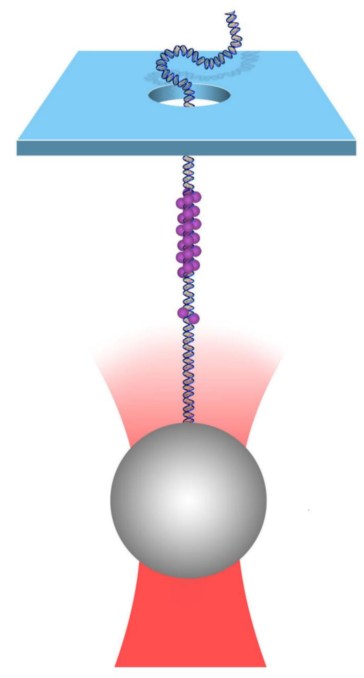
Universität Bielefeld
Experimental Biophysics and Applied Nanoscience



Measuring DNA Translocation through Nanopores in Graphene and Carbon Nanomenbranes with Optical Tweezers

Sebastian Knust*[1], Andreas Meyer[2], André Spiering[1], Christoph Pelargus[1], Andy Sischka[1], Peter Reimann[2], and Dario Anselmetti[1]

[1] Experimental Biophysics and Applied Nanoscience, Faculty of Physics, Bielefeld University
[2] Theoretical Physics and Soft Matter Theory, Faculty of Physics, Bielefeld University

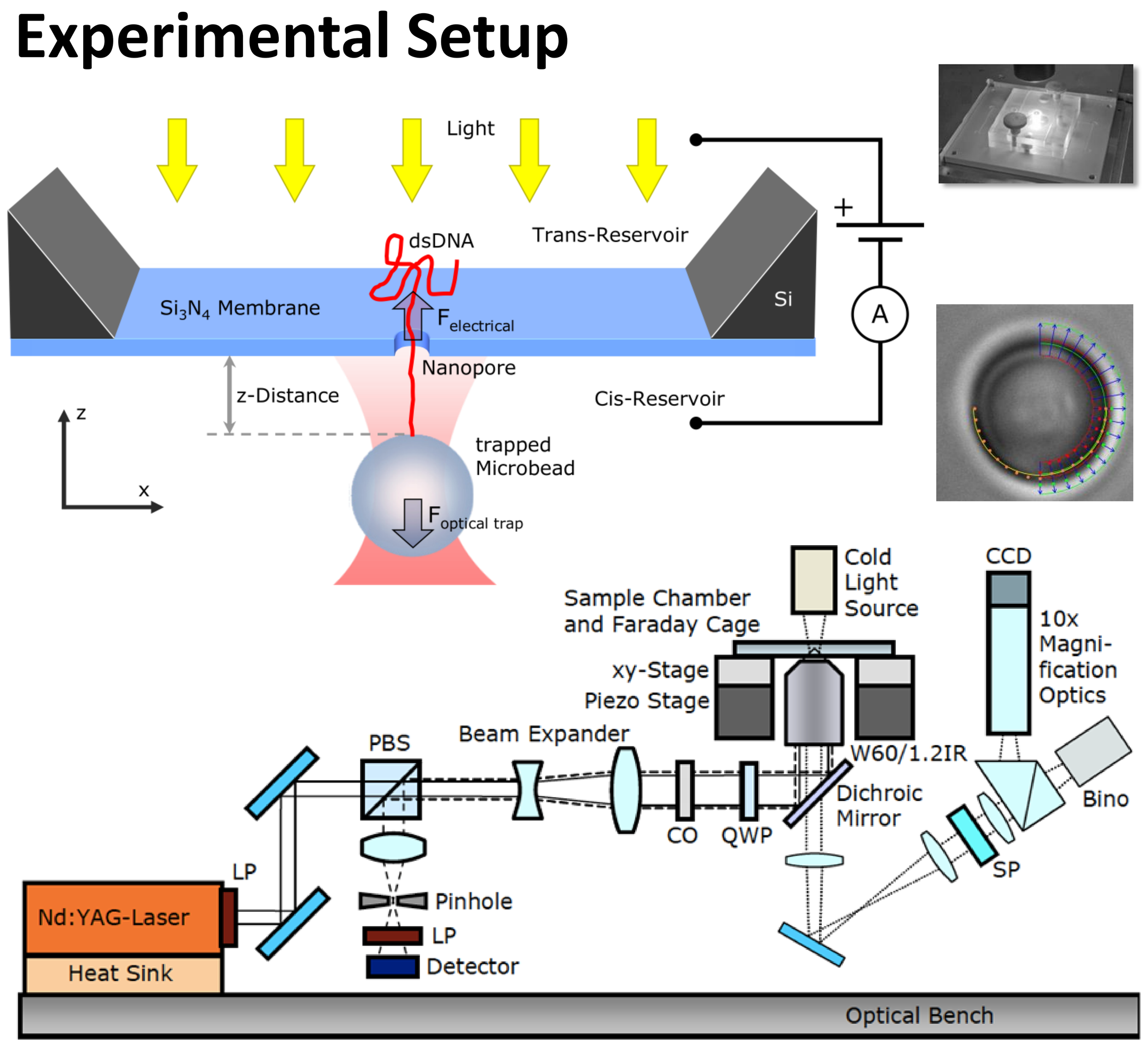
* sknust@physik.uni-bielefeld.de

Abstract:

We measured forces acting on DNA during translocation through a nanopore with Optical Tweezers. A video-based force detection and analysis system was developed, allowing for virtually interference-free axial force measurements with an overall force resolution of ±0.5pN at a sample rate of 123Hz [1].

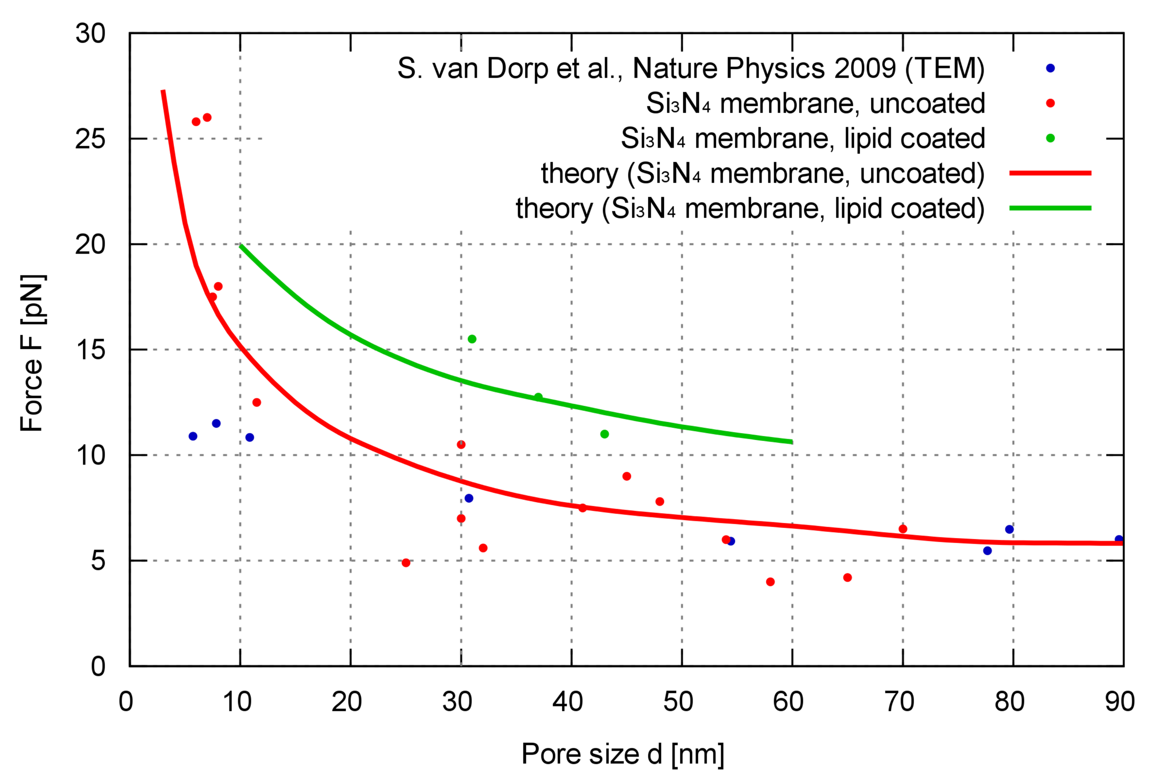
We previously measured the translocation of dsDNA through 20nm thick Si_3N_4 membranes (0.1pN/mV for pores ≥ 30nm) [2, 3]. Lipid coating as well as carbon nanomembranes and graphene with a thickness of 3nm and 0.3nm respectively allow for even more sensitive measurements.

Experimental Setup



- Video-based force detection → reduced interference
- Calibration via Stokes friction and Allan variance
- Force sensitivity better than 0.5 pN at 123 Hz sample rate

Translocation Theory



- Dynamics dominated by electrohydrodynamic effects (electro-osmotic flow)
- Modelling with combination of Poisson, Nernst-Plack and Stokes equations
- Mere zero surface charge on coated membrane does not explain high forces

→ Introduction of slip length at the DNA-solution-interface

- Supported by theoretical treatment of DNA nanostructure [3] and recent MD simulations [4]

Results:

Slip length $l_{\text{slip}} = 0.5\text{nm}$

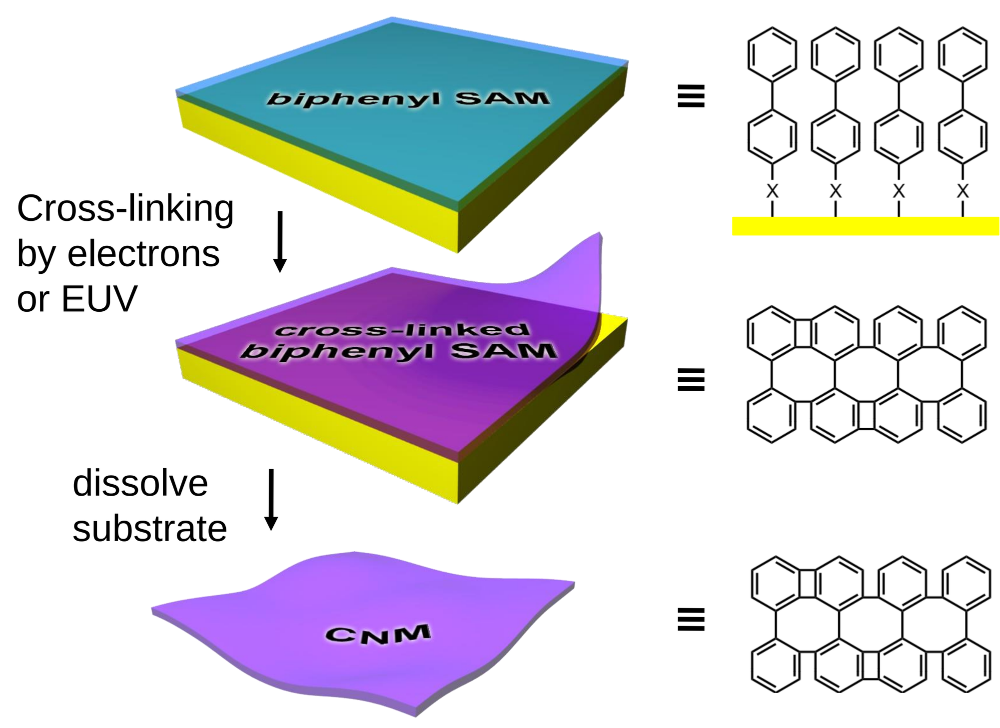
Surface charge for Si_3N_4 $\sigma_m = -60\,\text{mC/m}^2$

Nanomembrane Preparation

Graphene

- Mechanical exfoliation with nitto tape
- Automated searching routine for graphene flakes based on colour in light microscope
- Transfer on chip with cellulose polymer

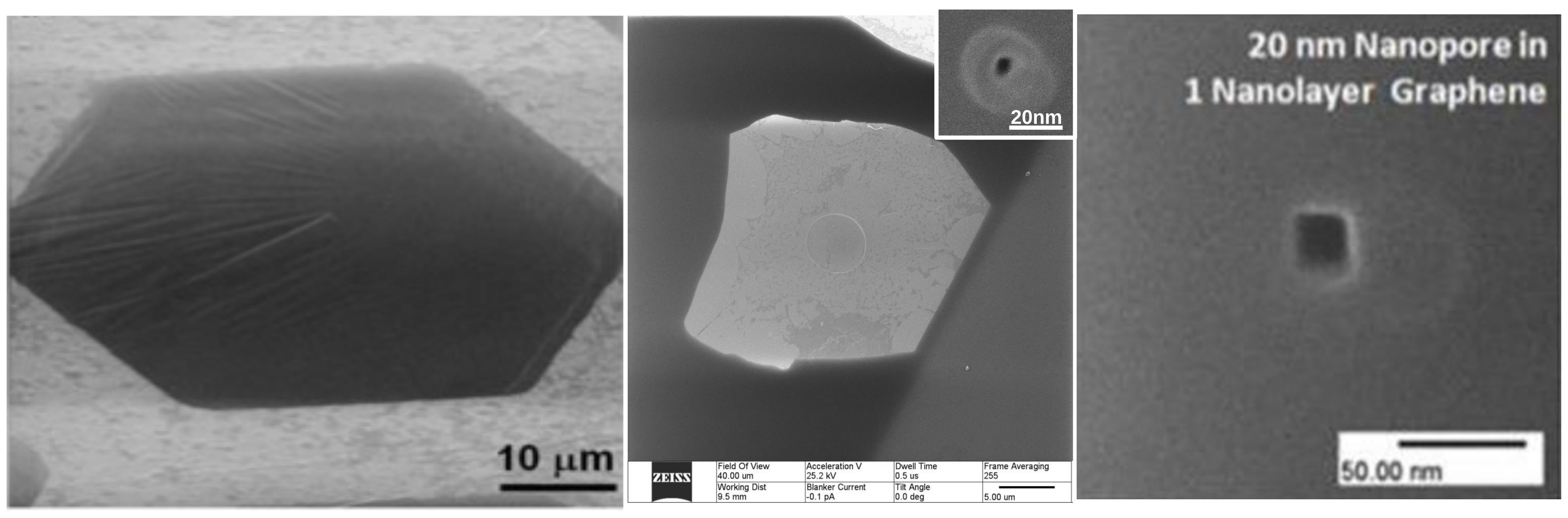
Carbon nanomembranes



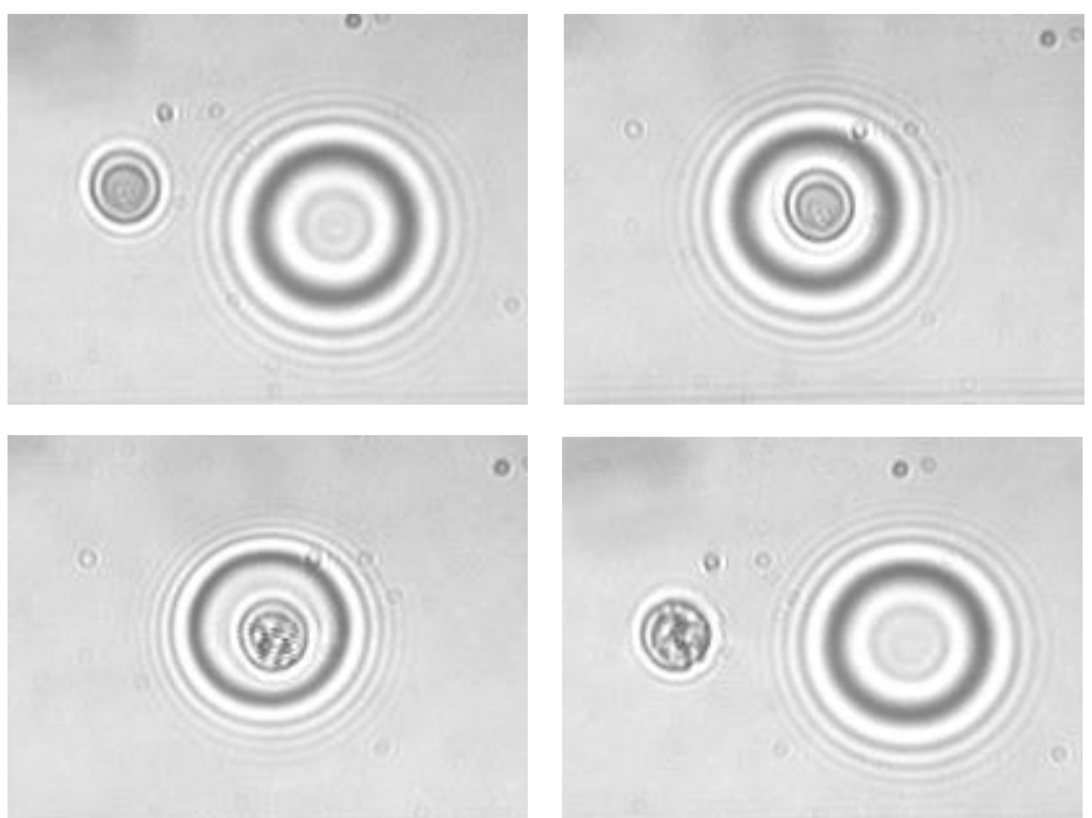
Resulting thickness of 1-3 nm

Nanopore Preparation

- Zeiss Orion Plus HIM
- 0.35 nm imaging resolution
- Pore sizes as small as 5-6 nm



Graphene

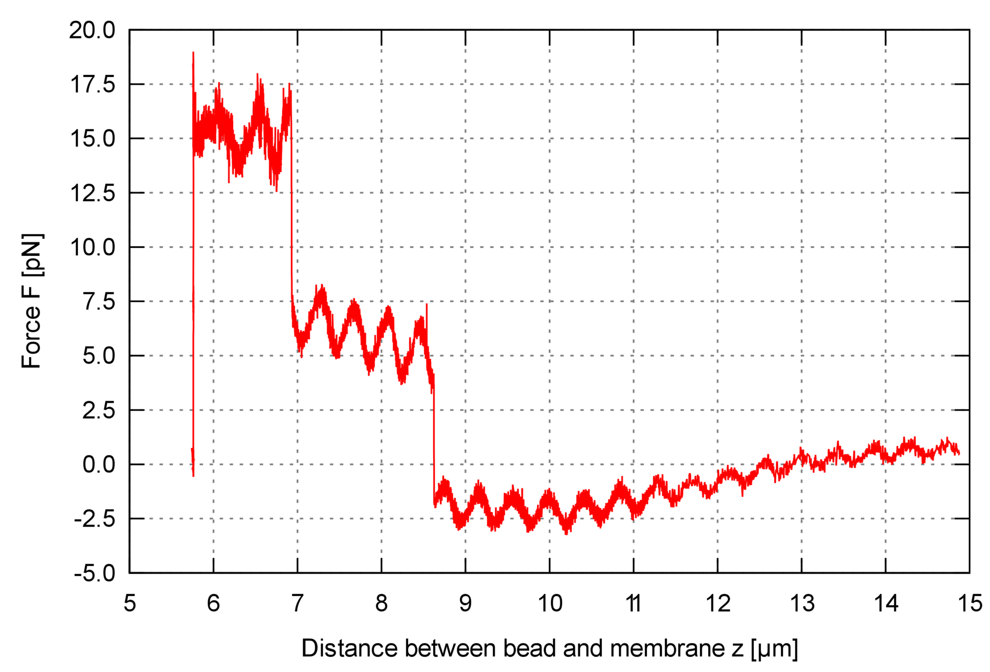


- Strongly localised heating phenomena (plasmon?)

→ Melts polystyrene beads

→ Dissipates biotin-streptavidin bond between bead and DNA

Carbon Nanomembranes



- 3 nm membrane thickness, 70 nm NP size, 50 mV, 20 mM KCl
- Interference caused by silicon chip geometry

BINAS
Deutsche Forschungsgemeinschaft DFG
PicoTweezers
Force Sensitive Optical Tweezers
www.picotweezers.com

References

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[2] A. Spiering *et al.*, Nanopore translocation dynamics of a single DNA-bound protein. Nano Lett. **11**, 2978 (2011)
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→ www.uni-bielefeld.de