

Charge pumping driven by a moving kink in graphene nanoribbon

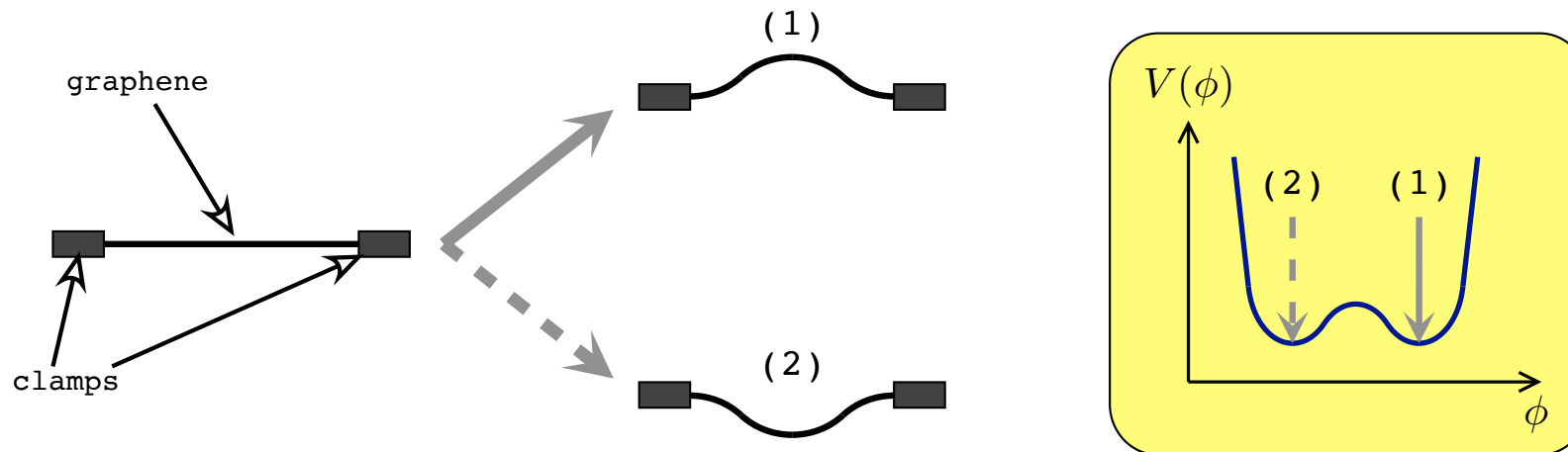
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<https://doi.org/10.1103/PhysRevB.102.165408>

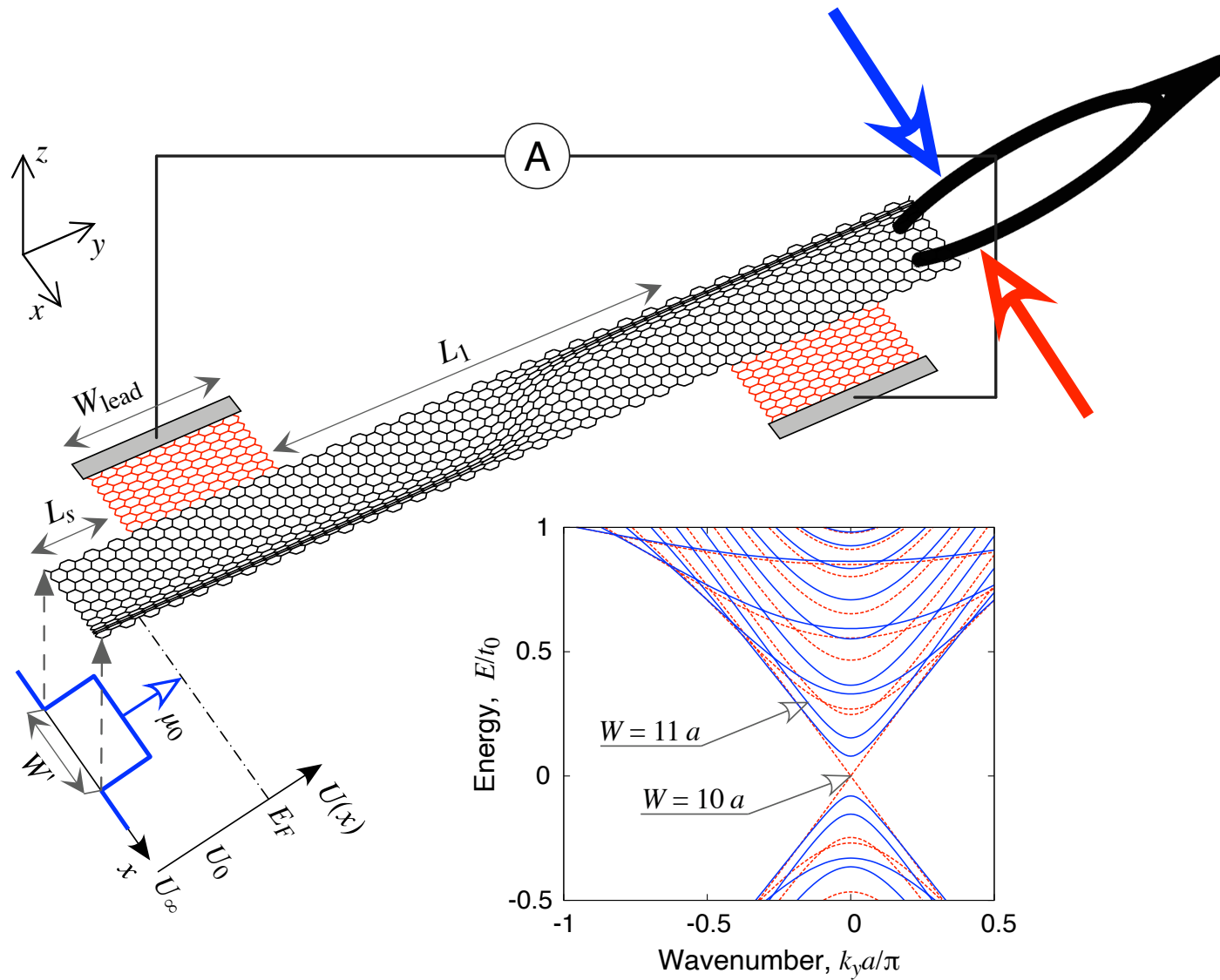
PRELIMINARIES: The ϕ^4 model in graphene



\implies Bending graphene strip (or *nanoribbon*) results in 2 different vacuum states; a domain wall (*kink*) moves along the strip

Further reading: R. D. Yamaletdinov, T. Romańczukiewicz, and Y. V. Pershin, *Manipulating graphene kinks through positive and negative radiation pressure effects*, Carbon **141**, 253 (2019). <https://doi.org/10.1016/j.carbon.2018.09.032>

The setup studied numerically



Model and methods (1/2)

Modified Su-Schrieffer-Heeger (SSH) model for graphene:

$$\mathcal{H}_{\text{SSH}} = T + V_{\text{bonds}} + V_{\text{angles}},$$

where

$$T = -t_0 \sum_{\langle ij \rangle, s} e^{-\beta \delta d_{ij}/d_0} \left(c_{i,s}^\dagger c_{j,s} + c_{j,s}^\dagger c_{i,s} \right),$$

$$V_{\text{bonds}} = \frac{1}{2} K_d \sum_{\langle ij \rangle} \left(d_{ij} - d_0 \right)^2,$$

$$V_{\text{angles}} = \frac{1}{2} K_\theta \sum_j \sum_{\Delta(j)} \left(\theta_{\Delta(j)} - \theta_0 \right)^2 + V_\delta \sum_j \left(2\pi - \sum_{\Delta(j)} \theta_{\Delta(j)} \right),$$

with a constrain: $\sum_{\langle ij \rangle} d_{ij} = \text{const.}$

Model and methods (2/2)

Landauer-Büttiker conductance:

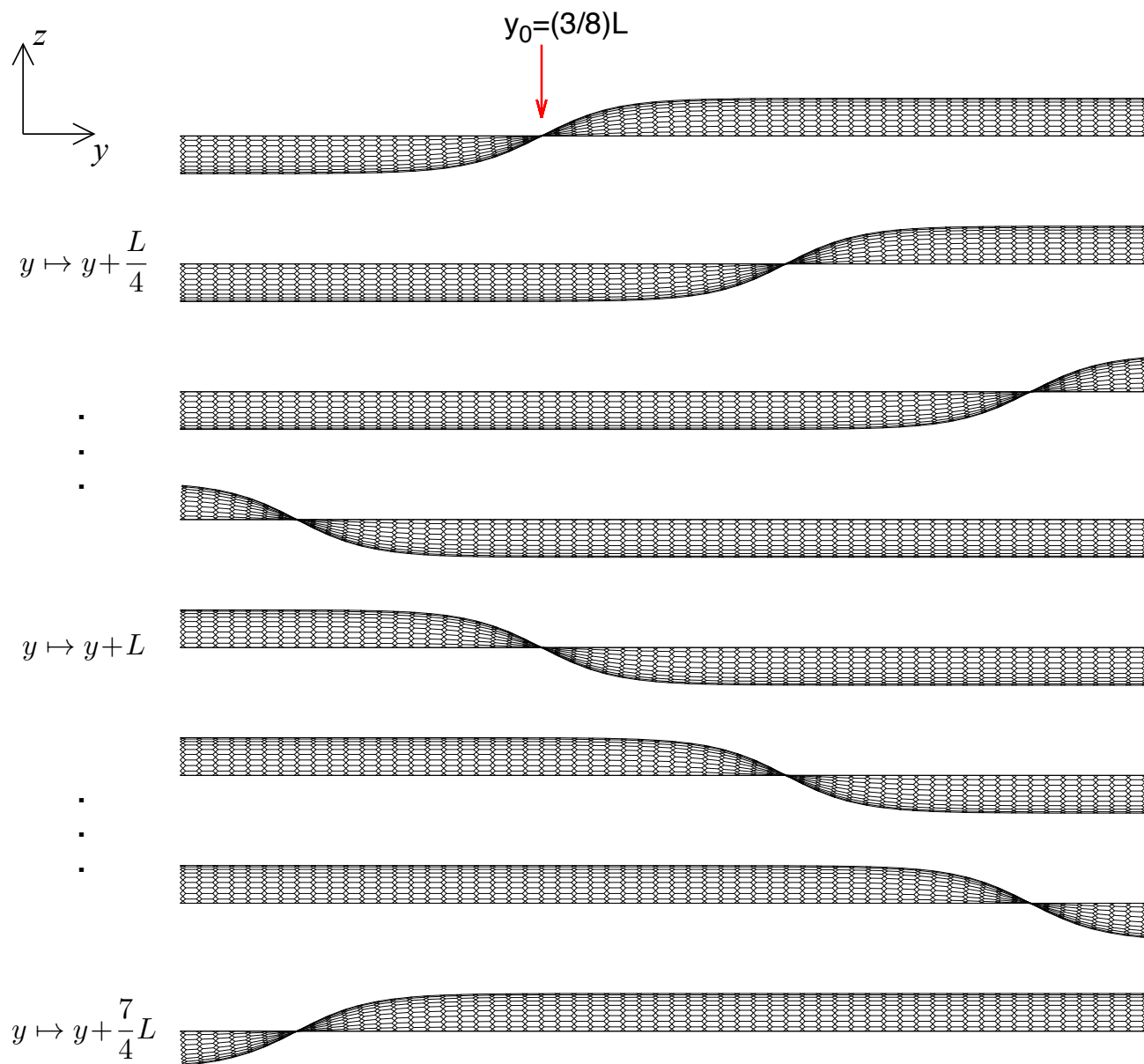
$$G = G_0 \text{Tr} \, tt^\dagger = \frac{2e^2}{h} \sum_n T_n,$$

where $G_0 = 2e^2/h$ (the conductance quantum), and T_n is the transmission probability for the n -th normal mode.

Charge pumped by kink:

$$\Delta Q = -\frac{ie}{2\pi} \sum_j \int dy_0 \left(\frac{\partial S}{\partial y_0} S^\dagger \right)_{jj},$$

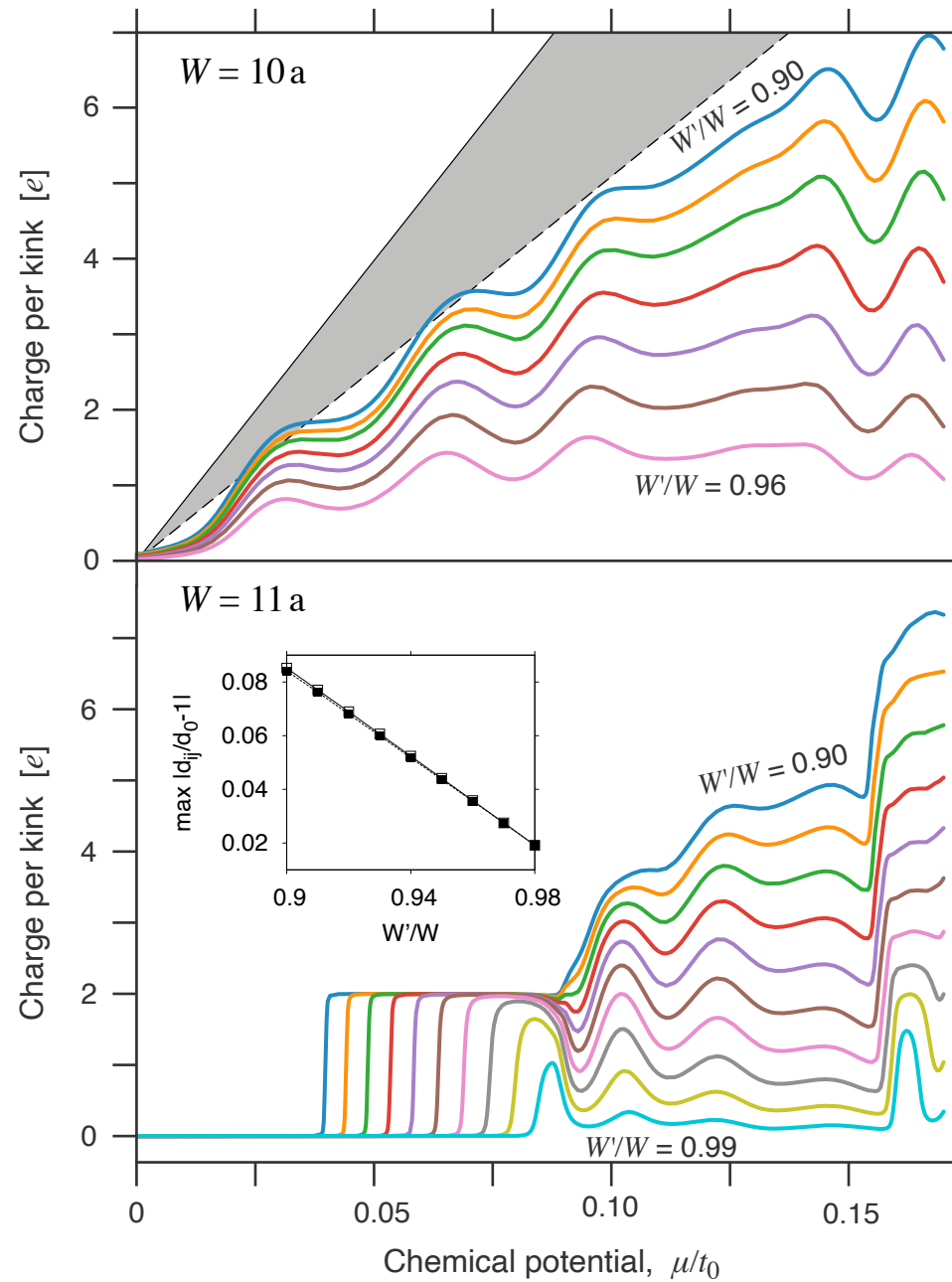
with j — the mode in *output* lead, and y_0 — the kink position.



Main results

*metallic
ribbon* \Rightarrow

*semiconducting
ribbon* \Rightarrow



Summary

Metallic ribbon: For moderate bucklings (with relative bond distortions $< 10\%$) the kink suppresses the current flow, and shifts the electric charge when moving between the leads.

\implies *The charge per cycle is not quantized.*

Semiconducting ribbon: States localized near the kink (with energies lying within the gap) can be utilized to transport a quantized charge of $2e$ per kink transition.

\implies *A candidate for the quantum standard ampere occurs.*

Acknowledgments

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Literature

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