Test Operation of Spin-Filter Polarimeter for Deuteron

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§1. Spin-Filter Polarimeter at LNS

We have developed a Lamb-shift type polarimeter for probing the polarization of an optical pumping polarized deuteron gas target. The Lamb-shift polarimeter [1,2] is based on the 3-level interaction between $D(2S_{1/2}, \uparrow_{electron})$, $D(2S_{1/2}, \downarrow_{electron})$ and $D(2P_{1/2}, \uparrow_{electron})$ states in the spin-filter cavity. The mechanism of the 3-level interaction in the spin-filter cavity is found elsewhere [3,4]. In this report the equipment and the test operation result are described briefly. A view of the spin-filter polarimeter is shown in Fig.1.
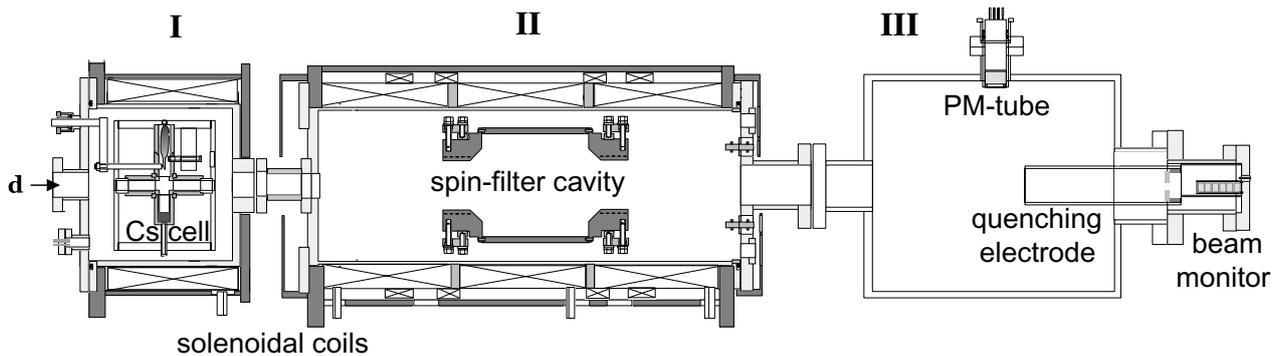
Fig.1   A view of the spin-filter polarimeter.

1-1   Charge Exchange Section

Some of the deuteron ions extracted from a deuterium gas target are converted to D(2S) atoms by the charge exchange reaction $d^+ + Cs \rightarrow D(2S) + Cs^+$ [5] in the Cs vapor cell. The cross-shaped Cs vapor cell is composed of inner copper sleeves and outer ceramic sleeves which are heated by a nickel-chrome ribbon heater. The cell is placed in the solenoidal coil to suppress the expected depolarization effect.

1-2   Spin-Filter Section

The spin filter cavity is placed in a solenoidal coil set which generates homogeneous magnetic flux in the central region of the cavity. The spin-filter coil set is composed of three main solenoidal coils of hollow conductor, two correction solenoidal coils and iron yokes. The D(2S) atoms are injected into the axial area of the cavity, and the longitudinal rf electric field and transverse static electric field quench the D(2S) atoms which are non-selected or off-resonance. The cavity is made of brass, 26cm in full-length, divided into 4-quadrant parts. It is operated at 1610 MHz in the TM_{010} mode with an rf power of about 0.1 W.

1-3   Photon Counting Section

In this section the number of the D(2S) atoms passed the spin-filter cavity is counted. The D(2S)

atoms contained in the beam are forcedly Stark-quenched in the electric field produced by a cylindrical quenching electrode, accompanied by the emission of Lyman-alpha photons. Some of the decay Lyman-alpha photons are detected by a UV PM-tube (Hamamatsu R6835) with MgF_2 window, CsI cathode, and AC-coupled output. The output signals from the PM-tube are pulse-height-analysed and counted by NIM modules and a DAQ-board on PC. The typical counting rate is ~400 photons/sec in the following polarimetry operation.

§2. Test Operation of the Polarimeter

2-1 RF ion injector and beam line

The test operation of the spin-filter was done by injecting unpolarized deuteron atoms from an RF-ion- source. The overview of the RF-ion-source and the ion beam optics is depicted in Fig.2.
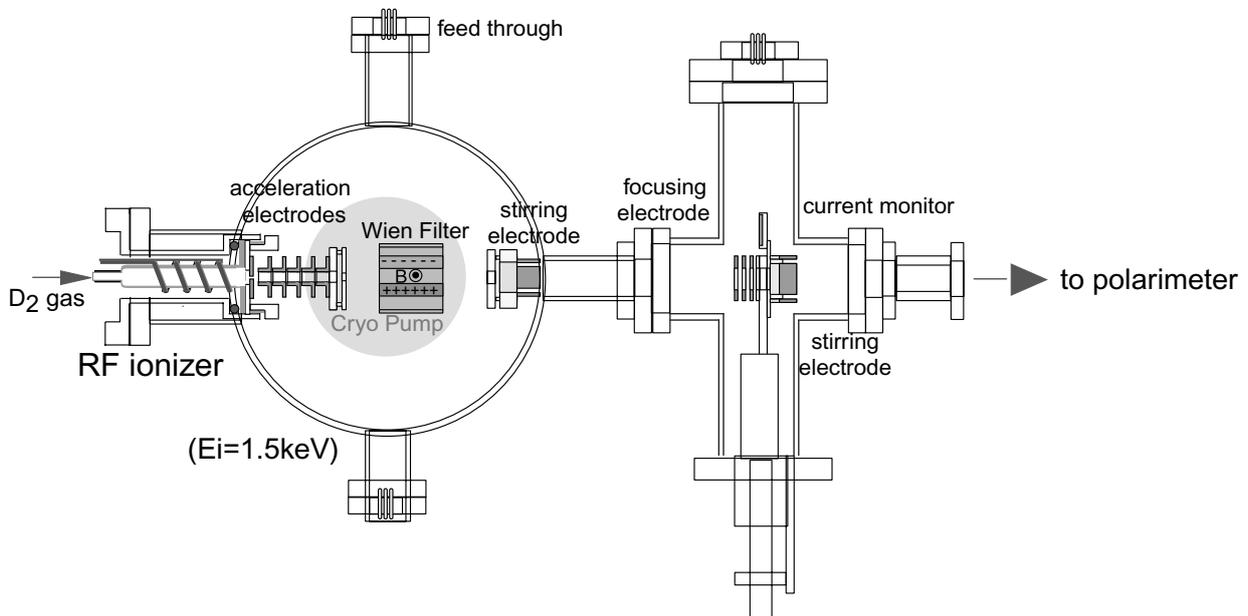
Fig.2　Test-ion injector and beam line components.

The RF ionizer is composed of a Pyrex glass tube and an RF-coil. An 13.6MHz rf power of 25W was supplied to the coil through a matching circuit. The partially-ionized and dissociated deuterium gas was ejected through a 1mm-diameter hole on a copper electrode. Ions were extracted and accelerated up to 1.5 keV by cylindrical electrodes and mass-analysed by a Wien filter. The magnetic flux (~1150 gauss at the central point) was generated by two square permanent magnets in the Wien filter. The ion beam was guided into to the Cs cell of the polarimeter by two stirring electrodes and a focusing electrode, and the beam current was measured by a beam monitor at the end of the polarimeter. A typical current of the passed ion beam was 0.3 nA at the monitor.

2-2 Test operation result

We measured the populations of the magnetic sub-states of unpolarized deuterons from the RF-ion source. The ion beam energy was 1.5 keV and the Cs-cell temperature was 313K. A typical result and fitted curves are shown in Fig.3. In the figiue, the averaged count rate of photons detected by the PM

tube are plotted as a function of a mean magnetic flux on the beam axis in the cavity. At each data point photon pulses were counted in 10 seconds.
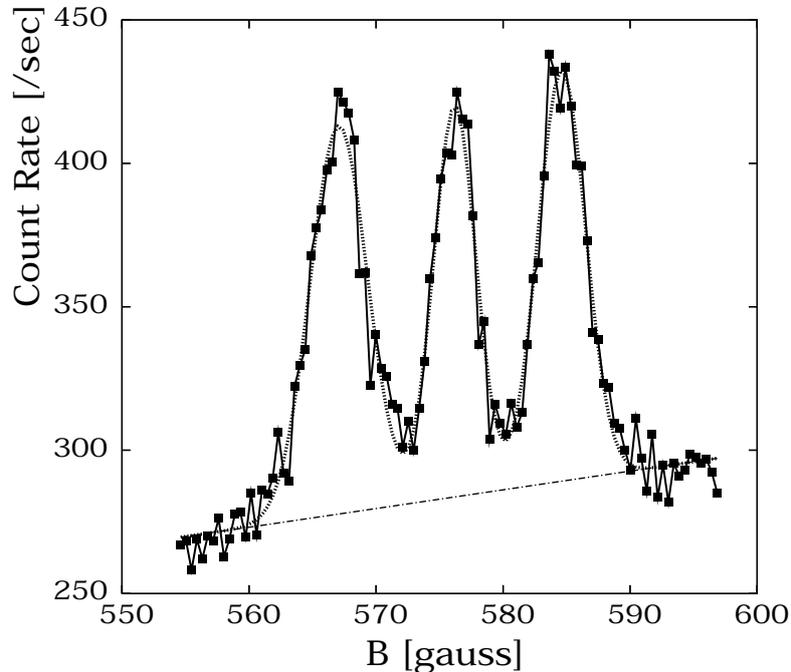
Fig.3.   Observed peaks of the deuteron magnetic sub-state population:, dashed line (Gaussian + linear), dot-dashed line(a linear part of the fitting.)

In the figure the relative height of the three peaks on the straight line corresponds to the relative populations of the nuclear magnetic sub-states of the D(2S) at the quenching electric field. From the Fig.3 we note S/N and stability are not sufficient. Improvement of the homogeneity of the magnetic flux in the spin-filter region and suppression of background photons will be required.

References

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