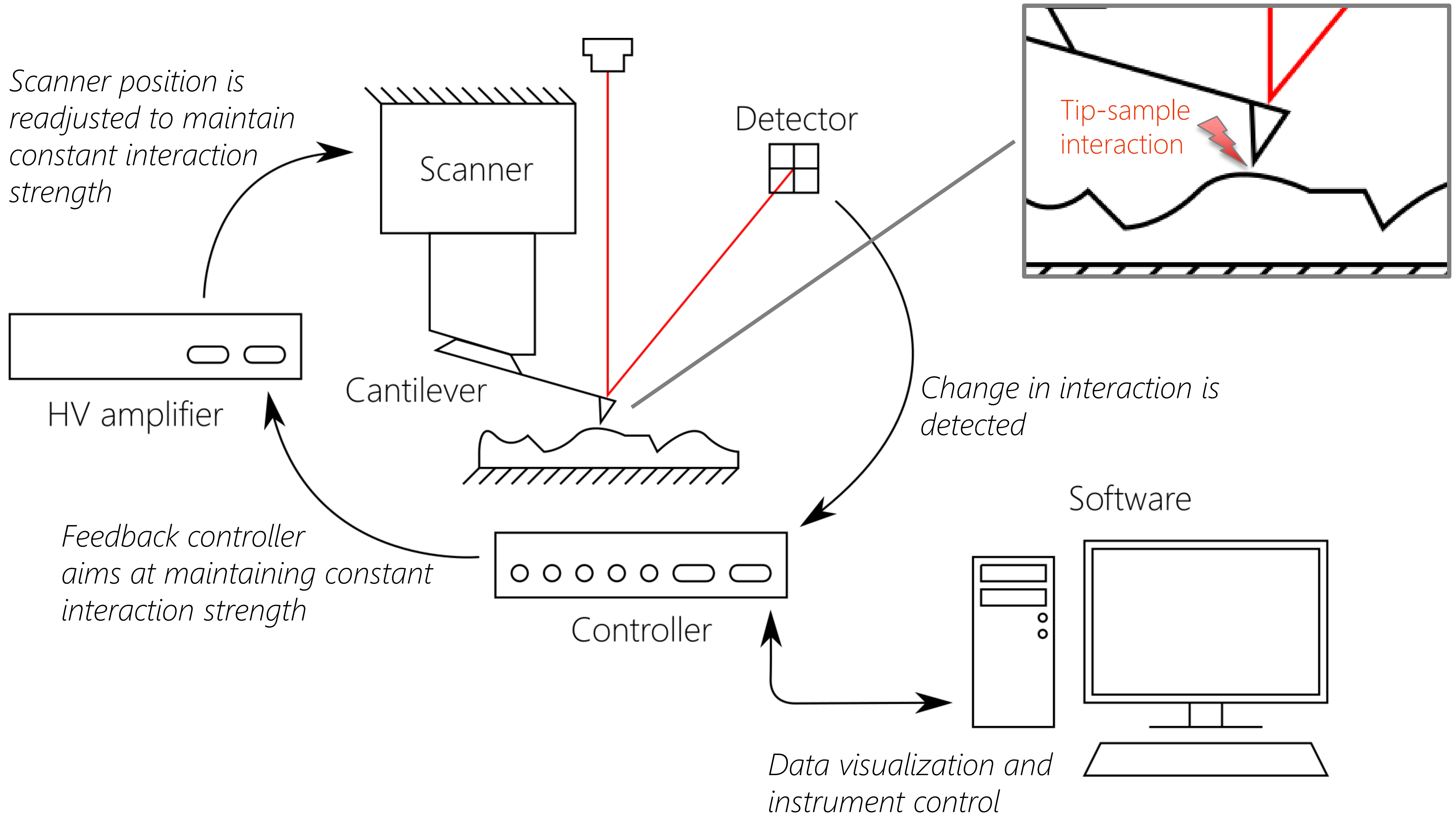
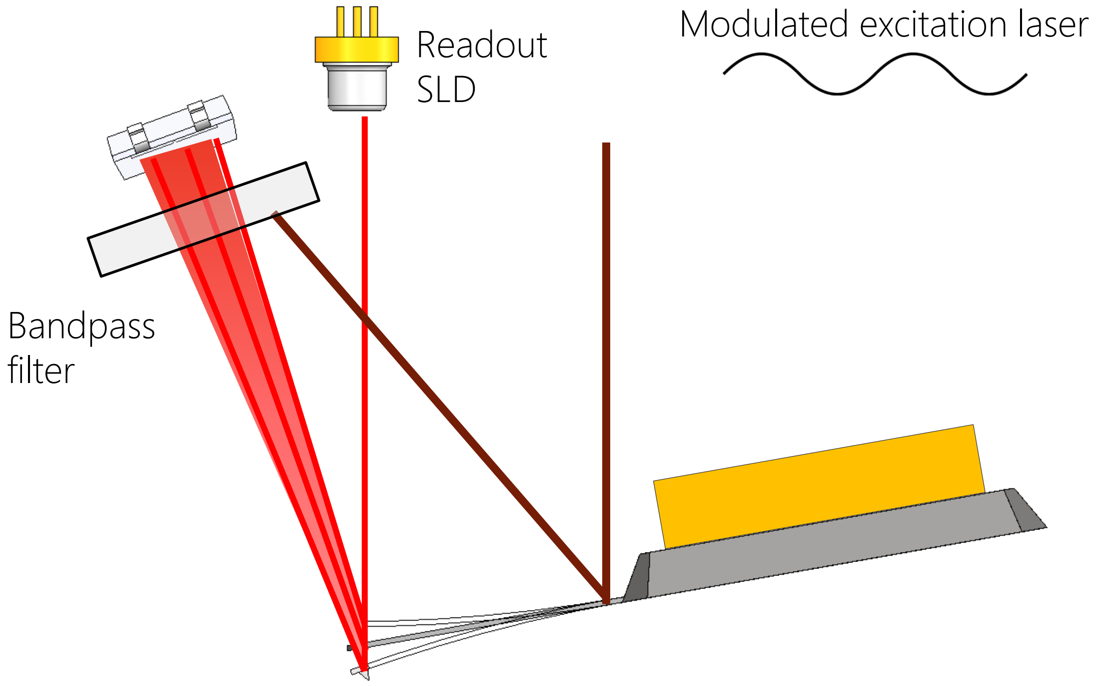
Mass and viscoelasticity of single cells

Dr. Marco Portalupi, Nanosurf AG

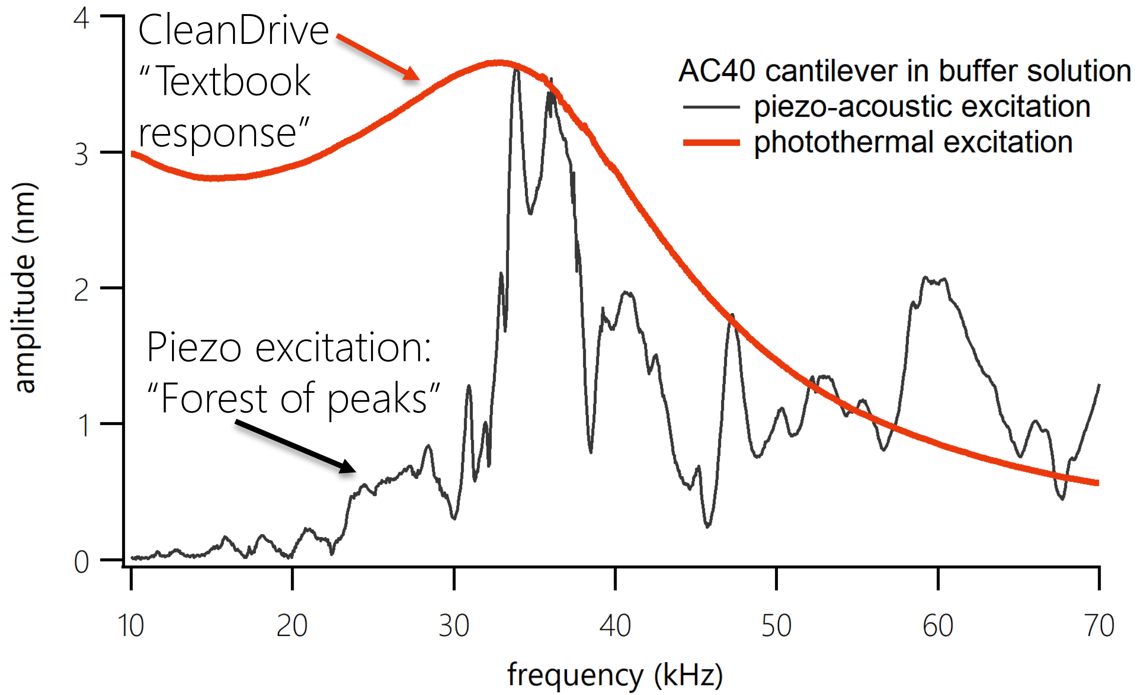
AFM – how does it work?



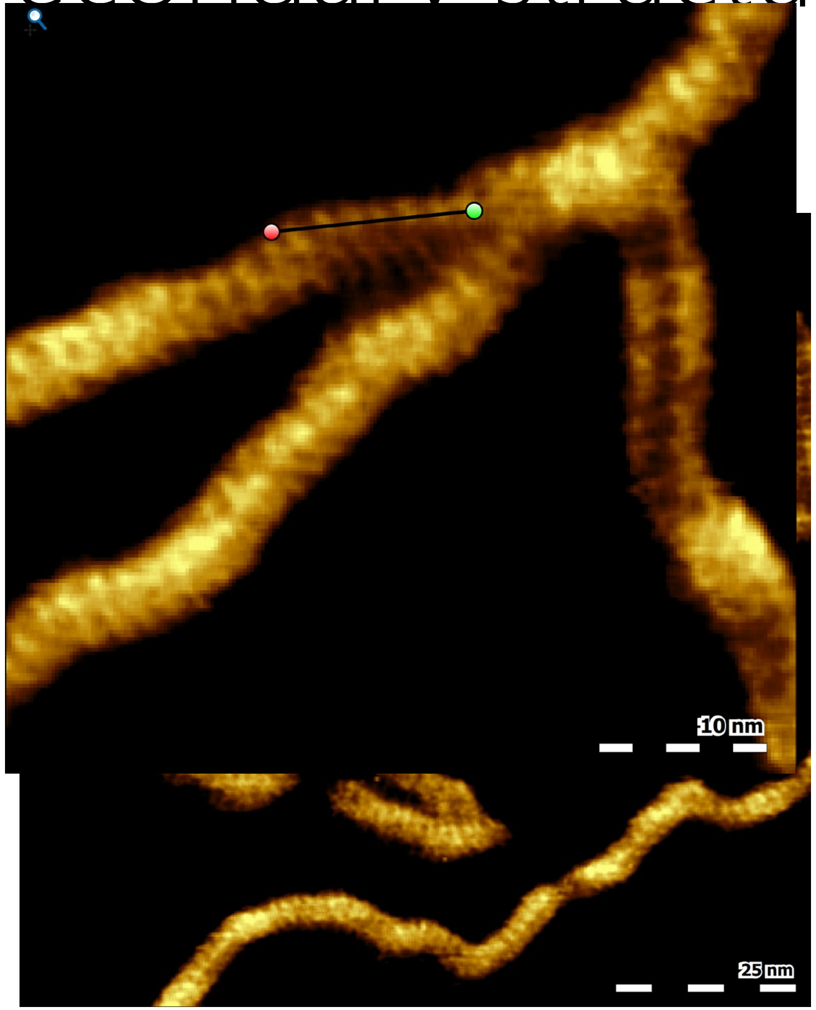
CleanDrive photothermal excitation

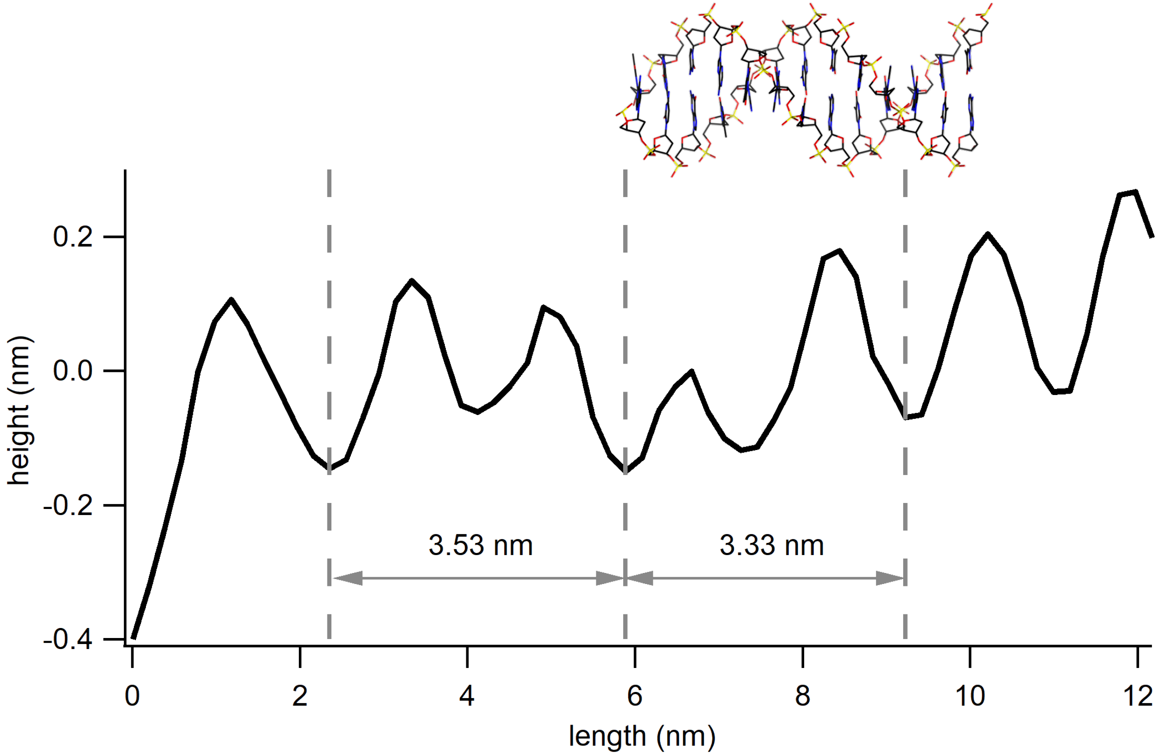


Bio-compatible 785nm NIR laser source
No "forest of peaks" in any environment
Reliable automatic tuning
Ultra stable excitation



Secondary structure of dsDNA





DriveAFM as a table-top system…

Stage mounted on Isostage 300 active vibration isolation

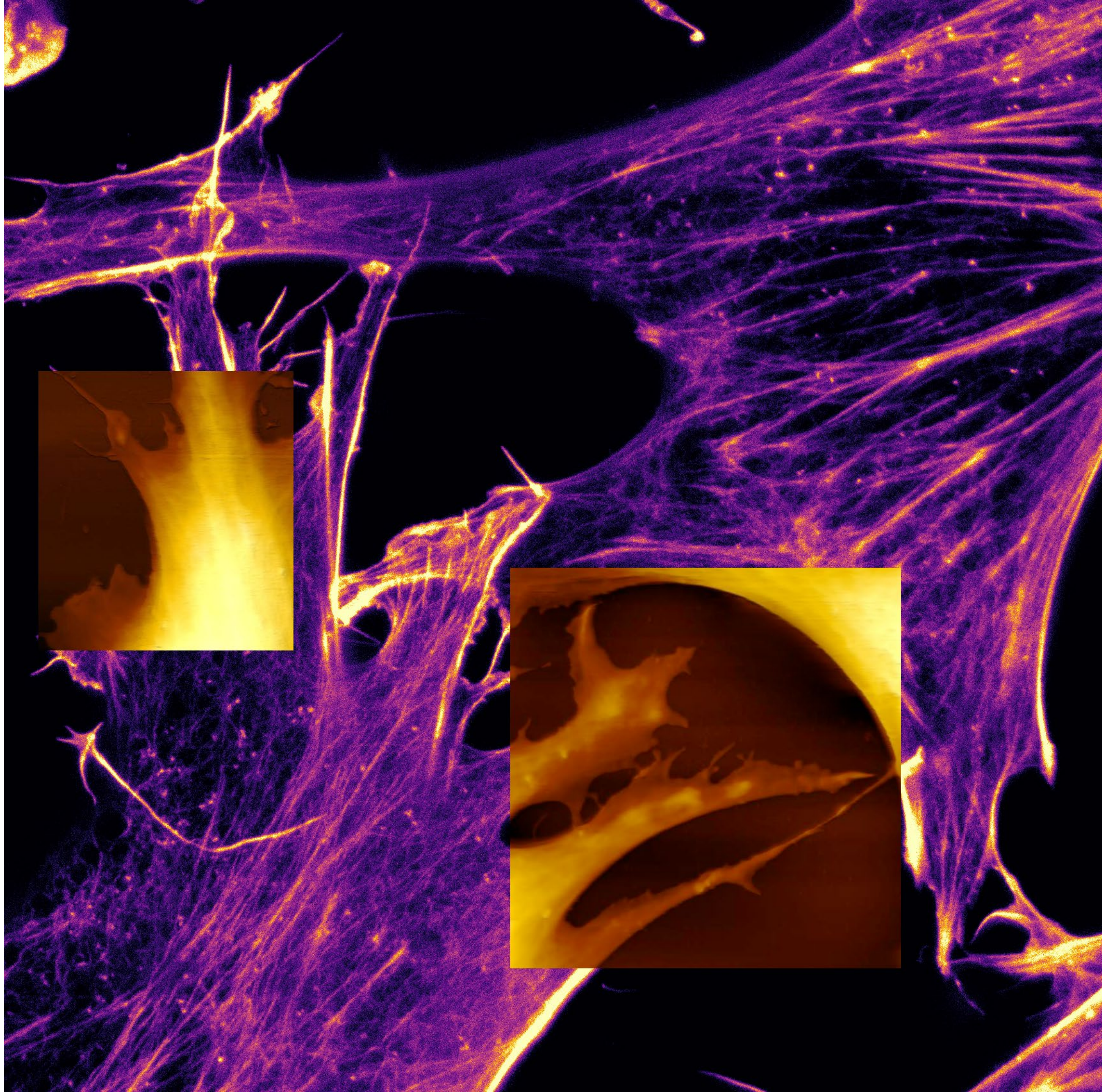
…or on an inverted optical microscope

A variety of stages for different inverted optical microscope brands is available.

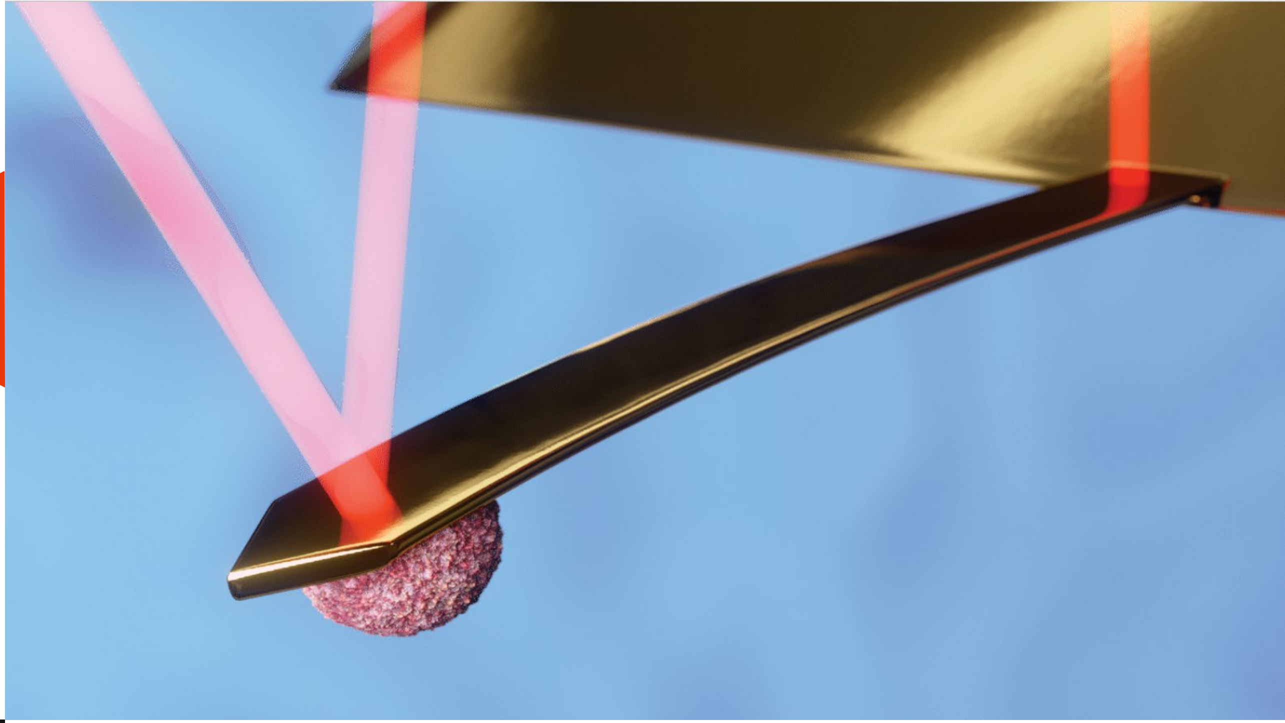
AFM +optical microscopy

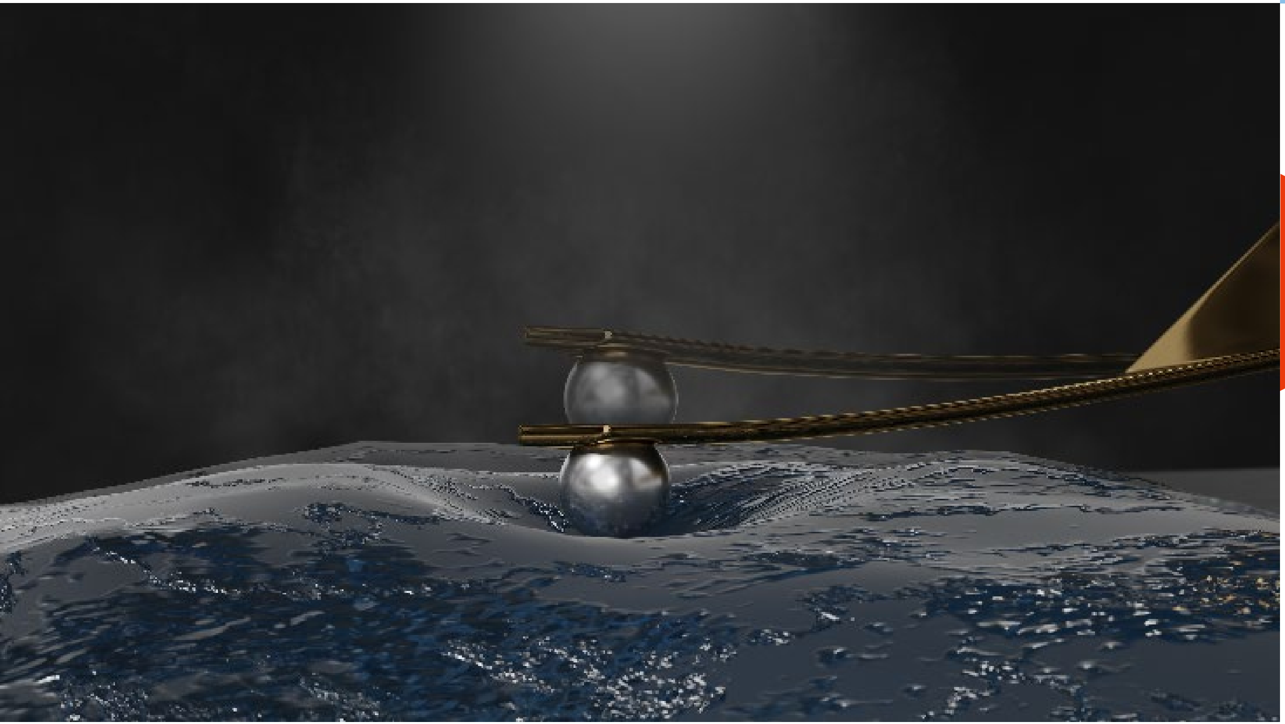
Super-resolution techniques challenge AFM in the biosphere

Mechanical interaction→ other insights than just structure



Mass measurements



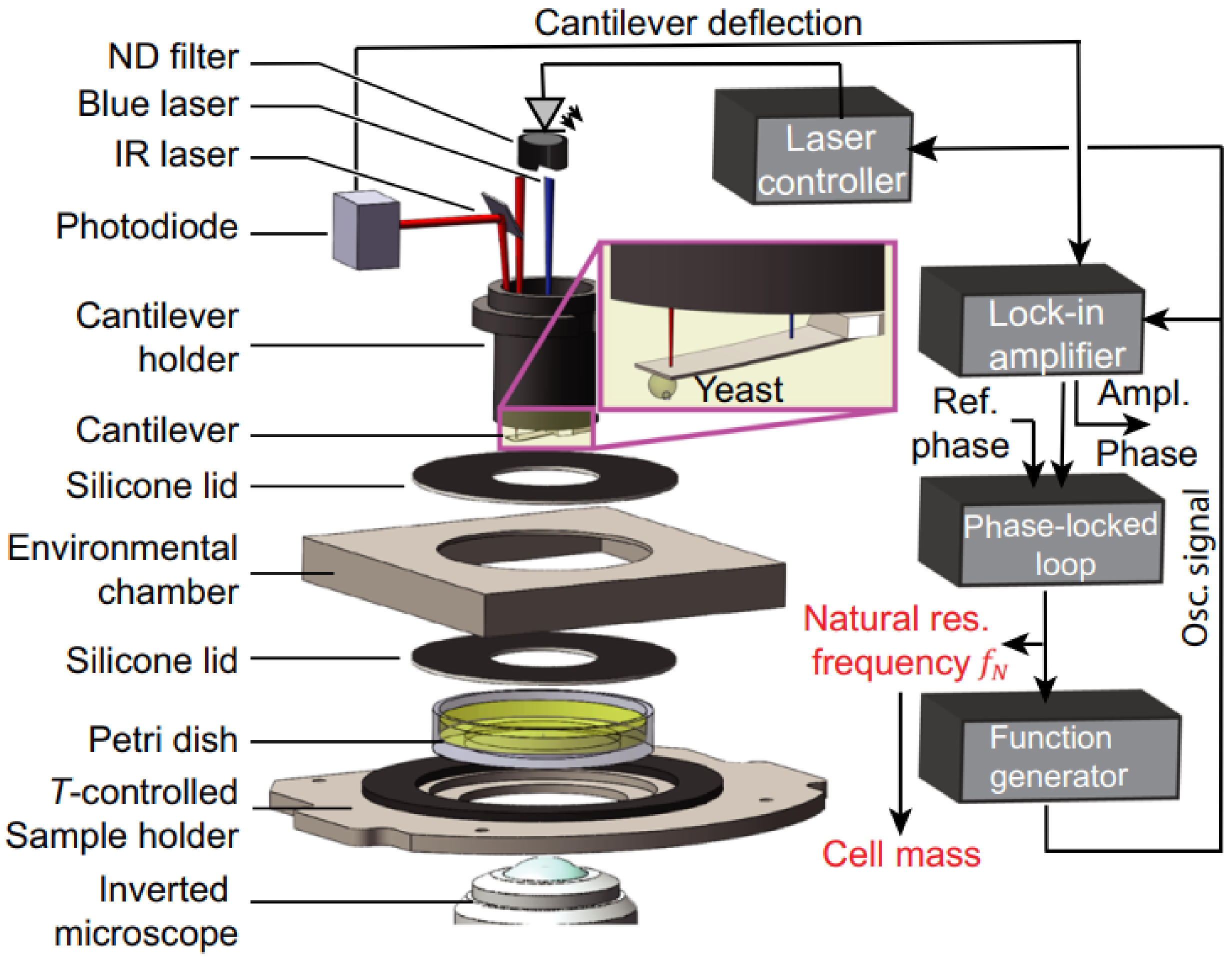


Viscoelasticity measurements

Mass measurements of single yeast cells

Advancing the original technology
(Martinez-Martin & Fläschner et. al. Nature 2017)

Increasing mass resolution, improving optical microscopy

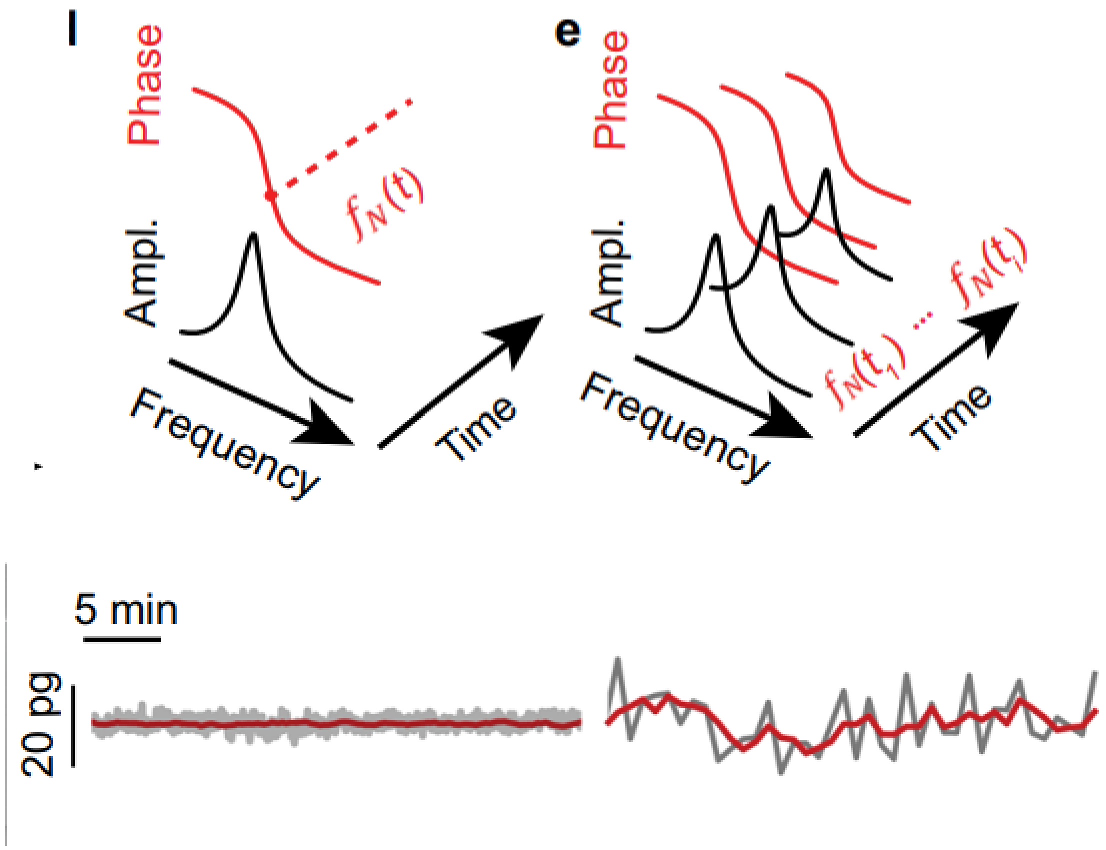


Cuny, Sapra, Martinez-Martin, Fläschner *et al.*, Nat. Commun. 2022

Mass measurements of single yeast cells

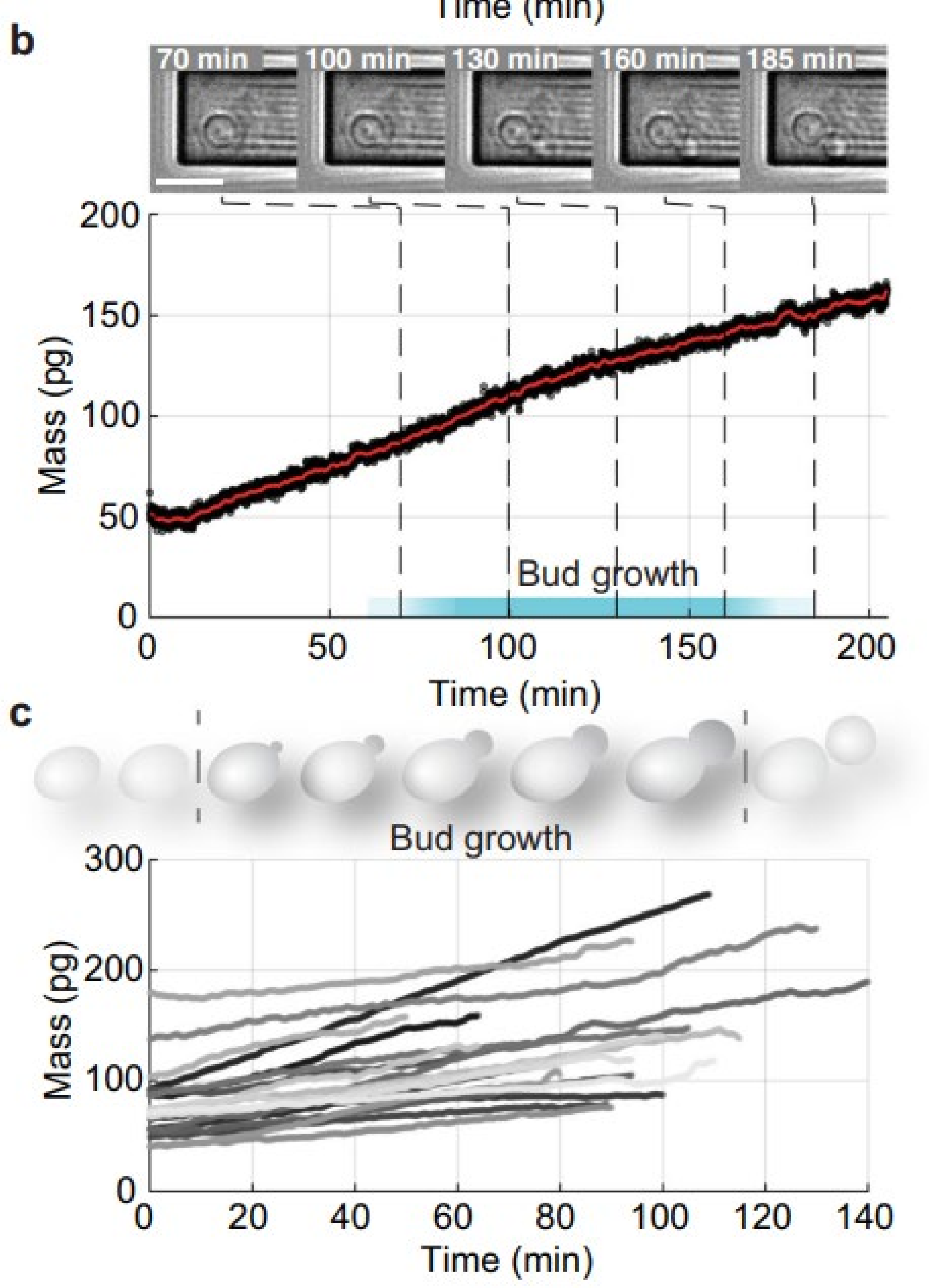
Two measurement modes:

- Continuous mode
- Sweep mode



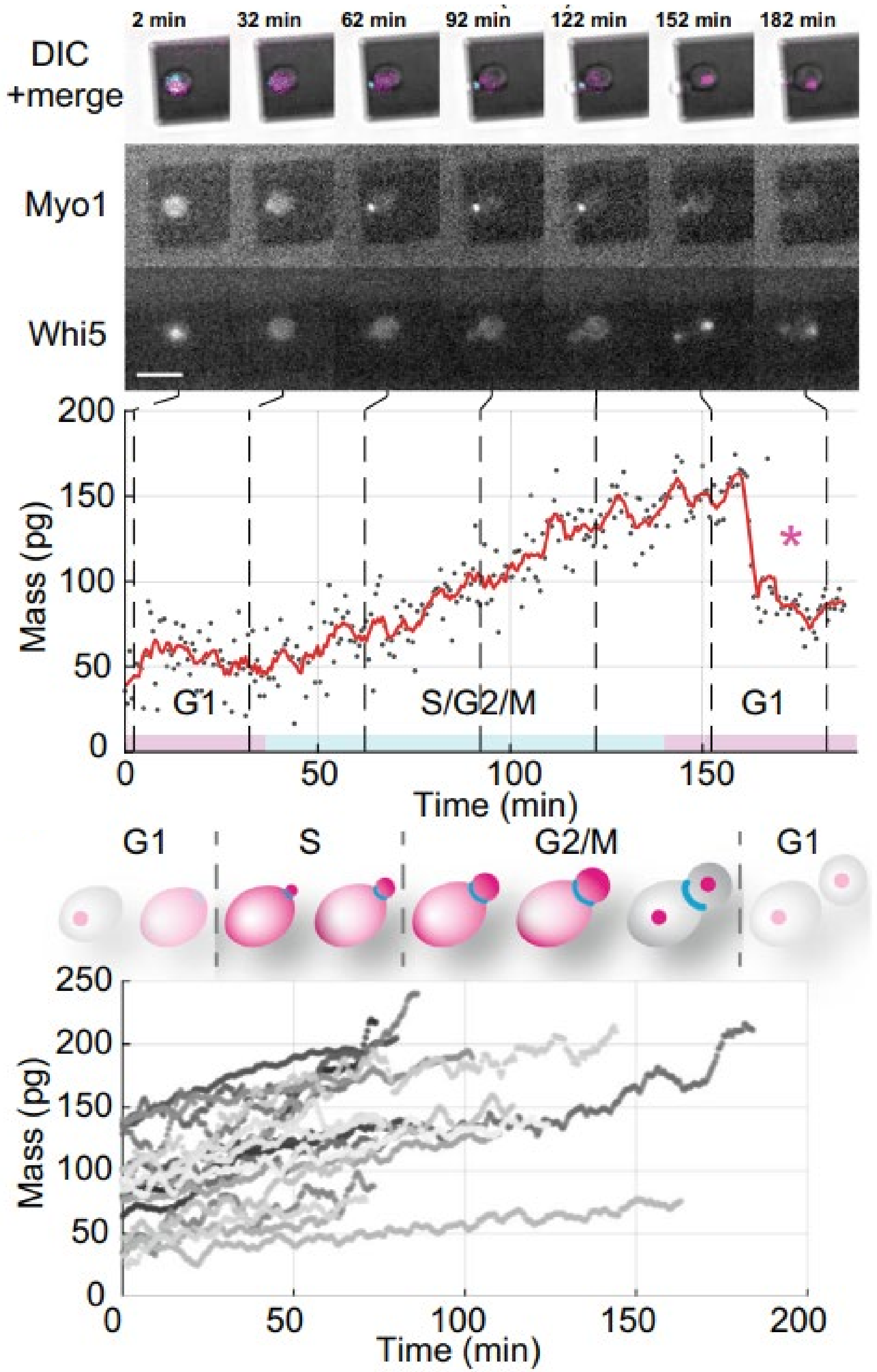
Mass measurements of single yeast cells

Increasing mass resolution

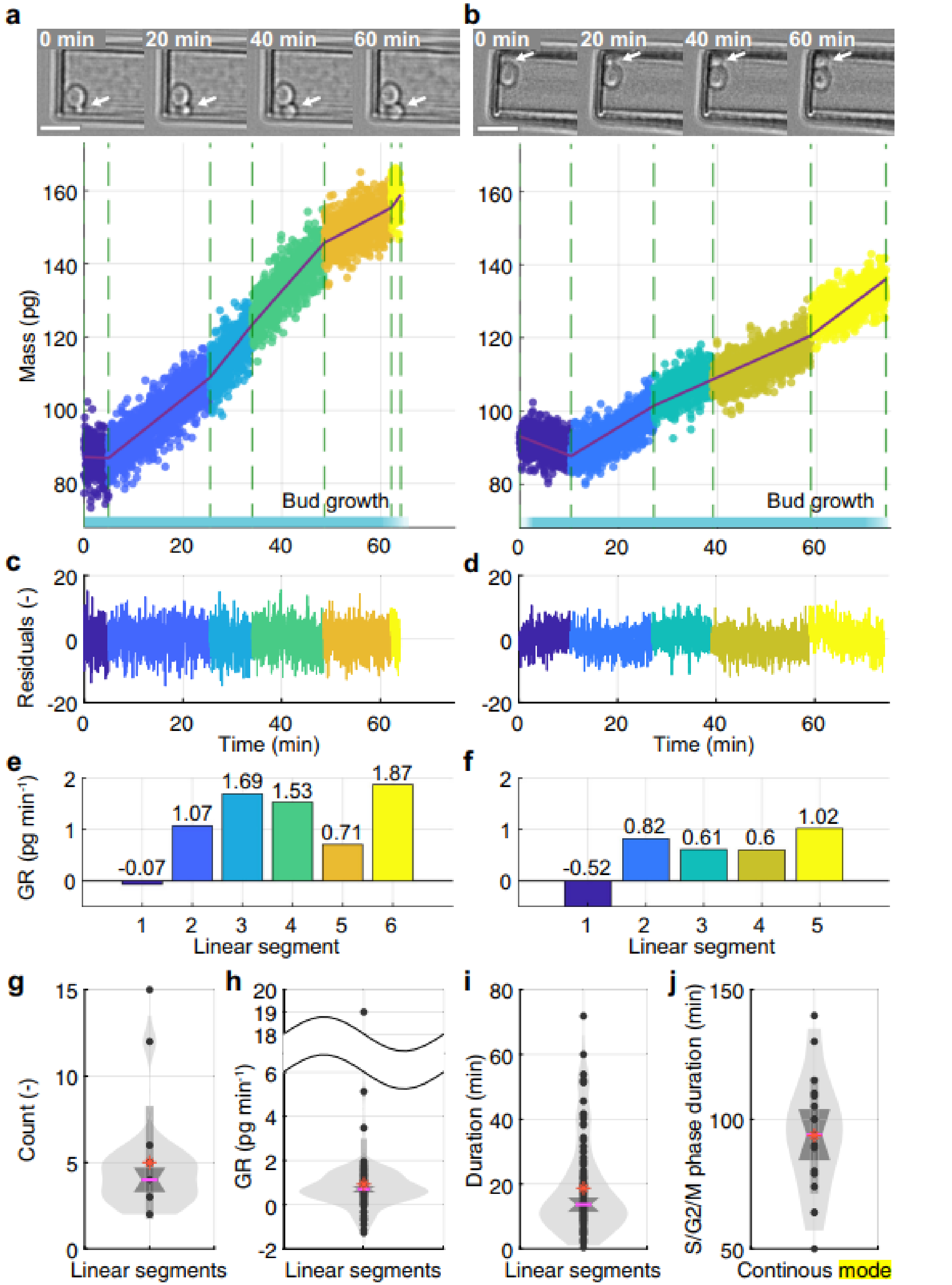


Mass measurements of single yeast cells

Increasing mass resolution, improving optical microscopy



Single budding yeast cells (S/G2/M phase) increase total mass in multiple linear segments sequentially



Cuny, Sapra, Martinez-Martin, Fläschner *et al.*,
Nat. Commun. 2022

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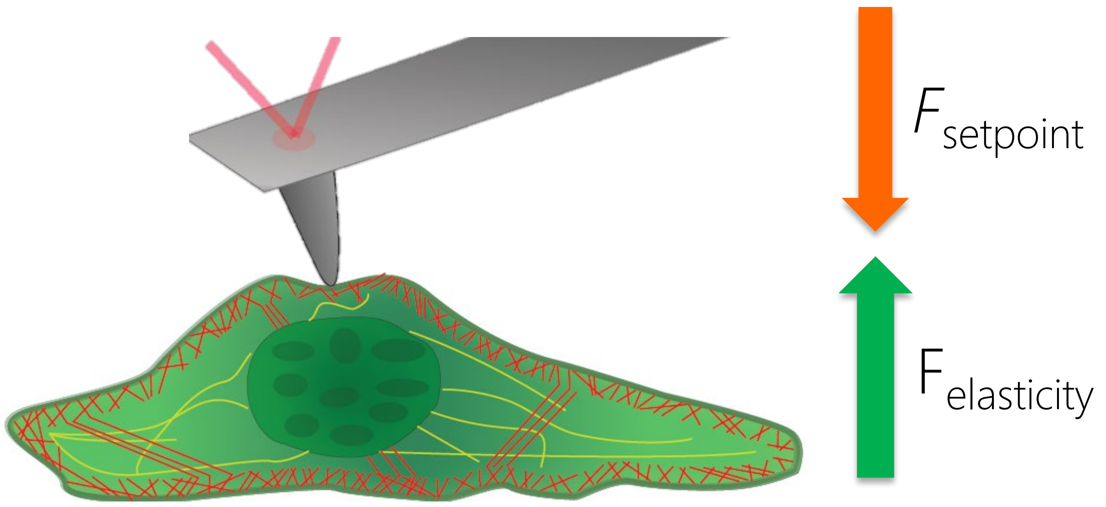
Viscoelastic measurements

Materials exhibit only elasticity

→ Reactive force: $F_{elasticity}$

→ All compression energy is stored

→ From $F_{elasticity}$ and probe geometry: E_{Youngs}



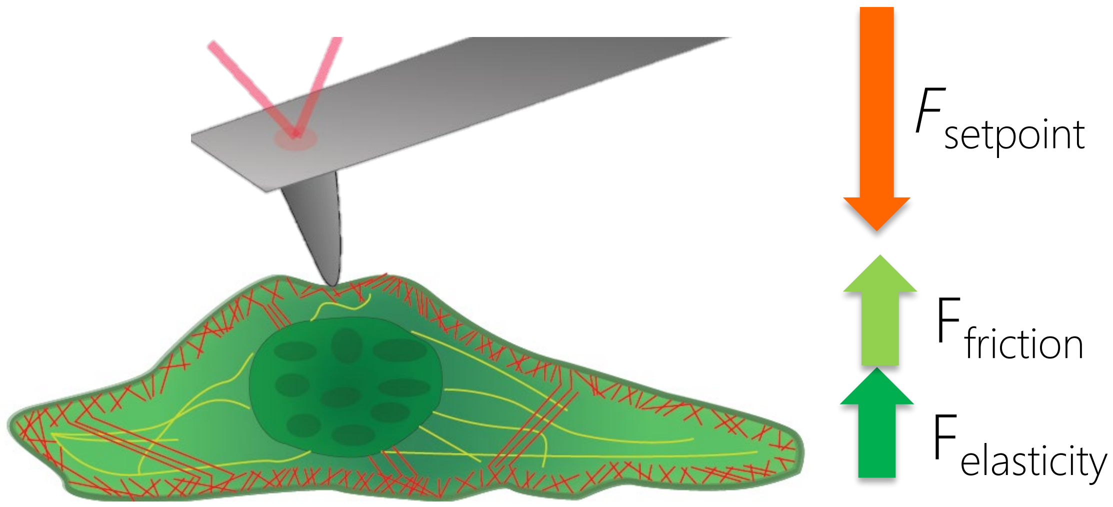
Viscoelastic measurements

Materials exhibit <u>elasticity and internal friction</u>

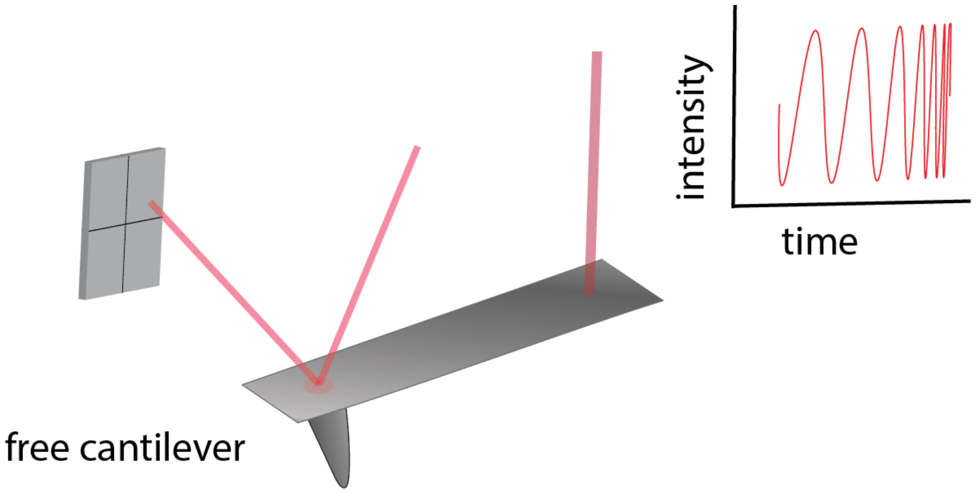
→ Some energy is stored, some lost

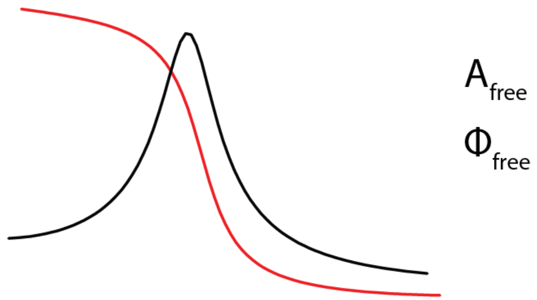
→ Two force components: $F_{elasticity}$ and $F_{friction}$

→ Analogous to E_{Youngs}: $E_{storage\ and}$ E_{loss}

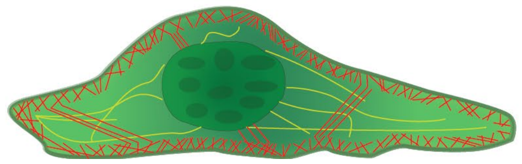


Calibration



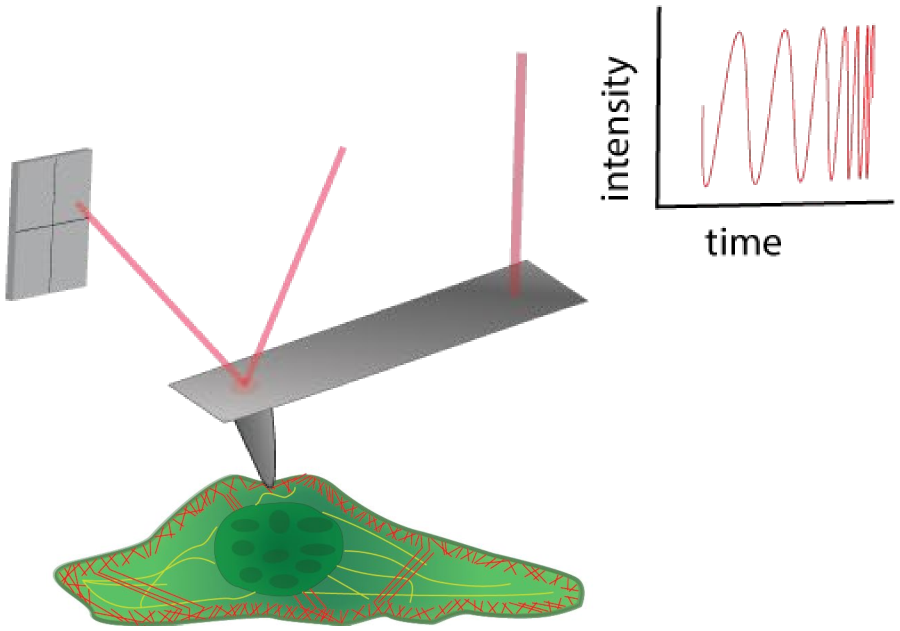


Amplitude $A_{\mathbf{free}}$, and phase $\phi_{\mathbf{free}}$ characterize the cantilever behavior in absence of conservative and dissipative forces of the sample (i.e. stiffness and viscosity of the sample)

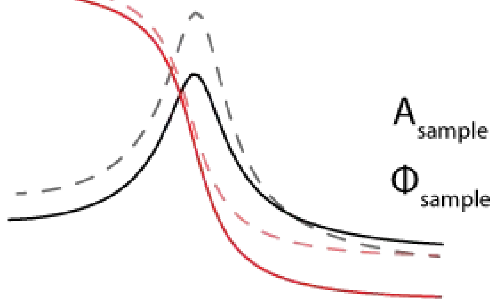


Characterization

Go in contact. Stay there. Modulate.



Using the same "driving" of the cantilever, the oscillation of the cantilever changes, characterized by its new amplitude $A_{\mathbf{sample}}$, and phase $\phi_{\mathbf{sample}}$



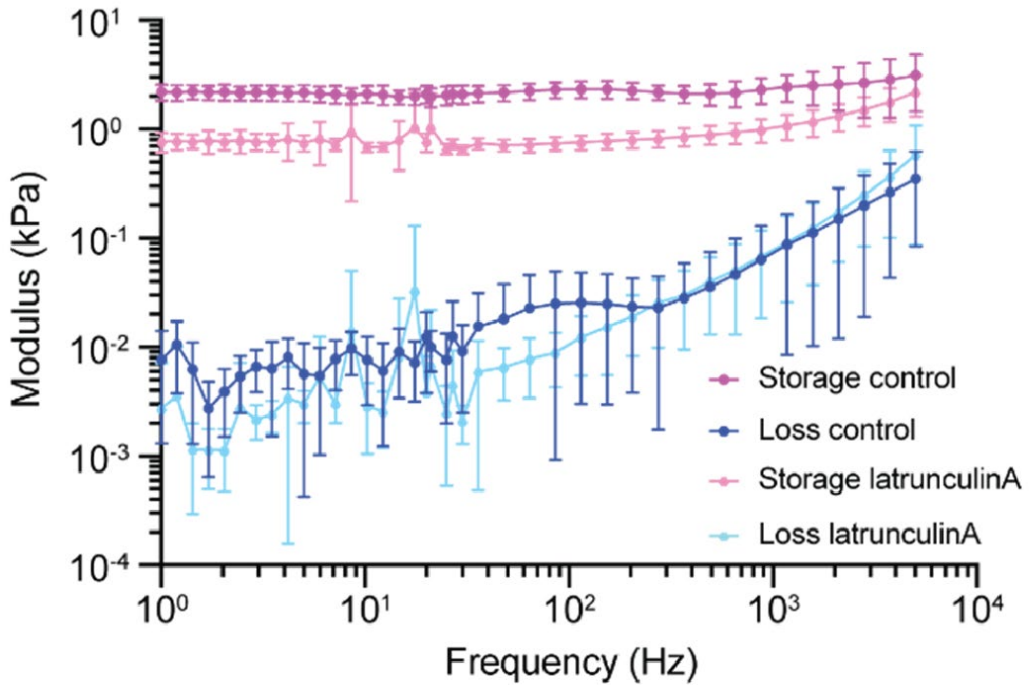
Calculation

Dynamic sample stiffness: $$k_{\mathbf{sample}} = k_{\mathbf{cantilever}} \left(\frac{A_{\mathbf{free}}}{A_{\mathbf{sample}}} - 1 \right)$$

Loss tangent: $$\tan(\delta) = \tan(\phi_{\mathbf{sample}} - \phi_{\mathbf{free}})$$

*L.M. Rebelo et al. Soft Matter 10 (2014) 2141

→ Use contact models to extract $E_{storage}$ from $k_{\mathbf{sample}}$
→ With $E_{storage}$ and $\mathbf{tan(\delta)}$ get E_{loss}



Acknowledgements

Biophysics lab, ETHZ, Basel

Prof. Daniel Müller

Dr. Nico Strohmeyer

Dr. Michele Nava

Dr. Laura Gonzales

Giulia Ammirati

Computational biology lab, ETHZ, Basel

Prof. Jörg Stelling
Dr. Andreas Cuny

School of Biomedical Engineering, University of Sydney

Dr. David Martinez-Martin

Nanosurf AG, Liestal

Dr. Jonathan Adams

Dr. Gotthold Fläschner

Hans Gunstheimer

Schweizerische Eidgenossenschaft
Confédération suisse
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Innosuisse – Schweizerische Agentur für Innovationsförderung

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