Non-linear current measurements in the high field phase of TaAs

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Introduction

Recently it was shown [1] that the Weyl semi-metal TaAs undergoes a drastic electronic structure transformation as a function of magnetic field B||c. Beyond the quantum limit (≈10T), where only the 0^{th} Landau level of the Weyl fermions are occupied, the resistivity is highly anisotropic and approximately constant up to ≈75T, where a breakdown of the original band structure is observed. The resulting two order-of-magnitude increase of the resistivity along J||c is suggestive of a gap opening in the chiral Landau levels. The essentially one-dimensional electronic structure favours the formation of a density-wave state and could be the origin of the Fermi surface reconstruction.

Nonlinear I-V curves can reveal the presence of a density wave: above a threshold electric field the density wave is de-pinned and acts as a secondary transport channel. Even if the high field state is not a density wave phase, nonlinear transport could shed light on whether the state is gapped or still contains gapless charged quasiparticles.

Experimental

In this experiment focused ion beam (FIB) microstructured devices were prepared for transport measurements. The fabrication of a long ‘wires’ with a small cross section (<10μm^2) is key to achieving a homogenous current flow and a large enough current density. This enables the investigation of non-linear I-V curves in an otherwise good metal [2]. Large gold contacts sputtered on the sample surface ensure a low contact resistance (<1Ω) and can easily withstand the applied current of up to 1mA.

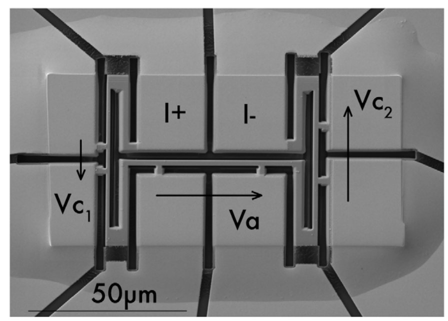

Fig.1 The TaAs sample was microstructured with a focused ion beam (FIB) and is designed to investigate the resistivity along the crystallographic a (Va) and c-axis (Vc_1 & Vc_2).

Results and Discussion

The magnetic field was applied along B||c and the voltage signals along the crystallographic a and c axes were measured. The 1^{st} and 3^{rd} harmonic signals are presented in figure 2. As the magnet field increases beyond the quantum limit (at ≈10T), the magnetoresistance stays constant up to ≈75T. There, the resistivity along J||c increases drastically and simultaneously drops in J||a yielding a nearly isotropic conductor in the ultra-high field state. The 3^{rd} harmonic shows pronounced quantum oscillations along the a-axis at low fields and signals a strong 3^{rd} harmonic generation in all channels at the high-field transition. Performing the same measurement at 43μA does not generate a 3^{rd} harmonic signal at high fields indicating that the threshold has not been exceeded.

Conclusions

This experiment has revealed a so far unobserved high-field transition in the a-axis resistivity and clearly demonstrates the existence of current dependent higher harmonic generation. These are compatible with a scenario of density wave formation, however other explanations, for example local current path inhomogeneities can currently not be excluded and require further investigation.

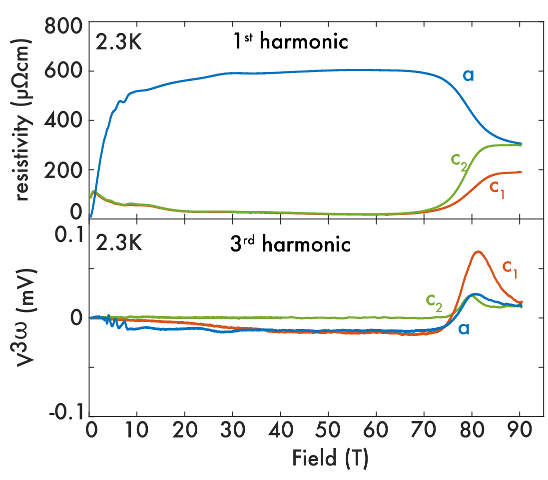

Fig.2 1^{st} and 3^{rd} harmonic signal of the TaAs sample shown in Fig 1. The magnetic field was applied parallel to the c-axis and a current of 310μA was sourced.

Acknowledgements

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References

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[2] Moll, P. J. W., *et al.,* Nat. Comml **6**, 6663 (2015)
[3] Bachmann, M. D., *et al.,* Sci. Adv. **3** (2017)