# Neutron spin filter with dynamic nuclear polarization using photo-excited triplet electron for T-violation search in a compound nucleus

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In a compound nucleus (*e.g.* $^{139}$La+n, $^{81}$Br+n), parity violation is enhanced due to the interference between s-wave and p-wave amplitudes. It is theoretically predicted that time reversal (T-) violation can be also enhanced by the same mechanism.[1)] We are planning an experiment for sensitive T-violation search using a polarized neutron beam. The p-wave resonances of the candidate nuclei are observed in the energy range of 0.1–100 eV. For this purpose, we need a neutron spin filter that is suitable for the energy region.

A neutron spin filter can polarize the neutron beam by passing it through a spin-polarized media, for example $^1$H or $^3$He because their cross-sections have a large helicity dependence. In particular, $^1$H has flat cross-section of 20 barn in the wide energy range mentioned above. Therefore, we selected neutron spin filter using $^1$H media.

A solid-state of $^1$H doped media is often polarized by Dynamic Nuclear Polarization (DNP). DNP is a technique of transferring spin polarization from electrons to nuclei with microwave irradiation. We applied DNP with photo-exited triplet electron spin (Triplet-DNP)[2)] because it can be used at a relatively high temperature ($> 77$ K) and in a low magnetic field ($< 1$ T) compared to the conventional DNP method. The neutron spin filter with Triplet-DNP was first developed at the Paul Scherrer Institut (PSI) in Switzerland. They achieved $^1$H polarization of 70% using a naphthalene crystal with the size of $5 \times 5 \times 5$ mm$^3$ in 0.36 T and at 25 K,[3,4)] and evaluated its performance using a polarized neutron beam in the meV region.

The neutron spin filter is characterized with a neutron transmittance $T$, a neutron polarization $P_{\rm n}$, and a figure of merit (FOM) which is defined as follows:

$$T = \exp\left(-(n\sigma_0 + n'\sigma'_0)d\right)\cosh\left(P_{^1\mathrm{H}} n \Delta\sigma d\right), \quad (1)$$

$$P_{\rm n} = \tanh\left(P_{^1\mathrm{H}} n \Delta\sigma d\right), \quad (2)$$

$$\mathrm{FOM} = P_{\rm n}^2 T, \quad (3)$$

where $\sigma_0$ and $\Delta\sigma$ are the spin-independent and spin-dependent cross section of $^1$H, respectively. $\sigma'_0$ is the spin-independent cross section of other nuclei. $n$ and $n'$ are the density of $^1$H and other nuclei. $d$ and $P_{^1\mathrm{H}}$ are the thickness and polarization of the filter. Here, the naphthalene crystal ($C_{10}H_8$) is assumed as a filter media. Based on the expression, a 15 mm thickness of the neutron spin filter can conform to the wide energy range. In addition, we need large acceptance of the spin filter to obtain high statistics. Therefore, we develop $\phi 15 \times 15$ mm$^3$ of the spin filter.

A setup of the neutron spin filter with Triplet-DNP is shown in Fig. 1. Triplet-DNP is carried out at 0.3 T and 100 K. A single crystal of naphthalene doped with deuterated pentacene with a size of $\phi 15 \times 15$ mm$^3$ is used as a filter. To polarize such a huge crystal, a high-power laser was implemented.

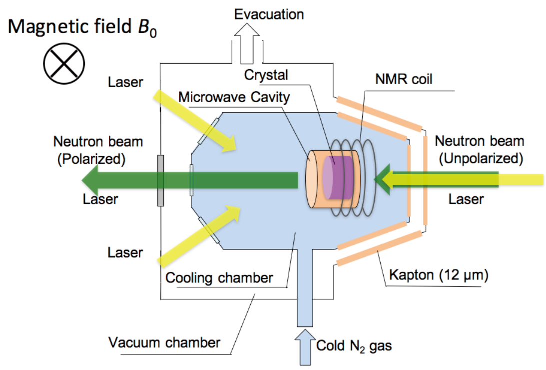


Fig. 1. Setup of the neutron polarization system using Triplet-DNP.

We are planning to check the performance of the neutron spin filter at RIKEN Accelerator-driven compact Neutron source (RANS) next year. We will measure the position dependence of polarization in the spin filter. In November and December 2017, we carried the existing polarization system to RANS and measured the position resolution to check whether performance measurement is possible. Since the position resolution was about 2 mm, it is possible to sufficiently measure the position dependence of the polarization and the transmittance of the spin filter.

References
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