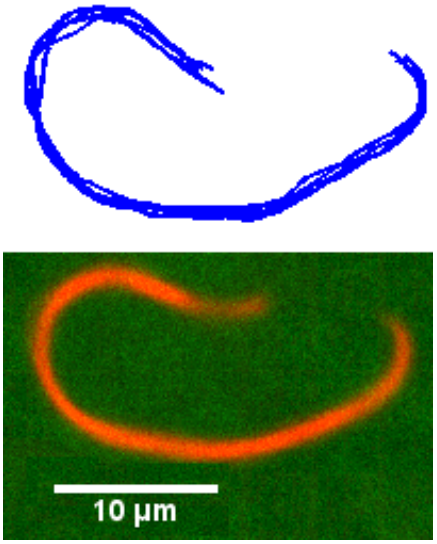
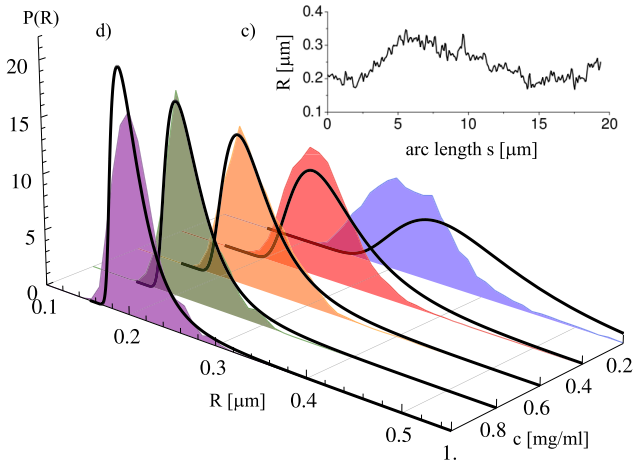
The true shape of the tube

Our physical understanding of polymeric materials as diverse as plastics, hair shampoo, or jello relies on the ``tube concept", viz., the idea that the individual chain molecules in a polymer melt or solution are confined to tube-shaped cages, from which they can escape only very slowly. So far, theorists idealized these cages as effective cylinders, but a forthcoming paper in PRL [1] now reveals strong heterogeneities in the tube width and explains them quantitatively by a systematic microscopic theory.



Visualization of the tube-shaped cage around a fluorescent actin filament in solution. [1]

This is an important step towards solving a modern version of the legendary Gordian knot riddle. If viewed with nanoscopic resolution, polymeric materials resemble enormous portions of spaghetti, and polymer scientists need to figure out how their often spectacular macroscopic material properties emerge from this molecular tangle. As Alexander the Great untied the Gordian knot with a sword stroke, so the eminent soft matter theorists S. F. Edwards and P.-G. de Gennes set out in the late 1960s to cut this intractable molecular maze into manageable pieces by introducing the tube. Yet, despite steady progress in the field, the tube itself remained a somewhat abstract hypothetical object that could never be grasped outside the realm of computer simulations [2]. A breakthrough came when the attention turned towards biopolymers such as actin and microtubules, which naturally self-assemble into entangled networks that give animal cells their shape and mechanical strength. Exploiting the much larger and stouter structure of such biopolymers as compared to their synthetic cousins, J. Käs, H. Strey, and E. Sackmann [3] achieved the first direct visualization of the tube using fluorescence microscopy, while D. Morse succeeded in developing a systematic theory for its average thickness [4]. Remarkably, this theory starts from a faithful representation of the entanglement topologies and constructs the tube on the basis of individual microscopic polymer-polymer collisions. Building on these advances and on some more recent contributions [5,6] two German groups from Leipzig and Jülich are now presenting the first systematic comparison of a microscopic theory for the true heterogeneous shape of the tube with comprehensive experimental observations (see Figures) [1]. "The tube, which used to be a fuzzy idea in our heads, is finally firmly in our hands, both mathematically and experimentally", the first author, Jens Glaser, comments, "and a whole range of intriguing new questions, e.g. concerning the curvature distribution of the tube and its consequences for polymer rheology, can now be addressed." The sound



The asymmetric and leptokurtic shape of the tube radius distribution P(R) (shaded areas) is now explained by a systematic theory (solid lines) for the local tube width R (inset) [1].

agreement of data and theory over a wide range of parameters means that the clouds of mystery around the tube are lifting, eventually opening the field to more quantitative molecular approaches.

[1] Glaser *et al.*, Tube Width Fluctuations in F-Actin Solutions, Phys. Rev. Lett. in press
[2] Everaers *et al.*, Rheology and microscopic topology of entangled polymeric liquids. Science 303 (2004) 823.
[3] J. Käs, H. Strey, E. Sackmann, Direct imaging of reptation for semiflexible actin filaments, Nature 368 (1994) 226.
[4] D. Morse. Tube diameter in tightly entangled solutions of semiflexible polymers. Phys. Rev. E 63 (2001) 031502
[5] H. Hinsch, E. Frey, Quantitative tube model for semiflexible polymer solutions, Euro. Phys. J. E 24 (2007) 35
[6] Wang *et al.*, Confining Potential when a Biopolymer Filament Reptates, Phys. Rev. Lett. 104 (2010), 118301