** Topological Spin Structures for GreenIT - from individual ultrafast motion to diffusion and collective crystallization of 2D lattices**

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**Abstract:**

Novel spintronic devices can play a role in the quest for GreenIT if they are stable and can transport and manipulate spin with low power. Devices have been proposed, where switching by energy-efficient approaches, such as spin-polarized currents is used to manipulate topological spin structures [1,2].

Firstly, to obtain ultimate stability of states, topological spin structures that emerge due to the Dzyaloshinskii-Moriya interaction (DMI) at structurally asymmetric interfaces, such as chiral domain walls and skyrmions with enhanced topological protection can be used [3-5]. Here we will introduce these spin structures ad we have investigated in detail their dynamics and find that it is governed by the topology of the spin structure [3]. By designing the materials, we can even obtain a skyrmion lattice phase as the ground state [4]. Beyond 2D structures, we recently developed also systems with chiral interlayer exchange interactions that lend themselves to the formation of chiral 3D structures [6].

Secondly, for ultimately efficient spin manipulation, we use spin-orbit torques, that can transfer more than 1ħ per electron by transferring not only spin but also orbital angular momentum. We combine ultimately stable skyrmions with spin orbit torques into a skyrmion racetrack device [4], where the real time imaging of the trajectories allows us to quantify the novel skyrmion Hall effect [5]. Recently, we determined the possible mechanisms that lead to a dependence of the skyrmion Hall effect on skyrmion velocity [7]. We furthermore use spin-orbit torque induced skyrmion dynamics for non-conventional stochastic computing applications, where we have developed a skyrmion reshuffler device [8] based on skyrmion diffusion [8]. Such diffusion can furthermore be controlled by symmetry – breaking in-plane magnetic fields [9] and this is useful for token – based Brownian computing.

Finally, we take the next step beyond studying the properties of topological skyrmions and use them as model systems to study phases and phase transitions in two dimensions. We determine the transition of skyrmions from a disordered “liquid” phase to a “hexatic” phase, which is a particular phase that only exists in 2D [10]. This demonstrates that skyrmion lattices are perfectly 2D systems, opening up an avenue to using skyrmions as model systems to study statistical mechanics, phases and phase transitions [10].

**References**

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