Improvement in incomplete persistent spin helix by dynamical Mn-spin polarization in dilute magnetic semiconductors

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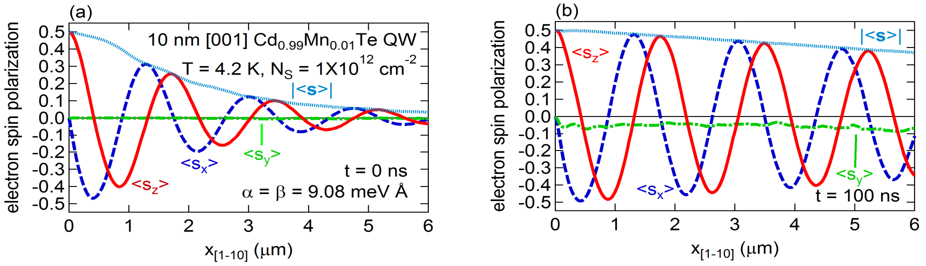
Magnetic and spin-related properties of semiconductors have attracted much attention in recent years, because of interests in the physics and spintronics device applications. One of the most important issues of this research field is spatial control of electron-spin polarization. For this purpose, we usually use electron-spin precession comes from spin-orbit effective magnetic fields, or the Rashba and Dresselhaus fields. This type of spin control, however, degrades spatial spin coherence through the Dyakonov-Perel spin relaxation mechanism. [1] For two-dimensional electrons in hetero-junctions and quantum wells grown in the [001] direction, it was found that the spin-coherence length is improved for electron transport along [110] or [1-10] under the persistent spin helix (PSH) condition, i.e., the coefficient α for the strength of the Rashba field proportional to the electron wavelength k, and β for the k-linear term of the Dresselhaus field are the same. [2,3] However, PSH is not really persistent, because of the inherent k^3-term of the Dresselhaus field.

Recently, we have proposed to use dilute magnetic semiconductors to improve the spatial electron-spin coherence. [4] Under electron-spin polarization, spins of Mn impurities are polarized by spin transfer comes from the s-d spin flip scattering. This induced Mn-spin polarization changes the electron-spin precession and improves the electron-spin coherence as a result. This method is expected to be valid even under the PSH condition.

In this study, we perform a numerical simulation for electron-spin transport in a 10 nm [001] $Cd_{0.99}Mn_{0.01}Te$ quantum well at 4.2 K. In this calculation, we take into account electron transport, by means of the Monte Carlo method, the spin transfer to Mn spins, and the electron-spin precession caused by the Mn-spin polarization and the Rashba and Dresselhaus fields. The direction of the electron transport is in [1-10], and the spins of electrons just injected from a ferromagnetic source-electrode are polarized along the z, or [001] axis. We assume that the electron injection starts at the time $t = 0$, and Mn-spins are not polarized for $t \leq 0$. In figures below, we show numerical results for $\alpha = \beta$, or the PSH condition. As is shown in Fig. (a), the electron-spin coherence length is limited even under the PSH condition, when the Mn spins are not polarized. On the contrary, it is clear in Fig. (b) that the electron-spin coherence is much improved under sufficiently induced Mn-spin polarization at $t = 100$ ns.



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