Single-Molecule Torque Spectroscopy for Biophysical Investigations

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Abstract:

The torsional properties of DNA play an important role in cellular processes such as transcription, replication, and repair. To access these properties, a number of single-molecule techniques such as magnetic tweezers have been developed to apply torque to DNA and coil it. I will briefly refer to investigations of DNA-protein interactions using these techniques, and describe what has been learnt.

I will then focus on the development of novel magnetic techniques that go beyond standard magnetic tweezers, such as the magnetic torque tweezers[1] and the freely-orbiting magnetic tweezers[2]. These approaches allow one to quantify conjugate variables such as twist and torque. For example, the magnetic torque tweezers rely on high-resolution tracking of the position and rotation angle of magnetic particles in a low stiffness angular clamp. We demonstrate the experimental implementation of this technique and the resolution of the angular tracking. Subsequently, we employ this technique to measure the torsional stiffness *C* of both dsDNA molecules and RecA heteroduplex filaments.

Lastly, I will describe novel applications of the optical torque wrench[3,4]. The optical torque wrench is a laser trapping technique developed at Cornell capable of applying and directly measuring torque on microscopic birefringent particles via spin momentum transfer. We have focused on the angular dynamics of the trapped birefringent particle[4], demonstrating its excitability in the vicinity of a critical point. This links the optical torque wrench to non-linear dynamical systems such as neuronal and cardiovascular tissues, non-linear optics and chemical reactions, which all display an excitable binary ('all-or-none') response to input perturbations. Based on this dynamical feature, we devise a conceptually novel sensing technique capable of detecting single perturbation events with high signal-to-noise ratio and continuously adjustable sensitivity. I will also highlight how our understanding of this physical system can be employed in biophysical investigations.

References:

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