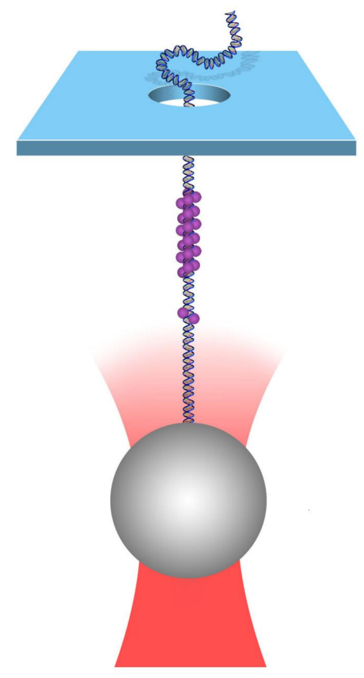
Universität Bielefeld

Experimental Biophysics and Applied Nanoscience, Faculty of Physics, Bielefeld University



Measuring DNA Translocation Forces through various solid state nanopores 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

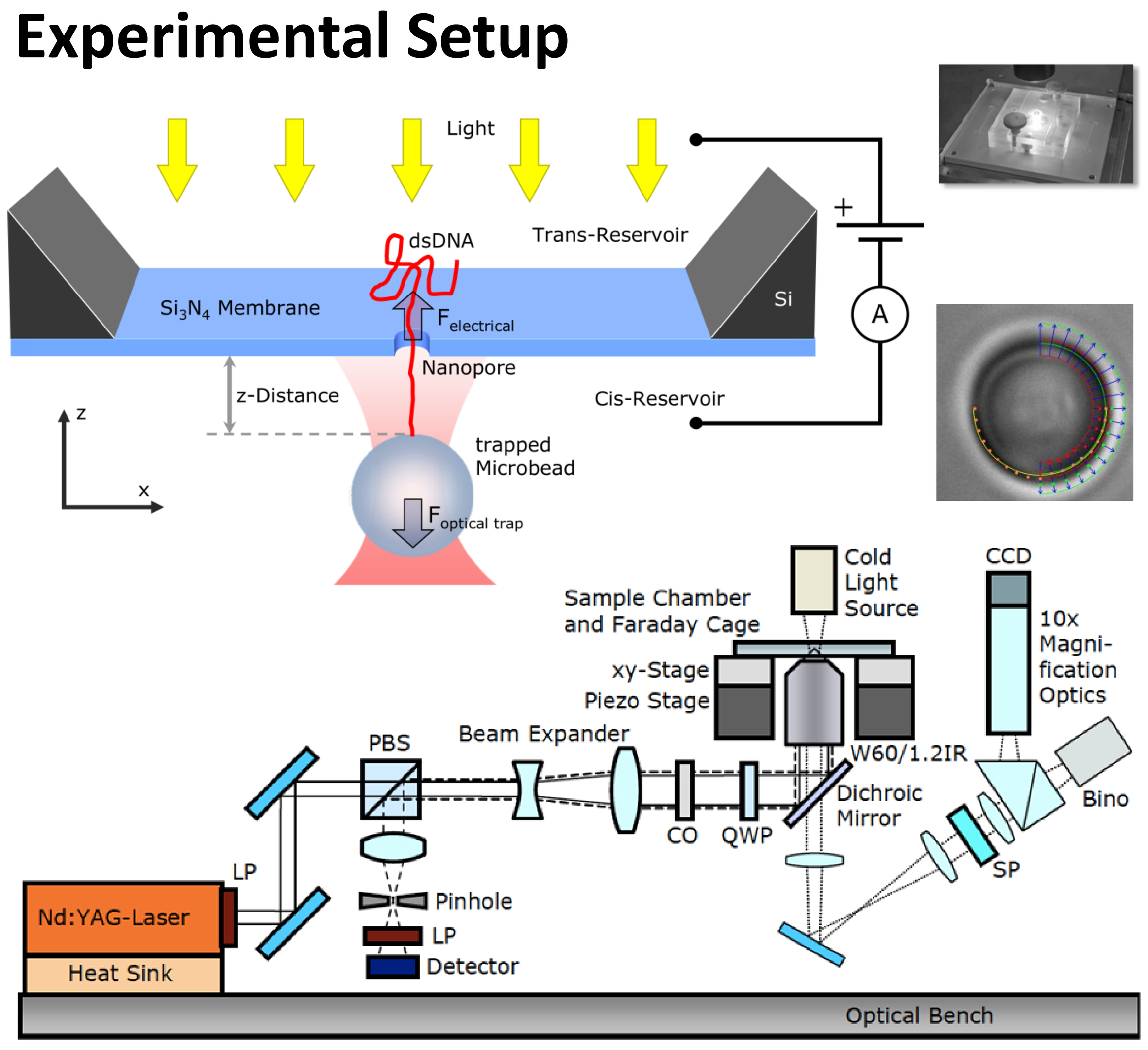
* sknust@physik.uni-bielefeld.de

Abstract:

We measured the forces acting on a single strand of dsDNA during translocation through nanopores in various solid state membranes by Optical Tweezers. The system includes a video-based force detection and analysis system allowing for virtually interference-free axial force measurements with sub-piconewton precision [1]. All measurements were performed with an overall force resolution of 0.5 pN at a sample rate of 123 Hz.

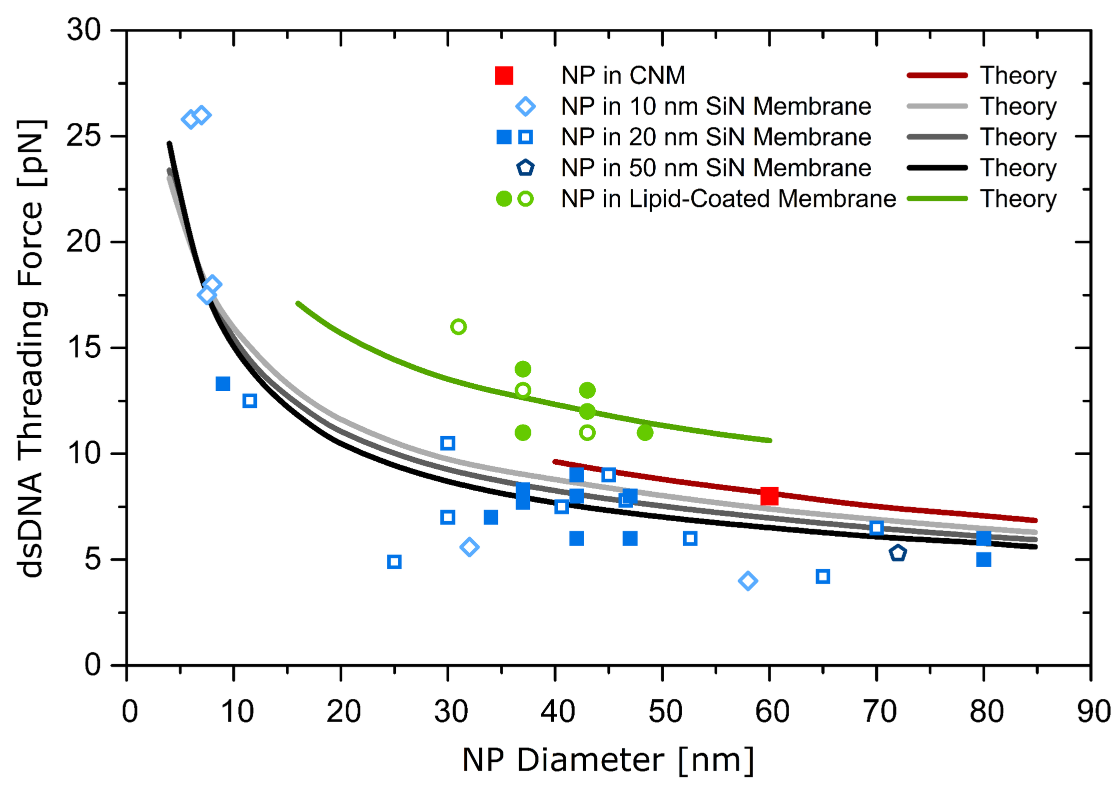
We show the controlled translocation through Si_3N_4 membranes both uncoated and lipid-coated [2,3]. Additionally, measurements of controlled dsDNA translocation through carbon nanomembranes (CNM) and through MoS_2 membranes were conducted.

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 [2,3] and recent MD simulations [4]

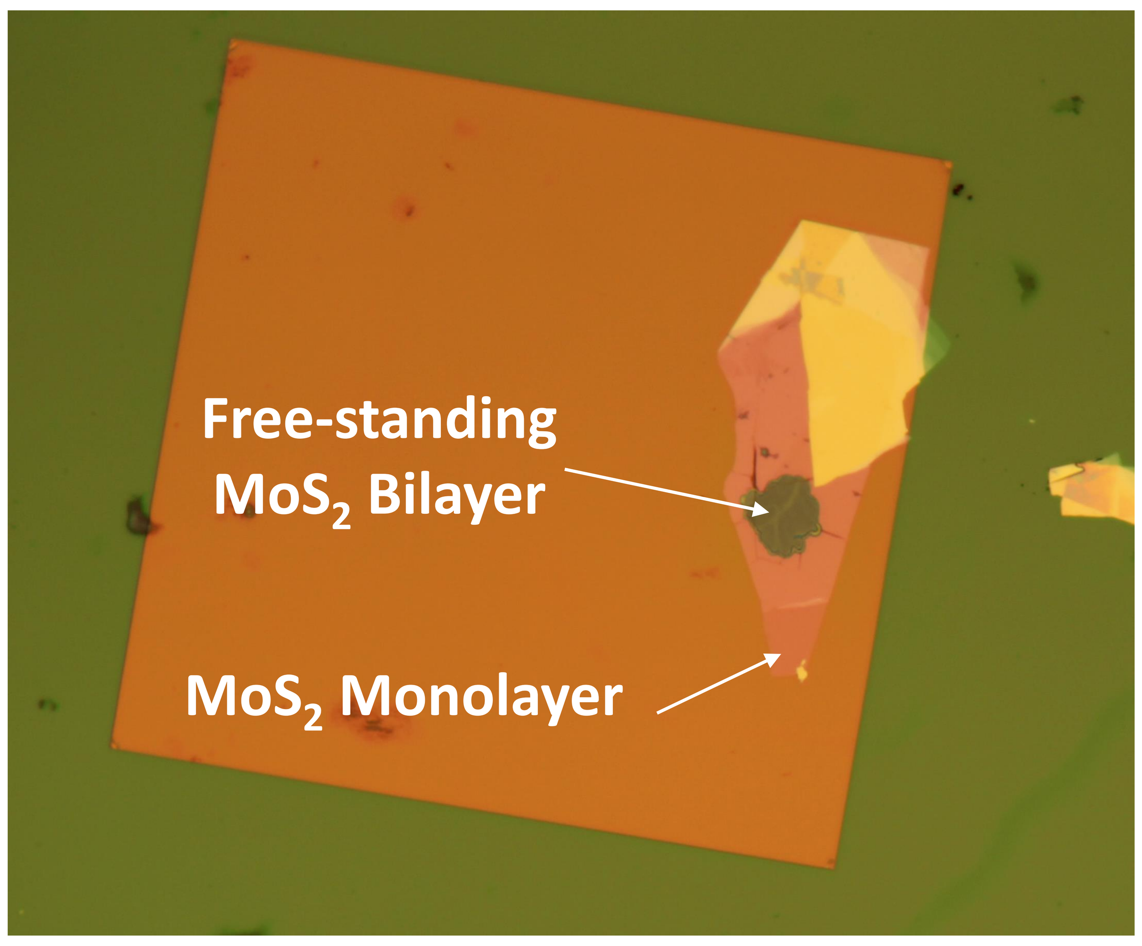
Results:

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

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

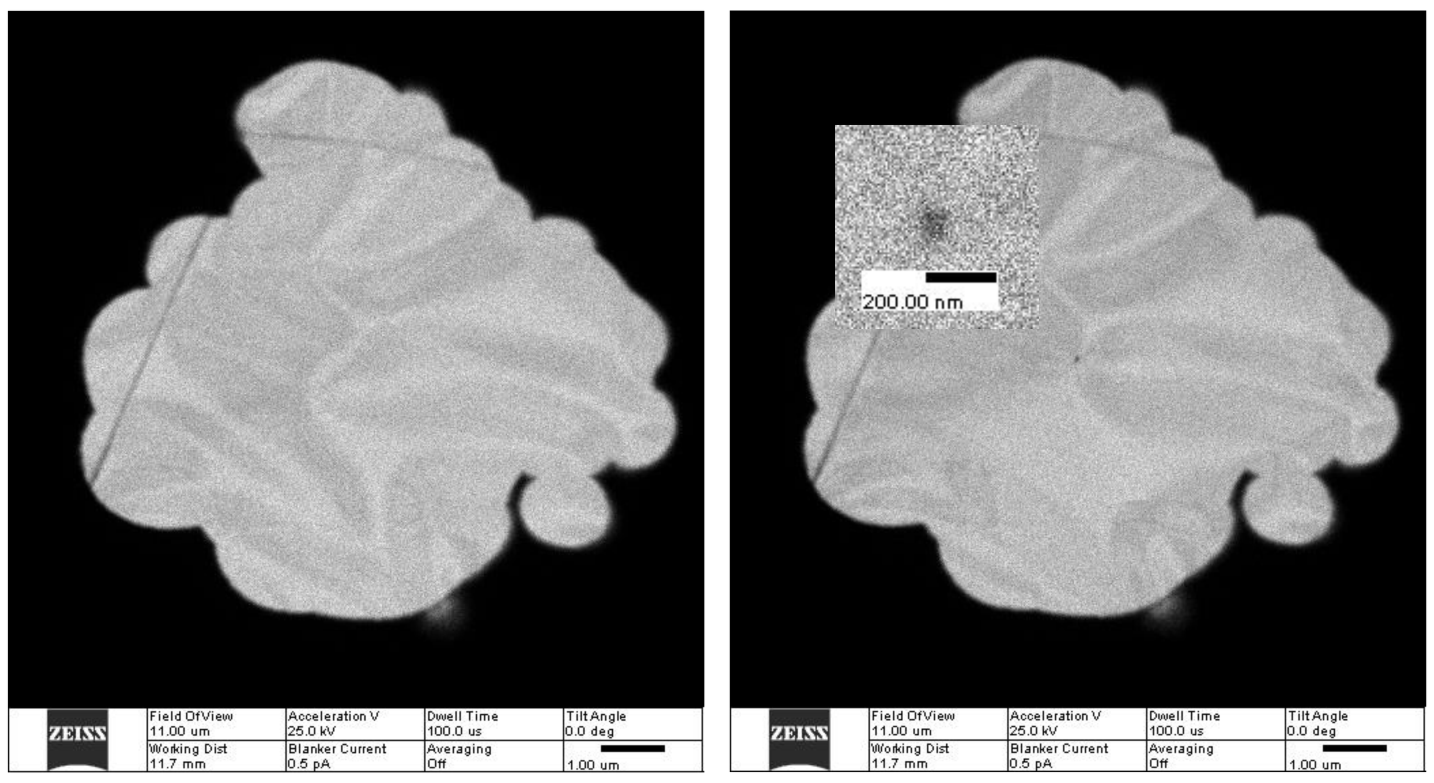
Nanomembrane Preparation

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

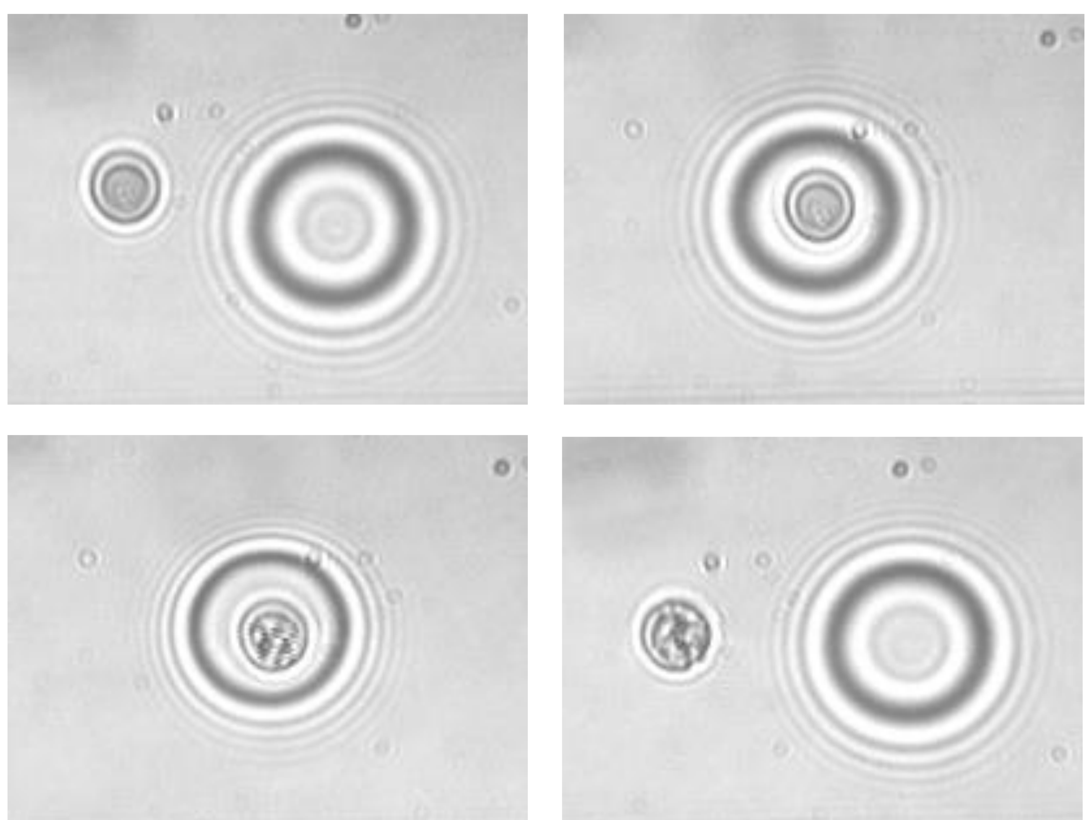


Nanopore Preparation

- Zeiss Orion Plus Scanning Helium-Ion Microscope
- Up to 0.35 nm imaging resolution
- Pore sizes as small as 5-6 nm
- Pore drilling by focussing ions on a single spot (2 min @ 0.5 pA for 40 nm pore size)
- No discernable damage even to monolayer membranes



Graphene

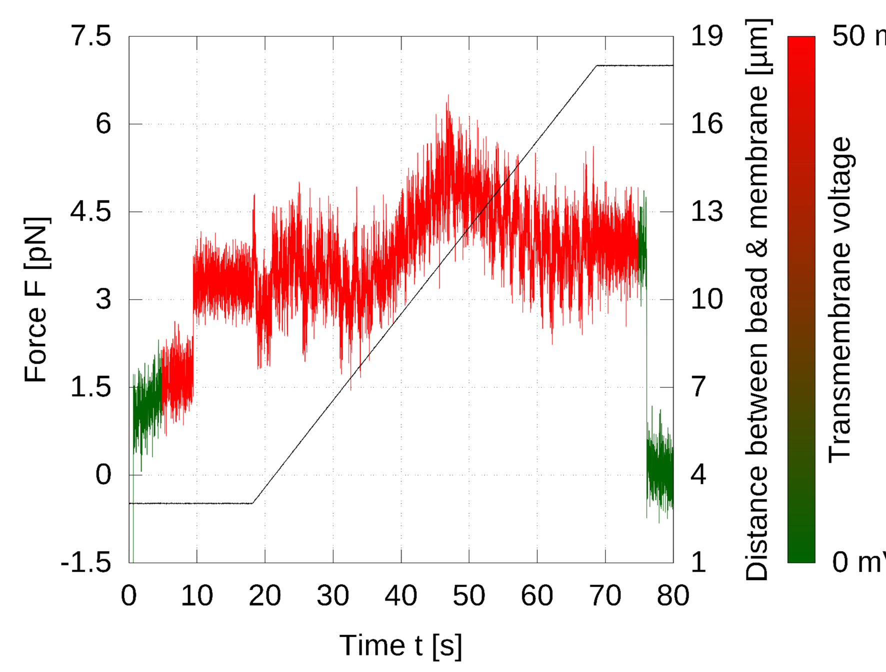


- Strongly localised heating phenomena (plasmon?)

→ Melts polystyrene beads

→ Dissipates biotin-streptavidin bond between bead and DNA

MoS_2 DNA Translocation



- 3 nm membrane thickness, 40 nm NP size, 50 mV, 20 mM KCl
- Artefacts caused by silicon chip geometry

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

References

[1] S. Knust *et al.*, Video-based and interference-free axial force detection and analysis for optical tweezers. Rev. Sci. Instr. **83**, 103704 (2012)
[2] A. Spiering *et al.*, Nanopore translocation dynamics of a single DNA-bound protein. Nano Lett. **11**, 2978 (2011)
[3] A. Sischka *et al.*, Controlled Translocation of DNA Through Nanopores in Carbon Nano-, Silicon-Nitride- and Lipid-Coated Membranes. Analyst, 2015, Accepted Manuscript
[4] S. Kesselheim, W. Müller, C. Holm, Origin of Current Blockades in Nanopore Translocation Experiments. Phys. Rev. Lett. **112**, 018101 (2014)

→ www.uni-bielefeld.de