Microwave system development of enlarged spin-polarized proton target for RI beam experiments

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A spin-polarized proton target provides opportunities to observe spin-dependent interactions in unstable nuclei. The center for Nuclear Study, University of Tokyo and RIKEN groups have developed a spin-polarized proton target system that is applicable to RI beam experiments.[1)] The method of generating spin polarization employed in the target system is based on the cross-polarization technique,[2)] where the polarization of an electron system is transferred to protons in the presence of a rotating magnetic field. The rotating field is generated as a standing electromagnetic wave using a microwave resonator.

Recently, the target system was upgraded to accomodate a target sample with a larger diameter (24 mm) compared with the diameter before (14 mm). This upgrade was carried out to increase the fraction of beam particles accepted by the target and to decrease the rate of background events from the target holder. One of the problems expected with this upgrade is that the standing electromagnetic wave in a large resonator is generally weaker than that in a small one, which might prevent us from producing a sufficiently strong field required for achieving optimal polarization conditions and attaining a high spin polarization.

To facilitate polarization transfer using the cross-polarization technique, electron and proton systems have to be coupled in order for spin-exchange interaction to occur. The coupling condition $\hbar\omega_e = \hbar\omega_I$ is known as the "Hartmann–Hahn condition"[3)]. Here, ω_e is the electron effective Larmor frequency in an external microwave magnetic field H_1, and ω_I is the proton Larmor frequency. The electron effective Larmor frequency is proportional to the amplitude of H_1, $\omega_e \propto H_1$, and therefore ω_e can be adjusted to match the proton Larmor frequency. In the experiment, ω_e is tuned by changing the H_1 field amplitude, which in turn is proportional to the square root of the input power supplied to the system, $H_1 \propto \sqrt{P_{MW}}$.

In the test we performed previously,[4)] it was found that the amplitude of the oscillating magnetic field was not sufficiently high to fulfill the Hartmann–Hahn condition. To address this problem, a redesign of the loop-gap resonator (LGR) has been attempted. LGR is the device responsible for generating a microwave field with power P_{MW} provided from an RF amplifier. It is made of a sheet of CuFlon material, which consists of a copper metal clad on both sides of a thin Teflon sheet. The CuFlon sheet is rolled around a holder to form a cylindrical resonator.[5)] Our estimation shows that there is a possibility to increase the efficiency of the resonator by increasing the thickness of its copper plates from 4.4 to 36 μm, as thicker plates better suppress radiation losses due to the skin effect.

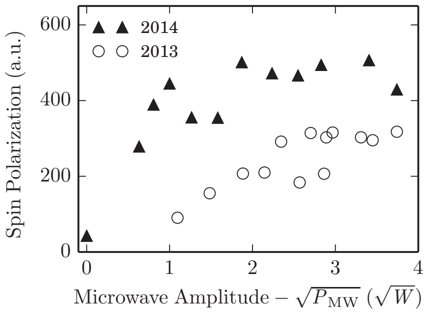

Fig. 1. Dependence of proton spin polarization signal intensity on the square root of the applied microwave power.

In Fig. 1, the closed triangles represent results of the present test carried out with LGR whose copper plates are 36 μm thick. It can be seen that saturation is reached at approximately 2.0 $\sqrt{W}$ of input power where the polarization stops increasing despite the increasing input power. The presence of saturation indicates that the Hartmann–Hahn condition was fulfilled, i.e., the polarization of electrons was fully transferred to the protons. In Fig. 1 the hollow circles indicate the results of the test carried out using LGR whose coppers plates are 4.4 μm thick. Here, the signal intensity rises across the entire region of powers applied, which means that the condition was satisfied only partially.

In summary, we designed LGR with thicker copper plates and performed test with it. The results of the test are promising – the Hartmann–Hahn condition is satisfied at reasonable microwave powers, which means that the newly constructed LGR should be suitable for application with enlarged target samples.

References
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