Stability of Dirac cone in artificial graphene

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What is the Artificial Graphene (AG)?
It's an artificial material that exploits the properties of graphene in a tunable setup. Actually it has been realized 3 different physical implementations:
- 2D electron gas in a semiconductor heterostructures
- Metal surfaces shaped by molecules
- Trapped cold atoms in an optical lattice

Benefits of using AG:
- Great spatial accuracy to better control Dirac Fermions
- Lattice constants from tenths nm to hundreds nm
- Alternative testing, like Kekulé distortion

Previous works:
- For electrons confined in GaAs quantum dots:
  - Confirmed by DFT results (Räsänen, Rozzi [2]).

Present work:
- Study of the stability of AG Dirac cone in GaAs QD with respect to changes in the following parameters:
  - Dots potential shape
  - Dots potential radius
  - Dislocations of atoms position
  - Lattice constant change.

AG system studied

System details
- Dot-dot distance = 150 nm.
- N = 1 electron per dot.
- Hard-wall potential (or exponential) \( V(x) = V_0 \exp(-x/a) \)
- Potential radius = 5.25 nm
- Potential depth = \( V_0 = 0.6 \text{ meV} \)

For reproducing electrons in GaAs QD:
- Electron effective mass \( m^* = 0.067 \)
- Dielectric constant \( \varepsilon = 12.4 \)

Change of lattice constant

Dot-dot distance from 105 nm to 250 nm (8190 for mGGA) and the Dirac cone is maintained.

Results:
- We can see that the system experiences a transition towards metallic for an increasing dot-dot distance.
- The process is faster in presence of \( e+e \) interaction than for IP calculation.

Future developments:
- Spin-polarized case
- Studying effect of repulsive potentials in triangular lattices instead of attractive potentials in honeycomb lattices
- Optical properties

Bibliography