Supporting Information

All Electrical Access to Topological Transport Features in Mn$_{1.8}$PtSn Films

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Thermometry and stability of the alternating thermal gradient

Prior to measuring the Nernst signal, we calibrate the resistance of the Pt thermometers by applying different, constant and uniform temperatures to sample rod and thus the sample. To measure the resistance, we apply a current $I = 100 \mu$A. Additionally, we use a current reversal technique to remove spurious thermoelectric contributions. The result of this calibration for one of the thermometers is presented in Fig. 1a.

We then use $R_T(T)$ of both Pt thermometers as calibration for the local temperatures above and below the structure. The resulting temperature differences between the thermometers for the heat flowing upwards $\Delta T(\uparrow)$ (positive gradient) and downwards $\Delta T(\downarrow)$ (negative gradient) are used to estimate the thermal gradient along the structure

$$\nabla T_x = \frac{\Delta T(\uparrow) - \Delta T(\downarrow)}{2d_{\text{therm}}}.$$  \hspace{1cm} (1)

Here, $d_{\text{therm}}$ is the separation of the thermometers along the heat gradient direction, i.e. along $x$. Please note, that a positive gradient is defined as being antiparallel to the $x$-direction.

In a next step we apply a constant field of $\mu_0 H = 2$ T along the film normal $n$. Then, we vary the applied heating power and observe the difference in the temperature of the two thermometers for the two gradient directions (cf. Fig. 1b). The temperature difference agrees for the two gradient directions and increases linearly with the applied heating power. As expected, the simultaneously obtained Nernst voltage (shown as green symbols) also depends linearly on the power (or more precisely on the temperature difference).

Finally, to determine the field dependence of the thermometers, we measure the temperature during a field sweep. The resulting temperatures are depicted in Fig. 1c. A weak dependence of the local temperatures on the magnetic field can be observed for both thermometers and gradient directions (most likely due to the ordinary magnetoresistance in Pt).
However, the visible field dependence in the temperature difference (cf. Fig. 1d) is smaller than 10%. Only a small drift of the temperature difference with time can be observed.

**Magnetization measurements**

The measurements of the out-of-plane magnetization were carried out in a QuantumDesign MPMS XL 7 SQUID magnetometer. The obtained magnetization curves for all temperatures are shown in Fig. 2a. Due to the diamagnetic MgO substrate contribution, the magnetization loop has additional zero-crossings at finite fields. At these zero-crossings of the measured magnetization, the fit of the SQUID magnetometer fails, leading to additional measurement artifacts. Thus, the data around the zero-crossings have been masked using the fit quality. To single out the magnetization of the film, the substrate contribution (i.e. a negative slope) has to be subtracted from the data. The resulting magnetization of the film $M_{\text{film}}$, which then is used for the extraction of the topological Hall and Nernst is shown in Fig. 2b. Please note, that at low temperatures ($T \lesssim 30\, \text{K}$) there is an additional paramagnetic contribution due to impurities within the substrate. Since this letter focuses on the new extraction technique and its possible applications, we do not account for its effect here. This will result in slightly different absolute values of the maximum topological Nernst and Hall contribution at these low temperatures. For more details on the proper way to analyze this additional contribution please refer to Ref. 2.

**Temperature and field dependent measurements of the Hall and Nernst signal**

The evolution of the Hall and Nernst response with temperature is shown in Fig. 3a,b, respectively.

When the temperature is below 150 K, i.e. below $T_{\text{SR}}$, similar to those observed at 100 K
(see main text) are found. In particular, a dip– or peak–like feature is present at low magnetic fields $\mu_0 H \ll 4 \text{T}$ in both Nernst and Hall signals and pertains to the lowest temperatures. Additionally, when decreasing the temperature to below 50 K, the Nernst signal decreases by roughly one order of magnitude. This behaviour is expected for the anomalous thermal signals due to the Mott relation: Since the weighting function of the anomalous Nernst approaches a delta distribution, the anomalous Nernst signals will be suppressed towards $T = 0 \text{K}$. Another interesting feature, is that towards lower temperatures, the field range in which the topological Hall and Nernst effects are observed increases (see also Ref.2). We speculate that at low temperature, the topological spin structure is stabilized due to lower thermal activation.

Please note, that the Nernst and Hall signals have opposite signs with respect to their anomalous counterparts below $T_{\text{SR}}$ which was not observed in the only other report of the topological Hall and Nernst in the same sample.2

When increasing the temperature above the spin reorientation the obvious peak– or dip–like feature visible below $T_{\text{SR}}$ vanishes in both signals and the curves exhibit the behavior expected for conventional ferromagnets (i.e. Eq. [2] and Eq. [3] with $S_{xy}^T = 0$ and $\rho_{xy}^T = 0$).

Additionally, the anomalous Nernst effect inverts its sign above $T_{\text{SR}}$. In contrast, the anomalous Hall signal, although increasing for increasing temperatures, always exhibits the same sign. We interpret this behaviour by considering the different contributing regions of the band structure: While the anomalous Hall effect (AHE) is sensitive to all states below the Fermi surface, the anomalous Nernst effect (ANE) only probes a small region around the Fermi energy. Thus, a change of the band structure close to the Fermi energy will reflect differently in the ANE compared to the AHE.

The TNE and THE extracted from the measured curves using

$$S_{xy}^T(H) = S_{xy}(H) - S_{xy}^A \frac{M(H)}{M_s}$$  \hspace{1cm} (2)

$$\rho_{xy}^T(H) = \rho_{xy}(H) - \rho_{xy}^A \frac{M(H)}{M_s}$$  \hspace{1cm} (3)
are shown in Fig. 3c,d. Here, $\rho_{xy}^A$, $S_{xy}^A$ and $M_s$ are the amplitudes of the anomalous Hall and Nernst effect as well as the magnetization in the saturated field region ($\mu_0 H > 4$ T), respectively. These equations neglect the ordinary Nernst and Hall, since their contributions are small compared to the anomalous counterparts. Both topological signals pertain down to the lowest measured temperature $T = 10$ K extending from very small fields until roughly 4 T. Interestingly, even above $T_{SR}$ small features remain visible in the Hall and Nernst signal. This observation would agree with the reported occurrence of Antiskyrmions above $T_{SR}$ in bulk Mn$_{1.4}$Pt$_{0.9}$Pd$_{0.1}$Sn.$^8$ However, a small misalignment or different temperatures of the sample during the transport or the magnetization measurements can give rise to slightly different $M(H)$ and $\rho_{xy}(H)$ viz. $S_{xy}(H)$ shapes and thus artifacts having a similar shape as the topological features. The regions where no data for the TNE and THE are shown correspond to the masked regions in the $M(H)$ loops as discussed in the previous section.

**Anomalous Hall and Nernst effect**

We show the amplitudes of the ANE $S_{xy}^A$ and AHE $\rho_{xy}^A$ as a function of the temperature in Fig. 4. As discussed above, the ANE (black symbols) changes its sign around 150 K while the AHE only increases monotonically from low to high temperatures. The maximum amplitudes are $S_{xy}^A \approx 110$ nV K$^{-1}$ and $\rho_{xy}^A \approx 29$ nΩ m.

**Determination of the topological quantity and prerequisites for the methodology**

To extract the topological quantity we normalize the Nernst and Hall signals to their saturation value in the field polarized configuration (i.e. where the magnetization texture and therefore the topological contribution is not present) and take the difference of both signals. Thus, together with Eq. (2) and Eq. (3), we get the following relation, again without
considering the ordinary effects:

\[
TQ = \frac{\rho_{xy}}{\rho_{xy}^A} - \frac{S_{xy}}{S_{xy}^A} = \frac{\rho_{xy}^T}{\rho_{xy}^A} + \frac{M(H)}{M_s} - \left( \frac{S_{xy}^T}{S_{xy}^A} + \frac{M(H)}{M_s} \right) = \frac{\rho_{xy}^T}{\rho_{xy}^A} - \frac{S_{xy}^T}{S_{xy}^A} = \tilde{\rho}_{xy}^T - \tilde{S}_{xy}^T \quad (4)
\]

To also account for the ordinary effects, they would need to be subtracted prior to the subtraction, by using a linear fit in the field polarized phase. From this result we infer, that as long as the ratio of the topological and the anomalous Hall and Nernst signals are not exactly the same, our method will yield usable results. Since all signals do change significantly with temperature – having vastly different temperature dependencies – for the material in this study, the method should be robust.

Considering all signs as observed in this manuscript, we see that at low temperature the most advantageous case is realized, i.e. where the two topological signals add. This can be understood as the topological and anomalous Nernst are both positive, while the anomalous and topological Nernst have opposite sign (i.e. \( TQ = |\tilde{\rho}_{xy}^T| + |\tilde{S}_{xy}^T| \)). However, at high temperatures \( (T > T_{SR}) \) the topological and Nernst have the same sign, thus the two fractions are subtracted (i.e. \( TQ = |\tilde{\rho}_{xy}^T| - |\tilde{S}_{xy}^T| \)). The only case where our method fails is if either the anomalous Hall or Nernst vanishes (as observed in this manuscript at the sign change close to \( T_{SR} \)). In this case the signal would be normalized by 0, such that the extraction method fails.

Although no exact numbers for the topological Hall and Nernst can be extracted using this method, a range for the two effect magnitudes can be given: For example, lets consider that there is only a topological Hall effect \( (S_{xy}^T = 0) \). In this case, we can see that the amplitude of the THE is given by \( \rho_{xy}^T = TQ \cdot \rho_{xy}^A \). In a similar fashion, if there would be only a topological Nernst effect, its amplitude would be given by \( S_{xy}^T = -TQ \cdot S_{xy}^A \). If both transport signals contribute to the \( TQ \), then these two values define the upper limit for the two effects, i.e. \( |S_{xy}^T| \leq |TQ \cdot S_{xy}^A| \) and \( |\rho_{xy}^T| \leq |TQ \cdot \rho_{xy}^A| \).
Validity of the extraction method for other materials

To further show the validity of our approach, we extracted the published data for the Hall and Nernst in bulk MnGe from Ref. 7 for $T = 20\,\text{K}$ and $T = 100\,\text{K}$ (cf. Fig. 5a,b). We then apply the same approach as for our Mn$_{1.8}$PtSn thin films, normalizing the signals and subtracting the normalized Hall and Nernst signals. The resulting curves for the topological Hall and Nernst as well as the topological quantity are shown in Fig. 5c,d. Again it can be seen, that although the THE and TNE are significantly different for the two temperatures, the $TQ$ is finite for the regions where either THE or TNE is present as expected from our preliminary discussion. Please note, that here, for both temperatures the anomalous Hall and Nernst as well as the anomalous Hall have the same shape (i.e. a dip–like structure when increasing the field). This shows that even in the “unfavorable” case, where the topological effects do not add, our approach is valid.

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SI-Figure 1:  

**a** Calibration curve for one of the thermometers. The green and red line represent the low and high-temperature fit used for the calculation of the temperature.  

**b** The measured temperature differences for the two heat flow directions (blue and red symbols) as well as the Nernst signal (green circles) scale linearly with the applied heating power. The measurements were taken with an applied magnetic field of $\mu_0 H_z = 2 \, \text{T}$.  

**c** The extracted temperatures on the hot and cold side recorded during one magnetic field sweep for the two heat flow directions are very similar and show only a small variation with the magnetic field.  

**d** The extracted temperature difference is constant apart from a linear drift as a function of the applied magnetic field.
SI-Figure 2:  a The out-of-plane magnetization measurements of the Mn$_{1.8}$PtSn thin film goes through zero at finite fields due to the diamagnetic substrate contribution, giving rise to measurement artifacts. Therefore, the zero crossings have been masked. b Out-of-plane magnetization with subtracted background as used for the extraction of the topological Hall and Nernst effect.
SI-Figure 3: The evolution of the Nernst and Hall signal as a function of field and temperature is shown panels a and b, respectively. The anomalous Nernst effect (i.e. the saturation value) changes sign below $T_{SR}$. The extracted topological Nernst and Hall signals are shown in c and d, respectively. For $T > 200\, \text{K}$ no clear topological Hall and Nernst can be observed. In contrast, for $T < T_{SR}$ and down to $T = 10\, \text{K}$, both, topological Hall and Nernst are present, indicating a non-coplanar spin texture in the film. At low temperature the Nernst signal decreases significantly as expected from the Mott relation.\textsuperscript{3,4}
SI-Figure 4: a The saturation values of the Nernst (black squares) and Hall (red circles) signals, i.e. the anomalous Hall and Nernst signals both show a dependence on temperature: While the AHE only decreases towards lower temperatures, the ANE changes its sign below the spin reorientation temperature.
SI-Figure 5: a,b Normalized Nernst $\tilde{S}_{xy} = S_{xy}/\max(S_{xy})$, Hall $\tilde{\rho}_{xy} = \rho_{xy}/\max(\rho_{xy})$ and SQUID magnetometry $\tilde{M} = M/\max(M)$ measurements for bulk MnGe as reported in Ref. 7. c,d The extracted topological quantity $TQ$ (blue triangles) also for this sample reflects the region where either topological Hall or Nernst are observed.