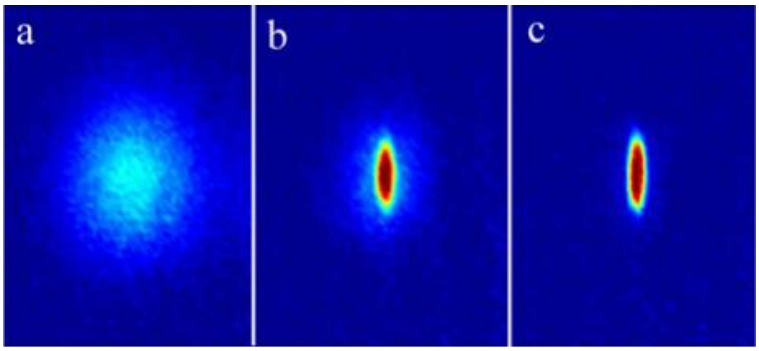
Ultracold Atoms - Thywissen Group

Summer 2025 Undergraduate Research Projects

Overview

Our research group strives to address fundamental questions about many-body physics by studying a model system: neutral atoms at nanokelvin temperatures. A collection of thousands or millions of atoms are manipulated and probed while they are levitated inside a vacuum system by magnetic or optical traps.

In order to create an ultracold sample, we employ a wide range of techniques: lasers locked to an atomic resonance, high-power fibre lasers, electromagnets to produce magnetic traps, fast electronics, microwaves and radio waves, optical modulators of various types, and imbedded computing for sequencing. We study atomic samples by taking images: see the example below.



Absorption images of (**a**) a thermal gas; (**b**) a Bose gas at a phase transition; and (**c**) a nearly pure Bose-Einstein Condensate.

Project 1: Construction of a new BEC machine

We are looking for one or two summer students to help build a new experimental apparatus. This experiment will study tunnelling of atoms through barriers and probe how superfluids move in optical lattices. As a summer student in the group, you would learn about lasers, vacuum systems, electronics, and imaging systems. Your daily work would be under the guidance and supervision of graduate students. The goal of the summer would be to progress as far as possible towards Bose-Einstein condensation.

The regime we intend to study is deeply quantum-mechanical, so coursework in quantum physics would be required. Most important is a strong interest in experimental work. Laboratory work in an atomic physics lab involves intense hands-on experimental work; this project may involve vacuum systems, optics, CAD design, programming, high-current electronics, and testing. All summer students will be enrolled in the basic training course of the physics machine shop, if they have not already taken it for prior summer work.

Project 2: Laser amplifier design

Do you want to build a laser? For years our labs have used the same design for a laser amplifier, which we are now considering revising. If you want to get involved in mechanical design, machine-shop work, and collimation of multimode laser beams, then this is the project for you. We have some first designs in hand, but they need to be improved, tested, and then iterated. The result of the summer would be an infrastructure upgrade to each of our experiments -- and perhaps those of other AMO groups in the basement of MP.

Project 3: Optical box traps for quantum gases

The most advanced of the three summer projects is to create prototype a "box"-type trap for atoms. This project is well suited for a student with prior research experience. So far, all experiments in our group use harmonic traps, which are quadratic potentials. While simple, this approach comes with a disadvantage: the atomic density is inhomogeneous, i.e., maximal at the centre of the trap, falling off to zero at the edges. A next generation of traps (proven to be useful by other groups in the AMO research community) confines atoms using sharp "walls", but are otherwise flat. This creates a large volume of uniform density, thereby simplifying the interpretation of any measurements. A recent review article on Quantum Gases in optical boxes can be found here [Nature Physics 17, 1334 (2021)] or here [on the arXiv].

Contact & additional information

For more information, visit https://www.thywissenlab.ca/, which includes recent publications, a list of former summer students (and what they are doing now), current group members, and contact information.