Bandpass Filtering of DNA Elastic Modes Using Confinement and Tension

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Summary: An apparatus combining modified Magnetic Tweezers and Nanofluidics is designed and fabricated to measure the elastic response of long double-stranded DNA under confinement and tension. Measured elastic responses are presented and an analytical theoretical model is also discussed to account for the data.

During a variety of biological and technological processes, biopolymers are simultaneously subject to both confinement and external forces. While significant efforts have gone into understanding the physics of polymers that are only confined [1-3], or only under tension [4-7], little work has been done to explore the effects of the interplay of force and confinement. Here, we study the combined effects of stretching and confinement on a polymer’s configurational freedom. We measure the elastic response of long double-stranded DNA molecules that are partially confined to thin, nanofabricated slits. We account for the data through a model in which the DNA’s short wavelength transverse elastic modes are cut off by applied force and the DNA’s bending stiffness (as in the Marko-Siggia model [5]), while long-wavelength modes are cut off by confinement. Thus, we show that confinement and stretching combine to permit tunable bandpass filtering of the elastic modes of long polymers.

Figure 1. Experimental geometry. A DNA molecule is threaded through a slit between two reservoirs on a microfabricated chip. It is tethered to the surface of one reservoir, and to a magnetic bead in the other. An external magnetic field manipulates the bead, applying a known stretching force to the DNA; optical bead tracking gives a direct measure of the extension 2B of the DNA in the bead-side reservoir. Insets: An electron micrograph of a slit (left) and an optical image of a fluorescently-stained DNA threading a slit (right). The autofluorescent bead is clearly visible, and overlaid white lines indicate the slit extent. Scale bars 5 μm.