FLAT BAND SUPERCONDUCTIVITY IN STRAINED DIRAC MATERIALS

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In conventional superconductors, the superconducting critical temperature $T_c$ depends exponentially on the electronic density of states $\nu$ at the Fermi level, $T_c \sim e^{-1/(g\nu)}$, where $g$ describes the strength of attractive interaction. Thus, when engineering materials for higher critical temperatures, it is natural to aim to increase the density of states. An extreme case of increased density of states is the flat band state, where the electrons within some momentum regime are completely dispersionless, leading to diverging density of states at the corresponding energy. In various different models, this has been shown to result in a parametrically enhanced critical temperature that is linear in the electron-phonon coupling constant, $T_c \sim g$ \cite{1,2}. It has also been shown that this type of an approximate flat band state is realized in graphene and other Dirac materials under periodic strain \cite{3,4}.

We consider a BCS-like model for superconducting properties of a two-dimensional Dirac material such as graphene under strain that produces a flat band spectrum in the normal state. We show that in the superconducting state, such a model results in a highly increased critical temperature compared to the case without the strain, inhomogenous order parameter with two-peak shaped local density of states and yet a large and almost uniform and isotropic supercurrent. This model could be realized in strained graphene or ultracold atom systems and could be responsible for unusually strong superconductivity observed in some graphite interfaces and certain IV-VI semiconductor heterostructures.

The figure shows: a) Schematic, highly exaggerated picture of a honeycomb lattice in strain field of the form $u_y(x) = a\beta \sin(2\pi x/L)/(4\pi)$, where $L$ being the strain period, $\beta$ is a dimensionless parameter describing the strength of the strain. b) The profile of the pair potential $\Delta(x)$ for $\beta = 20$ (blue), $\beta = 20$ (green) and $\beta = 20$ (red) and $g/(\hbar v_F L) = 0.01$.

\cite{2} V. Khodel and V. Shaginyan, JETP Lett \textbf{51}, 553 (1990).