Force-Detected Absorption Spectroscopy in Solution With Optical Tweezers

Alexander Parobek, Jacob W. Black, Qixuan Yu, Anna Chen, Rosa Romero, Maria Kamenetska, Ziad Ganim
Department of Chemistry, Yale University

Force-Detected Spectro/microscopy

FDS measures infrared-optical signals through a mechanical displacement. This family of techniques including PiFM (H.K. Wickramasinghe, E.O. Potma UCI), AFM-IR (Anasys/Bruker Instruments), and optical tweezers force detected spectroscopy (OT-FDS, this work).

Resonance Enhanced/Tapping AFM-IR

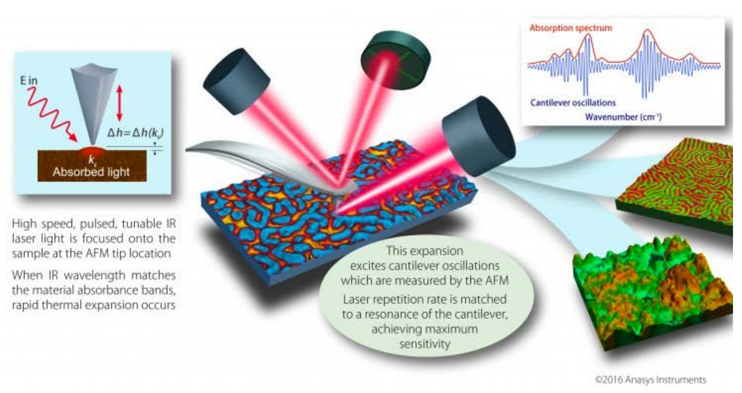
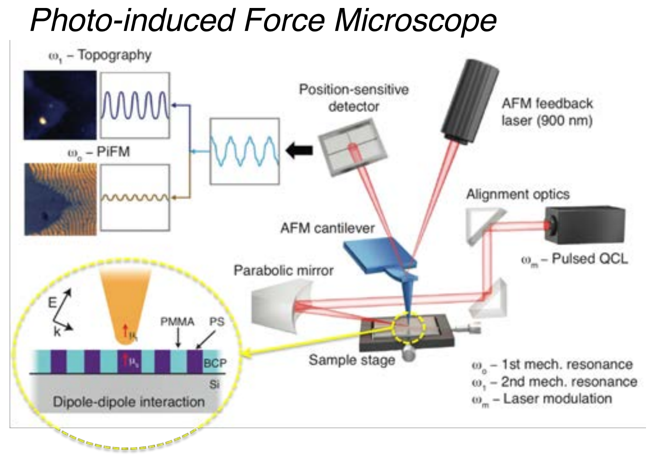
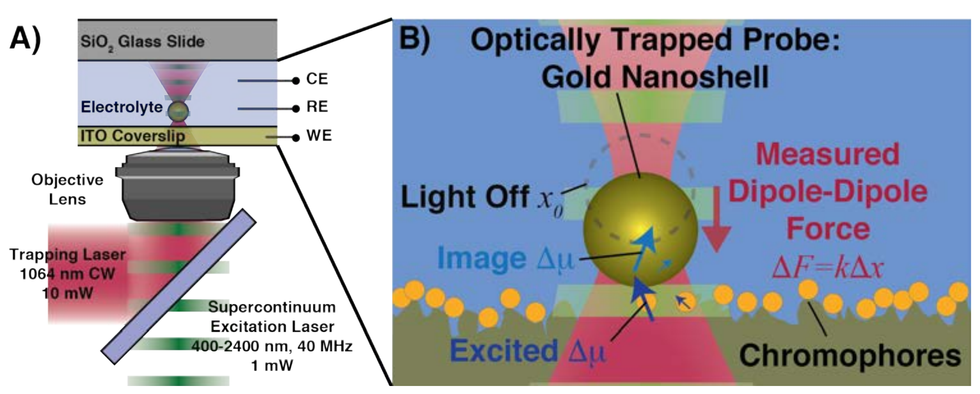


Photo-induced Force Microscope

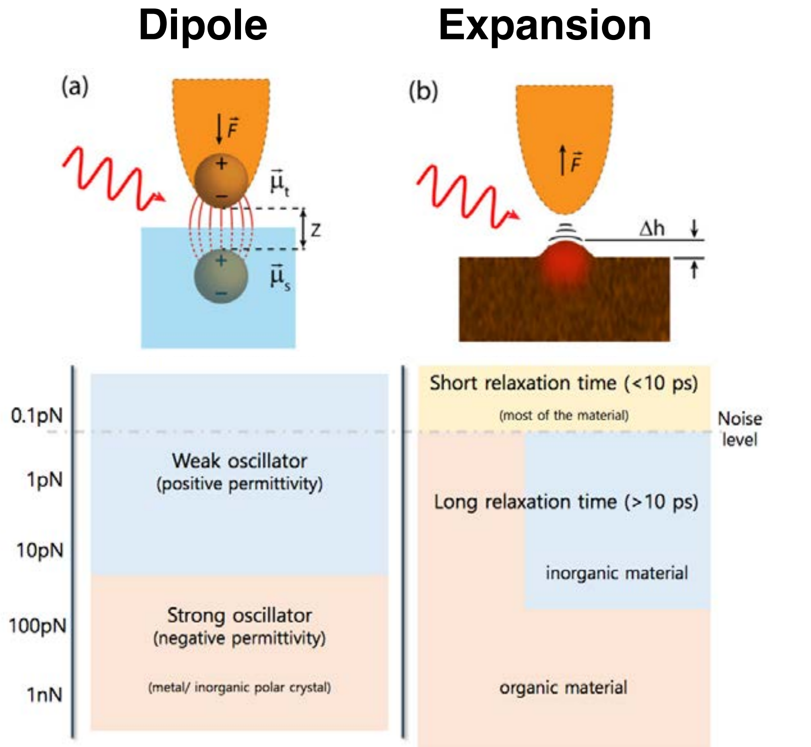


Optical Trapping Force-Detected Spectroscopy



(A) Schematic of OT-FDS in an electro-chemical cell and (B) a diagram of the force transduction provided by the gold nanoshell according to the electrostatic hypothesis.

Contrast Mechanism Hypotheses



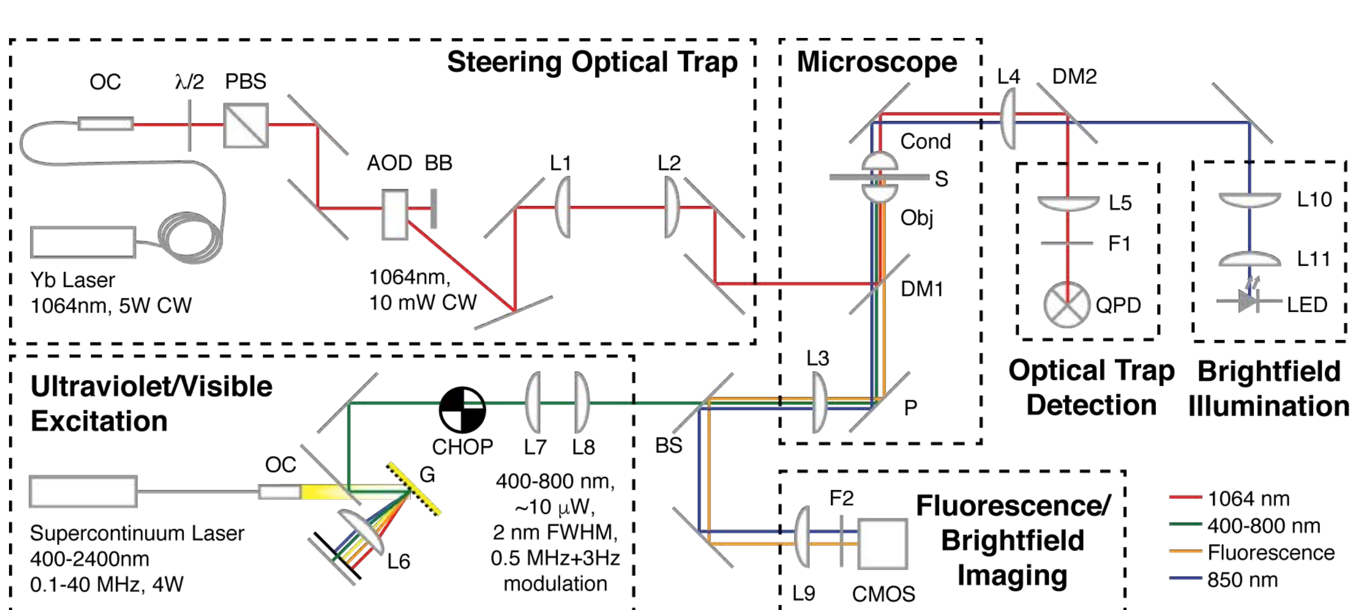
(a) Optical gradient force induced by excitation of coupled optical polarization between tip dipole and sample image dipole.
(b) The optical excitation is accompanied by absorption, with resulting thermal expansion at the AFM tip.

HU Yang and MB Raschke, New J. Phys. 18 (2016) 053042

Typical induced dipole and thermal force ranges for PiFM with respect to material's properties.

J Jahng, S Park, WA Morrison, H Kwon, D Nowak, EO Potma, ES Lee arXiv:1711.02479

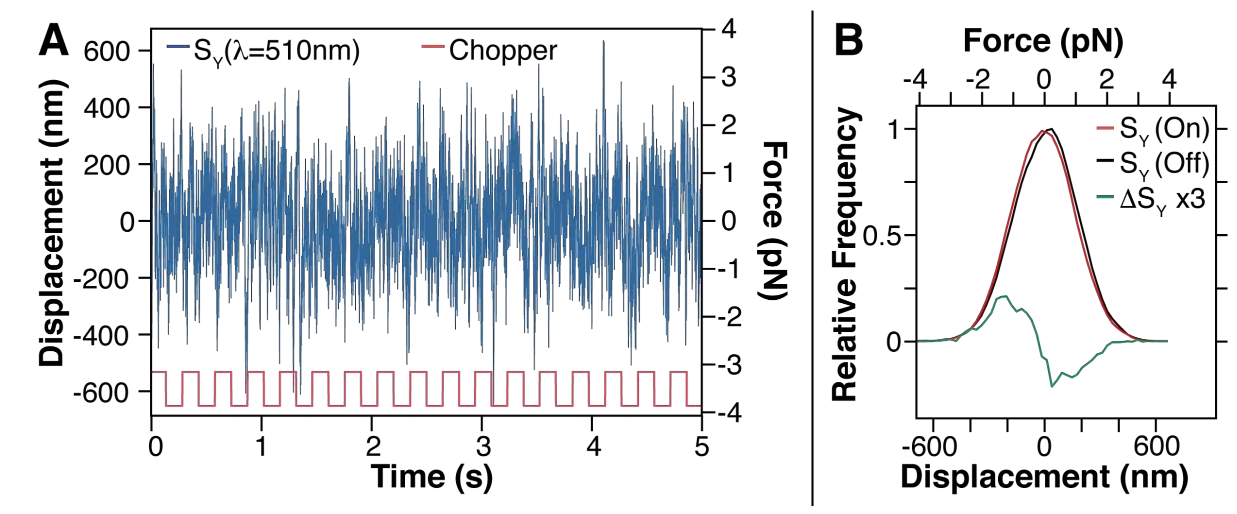
Optical FDS Microscope



L = lens, PBS = polarizing beamsplitter cube, OC = output coupler, AOD = acousto-optic deflector, BB = beam block, G = grating, CHOP = chopper, BS = 50/50 beamsplitter, DM = dichroic mirror, P = prism, Obj = objective, Cond = f = 16 mm NA = 0.79, S = sample chamber, F = filter, QPD = quadrant photodiode.

Optical Spectro/microscopy Results

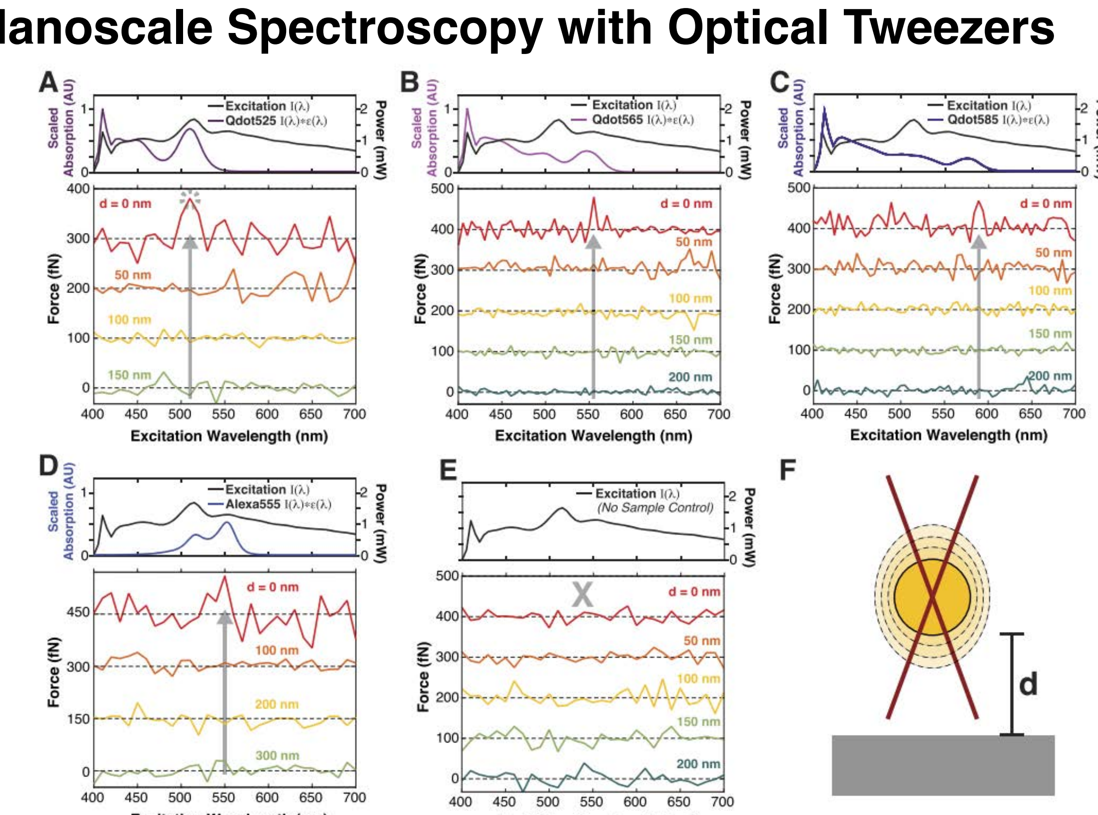
Light-Induced Force on Resonance



(a) Time-resolved displacement of the probe during a measurement at the peak in a force spectrum.

(b) Histogram of S_Y during excitation on/off periods, which reveals a slight shift in the probe position due to excitation of the sample on resonance (Qdot525).

Nanoscale Spectroscopy with Optical Tweezers

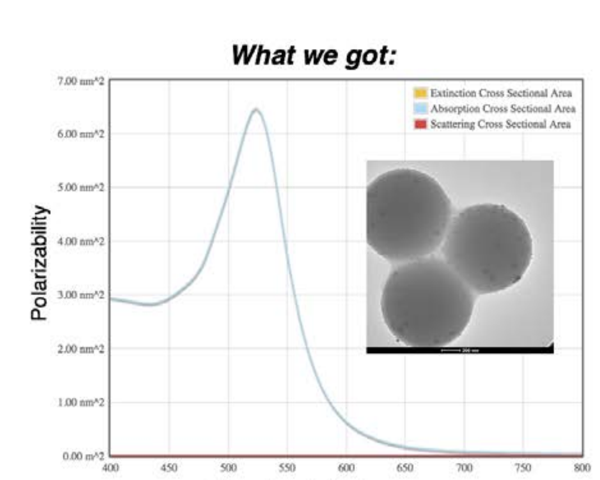


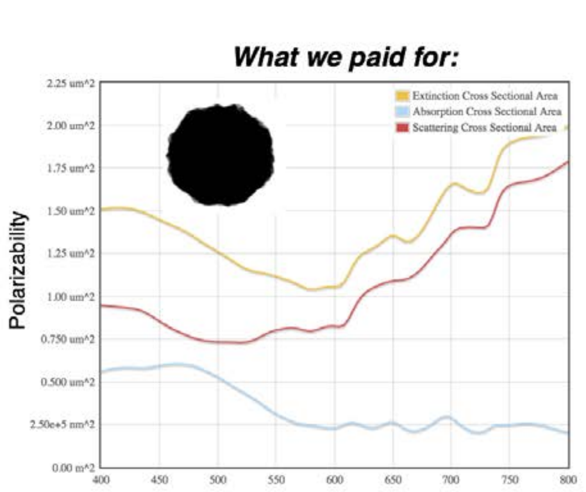
Distance-dependent force spectra demonstrate that the response is negligible for d>100nm for **(A-D)** various fluorophores.

A blankk slide control is shown in **(E)**.

A diagram drawn to scale in **(F)** illustrates the probability distribution for the optically trapped probe within the optical trap. (dashed lines are 1σ increments, σx = σy ≈ 85 nm, σz ≈ 150 nm).

Improving Gold Nanoshell Preparation:

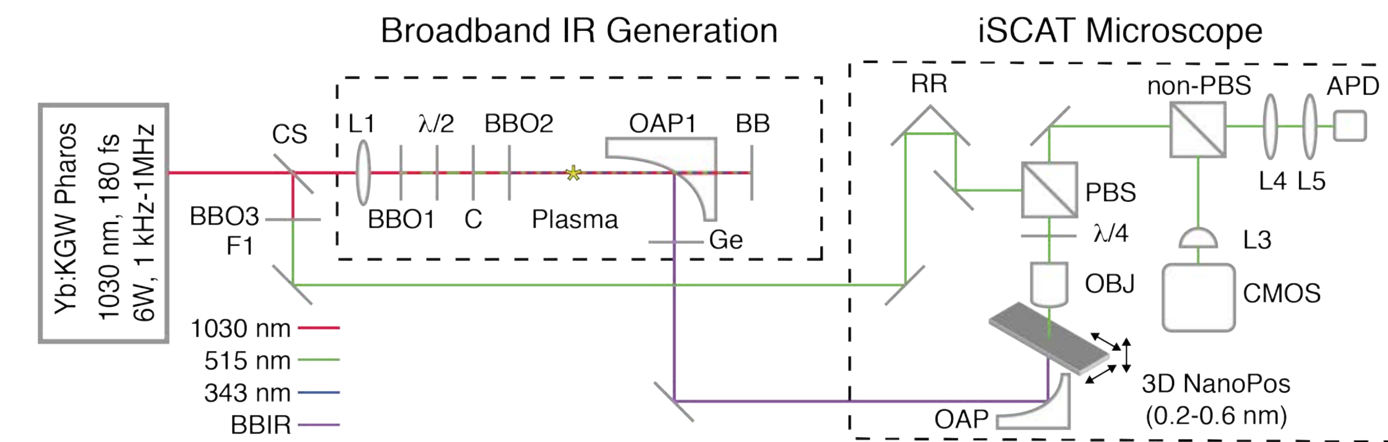




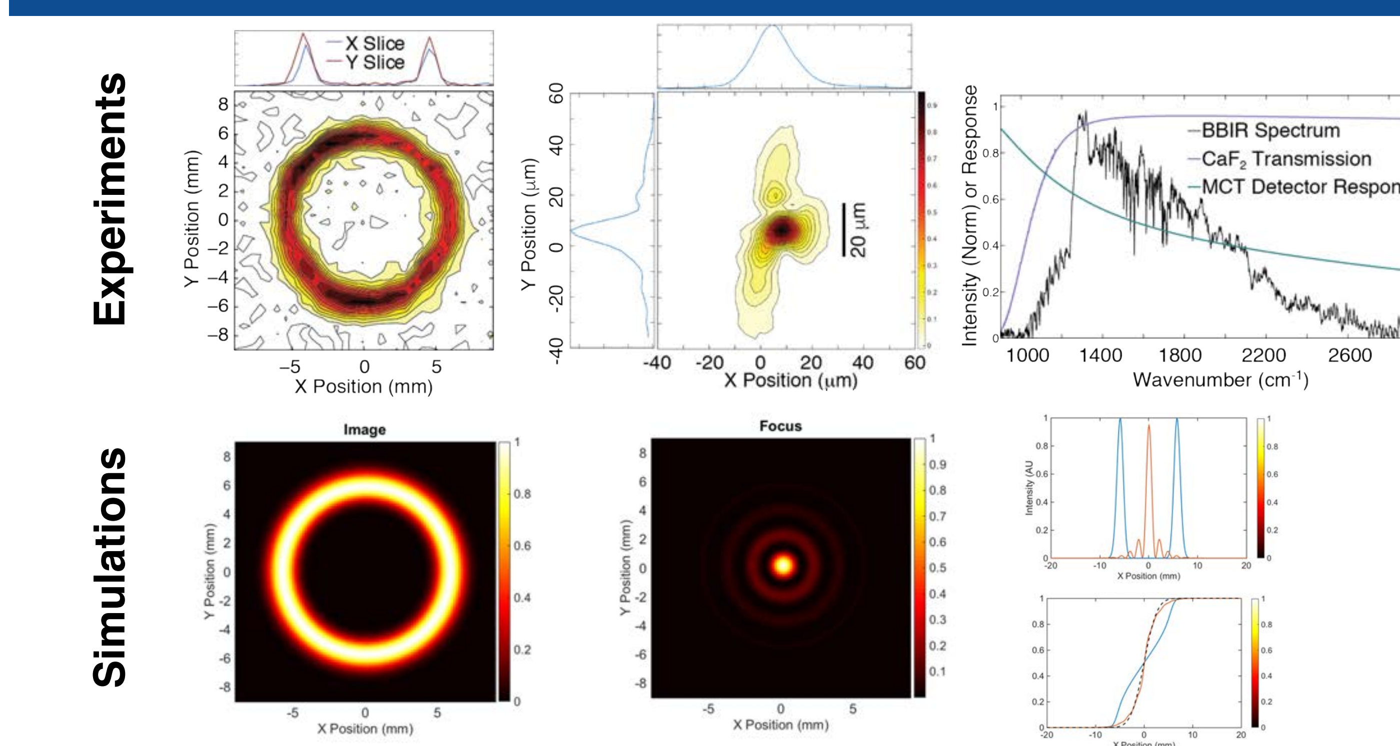
Early results suggest that organometallic gold, Me_3P-$AuMe_3$ (T_{vap} ~ 85C) was successfully synthesized.

Griffiths, M. B., Pallister, P. J., Mandia, D. J., & Barry, S. T. (2015). Atomic layer deposition of gold metal. Chemistry of Materials, 28(1), 44-46.

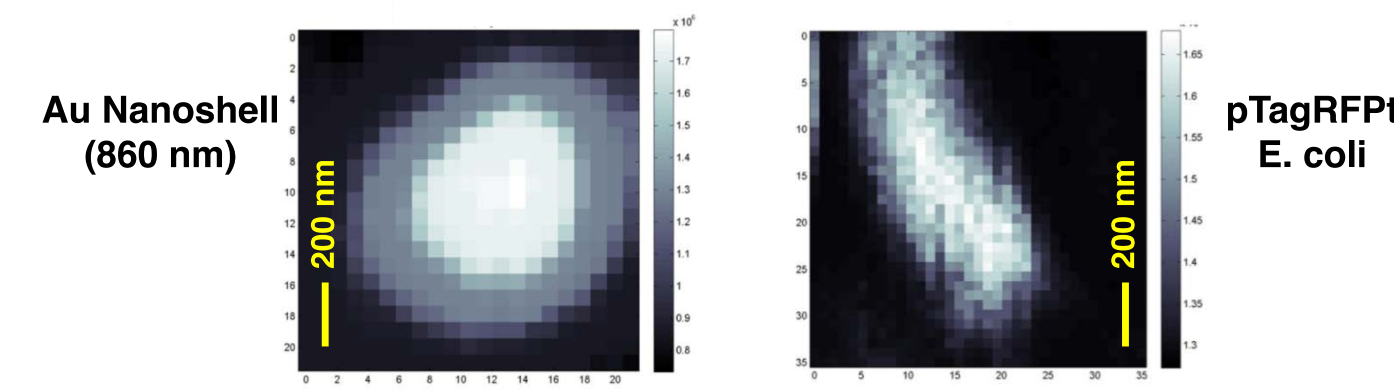
Broadband IR FDS Microscope



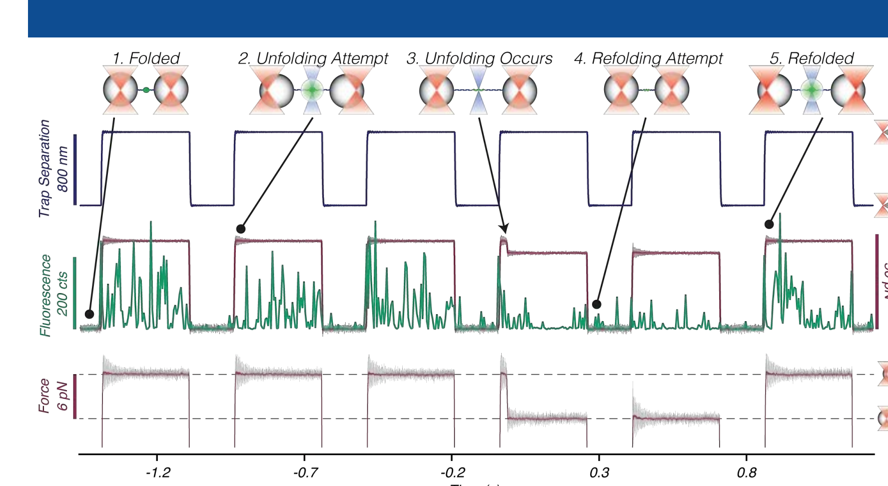
Focusing a Hollow Gaussian Beam



Interferometric Scattering Microscopy



Outlook



Single molecule absorption spectroscopy may be used to provide complementary information to conventional single molecule force measurements.

Z Ganim, M Rief, PNAS October 17, 2017. 114 (42) 11052-11056

Ganim Lab @ Yale University

This work: J. Chem. Phys., 2018, 148(14), 144201 and Opt. Lett., 2016, 41, 4855-4858