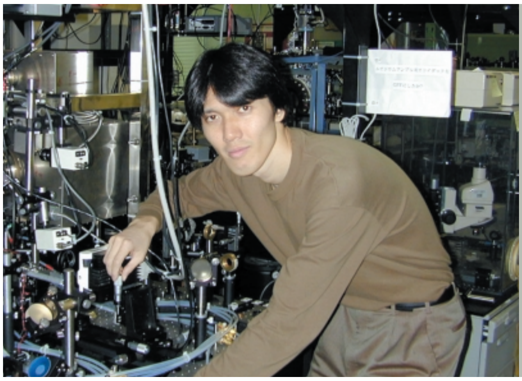
Young Scientists



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Dr. Kozuma received his Ph. D degree from Department of Applied Physics in Tokyo Institute of Technology in 1997 and joined Dr. W. D. Phillips's group in National Institute of Standards and Technology (U. S. A.) as a postdoc. Since 1998, he is a research associate in Prof. Kuga's group at University of Tokyo.

"GO HOME and SLEEEEEP!", Lu shouts. "This experiment is KILLING US", Ed shouts. I was just saying, "Something is wrong. Something is wrong...." "Yes, something is wrong, that's why the experiment doesn't work!" Ed and Lu laughed simultaneously. It was already past midnight and we were still trying to develop the technique of optically induced Bragg diffraction of Bose-Einstein condensed sodium atoms. The objective was to split the wavefunction of the condensate coherently. My friends Ed and Lu got the idea to make a well-collimated continuous wave atom laser, and Bragg diffraction was a key step toward making it. We checked everything and, in principle, it should have worked. But nothing happened.

Two years before, when I was a Ph.D. student at the Tokyo Institute of Technology under the guidance of Professor Ohtsu, I was engaged in experimental research on laser cooling and trapping of neutral atoms. If one irradiates atoms with properly chosen laser beams, their temperature can be reduced dramatically. In fact, one can cool atoms to a few microkelvin (a millionth of a degree above absolute zero!) within one second. As the temperature (or the kinetic energy) of the atoms decreases, the spatial size of the atomic wave packet (thermal De Broglie wavelength) increases. When the temperature reaches a critical value where the wavelength is long enough for these wave packets to overlap significantly, then suddenly the atoms should start sharing the same quantum state. This is referred to as Bose-Einstein condensation (BEC) and it only happens with bosons. Unfortunately, laser cooling by itself could not allow us to enter this regime. In fact, there is no single method that can be used to reach such an extremely low temperature. Therefore, one must combine several techniques such as laser cooling, magnetic confinement, and radio frequency excitation. The final mechanism on the road to BEC usually involves a technique called evaporative cooling. People use this technique every day to cool their coffee or soup by blowing on it. The idea is to remove the hot atoms and leave behind cooler ones that re-thermalize to a lower temperature. When the temperature of the trapped atoms is sufficiently low, a phase transition occurs and almost all atoms jump into a single quantum state. The observation of such phase transitions had been the holy grail of the atomic physics community and I was very interested in such studies.

After I received my Ph.D., I went to work in Dr. W.D. Phillips' laboratory at the National Institute of Standards and Technology (NIST) in the United States as a research scientist. Upon arriving at NIST I immediately joined a team of researchers attempting to achieve Bose-Einstein condensation with sodium atoms. We worked for over a year on rebuilding the entire apparatus towards this goal. It was a very challenging task and after countless sleepless nights spent in the lab; we finally managed to produce our first condensate in the early hours of the morning of January 25th, 1998. We continued to push on and advance the knowledge in the field by first developing Bragg diffraction techniques that have been widely adopted by many groups around the world, including MIT.

Although our experiment initially did not work as planned, we soon realized that its failure was most likely due to our inability to hit the small condensate. In principle, we could have calculated its position in the ultrahigh vacuum cell and aligned the laser beam to it, but there were always problems with vibrations that caused the condensate to move inside the trap. We therefore concluded that the fastest and surest way to ensure the proper illumination of the condensate was to use a larger laser beam diameter. Ed said, "Now no atom can escape us. There's no place for the atoms to hide!". We redid the experiment around three o'clock in the morning and it immediately succeeded[1]. About one month later, we used this Bragg diffraction technique to develop a well-collimated atom laser that emitted coherent matter waves just as an ordinary laser emits coherent light waves[2].

After my postdoc in the United States, I accepted a research assistant position in Professor Kuga's laboratory at the University of Tokyo. Although taking that position in Japan meant leaving Lu and Ed, our collaboration has continued to this day. It has yielded results such as the first coherent, matter-wave interferometer and the first phase-coherent amplification of matter waves[3]. The latter is analogous to laser amplifier, which led to practical applications of laser technology.

The future of this field is bright, and there are still many outstanding questions that remain to be answered. We are happy that we were fortunate enough to work in this exciting field, and we are grateful that we were able to make contributions to it. As for my friends Lu and Ed, we still continue our collaboration and hope that the future will be as fruitful as the past.

JSAP

References

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[2]. E. W. Hagley, L. Deng, M. Kozuma, J. Wen, K. Helmerson, S. L. Rolston, and W. D. Phillips, Science, **283**, 1706 (1999).

[3]. M. Kozuma, Y. Suzuki, Y. Torii, T. Sugiura, T. Kuga, E. W. Hagley, and L. Deng, Science, **286**, 2309 (1999).