Fiber Optic Feedthrough Design For Use In Cryogenic Dilution Refrigeration Systems

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Introduction

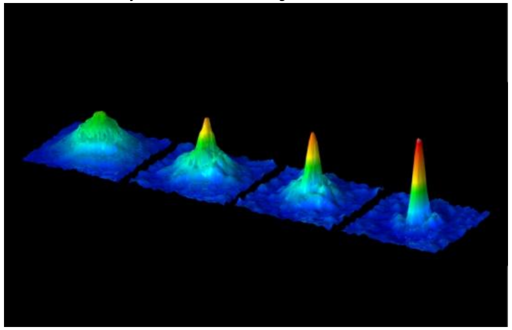
Bose-Einstein condensation is a fundamental state of dilute gases of bosons. It was originally predicted in 1924 by S. Bose and A. Einstein, and it refers to a quantum configuration at low temperatures in which a large portion (the condensate fraction) of particles collapse into the ground state. As can be seen in *Figure 1*, Rb-87 has been shown to exhibit the properties of Bose-Einstein condensation at low temperatures.

Our experiment focuses on studying superfluid Helium-4. A superfluid is a phase of matter with zero viscosity, infinite conductivity, and other unusual properties. It is generally accepted that the superfluid properties of supercooled Helium-4 is caused by the composite boson exhibiting behavior associated with Bose-Einstein condensation, but it has not yet been conclusively proven.

The goal of our experiment is to analyze the transmission characteristics of a slab of Helium-4 superfluid. These transmission characteristics could hopefully be used to offer some evidence of Bose-Einstein condensation in superfluid Helium-4. To accomplish this task, we used a dilution refrigeration system to cool our experimental cell down to extremely low temperatures. Inside the cell, we use a laser pulse in a fiber optic cable to produce a pulse of atoms at the bottom of the slab of Helium-4. These atoms are then transmitted through the slab and shot out the other side. The transmitted atoms are then detected on a series of superconducting bolometers. With bolometers, we are able to accurately and quickly determine energy levels of the transmitted atoms when they strike the surface of each bolometer.

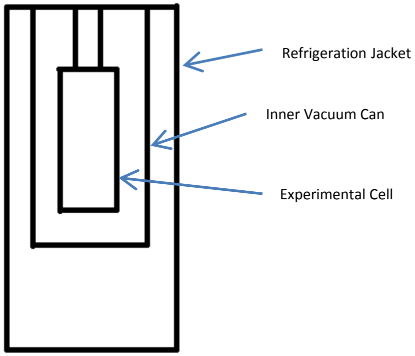
The purpose of my research focused on the design of our internal vacuum can and cell. The aspect of the design that needed modifying was the optical fiber feed through, which can be seen in *Figure 3*. These feedthroughs are essential in transferring laser pulses from an external source into the experimental cell. The feedthroughs must be leak proof in order to allow the dilution refrigeration system to run smoothly as well as to maintain accuracy within the experimental cell.

Figure 1: *Bose Einstein condensation in Rb87. The images were made at four different temperatures as the Rb87 was allowed to cool. The graph shows the velocities of particles in the system as a function of temperature. Red represent the slowest moving particles while blue represents the fastest. BEC occurs when a large number of the particles have collapsed into the ground state and are therefore the slowest moving.*



Experimental Set-Up

Our experiment consisted of a dilution refrigeration system in which we put our vacuum can and experimental cell. A diagram of this set-up can be seen in *Figure 2*.



An issue arises in our experiment because we desire to feed an optical fiber from an external laser to a source inside the inner vacuum can. An issue arises, though, in how exactly we can minimally modify the existing apparatus to feed in the optical fiber. We accomplish this through a cryogenic feed-through, which is shown in *Figure 3.* In general, we found that this design does not work well when cooled to any point below 77K (liquid nitrogen temperature). We believe this is caused by mismatched shrinking between the metal and the Kynar tubing. We run a metal tube from the inner vacuum can through the top of the refrigeration system using a hole in the top of the refrigeration jacket compartment. We then assemble the feedthrough using our leak-proof design displayed in Figure 3.

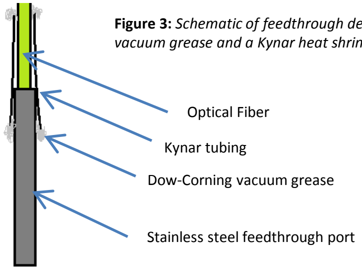


Figure 3: *Schematic of feedthrough design using Dow-Corning vacuum grease and a Kynar heat shrink tubing.*

Results

We combat the problem of feeding the fiber from the external environment into the Inner Vacuum Can by modifying the design of the feed-through piece. We attach a long metal tube that extends from the feed through all the way out the top of the fridge through preexisting holes (a vacuum seal is not as important in the jacket compartment.

The advantage of attaching this tube allows us to build the feed-through vacuum seal in a room temperature environment. This not only allows us to make a more reliable seal, but also allows us to quickly change and fix leaks mid experiment. We test this set-up with a leak detector to verify its effectiveness at both room and helium temperatures. Room temperature tests indicate helium leak rates of 10e-9 mtorr, which is within the acceptable range for our dilution refrigeration cooling system.

We also find through external tests in liquid nitrogen that this feedthrough is not reliable for use within the refrigeration system. We cool a test feedthrough in a bucket of liquid nitrogen and find large helium leak rates of approximately 10e-5 mtorr which beyond the bounds of an accepted rate for our experiment.

Conclusions

We have found through trial and error that external feedthroughs are more desirable than internal. Cryogenic cooling causes many unwanted effects that can result in leaks when the system is at low temperature. In our experiment, we must work with controlled quantities of helium, which means that we must deal with the tricky task of sealing our apparatus to helium. We accomplished this using our design of Kynar heat shrink tubing with Dow-Corning vacuum grease. At room temperatures, this creates a helium proof seal that is easily assembled and disassembled, leading to easier troubleshooting and quicker assembly of our apparatus.

Acknowledgements:

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