^{3}He Paper Contribution

Joseph M. Katich
College of William and Mary

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Abstract

Here is my portion of the ^{3}He paper. It includes ^{3}He set-up and cell creation.

1 The Creation of a ^{3}He Cell

There are many factors that motivate the current procedure that is used to create a ^{3}He cell. For a statistics-driven experiment, one wishes to maximize the achievable polarization of the cell while also allowing for as dense of a target as possible. The polarization process itself sets strict geometric requirements on the shape of the cell and the quality of materials used also plays a role.

The glass used to make the cell must be free of magnetic materials so as to not disturb the uniformity of the magnetic fields used in the polarization process. Magnetic materials can mostly be eliminated by beginning with clean glass and avoiding any processes which could introduce magnetic contaminates. This can be addressed further by heating and cooling the glass several times before the cell-fill begins (referred to as 'flame-baking' the cell). The cell performance is also dependent on the smoothness of the inside of the cell. For this reason, the glass is shaped by a professional glass-blower. When a cell is received from the glass blower, it is initially connected to a glass assembly ('string') that is used in the cell fill process to introduce both gas and alkali metal to the cell (Figure 1).

The most common type of glass used for ^{3}He cells is GE180 alluminosilicate. This glass has many desirable properties with respect to both the polarization process and electron scattering experiments. First, it contains very few magnetic compounds. It also has a low porosity to ^{3}He, meaning the high-pressure environment is reliably stable. The radiation length of GE180 compared to other suitable glasses is relatively low, which leads to less background scattering. Finally, its ability to tolerate electromagnetic radiation surpasses other glass options.

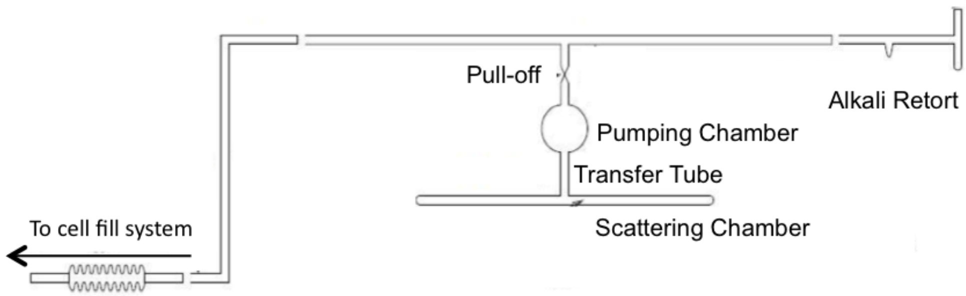

Figure 1: A ^{3}He cell before being removed from the string

The shape of the cell is constrained by the combination of the polarization process and the desire to maximize the probability of beam-target interaction. There must be an area designated to pumping the alkali metal and polarization ('pumping chamber') and an area for scattering the electron beam ('scattering chamber'). The pumping chamber is a sphere of a diameter that matches the profile of the incoming laser light (most recently, D=3"). Likewise, the scattering chamber is made to accommodate the incoming electron beam. The scattering chamber must be long enough ($\sim$40cm) to provide the electron beam sufficient scattering time, and only wide enough to allow for usual beam rastering - any wider would only be a waste of materials and increase final state interactions. The two chambers are connected via a tube that allows the transfer of polarized ^{3}He from the pumping region to the scattering region. The glass at where the electron beam enters and exits should be as thin as possible to reduce background scattering and electron beam energy loss. Figure 1 shows a cell that satisfies all of these requirements.

The actually process of filling the glass cell begins by connecting the string to a gas-fill set-up that includes a vacuum system. Before pumping begins, a small ampule containing alkali metal - a necessary component for the pumping process - is inserted into the 'retort' end of the string. The entire string and cell is then evacuated to the 1×10^{-9} Torr level over the course of several days. It is during this time that the cell is flame-baked in order to remove impurities from both the glass and the alkali metal. Once the vacuum pressure has stabilized, the alkali metal is chased from the retort to the cell using a methane/oxygen torch. Once a sufficient amount of alkali is present in the cell the alkali retort area of the string is removed.

The next step of the fill process is to flow gas into the string. This must be done very carefully so as to record the exact amount of gas that is in the cell. It is then necessary to know very precisely the volume of the cell and string. The measurement is performed by first flowing nitrogen into a small, well known volume and measuring the pressure. A valve is then opened such that the gas now fills the glass cell and string as well. Using the ideal gas law, the volume of the cell and string can be calculated. The volume of the cell and string are separated by making careful measurement of the dimensions of the cell. Once the volume measurement is complete, the system is again evacuated.

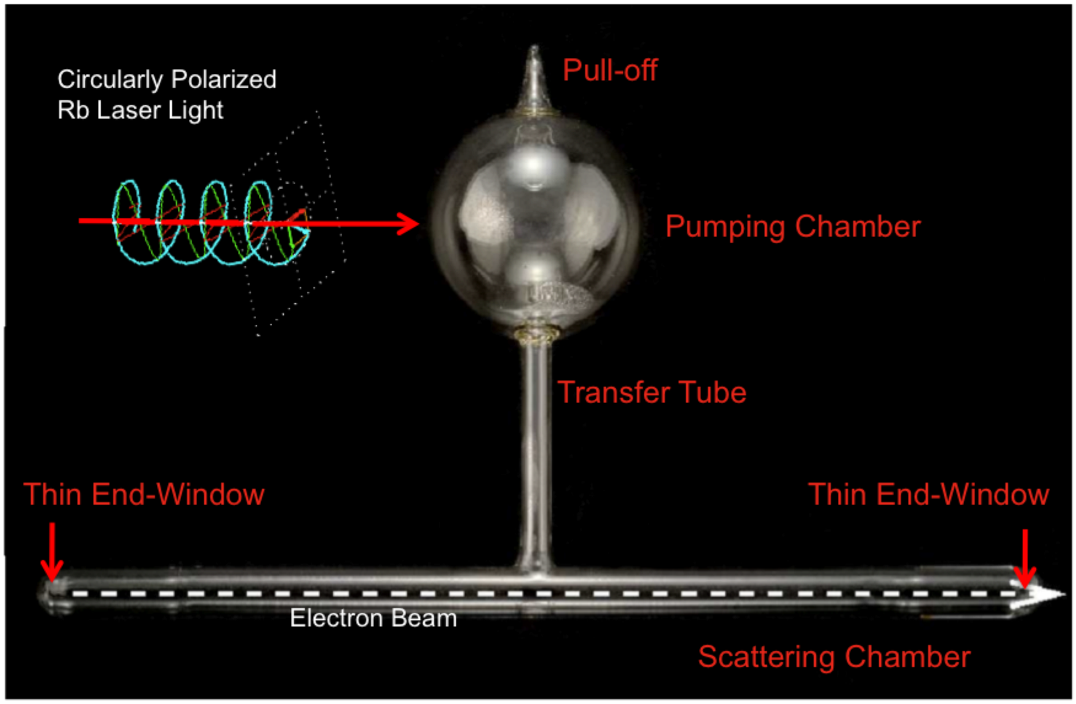

Figure 2: A typical ^{3}He cell, including the pull-off, pumping chamber, transfer tube, scattering chamber and thin end-windows.

Following the volume measurement, it is time to fill the cell with a known amount of both N_2 and ^{3}He. Nitrogen is first to be put in, and the insertion is performed at room temperature. Once the appropriate amount of N_2 is flowed into the cell and string, a valve is closed to isolate them. The cell is then placed into a liquid He bath that is held at 4 K. The purpose of the 4 K bath is two-fold. First, it is necessary in order to properly flow ^{3}He into the cell. The lower pressure within the cell ensures that ^{3}He will flow into the cell while no N_2 flows out. Once the temperature stabilizes at 4 K, the ^{3}He is flowed into the cell. The second reason for the 4 K bath is the removal of the cell from the rest of the glass string. In order to perform this separation, the pressure inside the cell must be less that 1 atm. Removing the cell involves heating the glass that connects the cell and string until it melts, at which point the cell can be pulled away from the string. Maintaining a pressure of less than 1 atm in the cell causes the glass to collapse in a self-sealing manner, creating what is called the 'pull-off'. If this low-pressure condition were not satisfied, the high pressure environment within the cell would force the gas out of the pull-off, and the amount of gas in the cell would not be well-known. Once the ^{3}He cell is removed from the string, characterization of the cell can begin.