Electron-hole superfluidity in 2D van der Waals heterostructures

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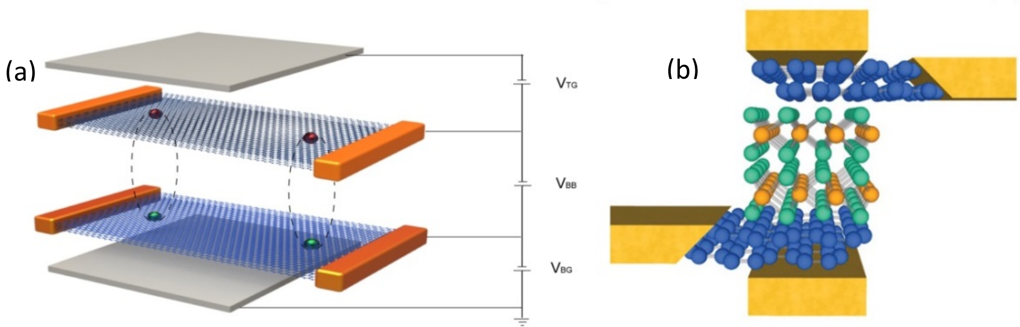
Now that 2D superfluidity in electron-hole double graphene bilayers has been observed [1] – in precisely the same system as had been theoretically proposed in Ref. [2] – there is potential for opening up a new field in vortex physics. This new field could be of particular interest to the vortex community, because some of the operating rules of this superfluid system differ strikingly from those for superconductivity. It is likely that the phenomenon will be found in many of the new van der Waals heterostructures.

Characteristics of this electron-hole superfluidity that differ markedly[2]-[5] from familiar superconducting systems are: (i) the long-range nature of the Coulomb pairing interaction makes screening a central feature of the phenomenon; (ii) by varying the carrier concentration from high density to low density, the strength of the coupling can be tuned continuously from weak-coupled BCS to strong-coupled BEC; (iii) in the strong-coupled BEC regime the compact pairs are nearly neutral; (iv) in the BCS-BEC crossover regime the pairs form dipoles that remain weakly interacting; (v) in what should be the weak-coupled BCS regime, strong screening kills the superfluidity.

I will go through these properties and then raise the question of what implications these unusual properties might have for vortices in these systems.



(a) Proposed system from Ref. [2}: electron-hole graphene bilayers with independent contacts and separated by 1 nm hBN insulator. Top and bottom gates tune the carrier densities
(b) Experimental system from Ref.[1]: e-h graphene bilayers separated by 1.4 nm WSe2 insulator.

References

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