Collective dynamics in a multi-filament actin bundle

J. Schnauß[1]*, T. Golde[1], C. Schuldt[1], B. U. S. Schmidt[1], M. Glaser[1], D. Strehle[1], C. Heussinger[2], and J. Käs[1]

[1] Institute for Experimental Physics I, University of Leipzig, Leipzig, Germany
[2] Institute for Theoretical Physics, Georg-August University of Göttingen, Göttingen, Germany
*email: joerg.schnauss@uni-leipzig.de

For living beings or general in biological systems force production is of inherent importance to achieve certain states or to fulfill crucial functions. These functions range from muscle contractions to cell movement or even to force production on the filament level [1]. In general, force production in biological systems is associated to filamentous proteins and their according motor proteins (e.g. actin – myosin, microtubuli – dynein & kinesin) depending on ATP or GTP consumptions and thus energy dissipation [1]. However, arguments pointing towards active, dissipating processes usually ignore the fact that these systems (e.g. actin – myosin) need to be arranged in elaborate structures to fulfill according tasks.

In this study, however, we show that contractions related to actin structures are possible without myosin motor proteins. The system is not driven by ATP hydrolysis and solely relies on filament – filament interactions induced by a crowded environment causing depletion forces. Dynamics of these contractions behave differently to a single filament pair shown in previous theoretical and experimental studies. We are able to show that the behavior of contractile actin bundles can be well described as an emergent phenomenon of multiple filament pairs. This crowding regime is well below the macromolecular content of cells and thus these effects have to be considered in cellular systems as well.

We measured contraction velocities ranging from 0.10 to 0.65 µm/s and evaluated a typical force regime of 0.5 to 3.0 pN. Dynamics and forces of this non-dissipative process correspond to an active behavior of single myosin motors.

These findings illustrate that not all biological processes rely on ATP or GTP consumption. Cells or biological structures can use simple physical processes to spare complex organizations of functional moduli. Cells, for instance, are very complex environments with a variety of interconnecting components. Physical effects are powerful tools to achieve ordering as a basis for a functional process without the need of extensive pre-organizations, which might require a comprehensive manipulation of the whole environment.

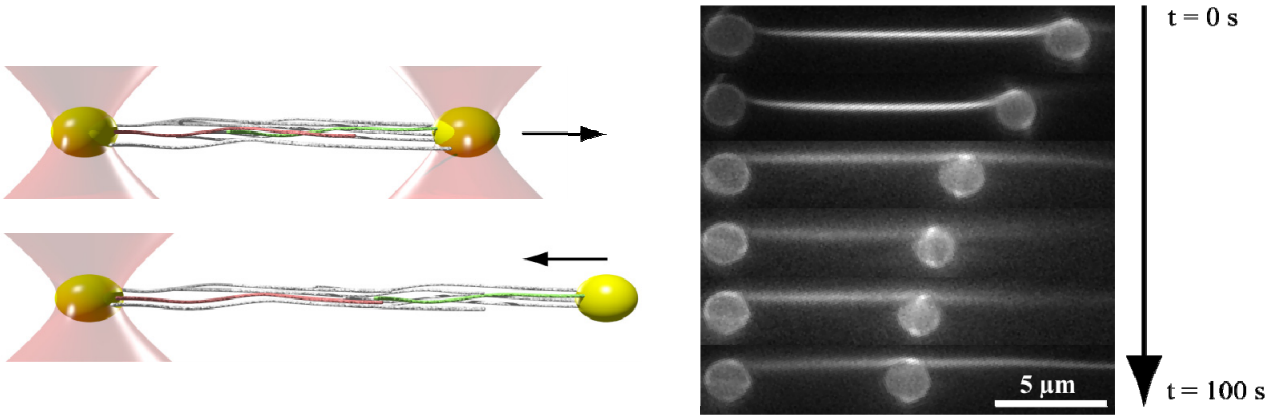

Figure 1: The bundle contraction experiment.
Bundles are formed by crowding effects inducing depletion forces. Thus, an ordering is achieved without applying molecular motors or any other actin associated proteins. By attaching beads, bundles can be manipulated by optical tweezers. A significant elongation of the bundle (exceeding normal elastic deformations) results in a contraction process solely driven by enthalpy gain.

[1] F. Huber, J. Schnauß, S. Rönicke, P. Rauch, K. Müller, C. Fütterer & J. Käs: *Emergent complexity of the cytoskeleton: from single filaments to tissue*. Advances in Physics **62**, 1-112 (2013).