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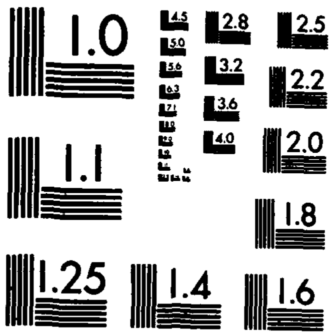
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Annual Summary Report

on

LASER COOLING AND TRAPPING OF NEUTRAL ATOMS

by

William D. Phillips
National Bureau of Standards
Electrical Measurements and Standards Division

work supported by
Office of Naval Research
Contract No. N00014-83-F-0037
Task NR 407-007

Date of Report: September 1983

Response to Summary Questionnaire
(Contract period ending 30 September 1983)

1. Principle Investigator: William D. Phillips

2. Contract Description: We are investigating experimental methods for laser cooling of neutral atoms, and possible applications of cooled atoms in trapping schemes, or slow beams, to high resolution spectroscopy and frequency standards.

3. The highest resolution spectroscopy is ultimately limited by processes which relate to atomic velocities such as second order Doppler shift and transit time effects. Laser cooling of ions in traps promises to deal with these problems, but there is a great deal of interest in achieving the same benefits for neutral species. Unfortunately compared to ions, neutrals interact very weakly with external electromagnetic fields, so that it is much more difficult to trap them. Proposed traps using laser fields, electrostatic fields, or magnetic fields, have not yet been realized. Much of the difficulty centers on the very small energy depth of the neutral traps, and the difficulty in cooling atoms contained in such a trap, in contrast to the situation with ion traps. As a result, much of the interest now centers on the deceleration of a free atomic beam, either for direct use in high resolution spectroscopy or as a preparation for loading atoms into a trap.

4. Deceleration of an atomic beam is accomplished by directing a resonantly tuned laser beam opposite to a beam of neutral atoms. Repeated absorption of the laser light by the atoms, followed by spontaneous re-emission results in deceleration. Use of a magnetic field along with circular polarization of the laser avoids undesired optical pumping of the sodium used in the atomic beam. Causing the magnetic field to vary in space allows the changing Zeeman shift seen by the atoms to compensate the changing Doppler shift as the atoms slow down. In this way, resonance is maintained throughout the deceleration process.

Using this technique, atoms have been decelerated to as little as 4% of their initial velocity with velocity spreads corresponding to temperatures of 70 mK.

5. During the past contract period we have extended the laser deceleration process with a different technique for compensating the changing Doppler shift. Instead of providing a spatially varying magnetic field, we have scanned or chirped the frequency of the laser so that it stays in tune with the atoms. Using this technique, we have achieved extreme velocity compression of the atomic beam. Velocity distributions with full width only 2% of their central velocity are obtained. Atomic density per unit velocity is increased by more than a factor of 20 over a thermal beam. Final velocities lower than 600 m/s have not been observed, and the reason for this limitation is under investigation.

In addition, various improvements have been made to the basic apparatus. One of the most significant is the installation of a specially designed magnetic hexapole lense for focussing the atomic beam after cooling. This increases the observed slow atom density by at least a factor of five.

We organized and hosted a workshop/conference which stimulated a large number of new ideas in the field of neutral atom cooling. The publication from this workshop has been distributed to a large number of interested investigators.

6. "Laser Production of a Very Slow, Mono-energetic Atomic Beam" by J. V. Prodan, W. D. Phillips and H. Metcalf, Phys. Rev. Lett. 49, 1149 (1982).

Laser Cooled and Trapped Atoms, Ed. by W. D. Phillips, Natl. Bur. Stand. (U.S.) Spec. Publ. 653 (1983).

The following articles appeared in the above publication:

"Neutral Atomic Beam Cooling Experiments at NBS", by W. D. Phillips, J. V. Prodan and H. J. Metcalf, p. 1.

"Chirping the light -- fantastic? Recent NBS atom cooling experiments" by J. V. Prodan and W. D. Phillips, p. 137.

"Laser Cooling of an Atomic Beam", by W. D. Phillips, J. V. Prodan and H. J. Metcalf, Digest of Technical Papers, CLEO 83, Optical Society of America, 1983, p. 34.

"Cooling Atoms with a frequency Chirped Laser" W. D. Phillips and J. V. Prodan, to be published in the proceedings of the 5th Rochester Conference on Coherence and Quantum Optics, June 1983.

"Laser Cooling of Free Neutral Atoms in an atomic Beam", W. D. Phillips, J. V. Prodan and H. J. Metcalf, to be published in the proceedings of the Sixth International Conference on Laser Spectroscopy, June 1983.

7. No extenuating circumstances.

8. No unspent funds are expected.

9. No graduate students are involved in this project.

10. The principle investigator is one of three NBS staff scientists who receive partial support for the determination of the fine structure constant from the Department of Energy and from the Air Force. Total DoE support is $20,000 for the period ending 30 June 1984 and total AF support is $16,700 for the period ending 30 September 1983.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This study ~~We have~~ extended techniques for laser cooling of atomic beams by using a frequency-chirped cooling laser to compensate for changing Doppler shifts. Magnetic focussing has been used to improve slow atom density.

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