseconds before the image is taken. In this time-of-flight imaging, the location of the atoms after being freed from the trap depends primarily on the kinetic energies (for thermal atoms) or the mean field energies (for condensed atoms) of the atoms while in the trap, so this technique gives information on the energies/momenta of the atoms prior to release. From time-of-flight imaging the temperature, chemical potential, peak density, and total atom number can be determined [17].

With the camera and the imaging optics in place, the procedure of loading the MOT atoms into the magnetic trap and the subsequent evaporation can be closely observed. However, these steps require precise control on millisecond and even microsecond time scales of: laser beams, magnet coil currents, RF emission, various shutters, and the camera. This will require a custom computer program which will be written using National Instruments LabWindows/CVI 8.1 computer interfacing software. The program will control two 12-bit, 8-channel PCI-6713 analog output boards, and two 32-channel PCI-6533 binary TTL (transistor-transistor logic) output boards. The analog outputs will control the power supplies, and the TTLs the various on-off/open-closed switches in the apparatus. The RF function generator will be controlled through a GPIB interface.

At this point, the only remaining task is to achieve a BEC in the main chamber. Upon successful loading of the magnetic trap, the BEC temperatures can be realized by RF evaporation. The success of this step often depends on the trap shape and rate of sweeping the RF frequency, and these can be optimized empirically. Successful achievement of a BEC will be identified in the time-of-flight absorption images; a clear bimodal distribution will be seen as the faster thermal atoms maintain an isotropic, Gaussian distribution profile, while the slower moving condensate atoms form a sharp edged, optically dense ellipsoid in the center of the image [16].

Plans for use of completed Rb Bose-Einstein condensate apparatus

With a completed ^{87}Rb BEC apparatus there are many different avenues of experimental work that can be pursued: atom lasers [24,25], atom interferometry [26-28], superradiance [4,29], the study of solitons [30-32], the slowing or stopping of light [33-35], spinor condensates [36-38], studies of BEC in one [39,40] and two [41] dimensions, squeezed states [42,43], and studies of the behavior of atoms in optical lattices [44,45,8,46-48,9,49] (low-dimensional studies and squeezed states also require optical lattices), to name just some of the options.

Of special interest to the PI, because they utilize her background in condensed matter physics, are experiments in which the BEC is loaded into an optical lattice. Optical lattices are formed when identical linearly-polarized counter-propagating laser beams interfere to form a standing wave at the location of the condensate. If the laser is red-detuned from resonance, the atoms will be attracted to the anti-nodes in the standing wave pattern and repelled by the nodes, so the standing wave will form a corrugated potential for the atoms (see Fig. 7a).

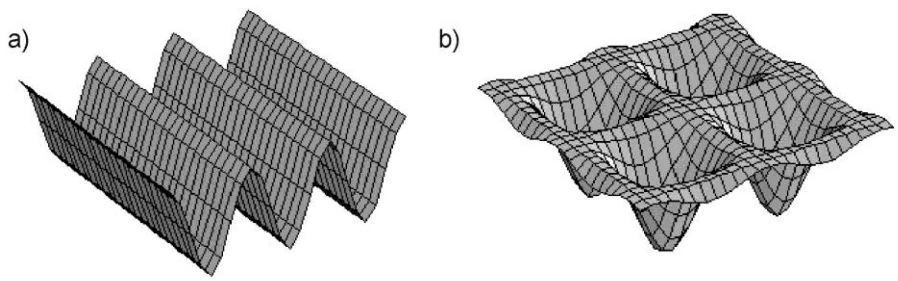

Figure 7. a) 1D optical lattice potential formed by two counter-propagating laser beams with the same linear polarization and wavelength , b) 2D optical lattice potential formed when another pair of beams with the same wavelength is added orthogonal to the first [50].

One pair of counter-propagating beams will produce a corrugated potential; two orthogonal pairs, an "egg crate" potential as shown in Fig. 7b, and three orthogonal pairs will produce potential-minimum dots arranged in a regular three-dimensional array – when loaded with atoms, this mimics the crystalline array of a solid – which brings the study of cold atoms into the realm of condensed matter physics. But unlike condensed matter systems, this array of atoms is free of many of the unwanted impurities and defects that plague the life of the condensed matter physicist – and parameters such as inter-atom spacing and the depth of the potential can be changed at will by changing the beam intersection angle and the beam intensity respectively.

The close theoretical relationship between BECs and condensed matter physics can be illustrated by the large number of theorists who publish in both fields. Here is a list just of theoretical physicists who have both cited the PI's condensed matter physics papers and published papers in the field of cold atoms: Eugene Demler [51,52], Nigel Cooper [53,54], Sankar Das Sarma [55,56], Leo Radzihovsky [57,58], Leon Balents [59,60], Allan MacDonald [61,62], and Steve Girvin [63,64].

One of the most intriguing applications of atoms in optical lattices is their potential for use in quantum computing. By loading a single atom into each lattice site, each atom can act as a single qubit, which is initialized in the state $|0\rangle$, $|1\rangle$, or some superposition of the two states, where $|0\rangle$ and $|1\rangle$ usually represent two possible spin states of the atom. Quantum gate processes are those that entangle the two qubits in a reversible manner, mediated either through tunnel coupling or controlled collisions.

Small registers of trapped ions have been successfully entangled (the coupling in this case is provided by their collective motional modes) [65], but ions, because they are charged, suffer from rapid decoherence – their states are randomly altered through electromagnetic coupling to the environment. Decoherence is a significant obstacle towards the realization of a practical quantum computer [66]. That is why neutral atoms in optical lattices are a promising new arena for practical quantum computation; cold neutral atoms isolated in a vacuum chamber are very weakly coupled to the environment, ensuring long decoherence times.

Although there have been many schemes proposed for quantum computation with neutral atoms in optical lattices [67-73], only two groups have made significant experimental progress in this new field. In Germany, Mandel *et al.* [74] have entangled multiple ^{87}Rb atoms in an optical lattice. The atoms were first initialized in the superposition state $(|0\rangle + |1\rangle)/\sqrt{2}$; where $|0\rangle$, $|1\rangle$ are the internal states $|F=1, m_F = -1\rangle$, $|F=2, m_F = -2\rangle$ respectively, using a π/2 microwave pulse. Then using a spin-dependent transport technique they developed [75], they move the $|0\rangle$ portion of the wavefunction to the left and the $|1\rangle$ portion to the right, where each interacts with its neighbor which also underwent the same spin-dependent motion. After some interaction time, the atoms are sent back to their original lattice sites and receive a second π/2 pulse – now the entire row of atoms is entangled in a so-called cluster state. Controlled entanglement such as this is an important step in implementing quantum computation.

Using a different technique in which only two qubits at a time are entangled, Anderlini *et al.* [76] in Maryland have recently succeeded in entangling pairs of ^{87}Rb atoms in a special double well optical lattice which they designed [77]. They control the double wells dynamically, merging two neighboring wells into a single well, forcing the two neighboring atoms to interact for some allotted time during which the atoms alternately become entangled and then swap their spin states ($|0\rangle \equiv |F=1, m_F = 0\rangle$ and $|1\rangle \equiv |F=1, m_F = -1\rangle$ for this experiment) and then become entangled again, and on and on. Thus their setup explicitly implements a quantum SWAP gate or a $\sqrt{SWAP}$ gate, depending on the hold time of the two atoms in the single well. The $\sqrt{SWAP}$ gate along with single-qubit rotations forms a complete set of universal gates for quantum computation [78].

An important precursor to both these experiments, and any experimental realization of a neutral atom quantum computer, is the ability to load exactly one atom into each lattice site. Such a definite lattice-site occupation number state is called a Mott insulator and occurs when the tunneling rate between the adjacent lattice sites is reduced below a critical value. This state can be detected by the loss of phase coherence across the lattice as the atoms transition from a superfluid state to the Mott insulator [79], or by a direct measurement of the in-trap density using microwave spectroscopy [8]. This transition has been experimentally detected by a number of groups, all using ^{87}Rb atoms [45,39,8,80,46]. Of particular interest is the group at MIT [8] for the machine that is being proposed here is identical to the one used by the MIT group, boding well for this machine's potential to be useful in the field of quantum computing.

<u>Facilities and Management</u>

This proposed Rb BEC machine will be housed in a 28' × 18' room that was specially designed with this proposal in mind and is currently being constructed as part of a $13 million state-funded renovation of the science building at UVa-Wise, expected to be completed by April 2009.

In anticipation of the BEC lab, this room is being outfitted with special high-current electrical outlets for the magnet trap power supplies. In addition, a large array of 110 V and 220 V, 3-phase and single phase outlets will be available both along a wall adjacent to the anticipated location of the two optical tables, and in a ceiling mounted electrical/data service carrier above the tables. Unistrut bars in the ceiling above both tables will make it easy to construct a Unistrut framework over the tables for holding controllers and other instruments as well as for hanging strip/black curtains around the laser table.

Since temperature stability of the room is critical for the success of the apparatus (temperature changes cause changes in the alignment of the optics), the heating/cooling system for the room will be independent of the rest of the building's and will be stable to within +/- 1 F°. To aid in this temperature stability, the chiller (an air-cooled Neslab HX-500AW) used for cooling the magnet trap, Zeeman slower, MOT coils, cold cup TECs, and IGBTs, and which thusly discharges a large amount of heat, will be located on the roof. The architects in conjunction with the chiller manufacturer have designed a conduit to take the coolant between the rooftop chiller and the first-floor lab (the science building is a two-story building). The chiller will be installed and paid for as part of the construction.

Also included in the design considerations are double doors on the lab opening out into the hallway, and double doors with a removable center bar where the hallway leads outdoors, this will allow problem-free delivery of the large optical tables into the lab. Laser safety signs outside the lab doors will also be included in the construction project.

In addition to the room to house the Rb BEC apparatus itself, a second room is being constructed to serve as a machine shop. This 200 square foot room is located in a different area of the building and will hold a lathe, drill press, band saw, milling machine, grinder, workbench and various tools as expected 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.

This instrument will be managed by the PI, who will use it in conjunction with students. Much of the equipment is standard physics laboratory equipment and requires only general physics lab experience, which the PI has gained during undergraduate, graduate, postdoctoral and teaching lab work. For example, the PI learned metal machining in her first summer physics research assistantship as an undergraduate in 1991 where she spent three months in the student machine shop constructing a vacuum chamber. She did metal machining again the following summer, and then again during physics graduate and post-doctoral work as needed. As a professor, the PI has taught electronics twice (and is about to teach it a third time this coming semester). This course covers both analog and digital electronics, and by teaching it the PI has gained a proficiency in constructing and analyzing circuits involving transistors and integrated circuits. This has augmented the more basic electronics knowledge (more focused on resistors, capacitors and inductors) gained from her Ph. D. thesis project in which the systems studied (excitonic BECs in semiconductors) were probed by driving electrical currents through them.

The PI's Ph. D. thesis project also involved the application of high magnetic fields, and so the PI is very familiar with electromagnets and their power supplies and protection circuits (these magnets were superconducting, however). The PI worked with ultra-high vacuum, thus ConFlat flanges and seals – this level of vacuum was a by-product of the ultra-low temperatures achieved in the helium dilution refrigerator used. The PI is proficient in leak-detection and the use and maintenance of mechanical pumps, having completely disassembled a two-stage rotary vane pump as part of a successful repair effort.

The PI worked with lasers as an undergraduate, indirectly with a Free Electron Laser (a large tunable far-infrared laser) the first two summers: first building a vacuum chamber for experiments, and then creating low-pass filters for the laser. The third summer the PI worked in a different lab which had a pulsed femtosecond Ti:sapphire laser; she built a laser pulse compressor which squeezed 100 fs pulses down to 30 fs pulses by coupling them into fiber optics having intensity-dependent refractive indices.

In four years of astronomy work, the PI gained valuable experience in the use of CCD cameras and the processing of CCD images, including some advanced techniques such as spatial filtering. Astronomy is also a very computer-intensive field where unix-based systems are used; much computer experience was gained then, including programming in Fortran. Windows systems were used in physics, where as a Ph. D. student the PI performed computer-electronics interfacing and wrote nearly a hundred control-and-collection programs using LabView.

Most importantly, the PI has experience with this Rb BEC machine as a post-doc in the Ketterle lab which included: documenting parts of the machine (the PI made Fig. 1b), taking trap frequency data, assisting in aligning the optics for the optical lattices, assisting in upgrading the water-cooling system for the magnets, and general observation of the use and maintenance of the machine.

Items which require technical expertise beyond the PI's include the setting up (specifically the internal alignment) of the Toptica TA100 laser which will be installed by a representative from the company, who has that technical expertise. Although the laser is very robust once it has been set up, eventually it may be necessary to replace a chip, which would also be done by a representative of the company. The Neslab chiller company (Thermo Fisher Scientific) also sends a representative during the chiller installation, this person's duties include training the users on proper system operation. The ion pumps are maintenance-free, and in the case of failure must be repaired by the company.

Once the apparatus has been built, there are very few consumables involved in its operation. The Rb ampule in the oven will need to be replaced approximately every six months, each ampule costs $215 at the time of this writing. Acetone, methanol, lens tissues and the like will be needed to clean the optics. These are all low-expense items. The chiller will require semiannual maintenance which includes inspecting the hoses and tightening the clamps, vacuuming the condenser fins, and cleaning out the reservoir. Occasionally hoses and cooling fluid may need replacing. The cooling fluid consists of de-ionized water with the algicide Chloramine-T added. Hoses and Chloramine-T are also relatively inexpensive items. For each FINS student that works in the lab, $500 is allocated from that same fund for lab supplies, and this can be used to offset some of these maintenance costs.

The largest cost in operating the apparatus will be for electricity, primarily due to the electromagnets and the chiller. Other parts of the apparatus use very little electricity, for example: the Toptica TA-100 diode laser uses less than 200W, including all of its driving electronics; the Agilent 33250A function generator uses less than 140W; the Varion VacIon Plus 75 Starcell pump plus controller use less than 40W; and the Ferrotec FTC100 TEC controller uses less than 5W. A generous upper estimate for the power consumption of all these electronics (for 2 master lasers, 2 slave lasers, a dozen AOMs, shutters, TECs, 3 ion pumps, computers, function generator, oscilloscopes, etc.), which will by and large always be on, is 2.5 kW, which comes to 60 kWh/day. The current electricity rates for commercial/industrial customers in Wise county is 7.3¢/kWh [81], so these electronics will cost up to $4.38/day to operate.

The electromagnets and chiller will only be on when an experiment is actually running, and even then the electromagnets will only be on during certain stages of the experiment. The majority of the power consumed by the electromagnets is dissipated as heat which is removed by the chiller. Since the chiller can remove a maximum of 15 kW of heat, a reasonable upper limit for the power consumed by the electromagnets (including the IGBTs) is 15 kW. The chiller uses under 5 kW, so again for a generous upper estimate, the chiller and electromagnets use 20 kW of power when an experiment is running. For a 10-hour work day this comes to an addition 200 kWh/day or $14.60/day.

Electricity is paid for by the college. If the Rb BEC apparatus is successful, future grant monies will be applied for to fund experiments utilizing the machine, and electricity usage will be covered under indirect costs.

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Biographical sketch for Melinda Kellogg (aka Mindy Kellogg)

Professional preparation:

- Massachusetts Institute of Technology, postdoctoral training in Atomic, Molecular and Optical Physics (Sep. 2004 – Dec. 2004).
- California Institute of Technology, PhD in Condensed Matter 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, worked in Rb BEC lab.
- **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:

- 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).
- K. L. Adelberger, C. C. Steidel, M. Giavalisco, M. Dickinson, M. Pettini, and M. Kellogg, "A counts-in-cell analysis of Lyman-break galaxies at $z \sim 3$," Astrophys. J. **505**, 18 (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, S. E. Ridgway, and M. Kellogg, "The position of the nucleus and the nature of the aligned component in 3C 368," Astron. J. **112**, 902 (1996).
- 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. Eight students signed up for it (this is a large number for a small school with no physics major), four of whom were local students from Wise County. 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:

- Gretchen K. Campbell, currently at JILA in Boulder, Colorado USA.
- Aaron E. Leanhardt, currently at the University of Michigan, Ann Arbor, Michigan USA.
- Jongchul Mun, currently at MIT-Harvard Center for Ultracold Atoms, Cambridge, Massachusetts USA.
- Ian B. Spielman, currently at the Joint Quantum Institute, University of Maryland, College Park, Maryland USA.
- Erik W. Streed, currently at the Centre for Quantum Dynamics, Griffith University, Brisbane, Queensland, Australia.

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's College at Wise				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 - Asst. Prof. of Physics	0.00	0.00	6.00	$ 30,000	$
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	6.00	30,000	
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				6,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				36,000	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				2,520	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				38,520	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Custom vacuum chamber by Sharon Vacuum			$ 12,890		
Lambda ESS 30-500 15kW power supply			21,984		
Newport optical table w/isolating legs			31,190		
Others (See Budget Comments Page...)			135,627		
TOTAL EQUIPMENT				201,691	
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				259,197	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				259,197	
H. TOTAL DIRECT COSTS (A THROUGH G)				499,408	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Salary and fringe benefits (Rate: 26.0000, Base: 38520)					
TOTAL INDIRECT COSTS (F&A)				10,015	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				509,423	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 509,423	$
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

** D- Equipment
PIXIS 1024BR infrared camera (Amount: $ 34000)
Toptica DL 100 diode laser (Amount: $ 21000)
Toptica Fabry Perot spectrometer (Amount: $ 6500)
Toptica TA 100 amplified diode laser (Amount: $ 47000)
Two Lambda EMS 20-250 5 kW power supplies (Amount: $ 21386)
Varian Vaclon dual pump controller (Amount: $ 5741)

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION	FOR NSF USE ONLY		
University of Virginia's College at Wise	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR	AWARD NO.		
Melinda J Kellogg			

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 - Asst. Prof. of Physics	0.00	0.00	6.00	$ 30,000	$
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	6.00	30,000	
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				6,000	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				36,000	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				2,520	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				38,520	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 201,691					
TOTAL EQUIPMENT				201,691	
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				259,197	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				259,197	
H. TOTAL DIRECT COSTS (A THROUGH G)				499,408	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				10,015	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				509,423	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 509,423	$

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

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

qty	description	company	$ ea	$ total	quote date
2	RS4000-58-18 optical table 5'x8'x18" w/304SS top	Newport Corporation	9341.00	18682.00	9/2/2007
2	Four 16" optical table legs I-2000-416tc	"	3950.00	7900.00	9/2/2007
2	tie bar/casters	"	604.00	1208.00	9/2/2007
2	shipping for above items	"	1700.00	3400.00	9/2/2007
0	HX-500 AW D2 CP 190/50 230/60/3 Chiller	ThermoFisher Scientific	31890.00	0.00	6/4/2007
0	shipping for above item	"	1200.00	0.00	6/4/2007
2	Sanyo DL7140-201S 70mW laser diodes	Thorlabs, Inc.	48.50	97.00	9/2/2007
2	LDM21 TE-cooled laser diode mount	"	432.00	864.00	9/8/2007
2	TED 200C temperature controller	"	968.00	1936.00	9/8/2007
2	CAB420-15 cables to connect temp controller	"	72.00	144.00	9/8/2007
2	LT220P-B collimator tubes	"	111.00	222.00	9/8/2007
2	LDC205C laser diode controller	"	950.00	1900.00	9/8/2007
2	CAB400 cables to connect current controller	"	66.00	132.00	9/8/2007
7	DET36A high speed Si detectors	"	104.00	728.00	9/2/2007
5	IRC3 infrared viewing card 700 - 1400 nm	"	113.00	565.00	9/3/2007
25	WPH05M-780 Zero-Order Half-Wave Plate	"	407.00	10175.00	9/8/2007
16	WPQ05M-780 Zero order Quarter Waveplate	"	407.00	6512.00	9/8/2007
41	PRM1 high precision rotation mounts	"	255.00	10455.00	9/8/2007
1	SPW602 spanner wrench for 1" rotation mount	"	28.40	28.40	9/8/2007
27	PM1 small clamping arms for beamsplitter cubes	"	9.50	256.50	9/8/2007
10	LJ750 lab jacks	"	314.00	3140.00	9/15/2007
3	ESK03 posts and accessories kit	"	931.80	2795.40	9/8/2007
4	ESK01 kit of post holders, bases, and clamps	"	741.80	2967.20	9/8/2007
90	TR075, TR1, TR1.5, TR2 posts	"	5.19	467.10	9/8/2007
10	TR2T 1/2" adjustable height posts	"	49.50	495.00	9/14/2007
2	ESK05 optical mount kit	"	2397.30	4794.60	9/8/2007
80	PF10-03-M01 1" gold mirrors	"	75.05	6004.00	9/14/2007
80	KM100 1" two-adjuster kinematic mirror mounts	"	42.00	3360.00	9/15/2007
24	LA/LC series plano-convex(concave) lenses	"	35.00	840.00	9/14/2007
24	LMR2 (comes w/SM2RR) lens mounts	"	23.50	564.00	9/14/2007
4	PS814-B 10 ° round wedge prisms	"	39.10	156.40	9/15/2007
2	LSB01 1" plano-convex Lens Kit	"	348.00	696.00	9/14/2007
10	LMR1 mounts for above kit	"	15.68	156.80	9/14/2007
1	SPW604 spanner wrenches for 2" mounts	"	49.00	49.00	9/14/2007
1	HW-KIT2 Set of 1/4-20 screws and hex wrenches	"	104.00	104.00	9/8/2007
1	HW-KIT1 Set of 8-32 screws and hex wrenches	"	52.50	52.50	9/8/2007
1	TC2 ball drivers w/stand	"	86.50	86.50	9/8/2007
3	LG4 laser safety glasses	"	153.00	459.00	9/8/2007
1	BP104-VIS optical beam profiler	"	3600.00	3600.00	9/15/2007
1	MB1824 18" x 24" breadboard	"	420.00	420.00	9/15/2007
2	CQ19075-RB87 87-Rb quartz reference cells	"	951.50	1903.00	9/16/2007
2	reference cell mounts	"	125.00	250.00	
6	P3-830A-FC5 single mode fiber optic patch cable	"	101.60	609.60	9/29/2007
15	F230FC-B laser fiber collimator	"	137.00	2055.00	9/29/2007
15	AD1109F adapter for above for mounting	"	29.00	435.00	9/29/2007
15	SMR05 mounts for above adapters	"	14.30	214.50	9/29/2007
10	ID25 iris diaphragm	"	50.40	504.00	9/14/2007
5	RA90 right-angle post clamp	"	9.93	49.65	9/14/2007
11	LB1 beam blocks	"	45.20	497.20	9/8/2007
5	S19909 9 drawer storage cabinets	"	108.00	540.00	9/14/2007
13	BX01/02 lens/mirror boxes 1" and 2" 10 pack	"	21.00	273.00	9/15/2007
2	TZ1 optics tweezers	"	41.10	82.20	9/15/2007
1	MC6 cotton optics gloves (12 pr)	"	13.10	13.10	9/15/2007
1	FCP forceps	"	18.30	18.30	9/15/2007
1	JEL10 jeweler's magnifier	"	15.86	15.86	9/15/2007
60	cables (BNC, SMC, USB, power etc)	"	20.00	1200.00	9/15/2007
50	electrical adapters (BNC, SMC, tees, etc)	"	15.00	750.00	9/15/2007
1	KW32 kimwipes (12 boxes)	"	43.70	43.70	9/15/2007

10	CTA10 cotton tipped applicators	"	4.10	41.00	9/15/2007
1	MC50-E lens tissues	"	75.00	75.00	9/15/2007
1	B2939 wash bottle kits	"	62.00	62.00	9/15/2007
5	CA3 Can-of-air duster	"	9.90	49.50	9/15/2007
2	acetone, methanol, per Gallon	"	10.00	20.00	
1	BK5 blackout rubber-coated cloth (5'x9')	"	43.30	43.30	9/28/2007
6	LB1 beam blocks	"	45.00	270.00	9/28/2007
1	T17251 power cords, pack of 5	"	32.00	32.00	10/20/2007
2	PM10-10 (or -3) optical power meter	"	922.00	1844.00	9/8/2007
3	PBG11101 Aluminum (non-mag) breadboards	"	586.50	1759.50	10/20/2007
2	BS011 non-polarizing beamsplitting cube	"	161.20	322.40	10/20/2007
8	KC45D Cage Assemply Turret mount	"	172.00	1376.00	10/20/2007
1	Tektronix TPS2024 digital oscilloscope	Allied Electronics	3220.00	3220.00	10/20/2007
1	find-r-scope 84499A infrared hand-held viewer	FJW Optical Systems	1445.00	1445.00	9/8/2007
1	80385 wrist strap for above	"	25.00	25.00	9/8/2007
4	IO-5-780-HP optical isolators	Optics For Research	2670.00	10680.00	9/28/2007
1	DL 100 tunable diode laser	Toptica Photonics	21000.00	21000.00	9/28/2007
1	TA 100 high powered amplified diode laser	"	47000.00	47000.00	9/28/2007
1	FPI-100-0750-y (y=1,4) Fabry Perot spectrometer	"	6500.00	6500.00	9/28/2007
1	FPI Thermokit (temp control of Fabry Perot)	"	2400.00	2400.00	9/28/2007
1	miniScan 102 (Fabry Perot driver)	"	2000.00	2000.00	9/28/2007
2	44F7739 Fluke digital multimeters	Newark	399.95	799.90	10/4/2007
6	LS6ZM2 uniblitz mechanical shutters	Vincent Associates	752.00	4512.00	9/8/2007
2	VMM-D3 for control of mechanical shutters	"	1425.00	2850.00	9/8/2007
27	03 PBB 011 polarizing beamsplitter cubes	Melles Griot	328.00	8856.00	9/8/2007
26	07 MHT 242 beamsplitter holders	"	61.00	1586.00	9/8/2007
8	ATM-801A2 and 901A2	IntraAction Corp.	877.00	7016.00	9/28/2007
1	ATM-2501A2	"	1215.00	1215.00	9/28/2007
1	ATM-3401A2	"	1395.00	1395.00	9/28/2007
8	DE-801 deflector driver for 80-90 MHz AOMS	"	1210.00	9680.00	9/28/2007
2	DE-2502 and DE-3402 deflector drivers	"	1575.00	3150.00	9/28/2007
1	unitstrut	Unistrut Corp.	700.00	700.00	
1	LK-120 magnetic shielding lab kit	Magnetic Shield Corp.	149.50	149.50	9/16/2007
1	6623A14 6-drawer toolbox	McMaster-Carr	312.37	312.37	9/28/2007
1	strip curtains	Strip-Curtains.com	918.00	918.00	9/29/2007
1	polarization-preserving fiber	OZ Optics	240.00	240.00	9/29/2007
1	VacIon Plus 55 noble diode Ion Pump	Varian, Inc.	2539.00	2539.00	10/16/2007
1	VacIon Plus 40 Noble diode Ion Pump	"	2095.00	2095.00	10/16/2007
1	Dual Controller controls 2 VacIon pumps	"	5741.00	5741.00	10/16/2007
3	9290705 HV bakeable cable 4m long	"	401.00	1203.00	10/16/2007
3	9595125 HV feedthrough with interlock	"	438.00	1314.00	10/16/2007
3	9190071 120V heaters	"	384.00	1152.00	10/16/2007
1	9698904 Turbo V 81 turbo-molecular pump	"	4230.00	4230.00	10/16/2007
1	9699942 Turbo V 81 extension cable 3m	"	272.00	272.00	10/16/2007
1	9699290 Turbo V 81 cooling kit	"	246.00	246.00	10/16/2007
1	9698989 Rack controller 81-AG RS232/485	"	1931.00	1931.00	10/16/2007
1	9499315 DS 102 mechanical forepump	"	1848.00	1848.00	10/16/2007
1	9499370 DS 102 minor maintenance kit	"	129.00	129.00	10/16/2007
2	9499390 DS 102 mechanical pump oil	"	13.00	26.00	10/16/2007
3	9160050 Titanium Sublimation Pump	"	851.00	2553.00	10/16/2007
2	9290022 TSP controllers	"	1743.00	3486.00	10/16/2007
2	9290024 RS232 computer interface	"	210.00	420.00	10/16/2007
2	9240730 TSP cartridge cables	"	438.00	876.00	10/16/2007
1	9190180 TSP cryopanel	"	1208.00	1208.00	10/16/2007
1	9191444 VacIon Plus 75 Starcell Ion Pump	"	3156.00	3156.00	10/16/2007
1	9297008 Dual controller 120V (negative)	"	3665.00	3665.00	10/16/2007
2	9290064 rack adapter	"	373.00	746.00	10/16/2007
3	Ion Pump Service Plan -extended warranty	"	1000.00	3000.00	
3	9715014 UHV-24p nude tungsten ion gauge	"	464.00	1392.00	10/16/2007

1	K2466303 563 Bayard-Alpert ion gauge	"	242.00	242.00	10/16/2007
3	F0472301 531 Thermocouple gauge tubes	"	55.65	166.95	10/16/2007
1	9515027 right-angle valve 2.75" flange	"	859.02	859.02	10/16/2007
10	FG0275C1 2.75" copper gaskets	"	18.25	182.50	10/16/2007
8	FG0450C1 4.5" copper gaskets	"	25.99	207.92	10/16/2007
15	FB0450C12S silver plated bolts/nuts (24)	"	48.50	727.50	10/16/2007
25	FB0275C06 bolts/nuts (24)	"	12.25	306.25	10/16/2007
5	FB04500275CR12 reducing flange bolts/nuts	"	41.25	206.25	10/16/2007
2	FR04500275E reducing flanges (4.5" to 2.75")	"	105.00	210.00	10/16/2007
1	FT0150 2.75" tees (2 rotatable cuffs)	"	85.50	85.50	10/16/2007
1	FE0150 Elbows 2.75" flanges	"	56.75	56.75	10/16/2007
1	FA04500275 Reducing Nipples 4.5" to 2.75"	"	123.50	123.50	10/16/2007
2	FL01500400 Bellows flexible coup 2.75" flange	"	128.75	257.50	10/16/2007
2	FA0275NW16S adaptors: CF to KF (NW16)	"	56.75	113.50	10/16/2007
5	KQ16AR NW16 clamp	"	5.00	25.00	
5	KC16SV NW16 O-ring	"	2.00	10.00	
1	FVS0062 sapphire viewport	"	394.00	394.00	10/16/2007
6	FVG0150 zero length glass viewports	"	108.25	649.50	10/16/2007
5	F02750100NCEW blank flanges	"	23.50	117.50	10/16/2007
5	F04500250NCE blank flanges (w/holes)	"	72.25	361.25	10/16/2007
1	L6691301 rotary feedthru 1.33" conflat flange	"	675.00	675.00	10/17/2007
2	407004 six-way crosses, 4.5" flanges	MDC Vacuum Products	820.00	1640.00	10/17/2007
1	407002 six-way cross, 2.75" flanges	"	265.00	265.00	10/17/2007
1	GV-1500M-P pneumatic 1.5" circular gate valve	"	1230.00	1230.00	10/17/2007
1	GV-2500M-P pneumatic 2.5" circular gate valve	"	1950.00	1950.00	10/17/2007
8	9722005 fused quartz viewports 2.75" flange	Insulator Seal	240.00	1920.00	10/17/2007
4	9722005 fused quartz viewports 4.5" flange	"	650.00	2600.00	10/17/2007
1	9222013 MHV floating shield RF feedthrough	"	300.00	300.00	10/17/2007
1	9943101 KAP2 kapton insulated wire 30ft	"	60.00	60.00	10/17/2007
1	rotary solenoid actuator	Cooke Vacuum Products	400.00	400.00	
1	33250A 80MHz function generator	Agilent Technologies	4696.00	4696.00	10/19/2007
1	82350B PCI-GPIB interface for above	"	501.00	501.00	10/19/2007
1	ZHL-5W-1 5 W RF amplifier	Mini-Circuits	995.00	995.00	10/19/2007
6	9520/185/065BS TEC coolers	Ferrotec Corp.	159.07	954.42	10/19/2007
1	FTC100 TEC controller	"	350.00	350.00	10/19/2007
1	8457K28 304L stainless steel 0.25"OD 12"	McMaster Carr	4.08	4.08	10/19/2007
5	8312K12 Alloy 101 OFE copper 2"OD, 1"	"	24.73	123.65	10/19/2007
4	8312K52 Alloy 101 OFE copper 2"OD, 5"	"	102.76	411.04	10/19/2007
1	89675K15 Alloy 101 OFE copper 6"x6"x1/4"	"	65.33	65.33	10/19/2007
1	2545T51 Alloy 101 OFE copper 12"x12"x1/16"	"	48.08	48.08	10/19/2007
2	89495K111 304SS tube 2"OD 12" long	"	53.79	107.58	10/19/2007
12	88685K61 aluminum plates 12" x 12"	"	28.83	345.96	10/19/2007
3	83375A22 1/8" T-handled hex wrench 6" long	"	18.79	56.37	10/19/2007
1	8976A11 electronic torque wrench	"	297.22	297.22	10/19/2007
3	2271K3 5 mils Kapton sheet 12" x 12"	"	19.89	59.67	10/19/2007
1	7666A1 silver solder kit	"	58.06	58.06	10/19/2007
1	7724A28 80 W mini-soldering station	"	120.93	120.93	10/19/2007
2	2245A23 Tool grade granite block 8"x12"	"	87.71	175.42	10/19/2007
2	pre-scored Rubidium ampules, 5 gm	ESPI Metals	215.00	430.00	10/19/2007
1	Nickel rod 4N5, 0.5" diam, 0.4" long	"	181.00	181.00	10/19/2007
12	2020 2" square T-slotted aluminum 145" long	80/20 Inc.	82.65	991.80	10/19/2007
50	3395 anchor fasteners 10 series	"	2.90	145.00	10/19/2007
12	4042 joining plates 10 series	"	17.85	214.20	10/19/2007
500	1/8" square OD, 0.032" thick wall 101 copper	Small Tube Products	1.00	500.00	1/1/2002
500	Double Dacron Glass Fuse insulation of above	Essex Group Inc	0.30	150.00	1/1/2002
25	Hysol Epoxi-Patch Kit 1C White 4oz	Dexter Corp.	6.10	152.50	10/19/2007
5	14210 Devcon 5-minute epoxy 2.5 oz	Devcon	6.98	34.90	10/19/2007
1	F.W. Bell 5180 gauss meter	Allied Electronics	1253.33	1253.33	10/19/2007
9	3PN1210B-MOD 120V 1 phase variacs 12 A	ISE, Inc.	332.00	2988.00	10/19/2007

2	CNi16D24-C24 Intelligent Temp Controller	Omega Engineering	305.00	610.00	10/19/2007
8	FGS101-040 Heater Tape 418W 1" x 4'	"	38.00	304.00	10/19/2007
6	strip/band heaters	"	50.00	300.00	
3	CF-090-K-4-60-2 k-type thermocouples	"	29.00	87.00	10/19/2007
1	HH20SW-K handheld thermocouple therm	"	149.00	149.00	10/19/2007
6	PGC-25L-300 pressure gauges	"	20.00	120.00	10/20/2007
1	RGA100 Residual Gas Analyzer	Stanford Research Sys.	3750.00	3750.00	1/4/2008
2	EMS 20-250 5kW power supply	Lambda Americas Inc.	10693.05	21386.10	10/19/2007
1	ESS 30-500 15kW power supply	"	21984.05	21984.05	10/19/2007
4	KLP-36-60-1200 DC power supply	Kepco	1795.00	7180.00	10/20/2007
6	SD600N04PC High current diode, 600A, 1200V	Newark	171.77	1030.62	10/19/2007
3	varistors	"	20.00	60.00	10/19/2007
30	0000 AWG stranded welding cable (#4/0)	North. Ariz. Wind & Sun	6.33	189.90	10/19/2007
5	3120E rack mount enclosures 16.7"x16.7"x5"	JDR Microdevices	108.88	544.40	10/20/2007
3	Powerex CM600HA-24H integ bipolar transistor	Richardson Electronics	330.63	991.89	10/20/2007
1	Powerex CM1000HA-24H IGBT	"	551.80	551.80	10/20/2007
4	Powerex BG1A-F circuit board	"	42.50	170.00	10/20/2007
1	IGBT cooling supplies	"	500.00	500.00	
1	Texas Instruments 595-INA117AM	Mouser Electronics	50.75	50.75	10/20/2007
64	551-PS250-1-A opto-isolator for digital	"	0.35	22.40	10/20/2007
4	40A MOSFETs (512-IRF550A)	"	2.04	8.16	10/20/2007
25	563-CU-123G die cast boxes 3.63"x1.5"x1.06"	"	6.45	161.25	10/20/2007
50	523-31-10 BNC isolated bulkhead connectors	"	2.17	108.50	10/20/2007
2	563-ER-16625-S electronics rack	"	862.26	1724.52	10/20/2007
8	512-74ACTQ16245MTD buffer chips	"	7.20	57.60	10/20/2007
1	545_SMART1500LCD 1.5kW UPS	"	360.00	360.00	10/20/2007
25	SAF2507 Swagelok tube fitting for 1/4" tube	Swagelok	46.43	1160.75	10/20/2007
25	B-400-2-1 Brass elbow fitting	"	6.04	151.00	10/20/2007
12	B-400-3 brass tee fitting	"	7.48	89.76	10/20/2007
15	B-4P4T1 1/4 turn plug valve	"	32.49	487.35	10/20/2007
25	SS-TBP4 p-clamp support	"	0.37	9.25	10/20/2007
25	PB-4 multi-purpose hose per foot	"	1.59	39.75	10/20/2007
1	additional plumbing supplies		500.00	500.00	
1	PB1914A201 2hp pressure booster pump	Dean Bennett Supply	774.00	774.00	10/20/2007
15	Model 101-7 flow meter w/100-17 cable assembly	MacMillan Company	230.00	3450.00	10/26/2007
1	interlock system		500.00	500.00	
1	8892 1" motorized flipper	New Focus	795.00	795.00	10/20/2007
2	OptiPlex GX745 computers	Dell	1443.05	2886.10	10/20/2007
1	business inkjet 2800 printer	Hewlett Packard	499.99	499.99	10/20/2007
1	LabWindows/CVI 8.1	National Instruments	2399.00	2399.00	10/20/2007
2	PCI-6713 8 channel, 12 bit analog output board	"	1299.00	2598.00	10/20/2007
2	SH68-68-EP cable for above	"	119.00	238.00	10/20/2007
2	SCC-68 unshielded connector block for above	"	299.00	598.00	10/20/2007
2	3 year warranty on above	"	99.00	198.00	10/20/2007
2	PCI-6533 32 channel, binary TTL output board	"	1199.00	2398.00	10/20/2007
2	SH68-68-D1 cable for above	"	129.00	258.00	10/20/2007
2	SCB-68 shielded connector block for above	"	299.00	598.00	10/20/2007
2	3 year warranty on above	"	99.00	198.00	10/20/2007
1	PIXIS 1024BR infrared camera	Princeton Instruments	34000.00	34000.00	10/25/2007
1	tanks of N2,Ar,He, dry ice, regulators, brackets	Air & Gas	1379.24	1379.24	10/26/2007
1	custom chamber	Sharon Vacuum	12890.00	12890.00	11/5/2007
4	custom chamber windows	Ukaea	1000.00	4000.00	
			Total:	460889.04	

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: Currently being constructed is a 28' x 18' lab to house the proposed Rb BEC machine. It is being specially outfitted for this machine, specifically there will be high-current electrical outlets, a roof-top chiller with a conduit to the lab, independent temperature control of the

Clinical:

Animal:

Computer: UVa-Wise has an office of Information Technology which provides computer support and servicing to the entire campus.

Office: The PI has a 10' x 10' office.

Other: An 11' x 18' machine shop is also being constructed in support of the proposed Rb BEC lab. It will contain a lathe, drill press, band saw, milling machine, and other items to support construction of the Rb BEC machine.

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.

The Natural Sciences department has one secretary who will help with purchasing for the project.

LABORATORY FACILITIES (continued):

lab, and lighted laser safety signs outside both lab doors. For more details, please see 'Project Description'.

THE UNIVERSITY OF VIRGINIA'S COLLEGE AT WISE

Financial Administration

One College Avenue
Wise, VA 24293

FAX (276) 376-4510

January 24, 2008

The University of Virginia's College at Wise is the performing organization for this proposal and is a non-Ph.D. granting institution.

Charles Banner
Comptroller
Comptroller's Office