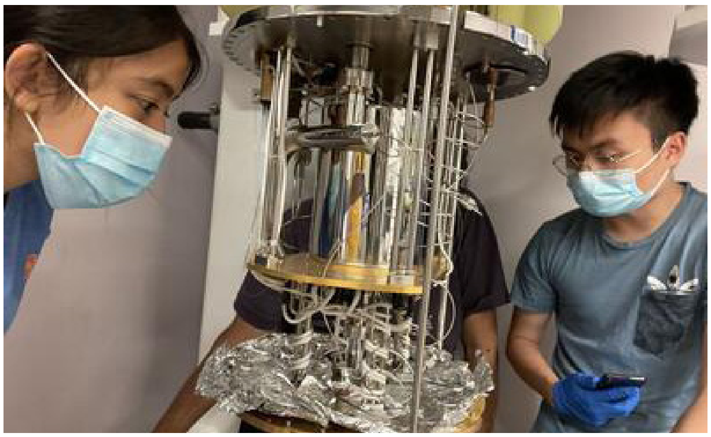
Probing the quantum realm

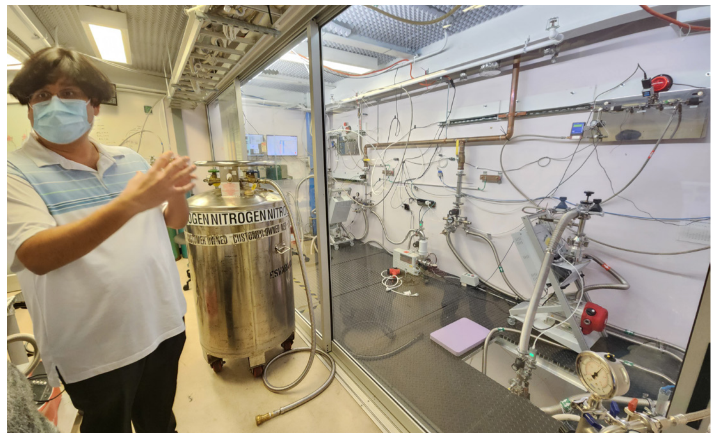
Jack Harris
Professor

Jack Harris explores the influence of quantum mechanics and topological effects upon the motion of macroscopic objects. He studies these phenomena in experiments that combine high-finesse optical cavities, ultrasensitive mechanical oscillators, and superfluid helium.

Harris is an American Physical Society (APS) Fellow and a Vannevar Bush Faculty Fellow. He was awarded the Arthur Greer Memorial Prize, the Defense Advanced Research Projects Agency (DARPA) Young Faculty Award, a Yale University Junior Faculty Fellowship, and the Sloan Research Fellowship.

Harris was a Lecturer for the Yale Warrior-Scholar Project and a mentor for the Research Experience for Veteran Undergraduates. He is the the faculty advisor for Queer Affiliated fRiends of physiKs (QuARK) in the Yale Department of Physics.





Single phonon detection using quantum acoustics

The Harris group is developing new technologies to control and study massive objects using light, and has been among the pioneers of the emerging field of quantum optomechanics. These quantum optomechanical sensors can detect tiny excitations of quantized sound (phonons).

The Harris group is exploring superfluid helium as a medium for use in ultraprecise and quantum-enabled sensors.

In one experiment, the group uses miniature, optical fiber-based cavities that are cooled in a dilution refrigerator and immersed in superfluid helium so that light and sound waves interact with each other. At the quantum level, this interaction allows a photon to occasionally emit or absorb a single phonon. When it does, the photon's wavelength is red-shifted or blue-shifted. The group collects light from the cavity, filters out all of the unshifted light, and passes only the shifted light to a single-photon detector. Each photon registered by this detector corresponds to the detection of a single phonon being added to, or removed from, the sound wave in the cavity. The ability to detect individual phonons, each with an energy in the microelectron volt range, is quite novel. The Harris group is exploring the possibility of using this type of control to prepare specific quantum states of sound that are particularly well suited to test the Standard Model of physics and to search for dark matter.

The Harris group is exploring similar scientific goals in a second experiment using a cavity formed out of superfluid helium that is free from any contact. The group achieves this by using magnetic levitation to suspend a millimeter-scale drop of helium in vacuum. The drop cools itself by evaporation, and the group has found that the drop's thermal, mechanical, and optical properties agree well with theory.

The Harris group is in the process of trying to trap photons in the drop's whispering gallery modes, with the goal of using single-photon and single-phonon techniques to study quantum features in the drop's motion.

These experiments are both table-top experiments supported by a range of collaborations, conducted in Wright Lab, and carried out by Harris group members.

By taking advantage of the unique mechanical properties of superfluid helium, sensors made by the Harris group might be able to enable new, ultra-sensitive searches for rare interactions from dark matter that complement other dark matter searches undertaken by Wright Lab researchers .