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The fate of the superfluid density near the superconductor-insulator transition

Superconducting films of amorphous Indium Oxide (a:InO) undergo a transition to an insulating state with increasing disorder, primarily due to the localization of pre-formed Cooper pairs. The continuous decrease in critical temperature as the critical disorder is approached suggests an equally continuous suppression of superfluid density. In this talk, I will discuss a systematic study of the superfluid density, measured via plasmon dispersion spectroscopy of microwave resonators made from a:InO, combined with DC resistivity measurements, as a function of disorder. We observed that the superfluid stiffness dictates the superconducting critical temperature over a wide range of disorder, underscoring the dominant role of phase fluctuations. Furthermore, we found that the superfluid density remains surprisingly finite at the critical disorder, indicating an unexpected first-order nature of the disorder-driven quantum phase transition to an insulating state.