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

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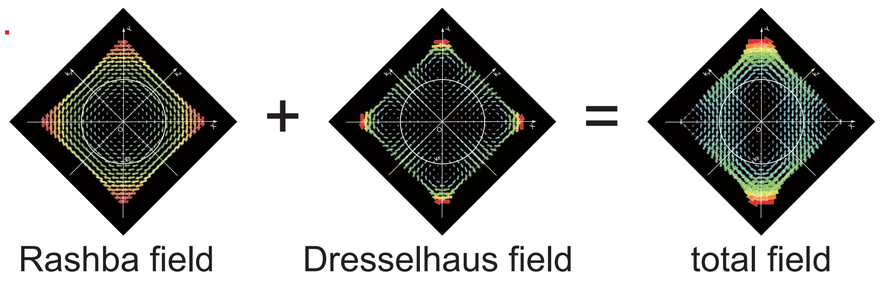
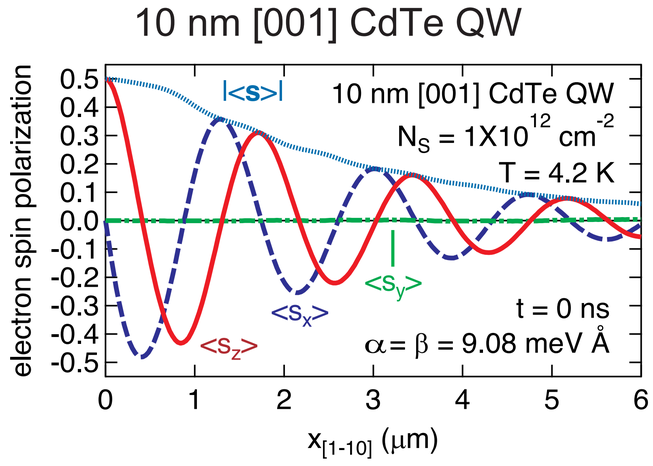
- Magnetic impurities improve the spatial coherence of electron spin polarization.
- Cooperative growth of the electron and Mn spin polarizations.

Persistent spin helix is not really persistent.

Persistent spin helix (PSH) improves the spatial coherence of electron spin polarization.
But the k^3-term of the Dresselhaus effective magnetic field degrades the coherence.
Actually, the spin coherence length is only 2.8 μm in a 10 nm [001] CdTe quantum well even under the PSH condition.



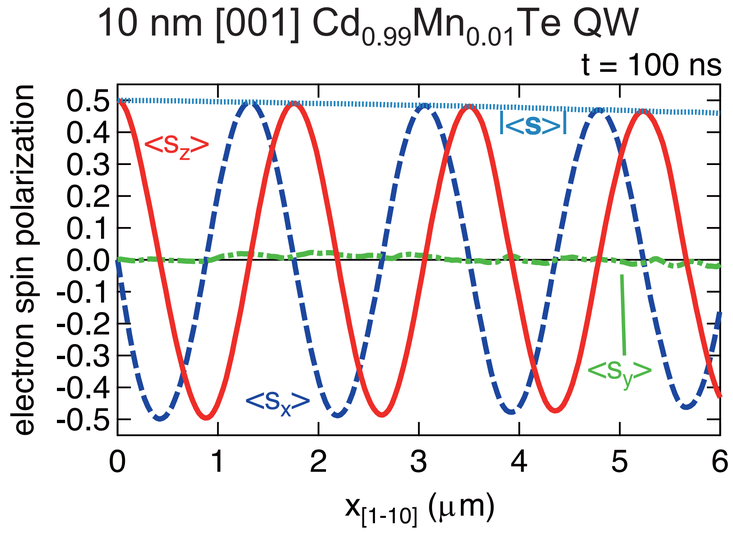


Coherence length l_{CdTe} = 2.8 μm

[1] B. A. Bernevig, J. Orenstein, and S. -C. Zhang, Phys. Rev. Lett. **97**, 236601 (2006).
[2] T. Tsuchiya, J. Phys.: Conf. Ser. **61**, 1191 (2007).

Spatial spin coherence is improved in magnetic semiconductors.

Mn impurities in dilute magnetic semiconductors are thought to destroy the electron spin coherence through the s-d spin flip scatterings.
But our numerical simulation shows that the spin coherence length is
35 times longer in a CdMnTe QW than in the CdTe QW.



l_{CdMnTe} = 97 μm = 35 l_{CdTe}

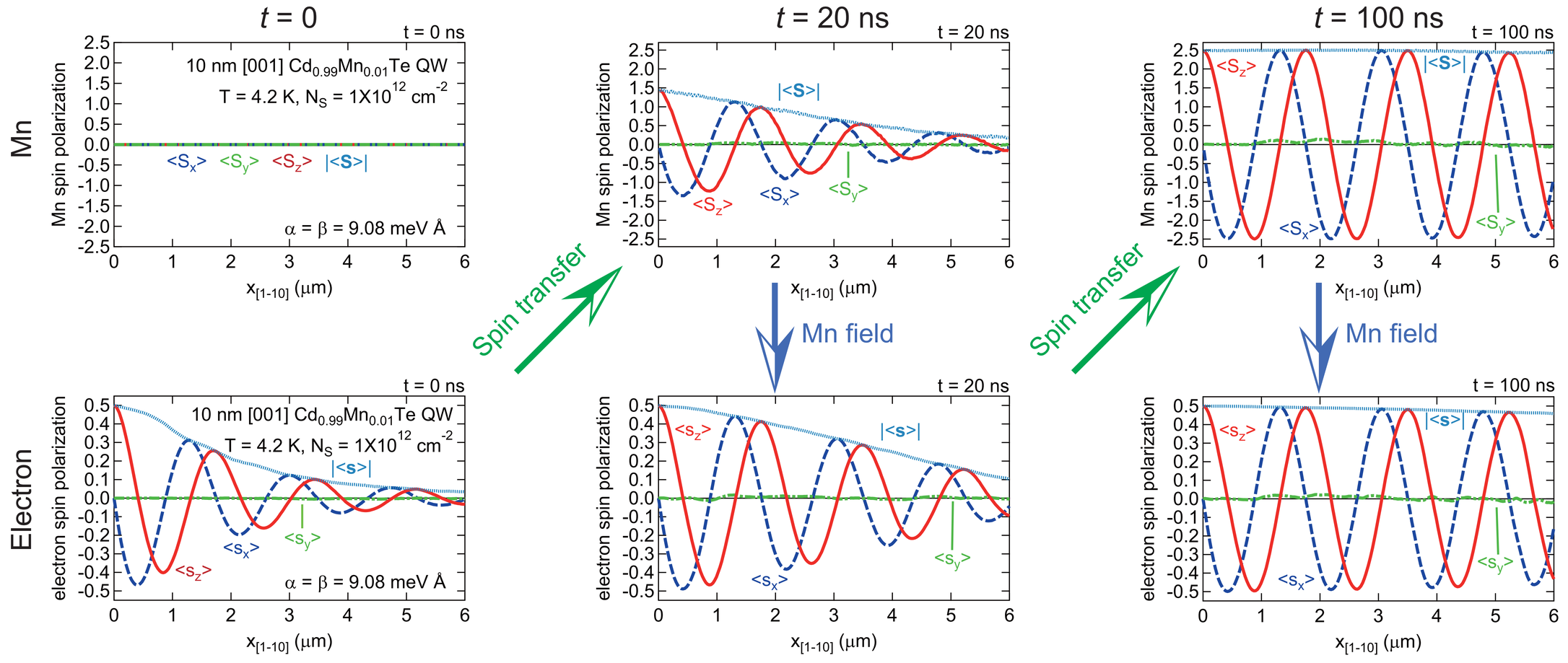
Mechanism: the s-d exchange interaction.

This improvement is due to the s-d exchange interaction between electrons and Mn impurities

$$H_{\text{s-d}} = a_{\text{s-d}} \sum_i \left[\frac{1}{2} \left(\hat{S}_{i+}^{\text{Mn}} \hat{s}_{-}^{\text{el}} + S_{i-}^{\text{Mn}} \hat{s}_{+}^{\text{el}} \right) + \hat{S}_{iz_{\text{p}}}^{\text{Mn}} \hat{s}_{z_{\text{p}}}^{\text{el}} \right] \delta\left(\vec{r} - \vec{R}_i^{\text{Mn}} \right),$$

which causes the following phenomena:

I. The electron spin polarization near the source electrode is transferred to Mn impurities.
2. *X*-dependent strong effective magnetic field that comes from this Mn spin polarization dominates electron spin precession.
As a result, all the electron spins change their direction coherently, and the electron spin coherence is improved.
3. The electron and Mn spin polarizations grow cooperatively along the *X*-direction.



Positive feedback: Cooperative growth of the electron and Mn spin polarizations.

[3] T. Tsuchiya, J. Phys. Soc. Jpn. **81**, 094706 (2012).