Superfluid ^{4}He phases on strained graphene

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Adrian Del Maestro
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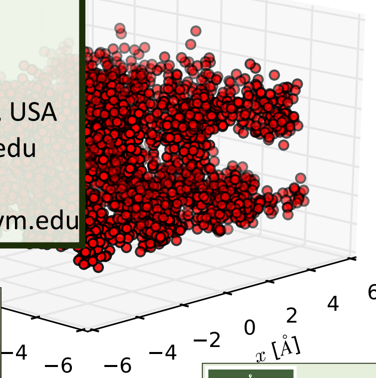

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Goals

The University of Vermont

Can mechanical manipulation of graphene produce exotic behavior in adsorbed helium?

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- appropriate potential for strained graphene

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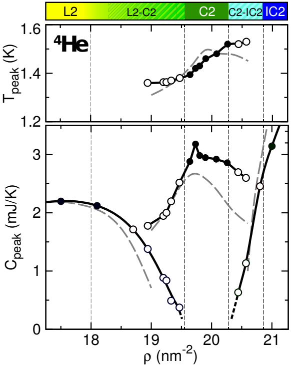
Can mechanical manipulation of graphene produce exotic behavior in adsorbed helium?

- appropriate potential for strained graphene
- perform PIMC and check for interesting results

Motivation - Experimental

anomalous low temperature phase



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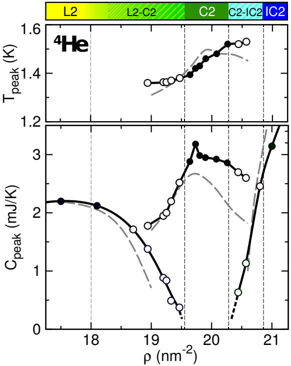

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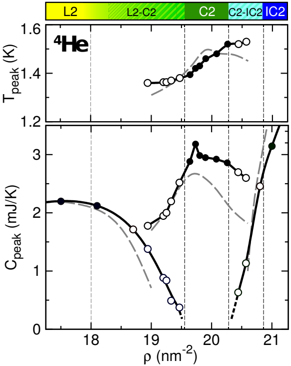

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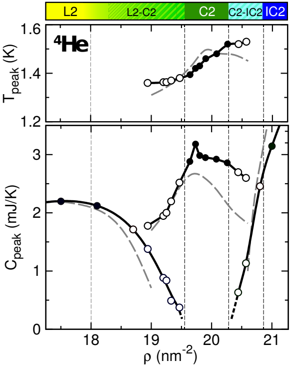
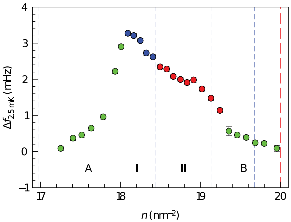
intertwined superfluid and density wave order





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Motivation - Experimental

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intertwined superfluid and density wave order

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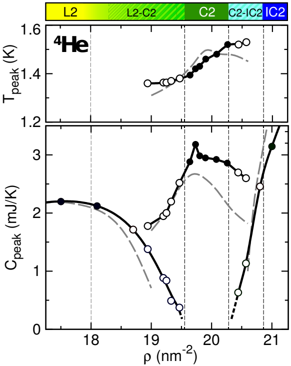

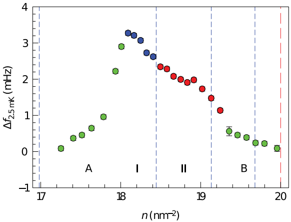

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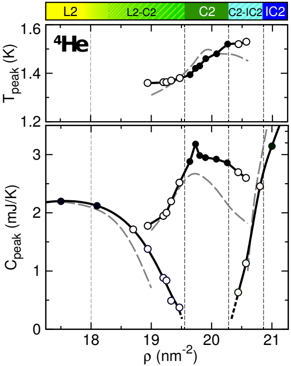
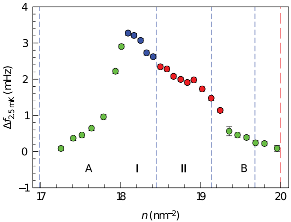
intertwined superfluid and density wave order

- frequency shifts of torsional oscillator
- large superfluid fraction at peak, $\rho_s(0)/\rho \sim 0.8$





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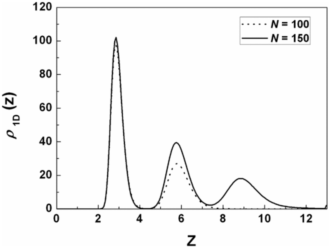
Motivation - Theory



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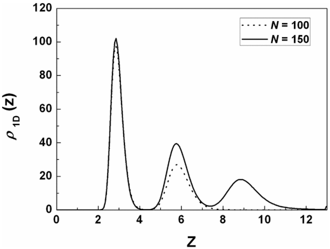

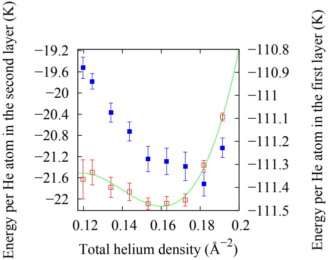

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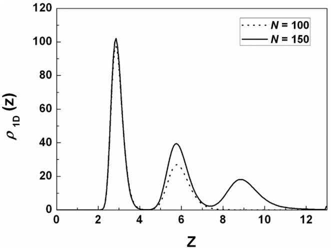

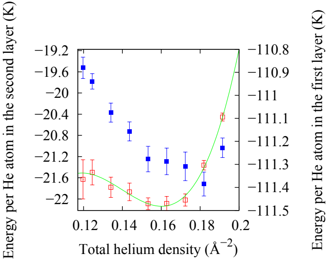

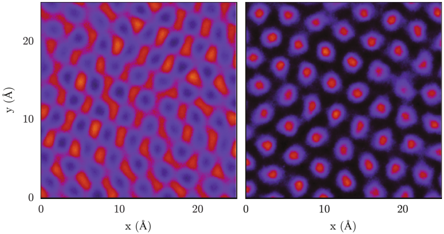

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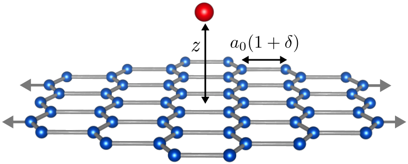
Uniaxially Strained Graphene Potential



straining graphene

Nichols, N. S., Del Maestro, A., Wexler, C., and Kotov, V., Phys. Rev. B 93, 205412, (2016).

Uniaxially Strained Graphene Potential

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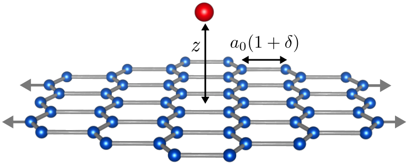
large strain



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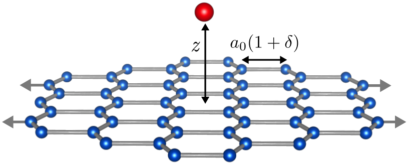

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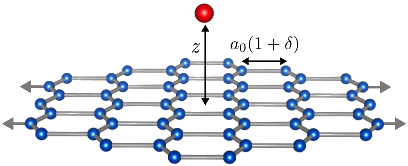

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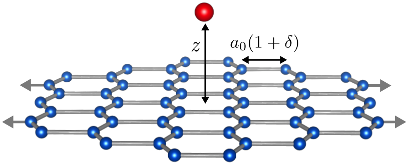

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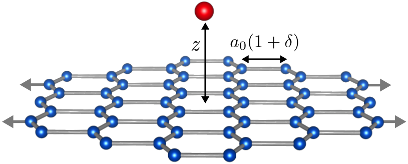

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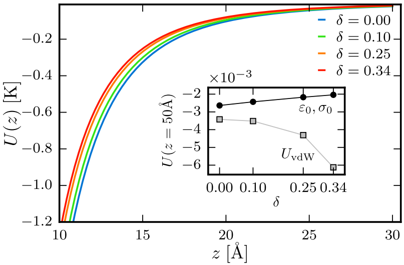

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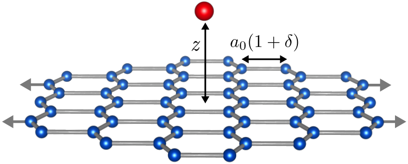

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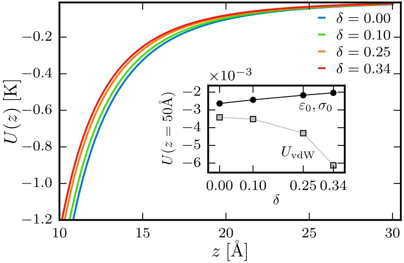

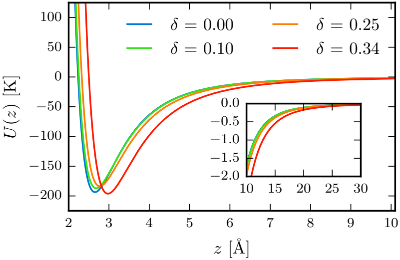

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Uniaxially Strained Graphene Potential

$$f(\chi, \Delta_r, \Delta_U) = \chi^2 \Delta_r \Delta_U$$

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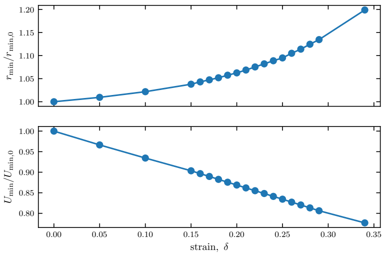

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0.05	2.66077881	17.08534452
0.10	2.69725342	16.66725476
0.15	2.74302978	16.16424290
0.20	2.80301514	15.54642137
0.21	2.81890869	15.37418917
0.22	2.83472900	15.20264301
0.23	2.85157471	15.02446149
0.24	2.86907959	14.84175555
0.25	2.88402099	14.68801113
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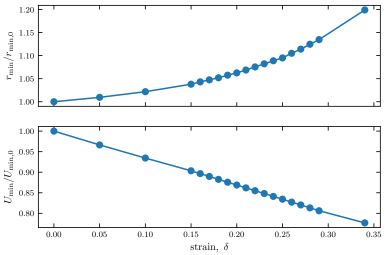

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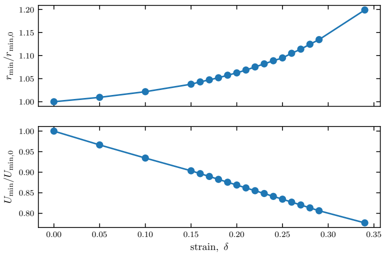

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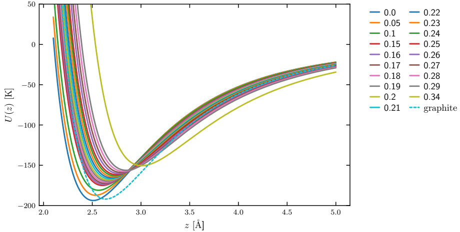

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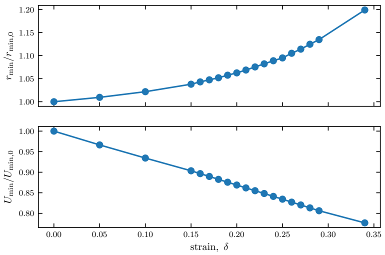

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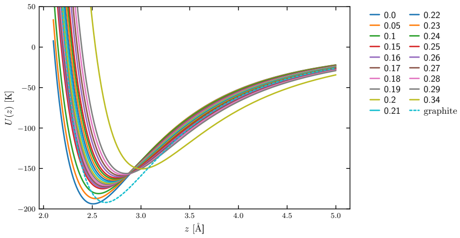

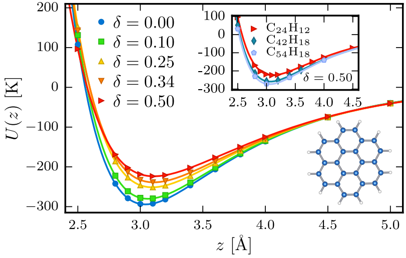

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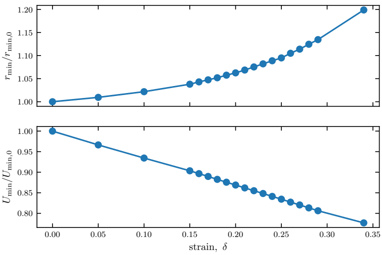

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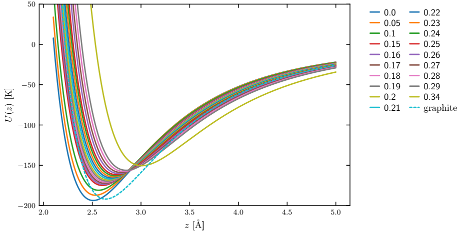

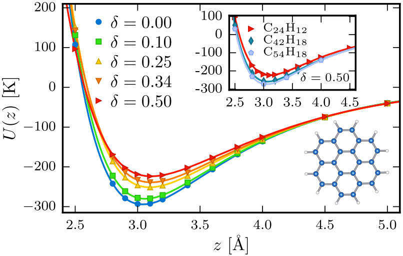

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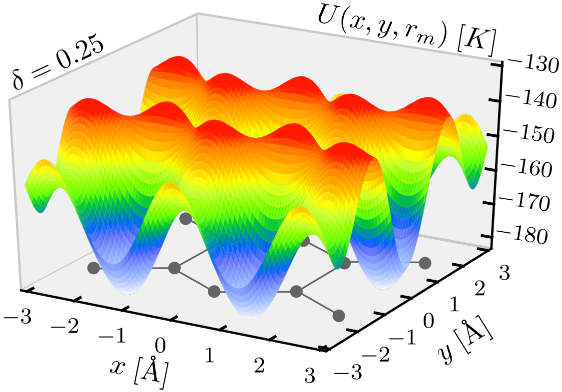
Potential



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Goals

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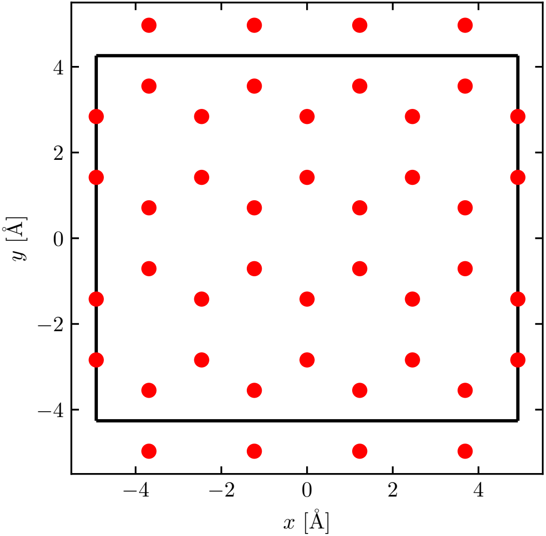
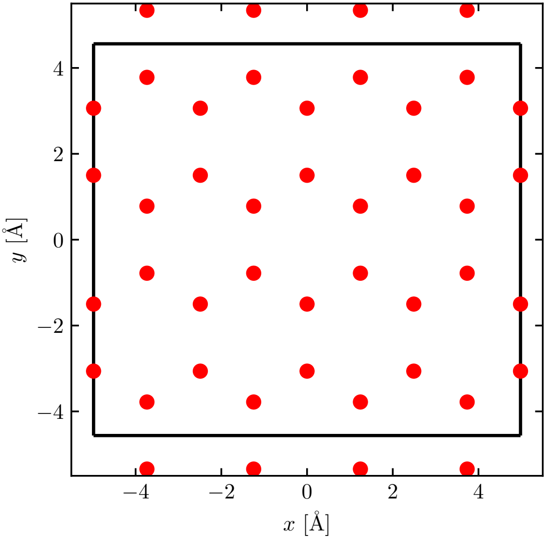
Simulation Box



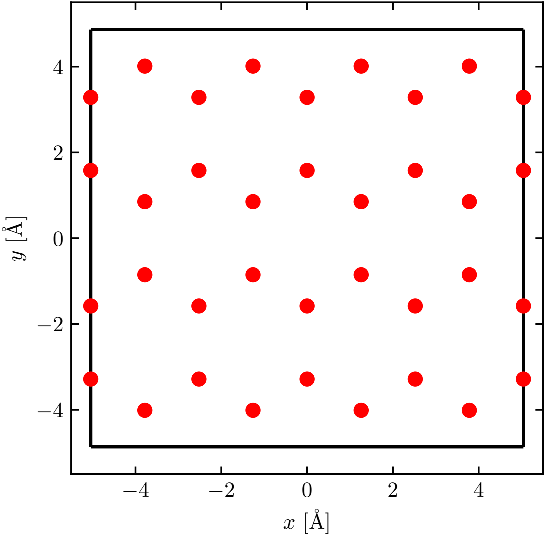
$$N_\mathsf{C} = 32,\ \delta = 0.00$$

Simulation Box

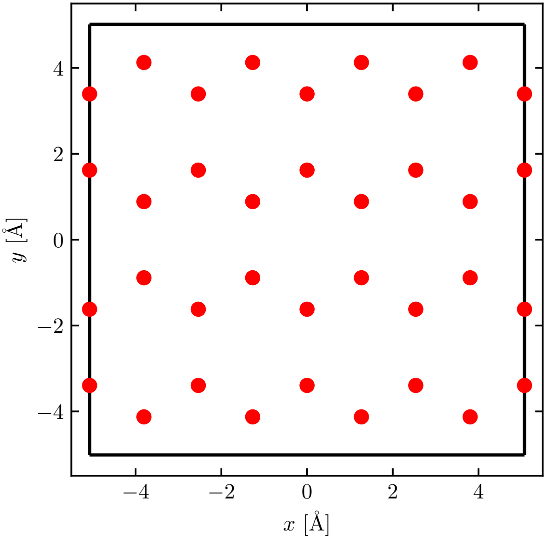


$$N_{\mathsf{C}} = 32,\ \delta = 0.10$$

Simulation Box

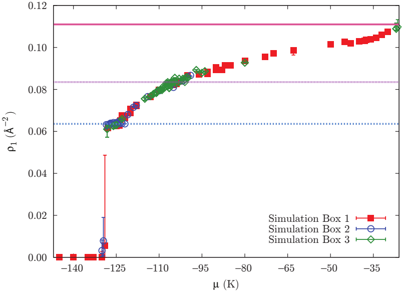


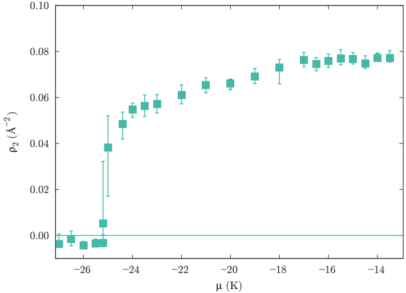
$N_{\mathsf{C}} = 32,\ \delta = 0.20$



$N_{\mathsf{C}} = 32,\ \delta = 0.25$

Layering





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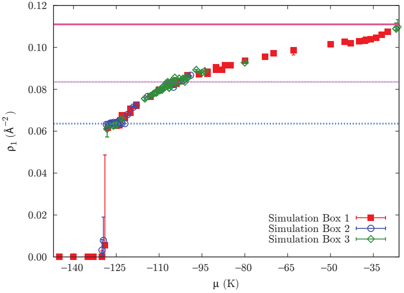

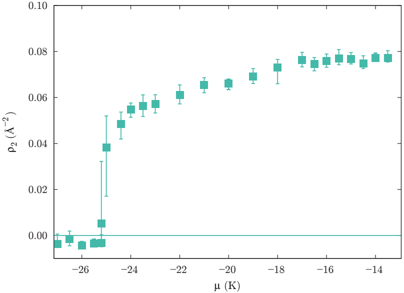

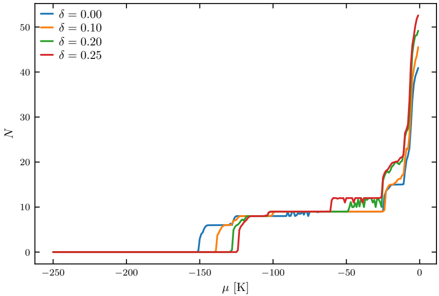

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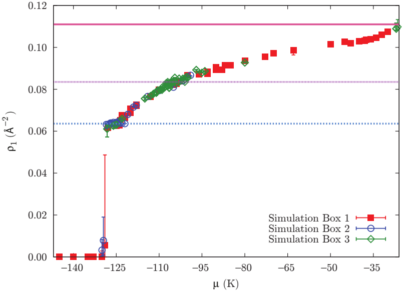
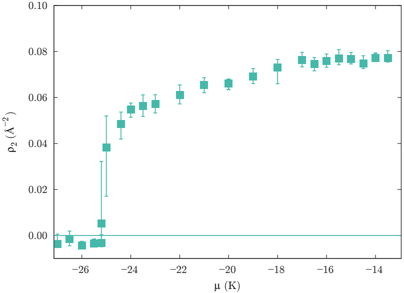
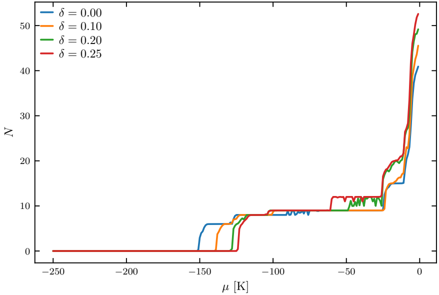
Layering





increasing δ pushes layering transition to larger μ



Happacher, J., Corboz, P., Boninsegni, M., and Pollet, L., Phys. Rev. B 87, 094514 (2013).

Preliminary Results - Superfluidity

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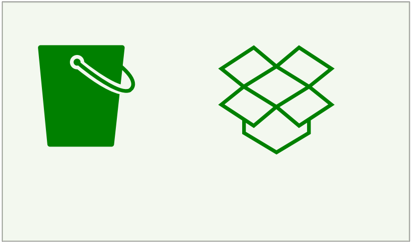


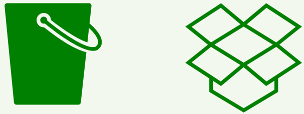
Preliminary Results - Superfluidity

$$\rho_s = \frac{m^2}{\hbar^2 \beta \Omega d}\left\langle \left(\sum_j L_j W_j \hat{r}_j \right)^2 \right\rangle$$

Pollock, E. L. and Ceperley, D. M., Phys. Rev. B 36, 8343 (1987).

Rousseau, V. G., Phys. Rev. B 90, 134503 (2014).

Preliminary Results - Superfluidity



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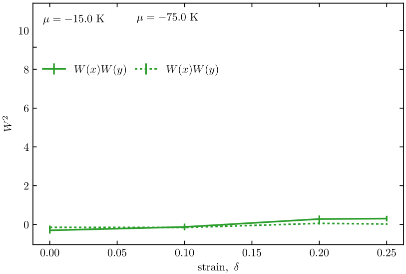

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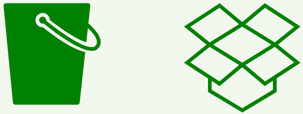

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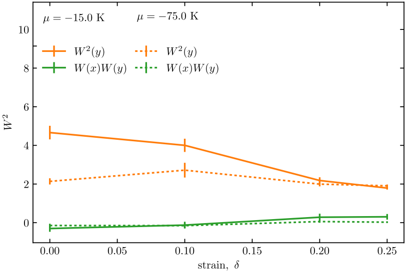

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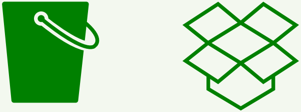

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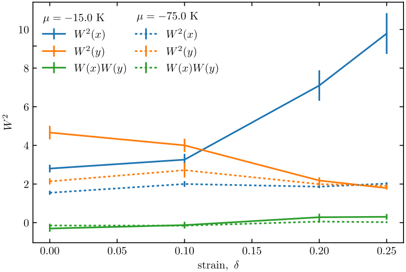

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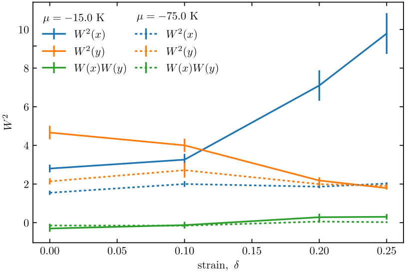

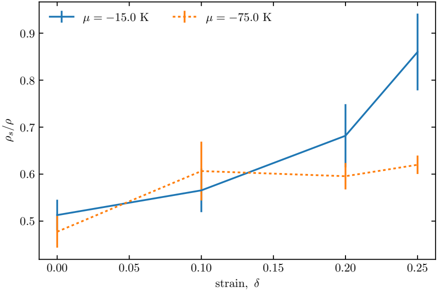

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Preliminary Results - Planar Density

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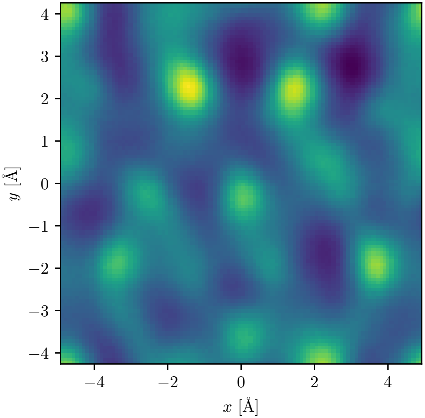
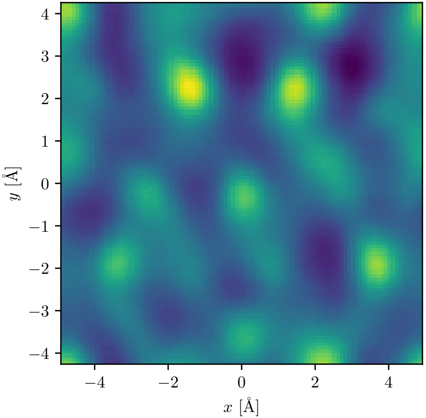
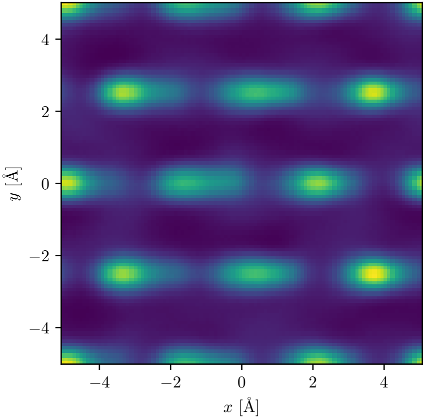


isotropic, $\delta = 0.00,\ \mu = -15$ K

Preliminary Results - Planar Density



isotropic, $\delta = 0.00,\ \mu = -15$ K

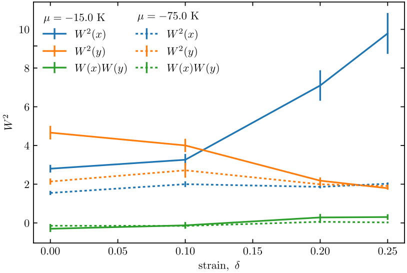


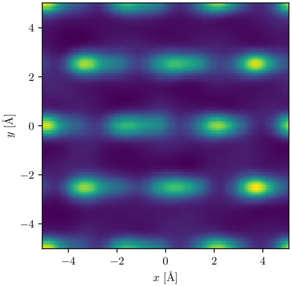
strained, $\delta = 0.25,\ \mu = -15$ K

Summary

The University of Vermont

straining graphene

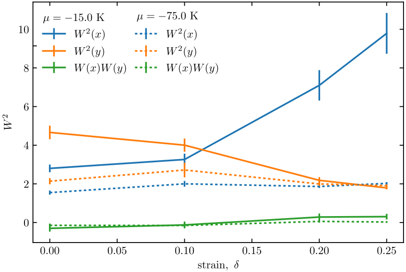


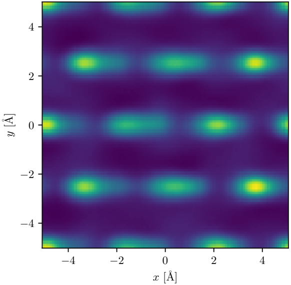


Summary

straining graphene

- pushes layering transistion to larger chemical potential

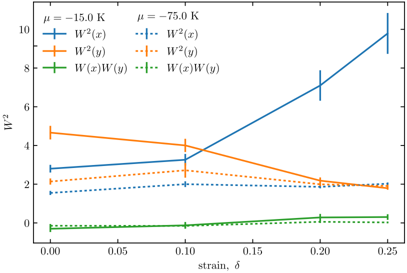


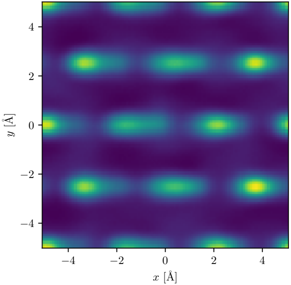


Summary

straining graphene

- pushes layering transistion to larger chemical potential
- increased superfluid response

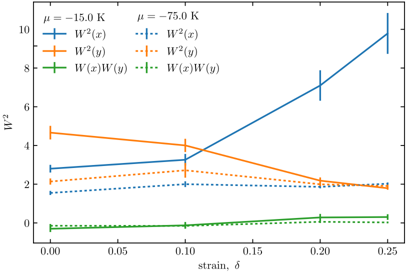


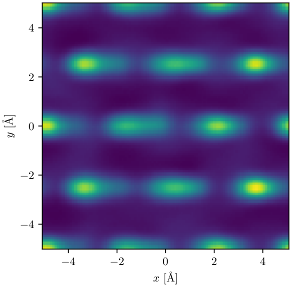


Summary

straining graphene

- pushes layering transistion to larger chemical potential
- increased superfluid response
- interesting planar density



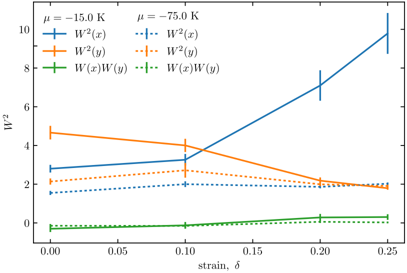


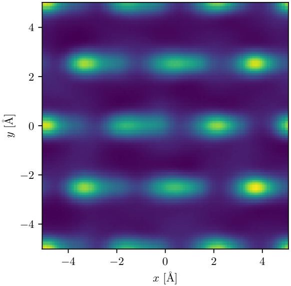
Summary

straining graphene

- pushes layering transistion to larger chemical potential
- increased superfluid response
- interesting planar density

future work





Summary

straining graphene

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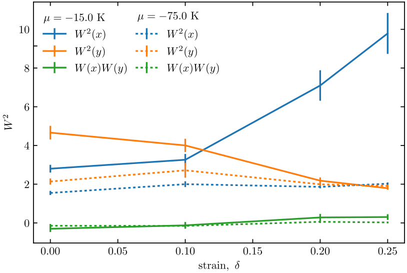
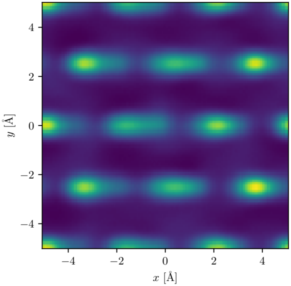
future work

- calculate structure factor





Summary

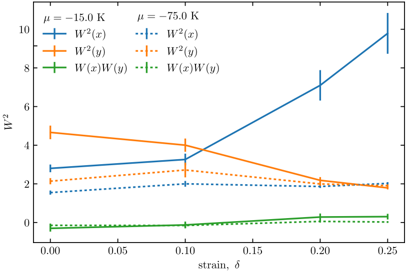
The University of Vermont

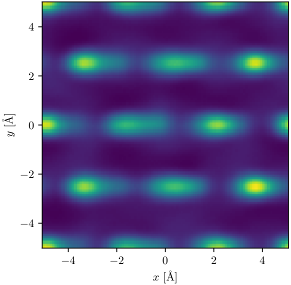
straining graphene

- pushes layering transistion to larger chemical potential
- increased superfluid response
- interesting planar density

future work

- calculate structure factor
- temperature scaling





Summary

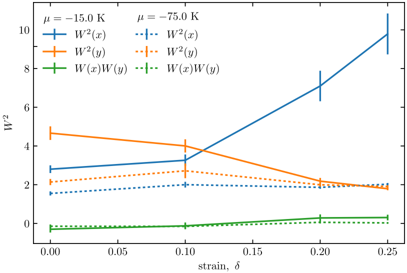
The University of Vermont

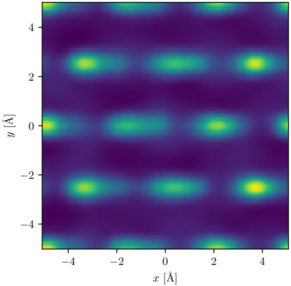
straining graphene

- pushes layering transistion to larger chemical potential
- increased superfluid response
- interesting planar density

future work

- calculate structure factor
- temperature scaling
- finite size scaling





Any Questions?

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