

# Enhanced Rashba Effect Observed in Capped Topological Insulator Thin Films Grown by MBE

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We have discovered a giant Rashba effect in high mobility, large grain, thin films of  $\text{Bi}_2\text{Se}_3$  induced by an overlayer of Se with a Rashba parameter of  $\alpha_R = 2.0 \pm 0.6 \text{ eV\AA}$ . Through breaking the inversion symmetry of the structure (Fig. 1), the Se overlayer has created an additional spin-orbit effect via the Rashba field adding to the intrinsic spin-orbit interaction of the  $\text{Bi}_2\text{Se}_3$ . The intrinsic spin-orbit lifetime ( $\tau_{\text{so}}$ ) is of the order of 60 fs, found by fitting the magnetoresistance including corrections for Dirac fermions. We determined the electron-electron interaction time,  $\tau_{\text{ee}}$ , over temperatures from 1 K to 20 K, and showed that the behaviour is consistent with confined electrons. Using dielectric constants to estimate the screening and the interaction times, we explained that the frequently observed increase in the low temperature zero-field resistivity is due to electron-electron interactions. We demonstrated the presence of spin-momentum locked states by showing that the spin-diffusion length is of the same order of magnitude as the elastic mean free path. Together these findings offer new insight into transport in topologically protected states.

A continuing question about transport in topological materials concerns identifying the signatures of the topological surface states, especially in thin films. Although it is now more than 15 years since topological materials such as  $\text{Bi}_2\text{Se}_3$  have been shown to exhibit weak localisation (WL) and anti-localisation (WAL) effects in the magnetoresistance [1, 2], there are many published results that are difficult to interpret because

the samples have defects and low mobility. In these cases, results reporting a mixture of WL and WAL [3], various numbers of conduction channels and suspected large contributions from bulk states [4] have made it difficult to understand the nature of the topological surface states. Despite the intense effort in growing thin films of topological materials, there are several questions about the nature of the topological states that remain unanswered. We address in the presentation: (i) what is the magnitude of the spin-orbit lifetime and how is it related to the topological Berry phase, (ii) how can we determine the effects of adjacent layers of different materials on the topological surface states and in particular, are Rashba effects induced, (iii) can we explain the effects of electron-electron interactions in the electron transport?

## References

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## Figures



**Figure 1:** Schematic diagram of the sample heterostructure; sapphire/buffer/topological insulator (TI;  $\text{Bi}_2\text{Se}_3$ )/cap layer.