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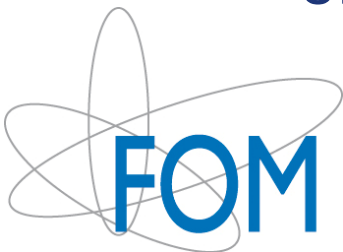
physics  
 of  
 nanodevices



# Graphene: High-energy physics in a solid-state nano-system

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 University of Groningen (RuG), The Netherlands



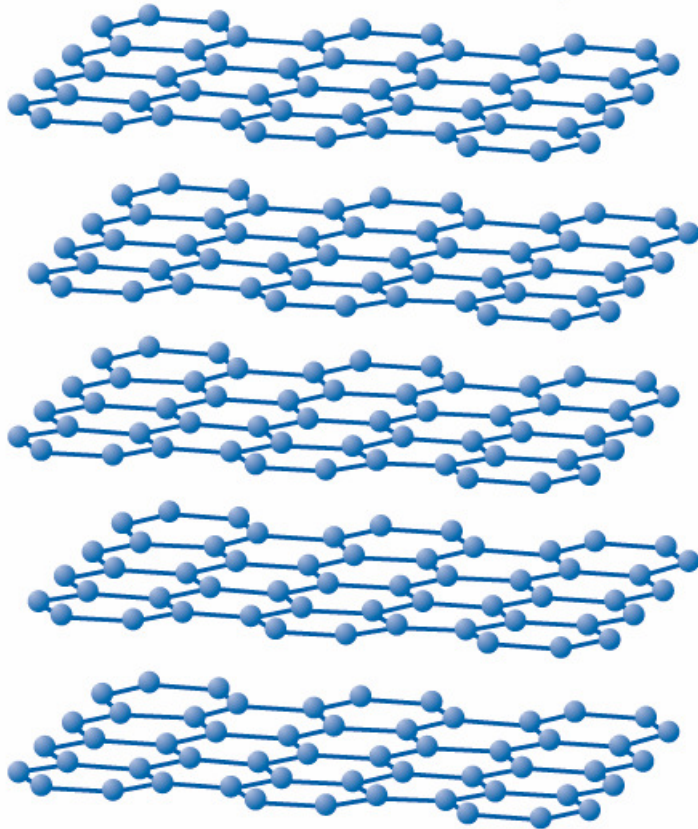
University of Groningen  
 **Zernike Institute**  
 for Advanced Materials

- **What is graphene?**
- **Electronic properties of graphene**
- **Klein tunnelling**
- **Pseudo-magnetic fields**
- **Conclusions**

# What is graphene?

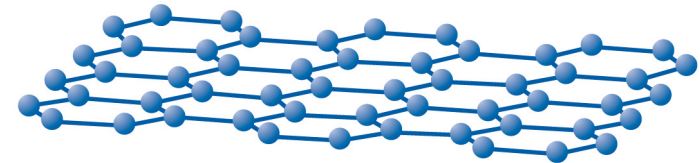
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## Graphite



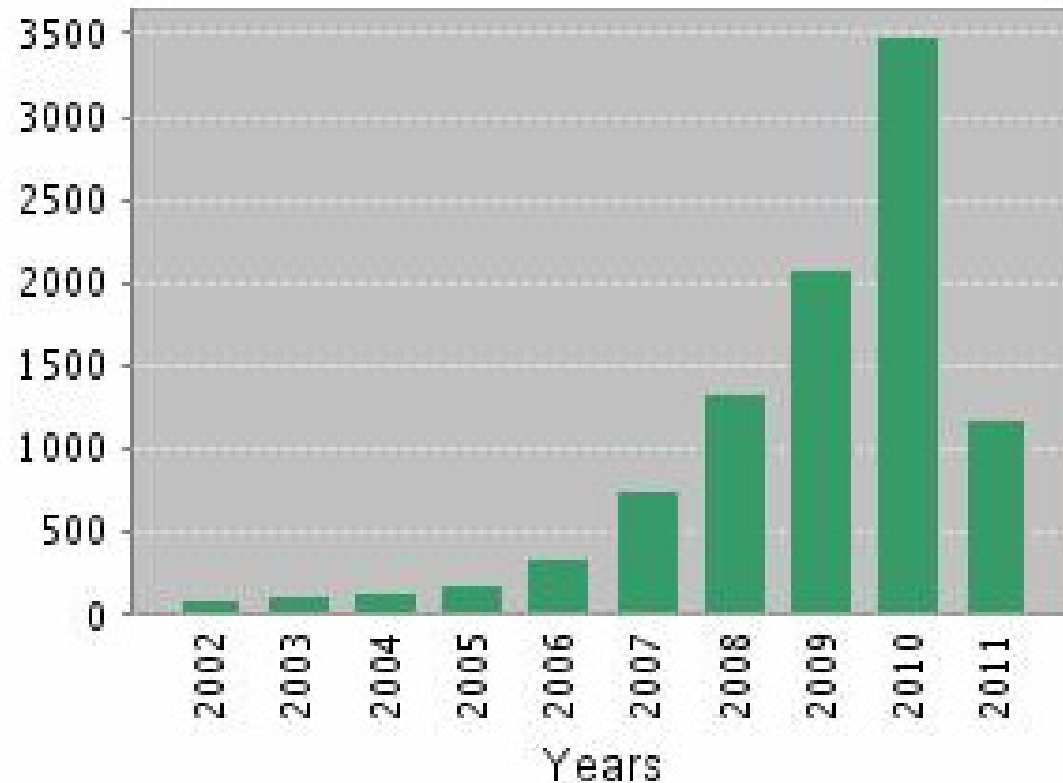
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## Graphene



# What is graphene?

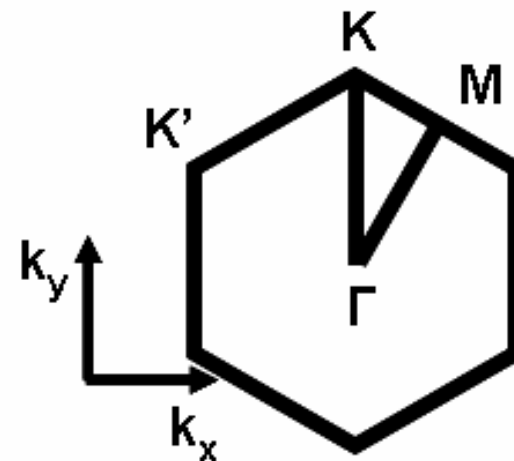
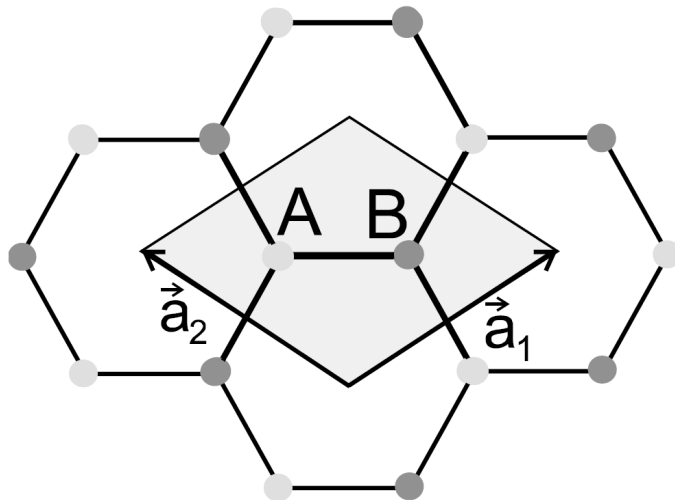
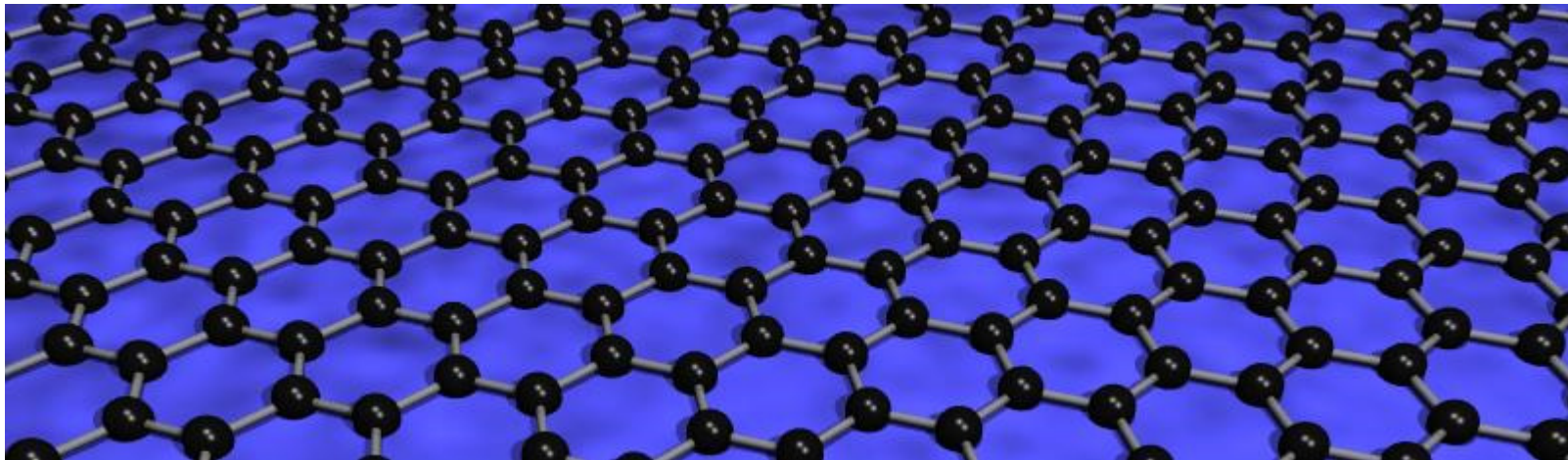
## Published Items in Each Year



From: Web of Science (<http://apps.isiknowledge.com/>)

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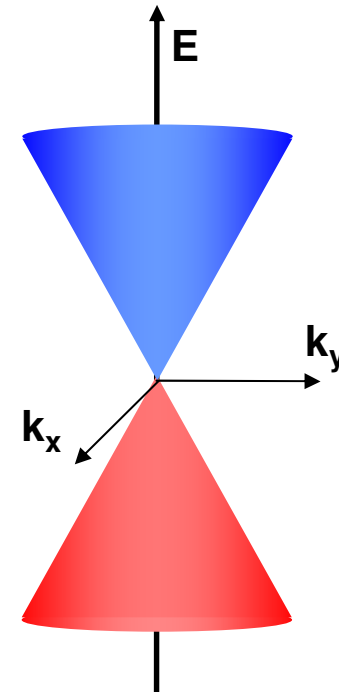
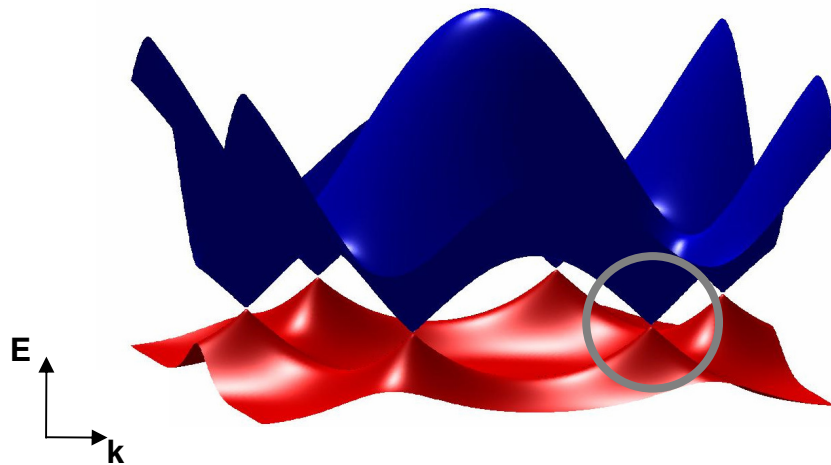
# What is graphene?



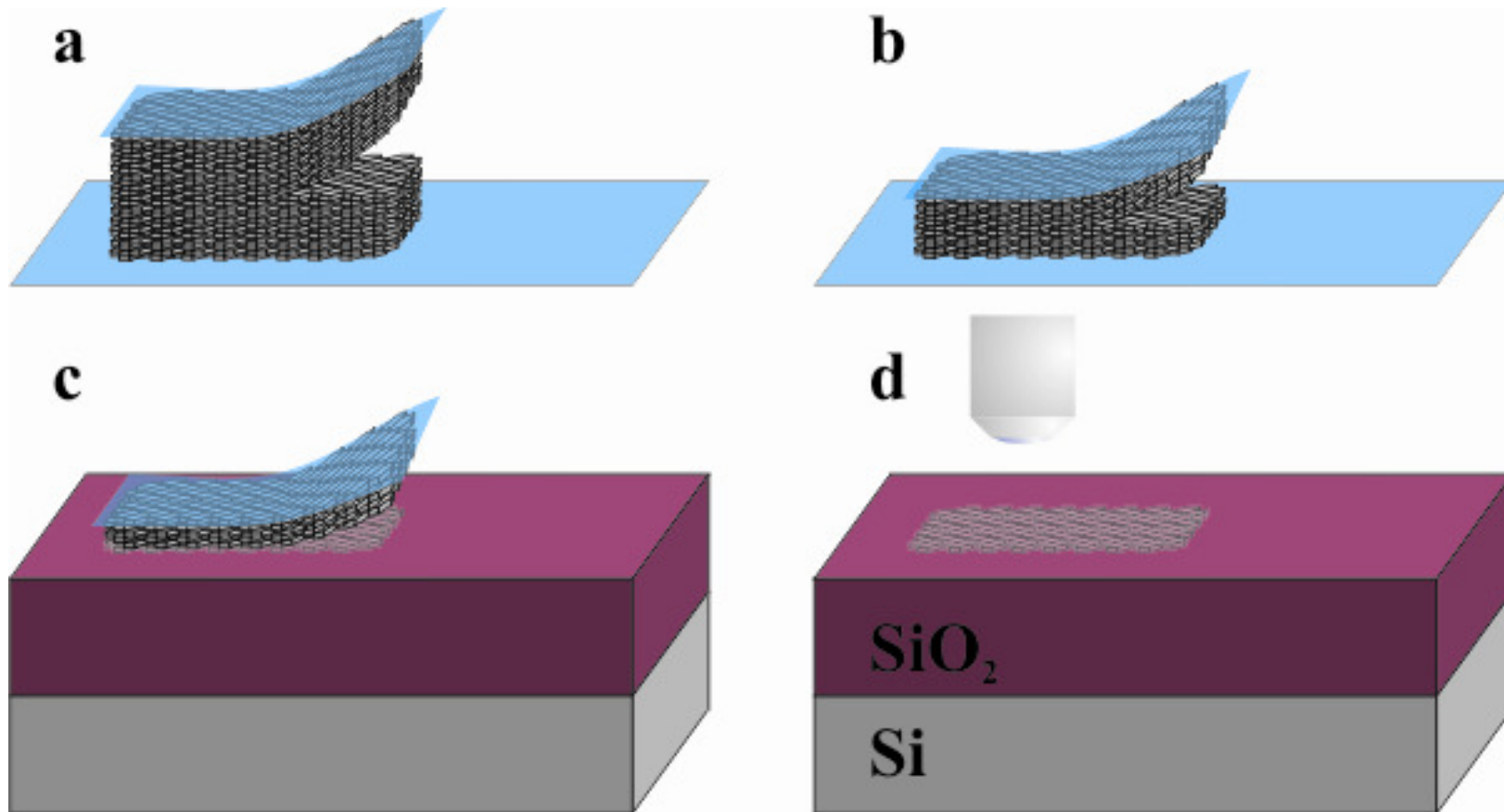
$$\hat{H} = \hbar v_F \begin{pmatrix} 0 & k_x - ik_y \\ k_x + ik_y & 0 \end{pmatrix} = \hbar v_F \boldsymbol{\sigma} \cdot \mathbf{k}$$

$$E = \pm v_F \hbar k$$

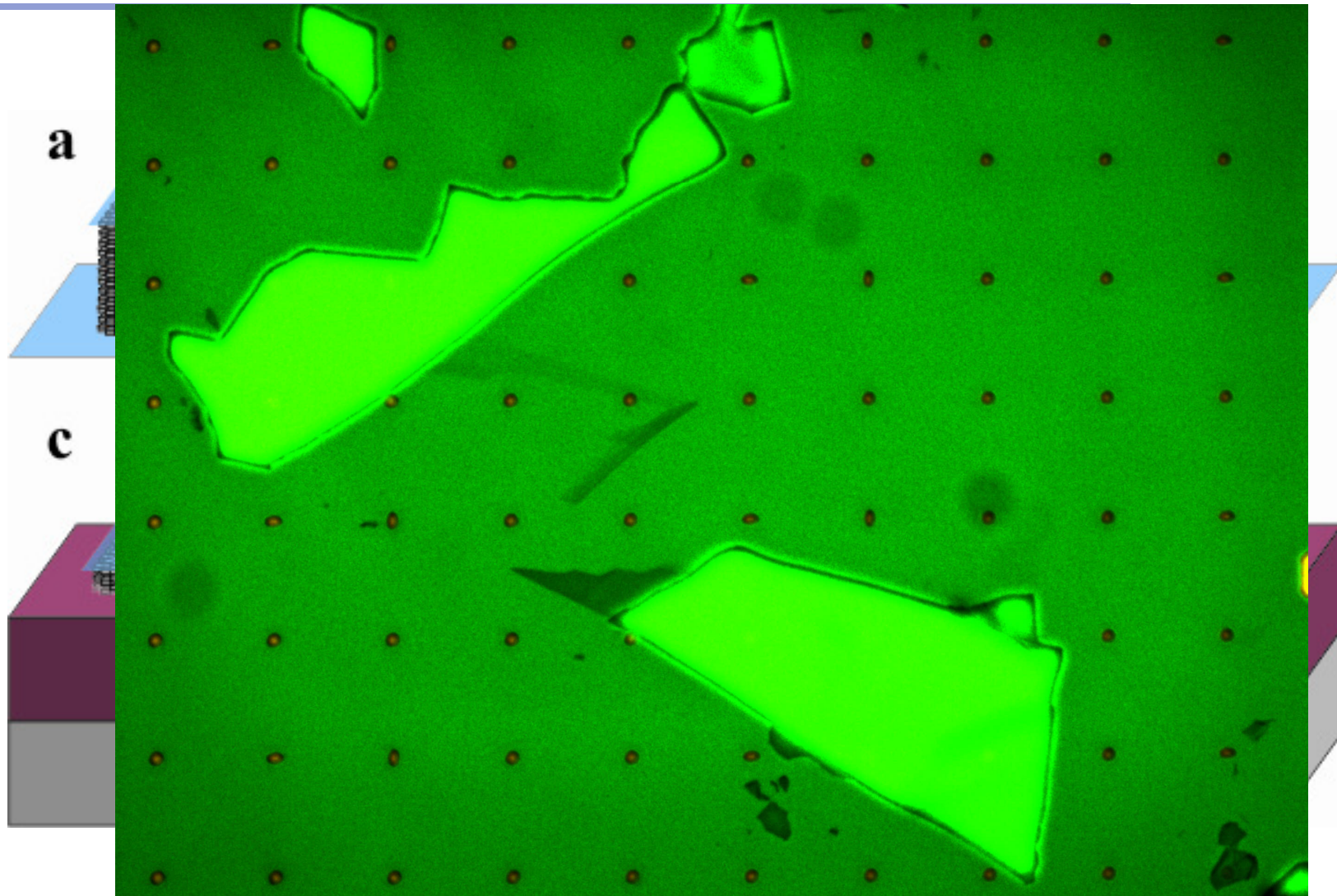
$$v_F \sim c/300 = 10^6 \text{ m.s}^{-1}$$







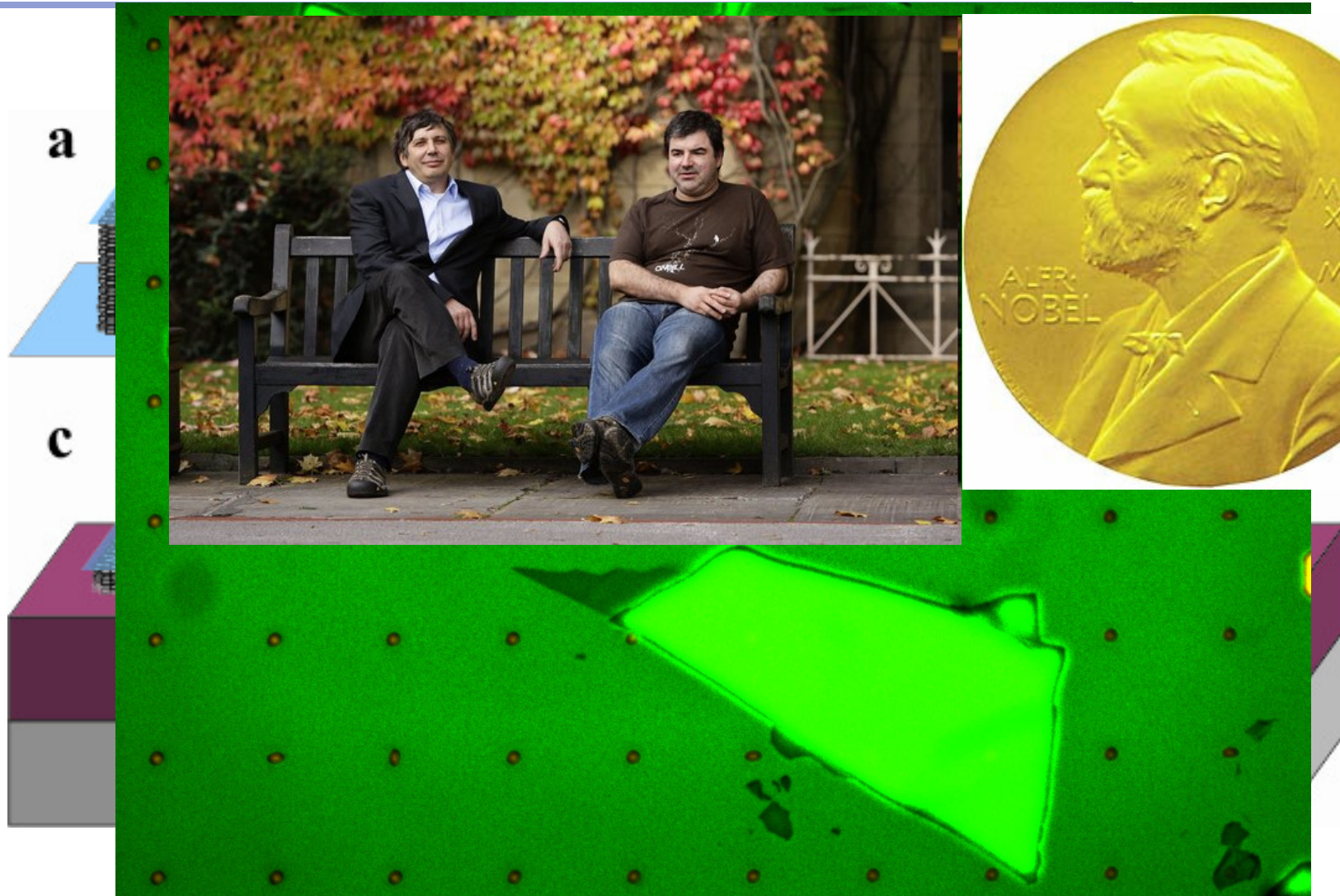
# Graphene: Do It Yourself!



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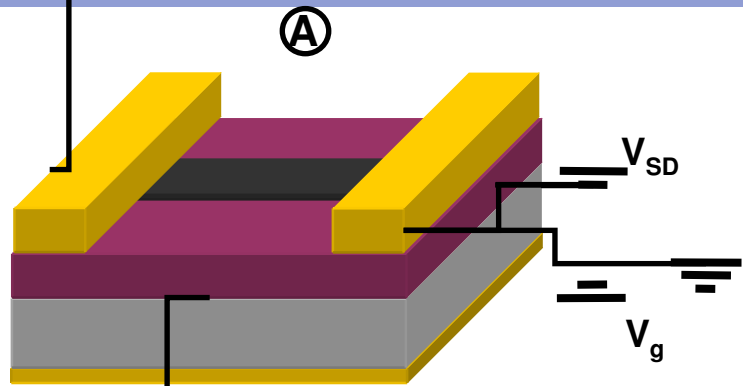


# Graphene: Do It Yourself!



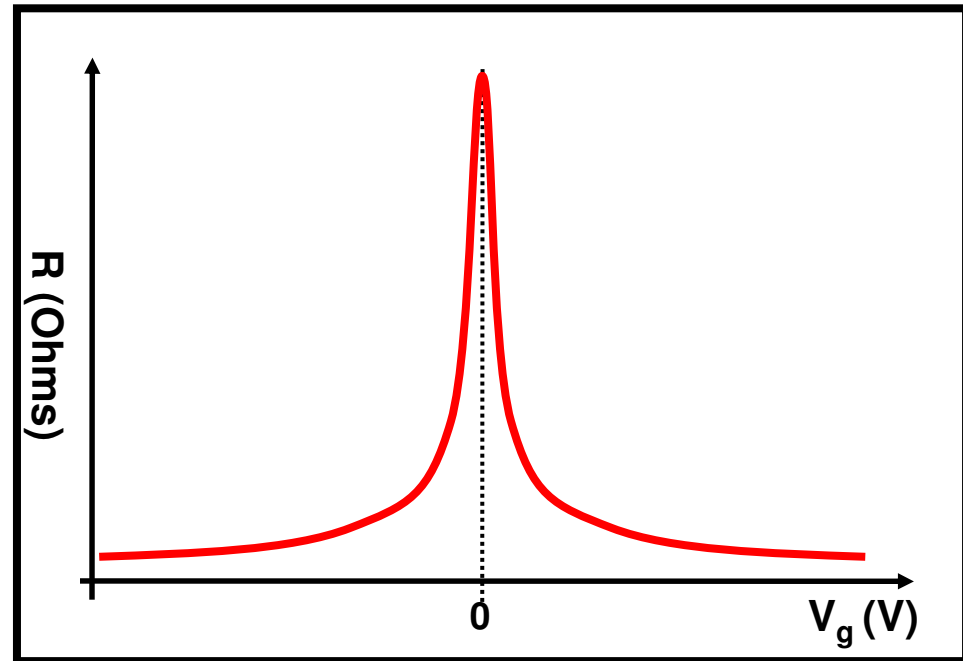
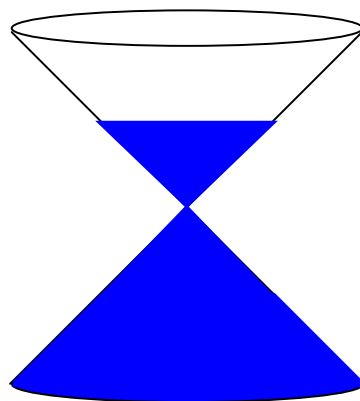
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# Graphene FET



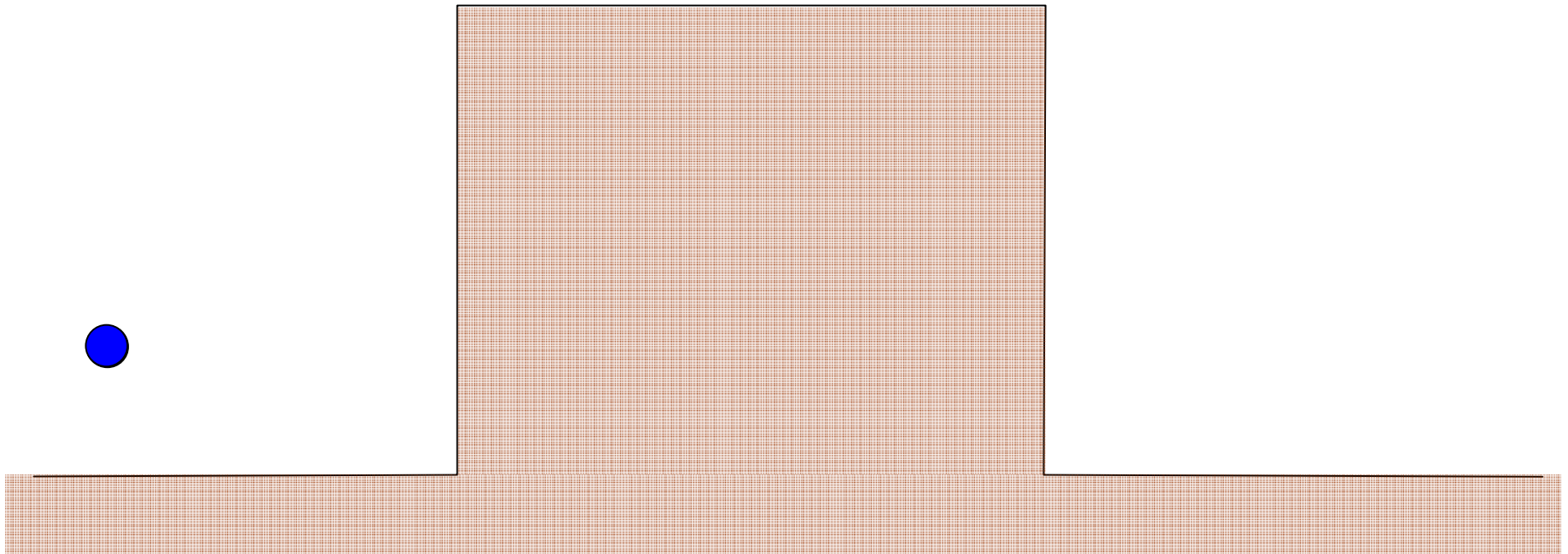
$$V_{SD} = R I_{SD}$$

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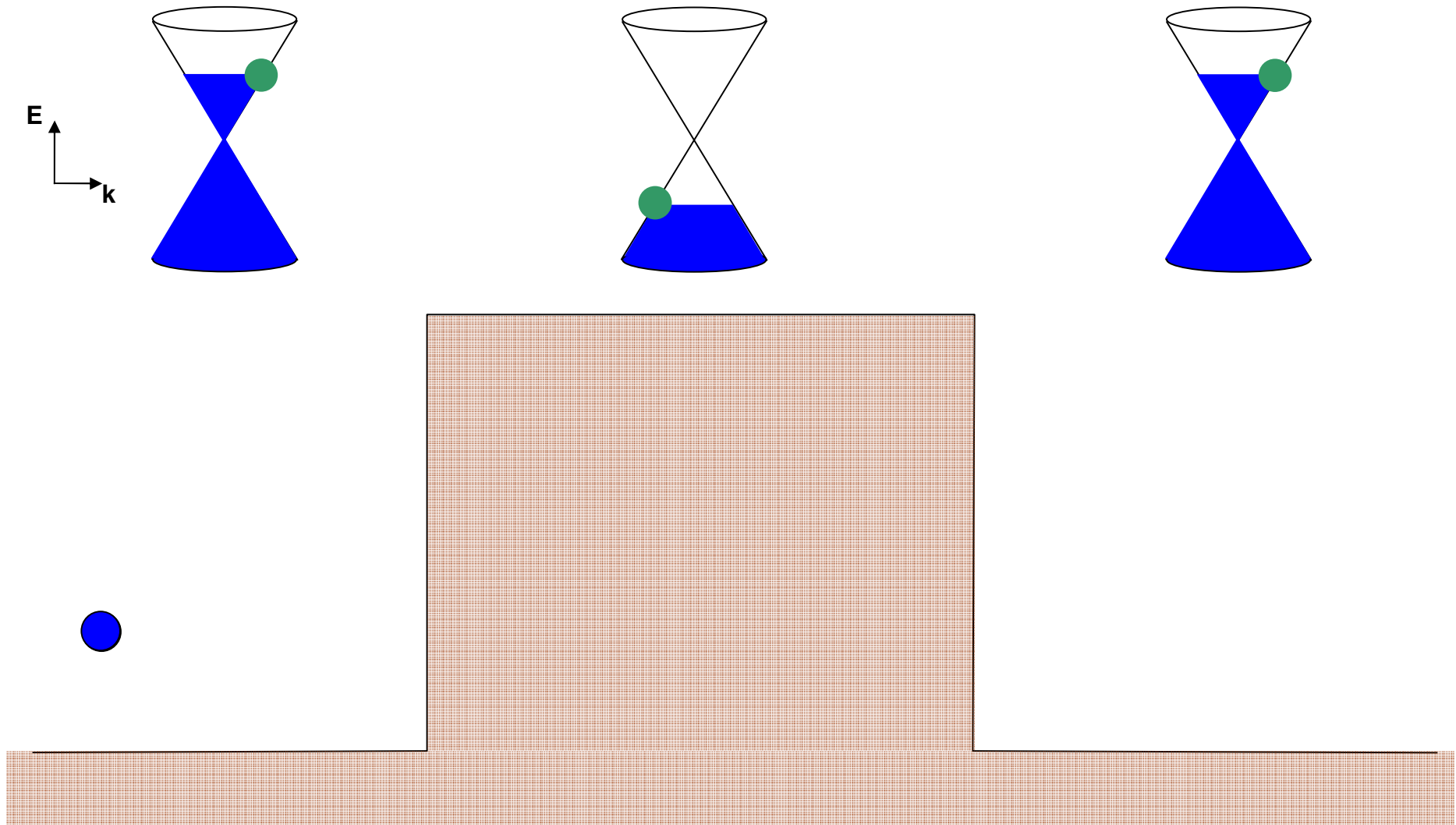


# Klein Tunnelling

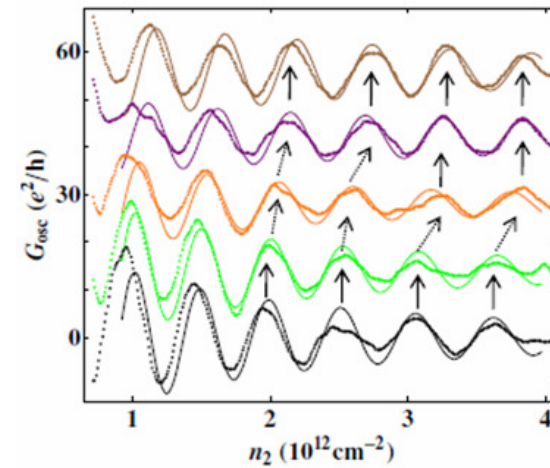
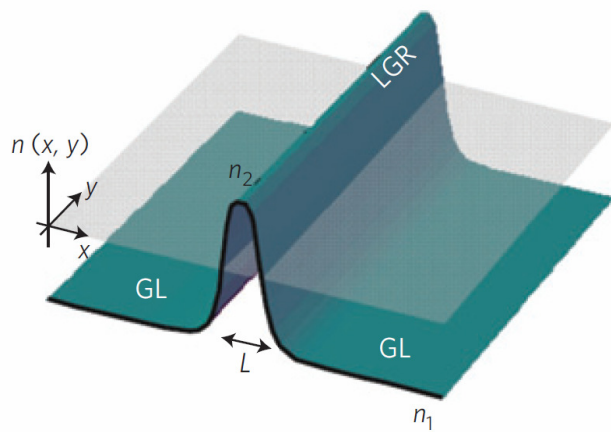
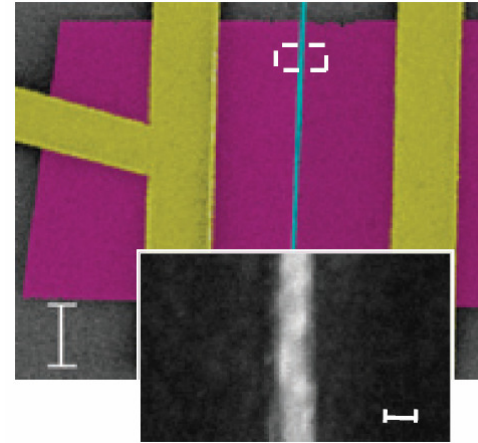
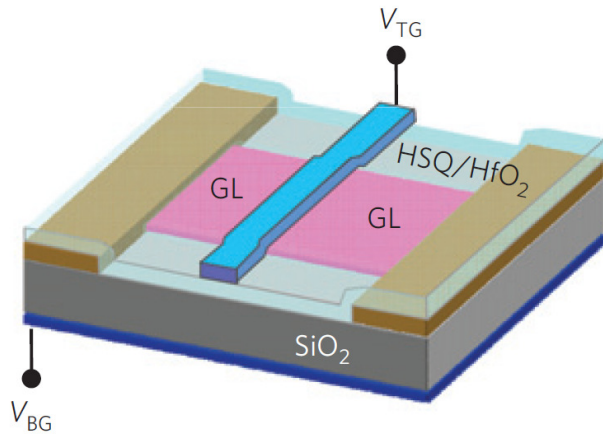
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# Klein Tunnelling



# Klein Tunnelling



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**In space...**

Neutron stars can reach more than  
**1 MT!**

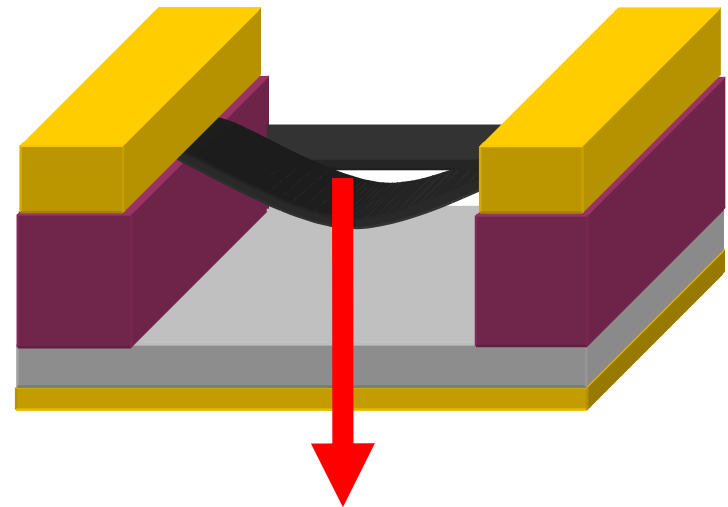
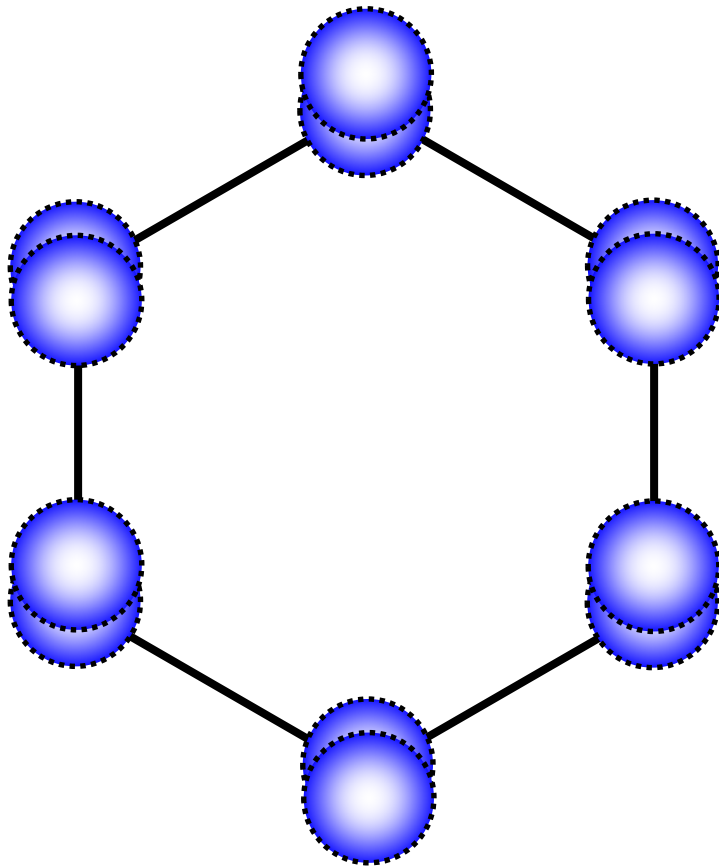
**Back on Earth...**

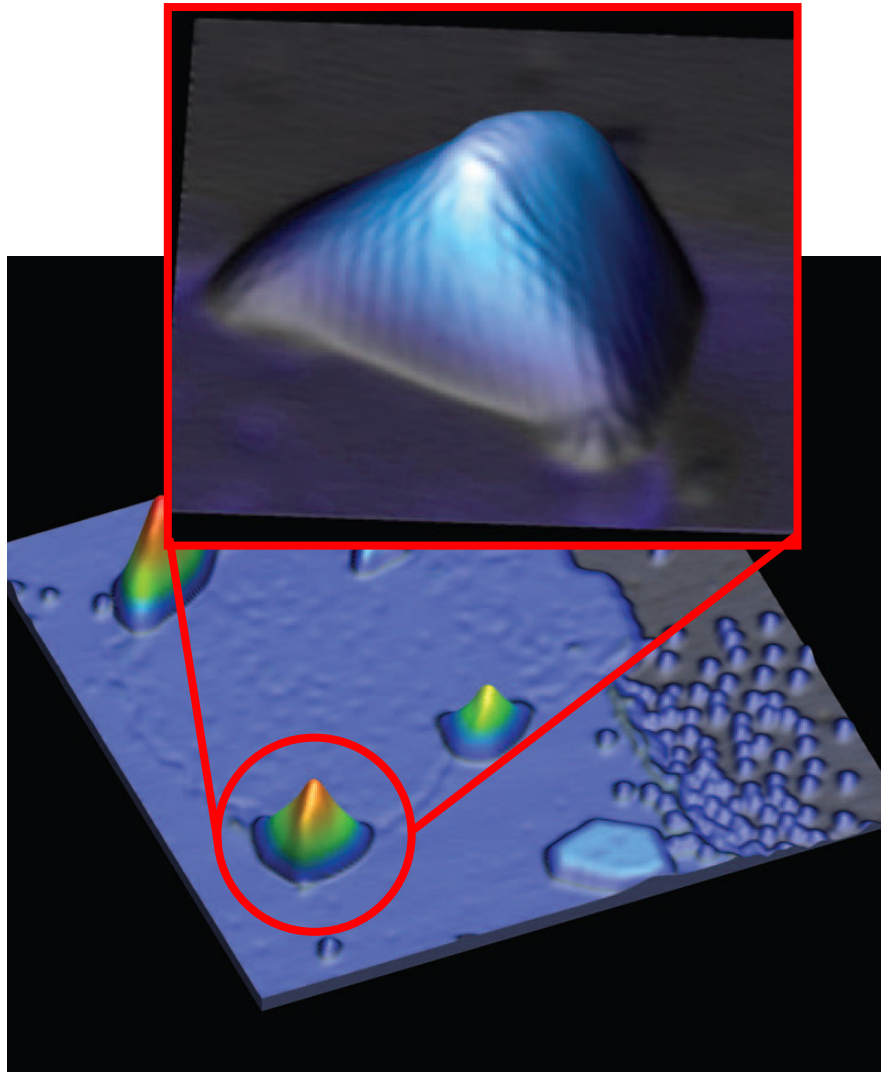
We struggle to get

**45 T (static) or  
100 T (pulsed)**

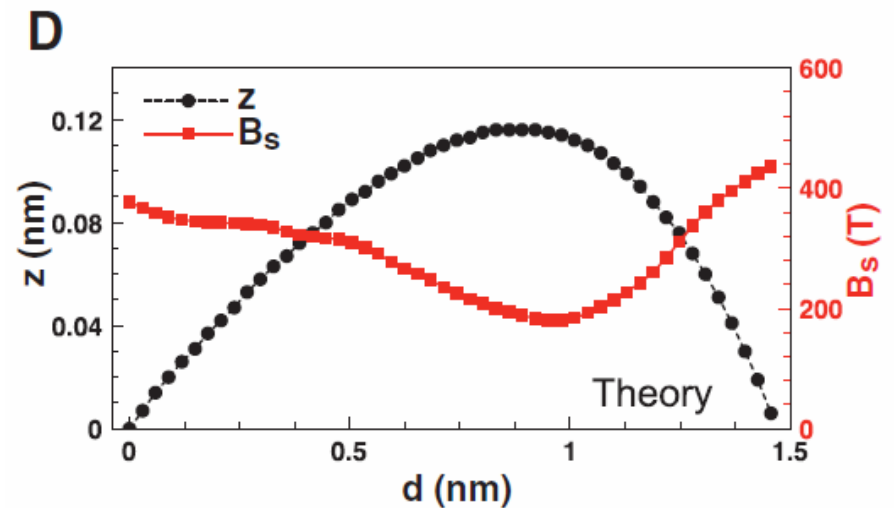
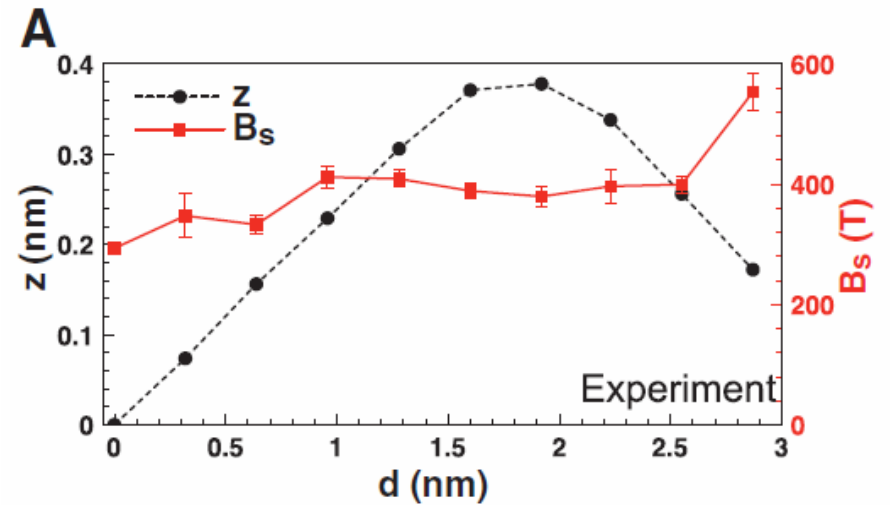
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 **HFML**  
Science in High Magnetic Fields





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# That's not all!!!

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- Spin-transport (long spin relaxation times)
- Gas sensors, can detect up to a single molecule
- High electron mobility ( $> 500\,000\text{ cm}^2/\text{V}\cdot\text{s}$ )
- Tunable band-gap for bilayer graphene
- VERY fast transistors (155 GHz)



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Thanks for your attention!

Questions?



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