Topological Floquet engineering of twisted bilayer graphene

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Paris 2019

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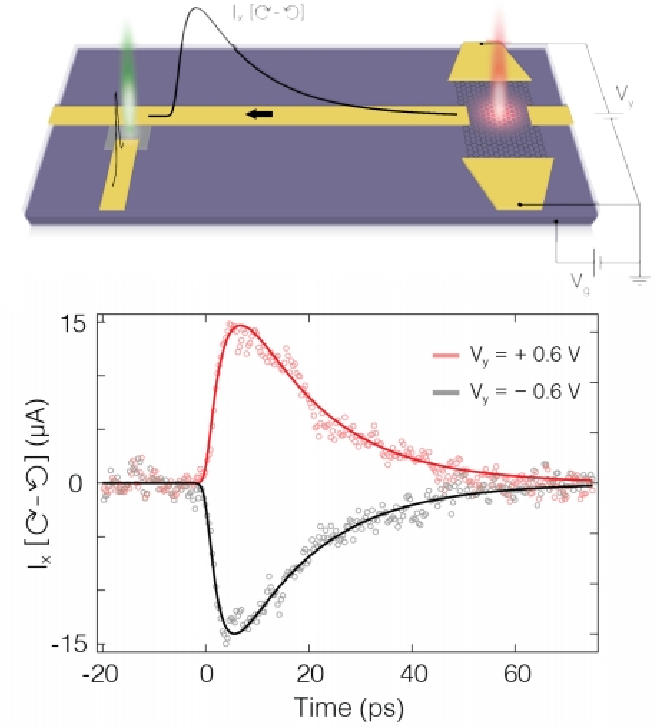
Struktur und Dynamik der Materie

Motivation: Light-induced anomalous Hall effect in graphene



McIver et al., arXiv:1811.03522 (2019)

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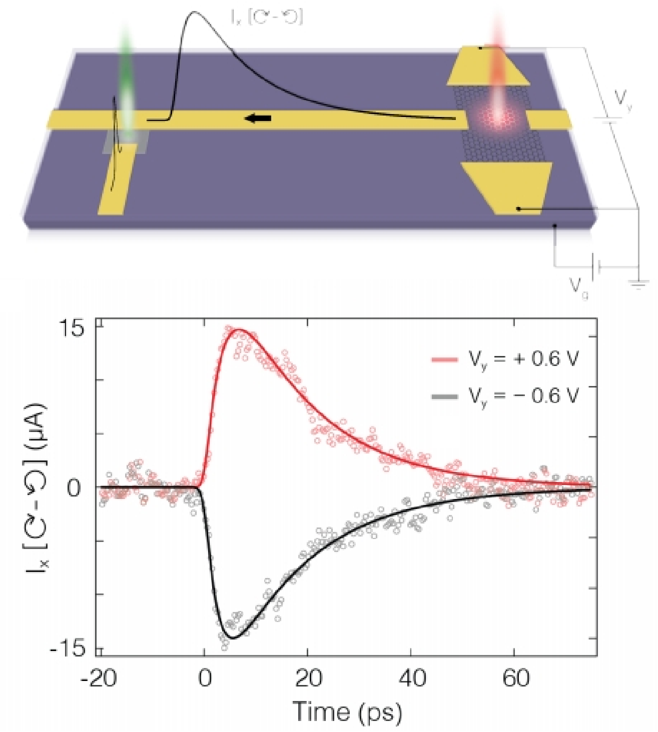

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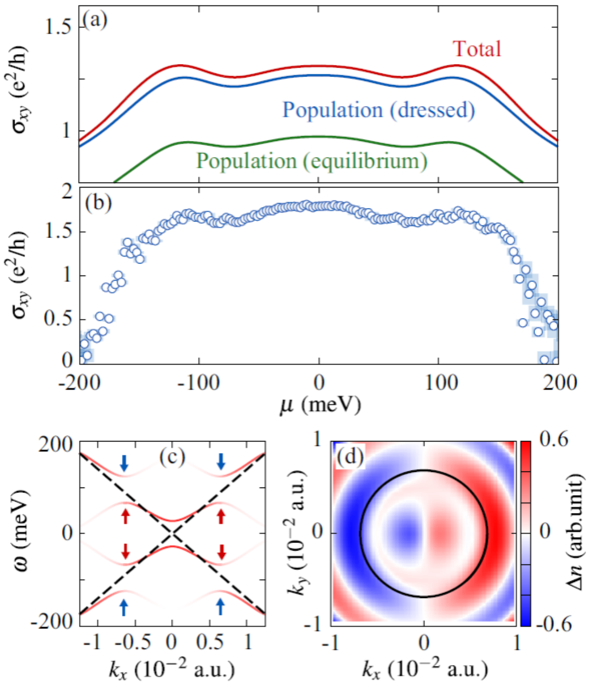

Sato et al., Phys. Rev. B 99, 214302 (2019)

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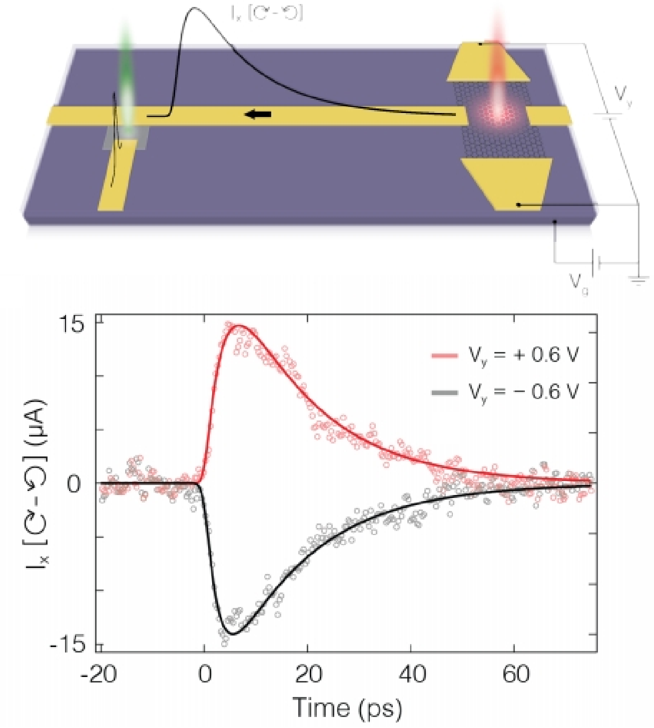

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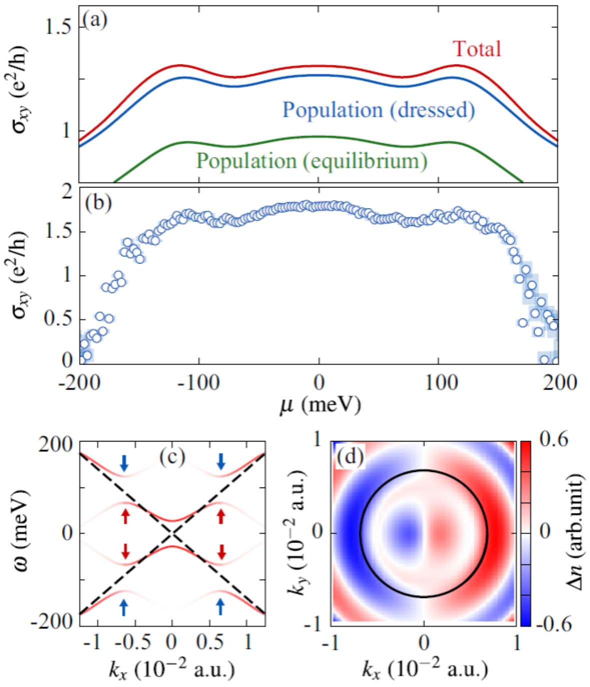

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- Can we tune the system in order to avoid heating and population effects?
- Can we control Floquet induced topology?

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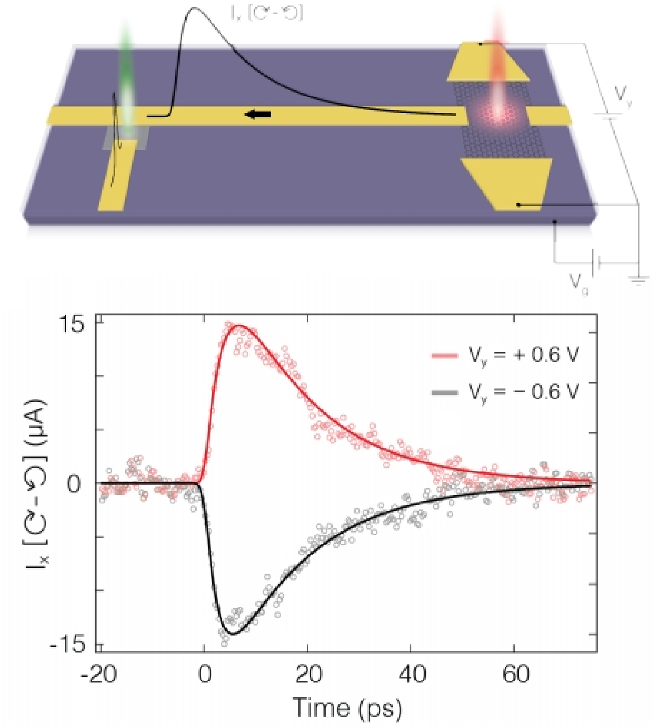

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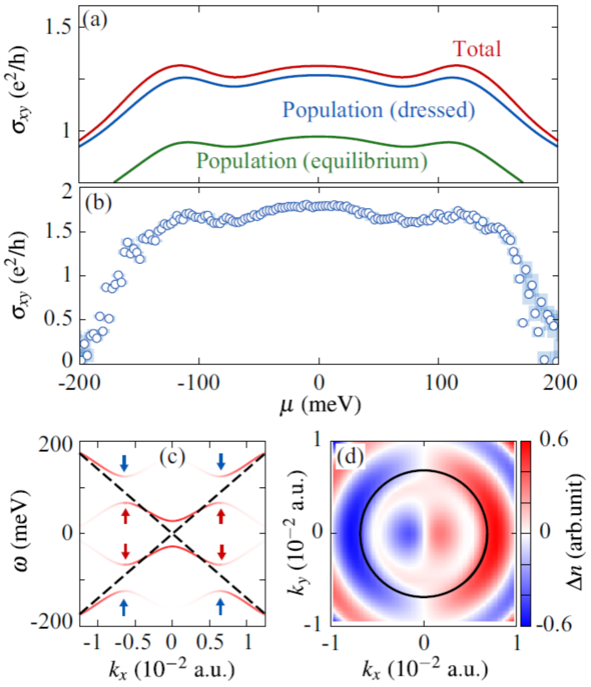

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- Can we tune the system in order to avoid heating and population effects?
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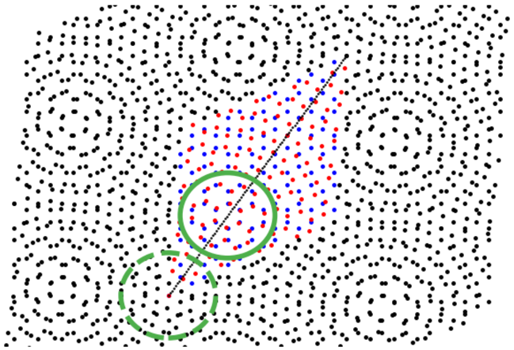
→ In twisted bilayer graphene we can!

Equilibrium band structure of twisted bilayer graphene

arXiv:1906.12135

(a)



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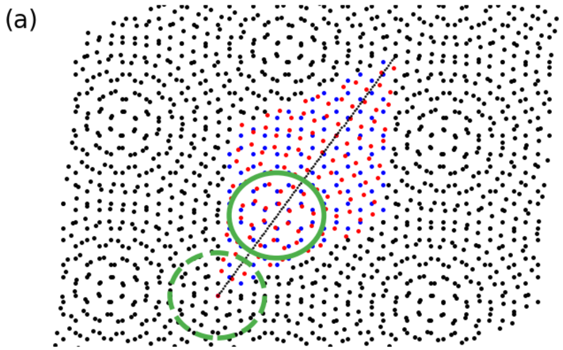

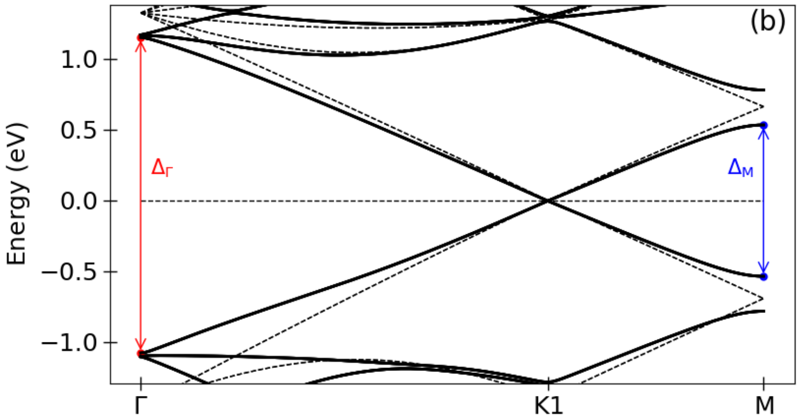

$$H = \sum_i \epsilon_i c_i^\dagger c_i + \sum_{i \neq j} t_{ij} c_i^\dagger c_j$$

$$t_{ij} = n^2 V_{pp\sigma}(r_{ij}) + (1 - n^2) V_{pp\pi}(r_{ij})$$

$$V_{pp\pi} = \gamma_0 \exp\left[q_\pi (1 - r_{ij}/a)\right]$$

$$V_{pp\sigma} = \gamma_1 \exp\left[q_\sigma (1 - r_{ij}/a_1)\right]$$

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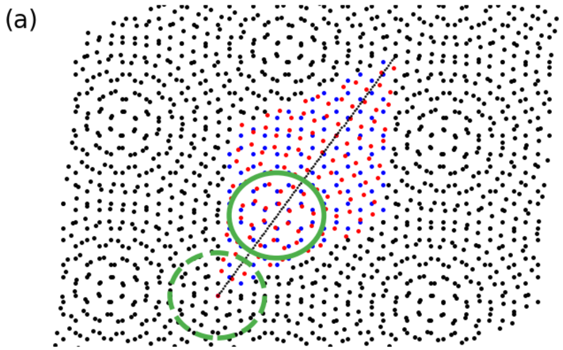

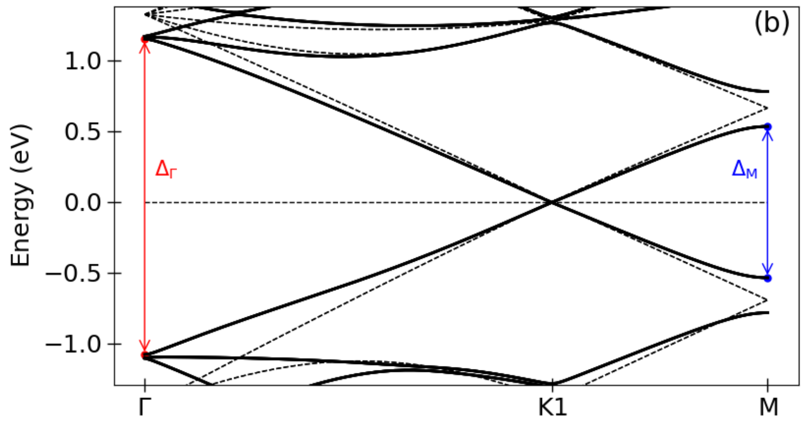

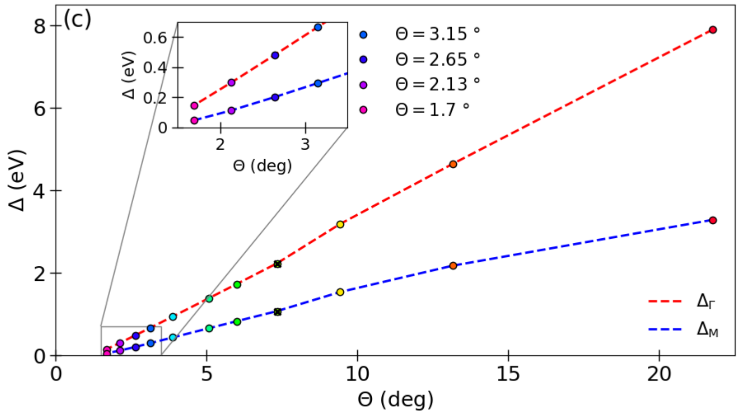

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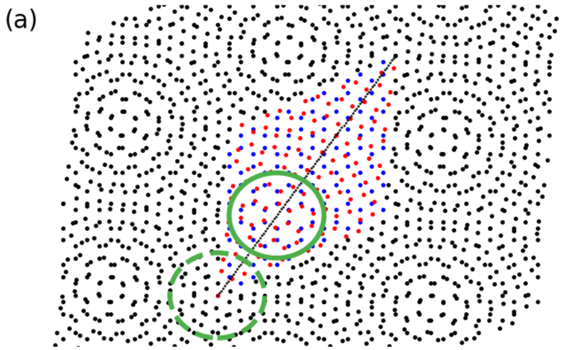

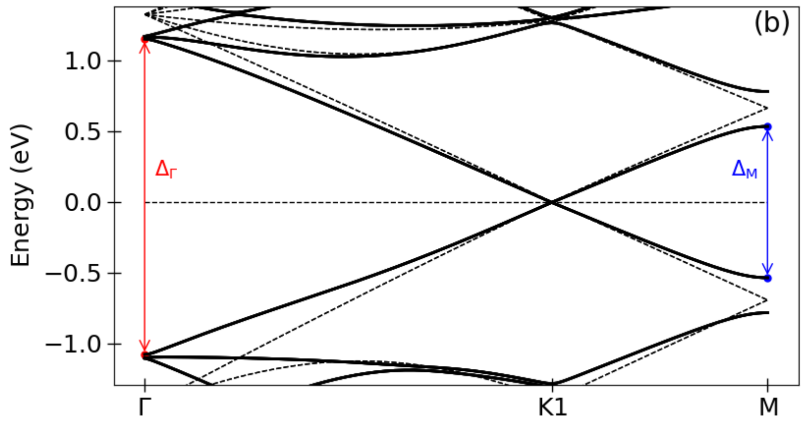

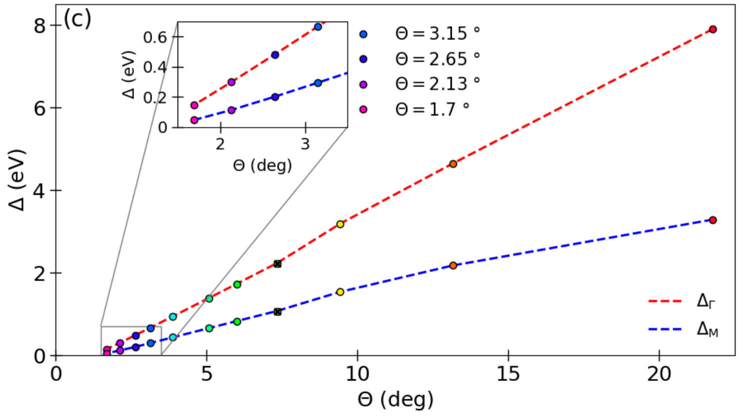

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➡ Band tunability offers optimal playground for Floquet topological engineering!

Equilibrium topology à la Haldane* $(\Theta = 7.34°)$

*Phys. Rev. Lett. 61, 18 (1988)

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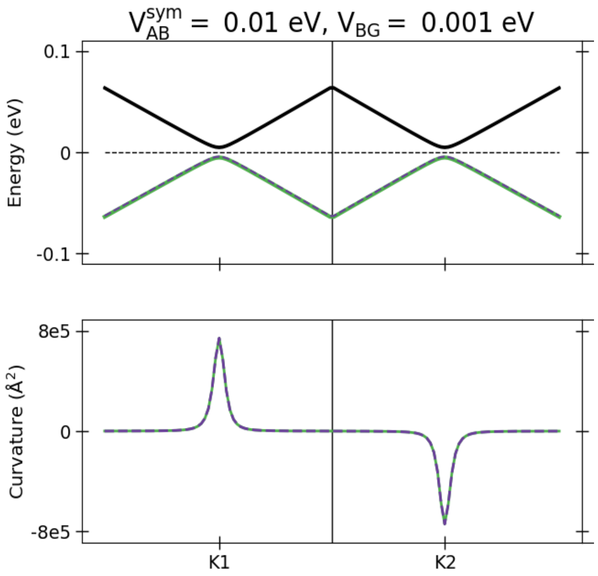

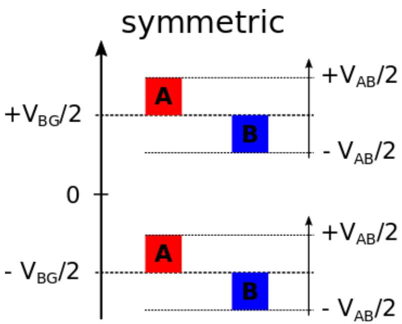

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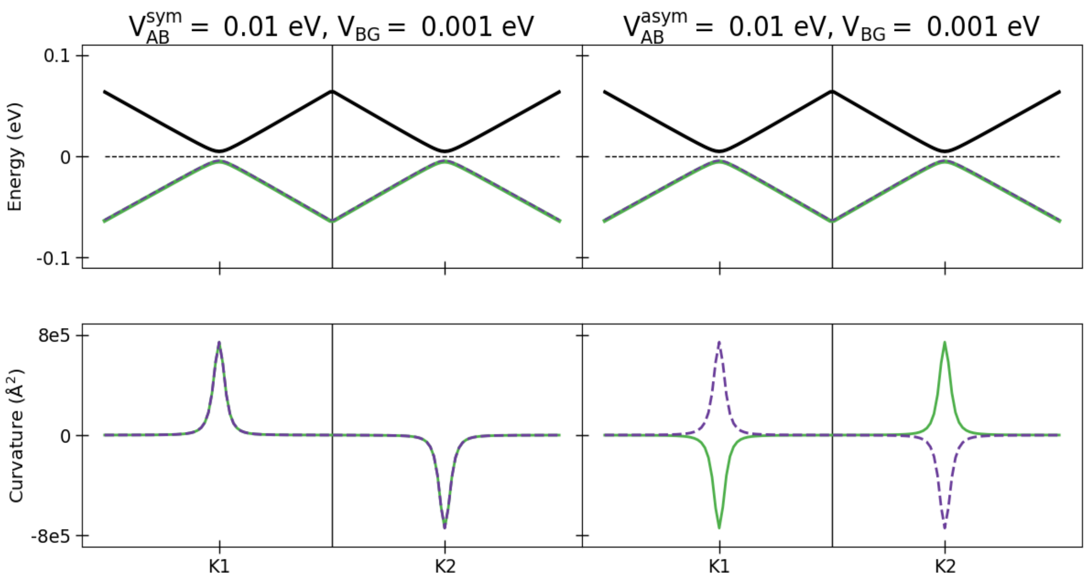

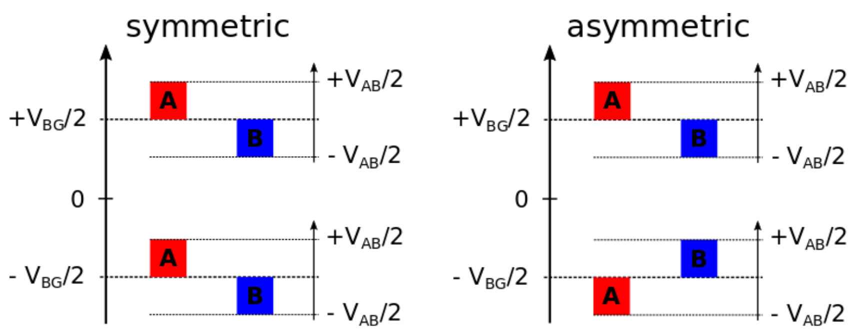

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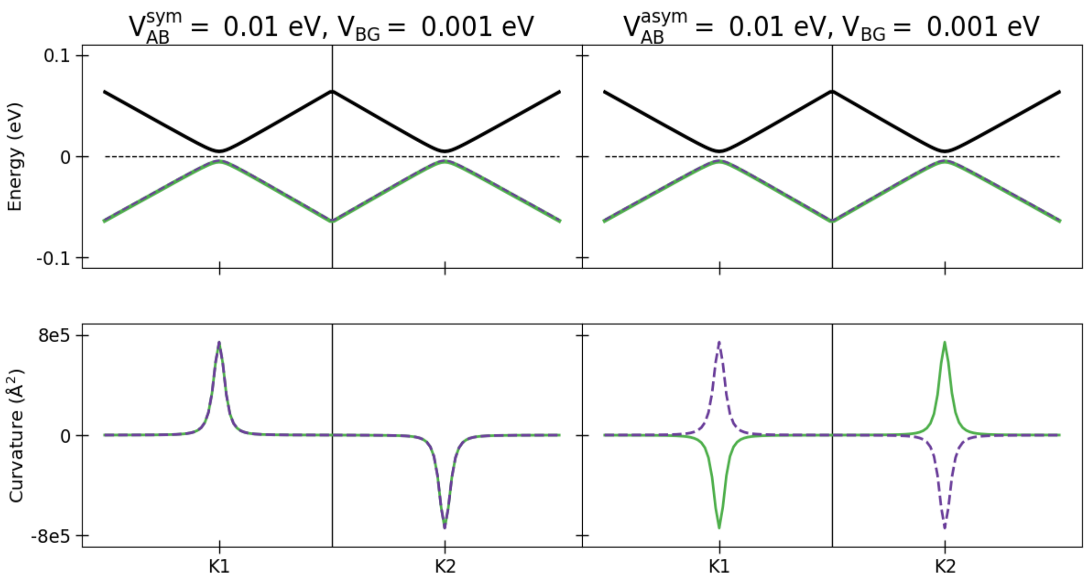

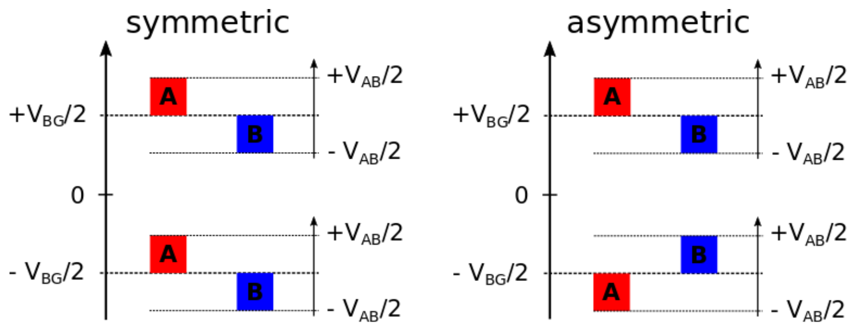

Valley Berry curvature can be tuned by sublattice potential

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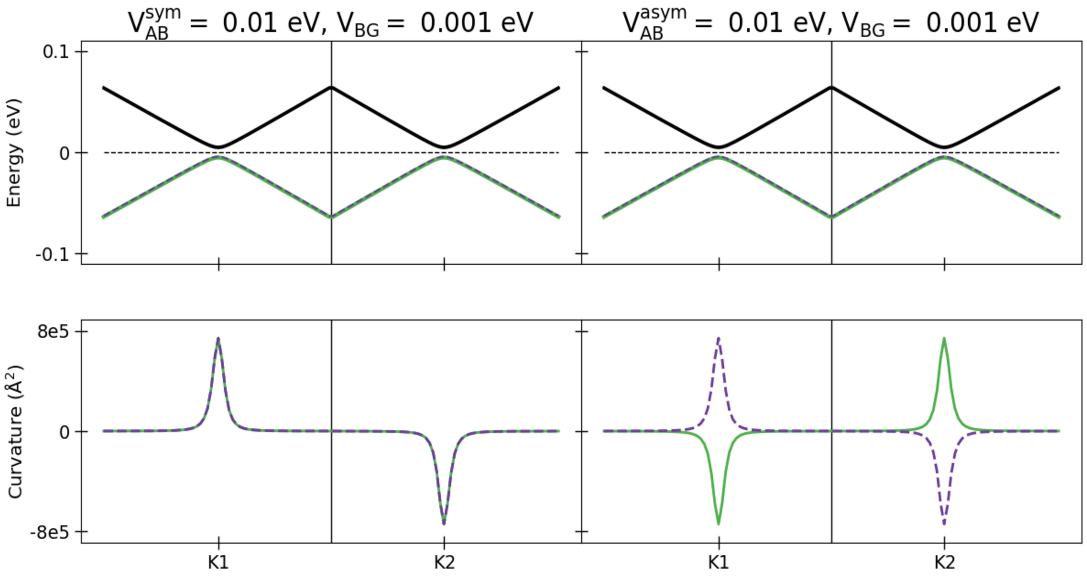

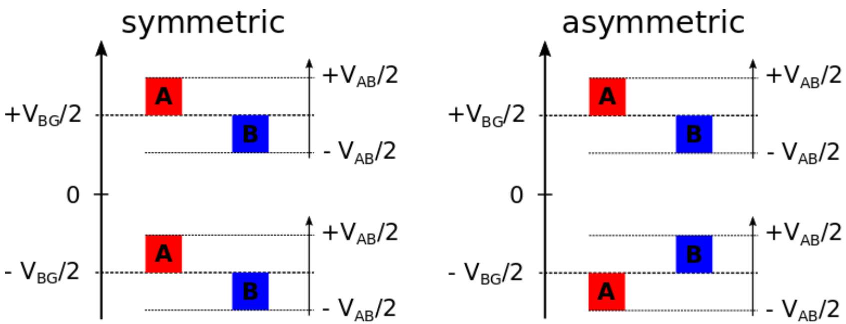

- Valley Berry curvature can be tuned by sublattice potential
- Zero integrated Berry curvature in undriven TBG above the magic-angle regime

Floquet band structure $(\Theta = 7.34°)$

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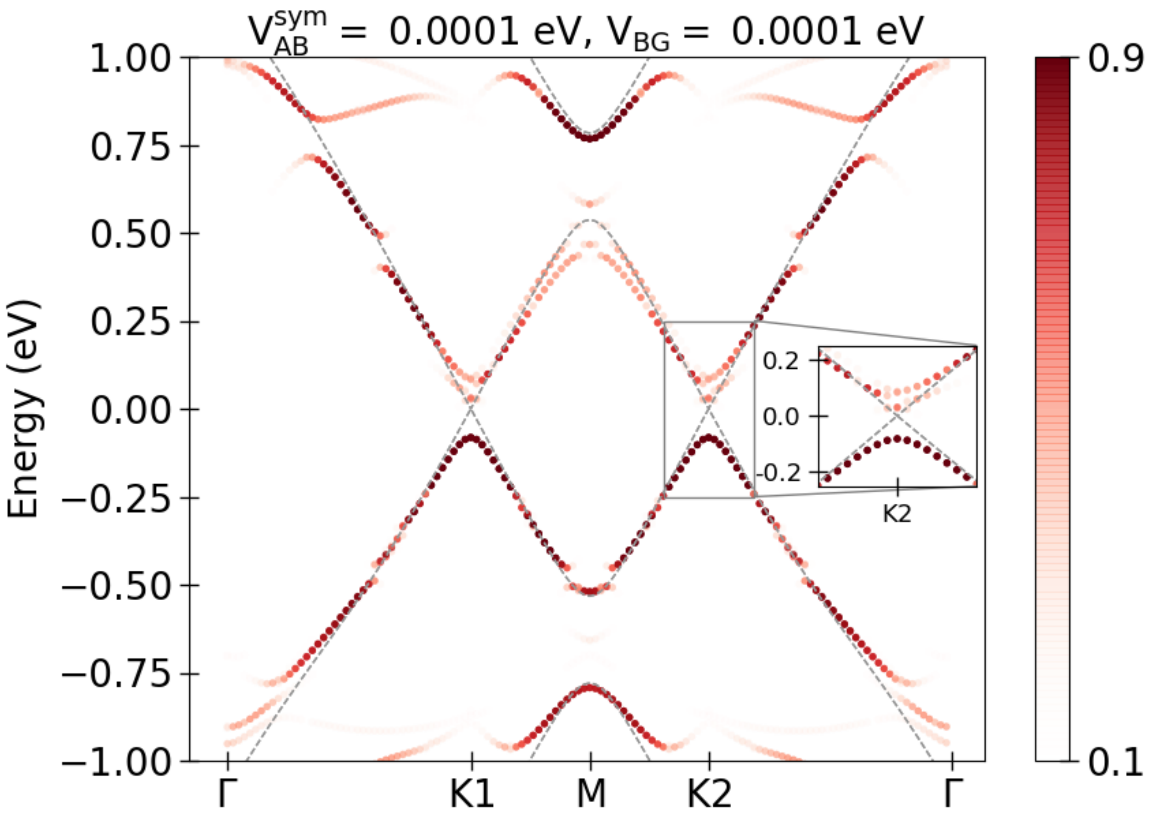

- Γ-resonant circularly driving field
- Peierls substitution: $t_{ij} \rightarrow t_{ij} e^{i \boldsymbol{A}(t) \boldsymbol{r}_{ij}}$
- $H^{mn} = T^{-1} \int_T dt\, e^{i(m-n)\Omega t} H(t) + \delta_{mn} m \Omega$
- Color indicates bare-band overlap

➡ Gap opening at Dirac points due to broken TRS

Topological Floquet engineering $(\Theta = 7.34°)$

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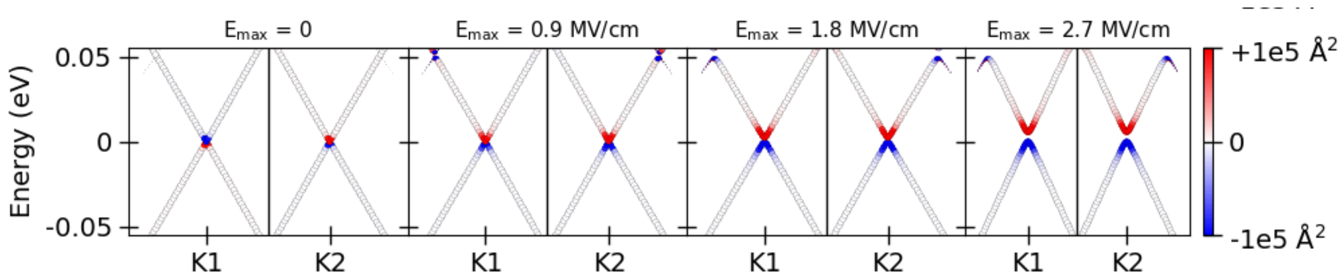

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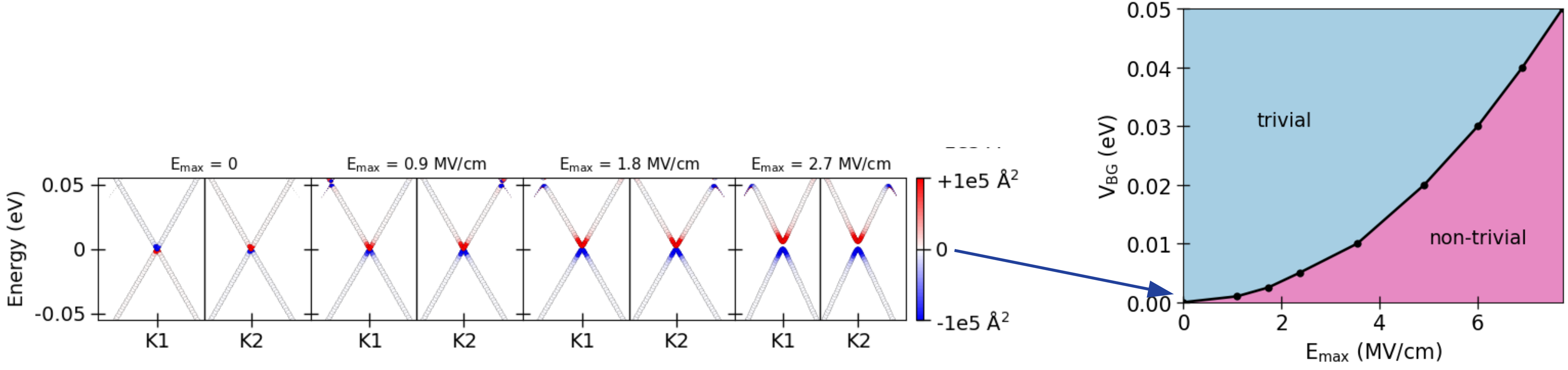

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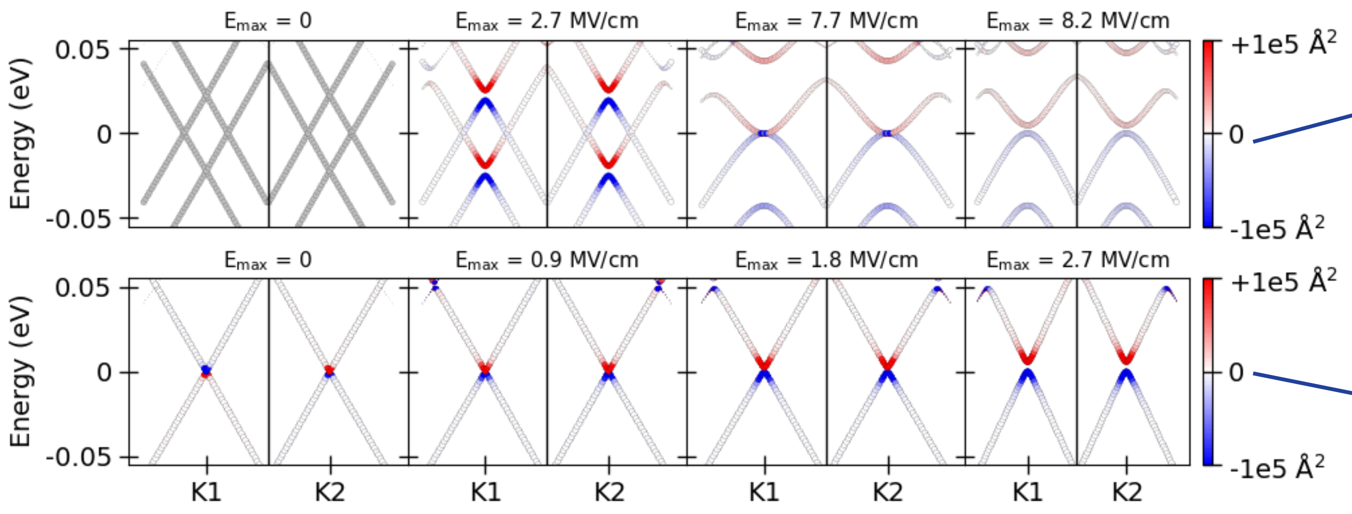

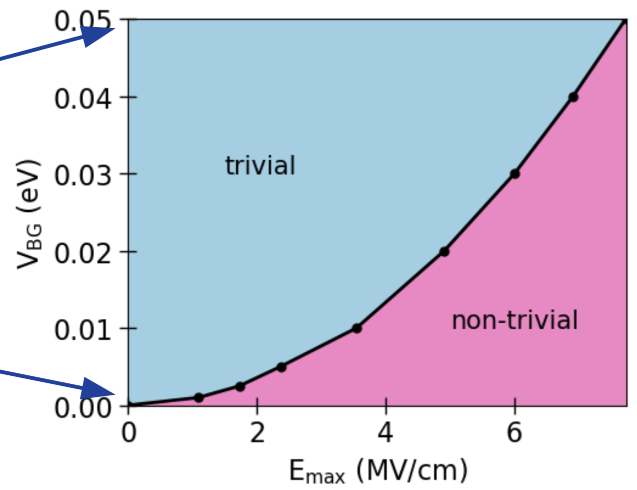

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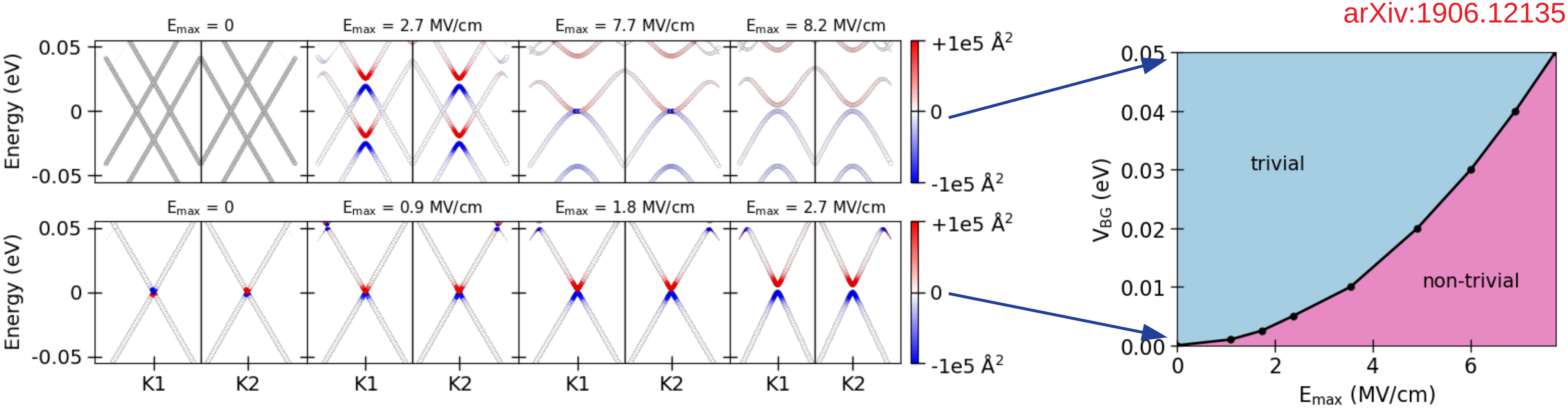
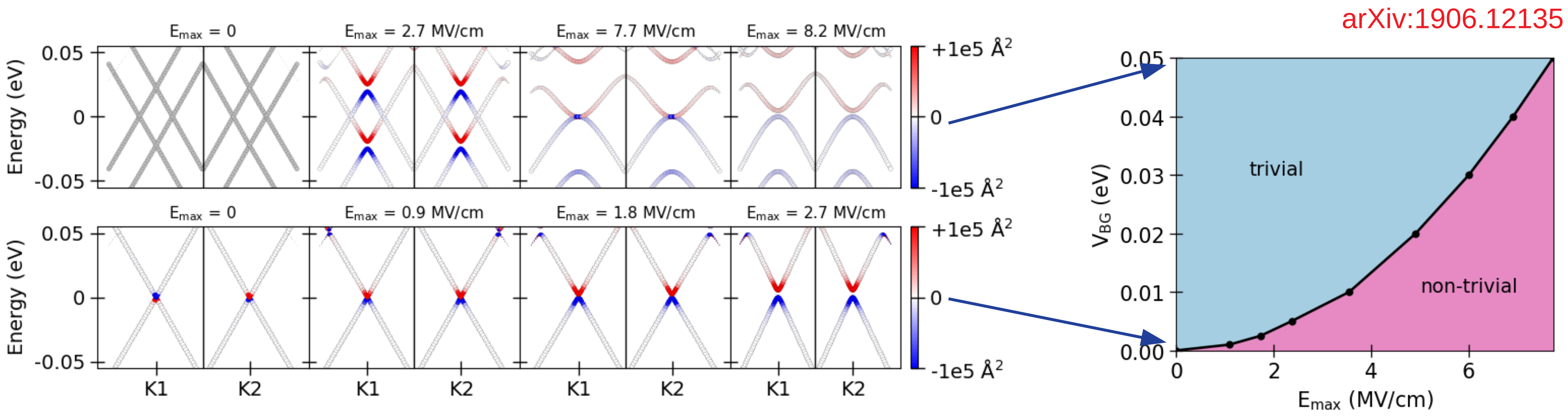


Back-gate potential leads to topological phase transition at critical field strength

Topological Floquet engineering ($\Theta = 7.34°$)



- Back-gate potential leads to topological phase transition at critical field strength
- Effective winding number analogous to Chern insulator (C= 4)

Gap scaling with field and twisting angle

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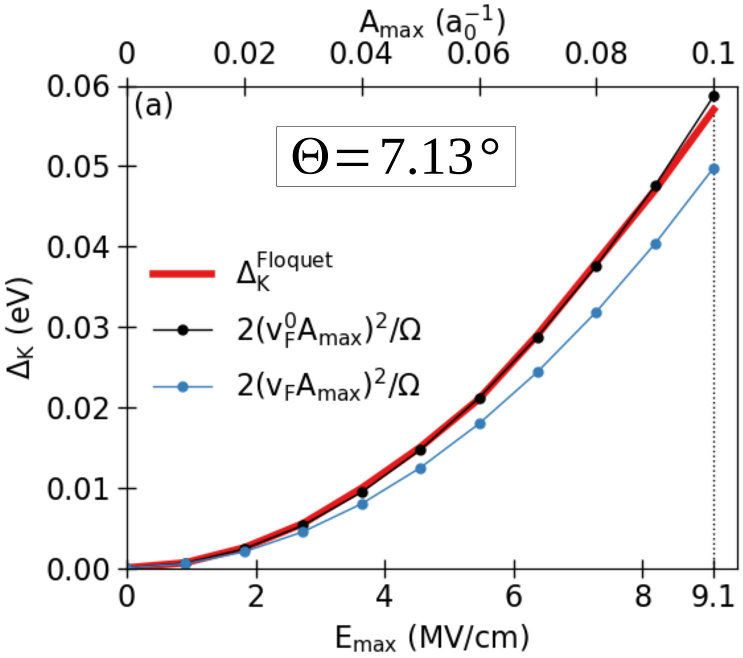

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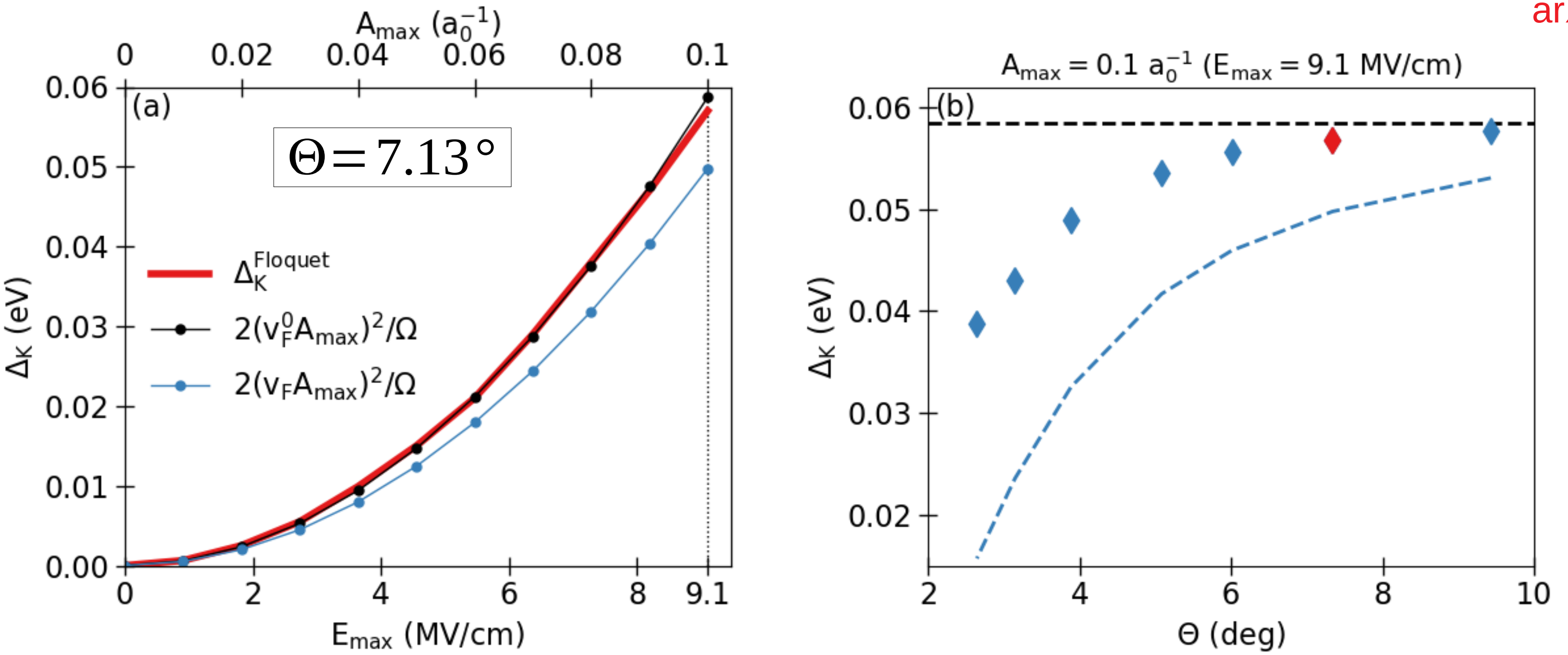

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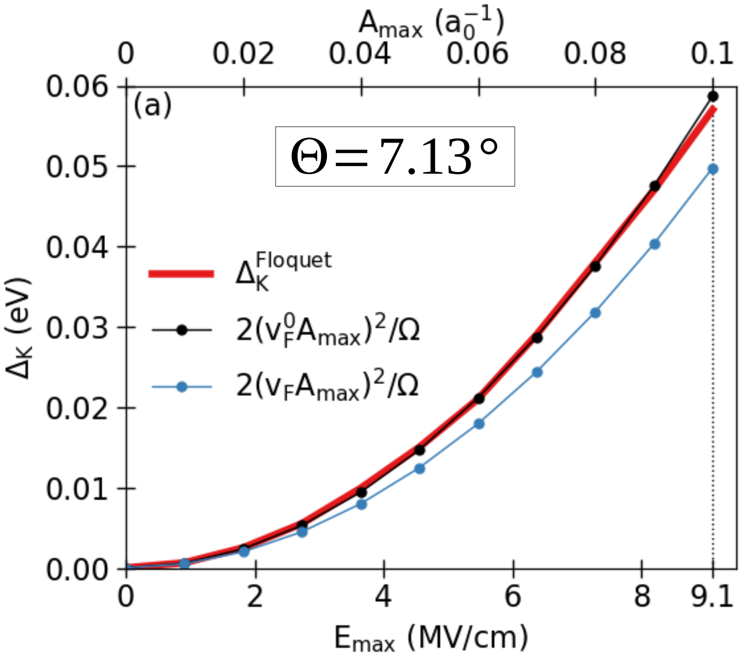

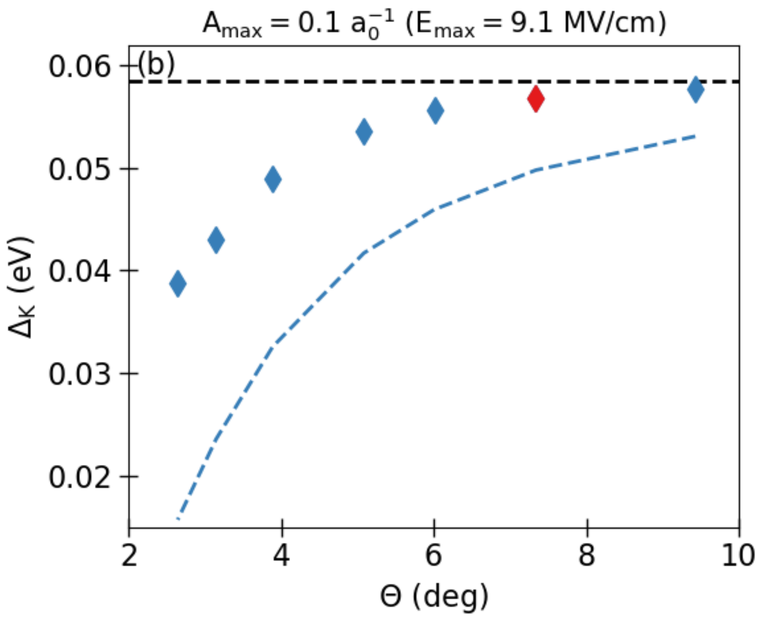

Light-induced gap larger than naive expectation from renormalized Fermi velocity

Gap scaling with field and twisting angle

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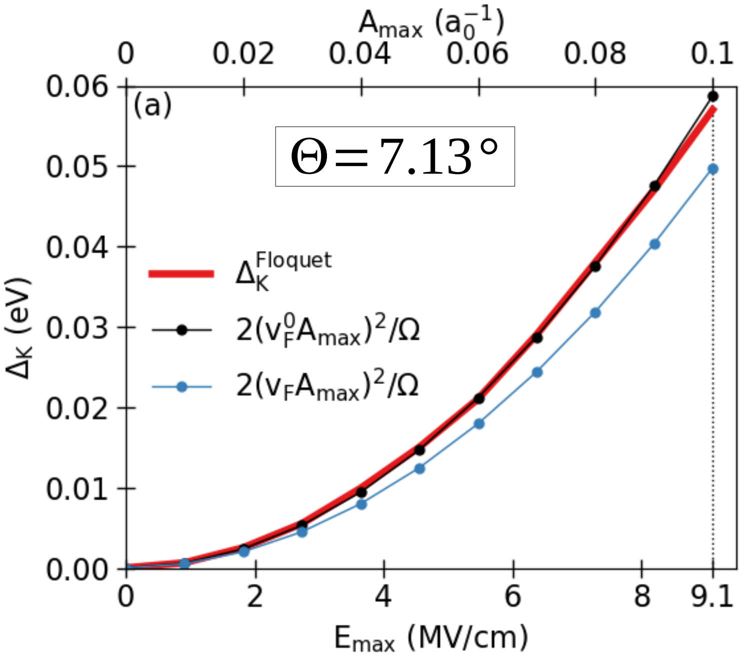
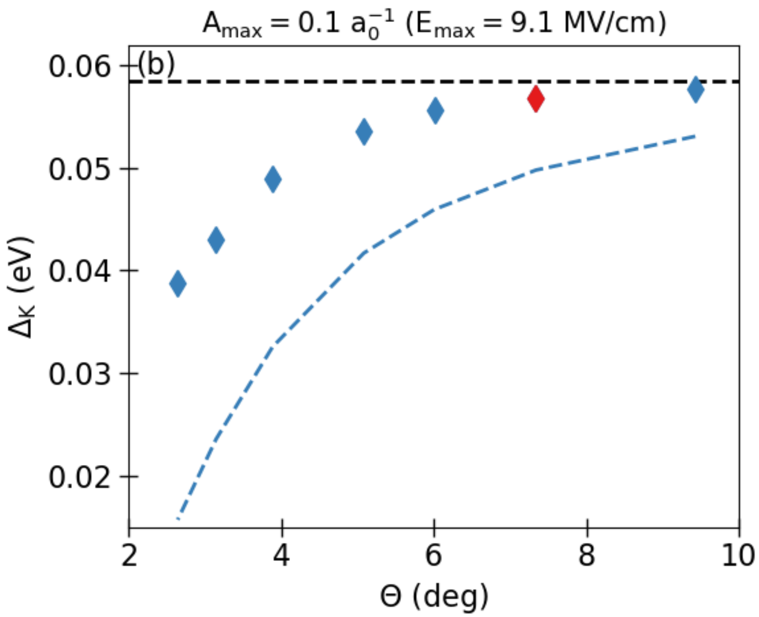
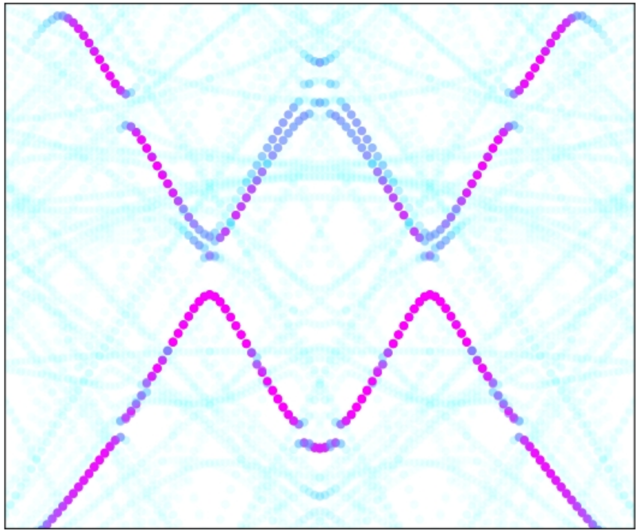




- Light-induced gap larger than naive expectation from renormalized Fermi velocity
- Might play a role when approaching magic angle

Conclusion



A promising combination of twistronics and Floquet topological engineering:

Topp et al., arXiv:1906.12135 (to appear in Phys. Rev. Research)

Work in progress: real-time dynamics w/ dissipation

Looking for a postdoc position :)

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