Transport Measurements of Feas Superconductors in the 150T Single-Turn Magnet

P.J.W. Moll, N.D. Zhigadlo, J. Karpinski, B. Batlogg (ETH Zurich, Switzerland); R. McDonald, D. Rickel, C. Mielke, F. Balakirev, J. Betts (Los Alamos National Lab, NHMFL)

Introduction

The large upper critical fields in the iron-pnictides well in excess of 100T at low temperatures render them prime candidates for high magnetic field applications. To reliably estimate such high upper critical fields, however, poses a significant experimental challenge. The multi-band nature of this material class has a profound impact on the $H_{c2}(T)$ behavior due to the additional degrees of freedom arising from the difference between inter- and intra-band scattering, and the conventional means of extrapolating $H_{c2}(0)$ from high-temperature measurements, such as the WHH formalism, must be considered with caution. Therefore establishing new experimental techniques to follow $H_{c2}(T)$ to fields above 100T sheds light on the ultimate limits of applicability of pnictide superconductors as well as the temperature dependence of the internal scattering mechanisms that lead to the multi-band nature of superconductivity.

Experimental

Currently magnetic fields in excess of the 100T multi-shot magnet can only be created in destructive magnets. The single-turn system at NHMFL-PFF routinely delivers pulses of 150T and above. The short duration of the pulses (~4-8μs) and the increased noise levels compared to non-destructive pulse magnets are a serious experimental challenge. We have worked extensively on a combination of Focused Ion Beam micromachining and GHz stripline sample holder design to address these issues.

Results and Discussion

The striplines and sample shape were designed to change from a 50 Ohm termination in the superconducting state to an essentially open circuit (>500 Ohm) in the normal state. This approach was successful and yielded a high contrast in GHz transmission between the normal and SC states. The transition midpoint shown in the figure below, however, occurs at significantly lower fields than estimated from previous measurements in the non-destructive NHMFL-PFF magnets. We attribute this to large low-frequency currents j induced by the enormous dB/dT (~10^8 T/s), thus the sample reaches the normal state at a field $H_c(j,T)$ through a combination of j and T. In the next iteration of the design, we address this issue by placing microcapacitors right next to the sample, in order to prevent such low-frequency currents to flow through the sample.

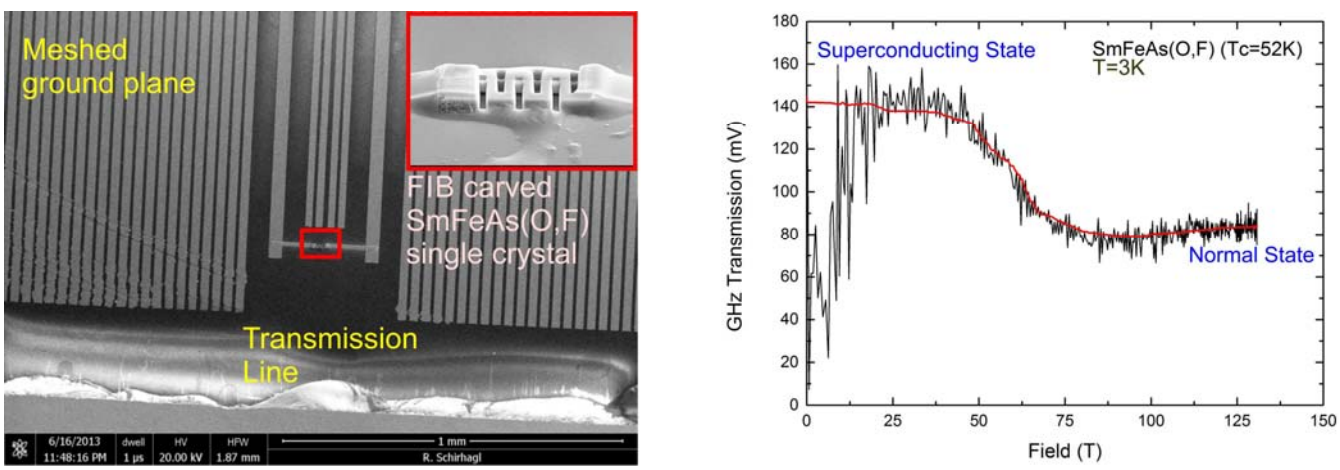

Figure: (left) SEM image of the stripline design, employing a meshed ground plane to reduce eddy current heating and two center conductors. The 50 Ohm stripline is terminated by a Focused Ion Beam micromachined crystal. It was machined to give a 50 Ohm termination (including contact resistance) in the superconducting state, and a significant increase to >500 Ohm in the normal state. (right) Measurement in the HIIc configuration at base temperature (3K). The transition into the normal state is clearly visible.

Conclusions

The signal quality achieved in such extreme conditions from sub-microgram crystallites demonstrates the progress of this novel measurement approach. If the noise currents in the sample can be suppressed, the goal of upper critical field measurements in the 100-200T range can be reached.

Acknowledgements

Work at NHMFL-LANL is performed under the auspices of the NSF, DoE, and State of Florida.