# $J_c$ Oscillations in the Hybrid Vortex State of SmFeAs(O,F)

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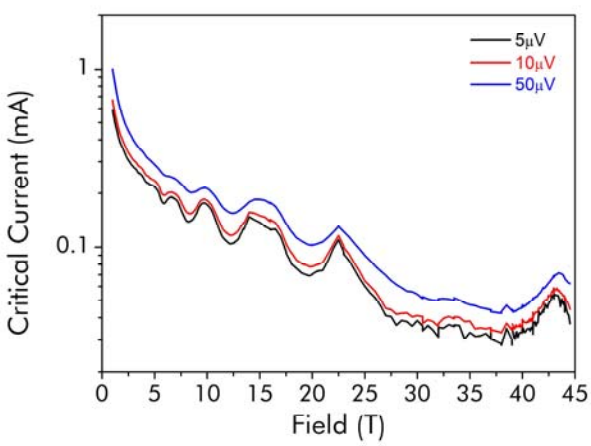
## Introduction

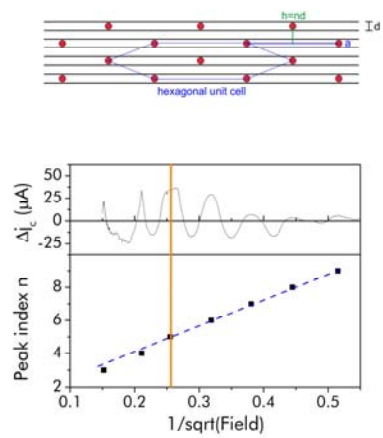
The superconducting order parameter in layered structures, such as the iron-pnictides, may be strongly modulated within the unit cell. In SmFeAs(O,F) ($T_c$~55K), these modulations cause a transition from well-pinned Abrikosov-vortices to highly mobile Josephson vortices at a cross-over temperature T*~ 41-42K, despite its low electronic anisotropy[1]. The unique combination of parameters in this material results in a borderline Josephson-vortex like behavior at low temperatures, leading to exotic, vortex related transport behavior in an extended cross-over region around T*.

## Experimental

We investigate the vortex system for fields applied along the FeAs layers, and currents flowing perpendicular to them (i.e. along the c-axis). In this configuration, the in-plane Lorentz force induces an in-plane sliding motion of the vortices in FIB-microsculptured single crystals[1,2]. By studying the I-V characteristics for currents along the c-axis and by extracting critical current values in fields up to 45T in the hybrid magnet in Tallahassee, we were able to investigate vortex configurations at high densities (<3 unit cell inter-vortex distance).

## Results and Discussion




The critical current $j_c(H)$ at T* shows clear modulation, with a pronounced enhancement of $j_c$ which becomes periodic in $1/\sqrt{H}$. These $j_c$ maxima occur at magnetic fields $H_n$ well explained by commensurability between an anisotropic hexagonal vortex lattice and the FeAs layer spacing (see sketch). The layer potential dominates over the vortex interactions even in the dense vortex matter at 43T (= 3 FeAs layer spacing). These $j_c$ modulations are observed only for T ~ T*, thus we conclude that they are a characteristic feature of hybrid vortices between Josephson- and Abrikosov-character. Increasing the interlayer spacing by replacing Sm(O,F) with a thicker $VSr_2O_3$ layer leads to fully developed Josephson behavior without these $1/\sqrt{H}$ oscillations, highlighting the delicate balance of vortex interaction and layer potential energies in the hybrid vortex matter of SmFeAs(O,F).

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## References

[1] P.J.W. Moll et al., Nature Materials 12, 134-138 (2013)
[2] P.J.W. Moll et al., Nature Materials 9, 628-633 (2010)