R&T 4124128

MATTER-WAVE INTERFEROMETRY WITH LASER COOLED ATOMS

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Summary Questionnaire

1. Research Description:

This program is investigating matter wave interferometry with laser cooled atoms. A slow beam of laser cooled rubidium atoms will be used as the matter wave source. The atom optical elements will be microfabricated amplitude transmission gratings which will be used in a three-grating interferometer to split and recombine the rubidium beam. The interferometer will be a useful new tool for precision atomic physics and a sensitive inertial sensor.

2. Scientific Problem:

The principal tasks in this research program are production of a laser cooled rubidium atomic beam, fabrication of submicron amplitude transmission gratings, and construction and testing of the atomic interferometer. Several technical issues must be addressed in each task. The atomic beam must have high brightness to ensure adequate signal to noise ratio and a low temperature to ensure a long coherence length. The gratings must be phase coherent over their area so that the interferometer fringes are not washed out. The interferometer must be vibration isolated so that the fringes do not move appreciably during the signal integration time. Once these technical issues are resolved, the atomic interferometer will be a useful new tool with which to perform precision experiments in atomic physics, quantum optics, and gravitation.

3. Scientific and Technical Approach:

This research program will take advantage of and incorporate three new technologies. A beam of slow rubidium atoms will be produced by combining the techniques of chirped laser cooling, optical molasses, and magneto-optic trapping. The rubidium cooling transition at 780 nm will be excited with commercial diode lasers which are frequency stabilized using optical feedback

from Fabry-Perot etalons. The cooled rubidium beam will have a de Broglie wavelength of 0.5 nm. The interferometer will use amplitude transmission gratings fabricated with high-resolution electron-beam lithography. The atomic interferometer will be similar to the three-grating Bonse-Hart interferometer used in neutron interferometry. The combination of laser cooled atoms and microfabricated gratings will allow for a compact and stable interferometer design.

4. a. Progress:

Since the start of this grant (1/1/91), we have completed two stabilized diode laser systems and are presently building three more systems. The vacuum chamber for the rubidium source has been built and the vacuum system is being assembled. Silicon wafers for the gratings have been coated with silicon nitride and we will soon begin fabrication of the gratings.

b. Special Significance of Results:

These preliminary results are not especially significant, but work is proceeding smoothly, now that machining facilities are again available (see 5).

5. Extenuating Circumstances:

Our department machinist took early retirement in March and on-campus replacement services were arranged only in May. This has led to a delay of two months in machining projects.

6. Publications:

None

7. Unspent Funds:

I do not expect any unspent funds.

8. Other Government Support:

None

9. Major Equipment Purchases:

Vacuum chamber $5565

Statement A per telecon
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Progress Report July 1991

This research program is investigating matter wave interferometry with laser cooled atoms. A slow beam of laser cooled rubidium atoms will be used as the matter wave source. The atom optical elements will be microfabricated amplitude transmission gratings which will be used in a three-grating interferometer to split and recombine the rubidium beam. The atomic interferometer will be a useful new tool with which to perform precision experiments in atomic physics, quantum optics, and gravitation.

The principal tasks under way during the first seven months of this grant (1/1/91-7/31/91) are production of a laser cooled atomic rubidium beam and fabrication of submicron amplitude transmission gratings. We are working in parallel on these two projects.

The recently developed atomic funnel[1] will form the basis for the cooled atomic beam. In this device, atoms from a thermal source are cooled longitudinally with chirped laser cooling and are fed into the funnel which uses two-dimensional magneto-optic trapping to achieve transverse cooling as well as spatial compression of the beam. The rubidium atoms will be cooled using frequency stabilized 780 nm diode lasers. We have built precision current and temperature controllers for six diode lasers. We have constructed two complete laser diode systems using optical feedback stabilization from Fabry-Perot confocal cavities.[2] Each of these systems is capable of single mode scanning over several GHz. We have not measured the linewidth of these lasers but expect that it is well below 1 MHz. Four more such systems are currently being assembled. We are also investigating the use of grating feedback configurations which might be easier to implement.

The differentially pumped vacuum system in which the experiments will be performed is under construction. The Rb atomic beam source chamber has been constructed and that part of the vacuum system is being assembled and tested. The high vacuum chamber which will house the magneto-optic atomic funnel and the atomic interferometer is being designed and will be ordered next month along with a turbomolecular pumping system.

While the vacuum system is being built, we are refining our laser cooling and trapping techniques in a small Rb vapor cell. This simple system uses a magneto-optic trap to cool and trap the low velocity tail of the room temperature sample of atoms in the cell.[3] This will permit us to test laser frequency control, beam focusing and spatial mode quality, beam polarization, fluorescence detection, and magnetic field control, which will all be needed in the atomic beam cooling and trapping system. We have just begun to use this system and have not trapped any atoms yet.

We are also working on a simplified frequency offset locking scheme. Using a digitally programmable delay generator, we have built a frequency discriminator which operates up to 8 MHz on a breadboard, but which should work up to 50 MHz on a printed circuit board. We have also built a fast ($\approx$ 100 MHz) photodiode amplifier and several other rf amplifiers to detect the beat frequency between two diode lasers. With the beat note as input into the frequency discriminator, two lasers can be locked to a controllable frequency difference without an external frequency reference. We have not yet tested the complete system. We plan to use this system to control the frequencies of the laser beams making up the atomic funnel, which will allow precise control over the velocity of the beam leaving the funnel. This simple scheme should also be an attractive addition to the economical use of diode lasers in high resolution laser spectroscopy.

The amplitude transmission gratings for the atomic interferometer will be microfabricated in silicon nitride coated on silicon substrates. A 4" silicon wafer with both sides polished has been coated on both sides with 100 nm of silicon nitride using plasma enhanced chemical vapor deposition in a facility in the Electrical Engineering Department here at Oregon State. We will soon begin fabrication of the gratings at the electron beam lithography facility of Professor Martin

Wybourne at the University of Oregon. Optical lithography will first be used to pattern small (1 mm^2) windows on one side of the wafer, then the silicon substrate will be etched away to leave free standing silicon nitride films on the other side. The gratings will then be patterned in the films using electron beam lithography. We already have a small sample of free standing silicon nitride windows from another University of Oregon group doing work with an ambient air proton beam microprobe. We will try to make some gratings with these windows as well as making more windows ourselves. As a backup to local grating fabrication, I have contacted the National Nanofabrication Facility (NNF) and been assured that the gratings could be made with equipment there should that be necessary. (The gratings used in the recent experiment of Keith *et. al.*[4] were made at the NNF, using techniques developed by Wybourne and co-workers.[5]) However, utilizing and developing local expertise will be a valuable asset for future experiments.

We have assembled a three grating optical interferometer similar to the atomic interferometer using a helium-neon laser and coarse Ronchi rulings. We are using this to become familiar with the operation of this type of interferometer, especially with the alignment requirements. We will also use this optical interferometer to test the active stabilization scheme which will be used to damp vibrations of the atomic interferometer. We are using a sensitive accelerometer to measure the vibrations in our laboratory and test different passive vibration damping ideas. There are no quantitative results yet.

During Winter and Spring terms of 1991, there were six graduate students and two undergraduate students working part time on this research. The graduate students were all funded by department teaching positions (4) or fellowships (2). During this summer, there are five graduate students and one undergraduate student working full time on this research. Two of the graduate students are funded by department fellowships; the rest are funded by this grant.

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