

# Lab 5: Optical trapping and single molecule fluorescence

**PI:** Matt Lang

**Lab Instructor:** Jorge Ferrer

## Summary

Optical tweezers are an excellent experimental tool to study the biophysics of single molecule systems including the mechanics of molecular motors (kinesin, myosin, RNA polymerase), mechanical conformations/transitions of molecules (dsDNA, RNA hairpins, filamentous proteins) and interactions of receptor-ligand systems (antigen-antibody). In the most common assays, the mechanical state of the system is monitored by tracking the position of a handle (usually a dielectric microsphere with diameter of 0.5-2 $\mu$ m) tethered to the molecule of interest (protein, DNA, etc), with nanometer and piconewton resolution. The handle also serves as probe to apply force to the system to study the energetics of mechanical changes. Single molecule fluorescence allows the direct observation of the mechanical/conformational changes of the system as it is subjected to perturbations, such as force. The combination of these two techniques allows researchers to study the biophysical properties of single molecules. In this lab you will learn the basics of operating a high-end optical tweezers to record mechanical transitions of single molecules. The instrument is also equipped with a novel single molecule fluorescence technique to allow simultaneous, coincident optical trapping and single molecule fluorescence. In our demonstration we will measure the force required to unzip a double-stranded DNA molecule, with a resolution of  $\sim$ 5nm and  $\sim$ 0.1pN, while using single molecule fluorescence to confirm the location of the break. Alignment and calibration procedures will also be presented.

## Recommended Reading

R. R. Brau *et al.*, "Interlaced Optical Force-Fluorescence Measurements for Single Molecule Biophysics," *Biophys. J.* **91** (2006).

M. J. Lang *et al.*, "Simultaneous, Coincident Optical Trapping and Single-Molecule Fluorescence," *Nat. Methods* **1** (2004).





## Optical Trapping and Single Molecule Fluorescence Lab Demonstration Dual Confirmation of double-strand DNA Unzipping

### *Lab contact information:*

Supervisor: Matthew J. Lang

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M.J. Lang *et al*, "Simultaneous, coincident optical trapping and single-molecule fluorescence," *Nature Methods* **1** (2004).

(optional) Optical Trapping Review : K.C. Neuman & S.M. Block, "Optical trapping," *Rev. Sci. Instrum.* **75** (2003).



### **Equipment you will see in the Lang Lab:**

- Modified Nikon TE2000 microscope (100X, 1.40NA oil immersion objective)
  - Piezo-electric stage (1-nm resolution, 100x100x20  $\mu\text{m}$  range)
  - Manual stage
  - Position detection branch with photodiode
- Main optics box (right of microscope): enclosed breadboard housing the trapping (1064nm), detection (975nm) and fluorescence excitation (488nm and 532nm) lasers, and optics to align the beams. A pair of acousto-optic deflectors (AODs) provides 2-D control of the trapping laser location in the specimen plane and a single AOD provides modulation of the fluorescence excitation laser.
- Dark box (left of microscope): contains a CCD for bright field imaging, an intensified CCD for single molecule imaging and a pair of silicon avalanche photodiodes (SAPDs) for single molecule detection and fluorescence resonance energy transfer (FRET) detection.
- All of the above mounted on top of an optical table.

### **Experimental procedure for single molecule fluorescence using total internal reflection fluorescence (TIRF) microscopy:**

- Set up slide in scope, adjust bright field illumination and position detection branch (attached to condenser).
- Locate single dye on surface using intensified CCD.
- Move the molecule to the fluorescence collection region (pinhole) using piezo-stage.
- Collect fluorescence emission with SAPDs (counts per unit of time) until dye photobleaches (discrete reduction in fluorescence signal).

### **Combined OT and SMF to detect dsDNA unzipping:**

- Find a tethered bead, find the tether point and reposition it to the fluorescence collection region.
- Trap the bead and simultaneously record bead displacement from the center of the trap and fluorescence emission.
- An unzipping event will show both a sudden change in bead position and a discrete decrease in fluorescence emission (dye no longer in collection region).
- Calibrate the bead for both position and obtain trap stiffness using variance method (see review by Neuman & Block for details).

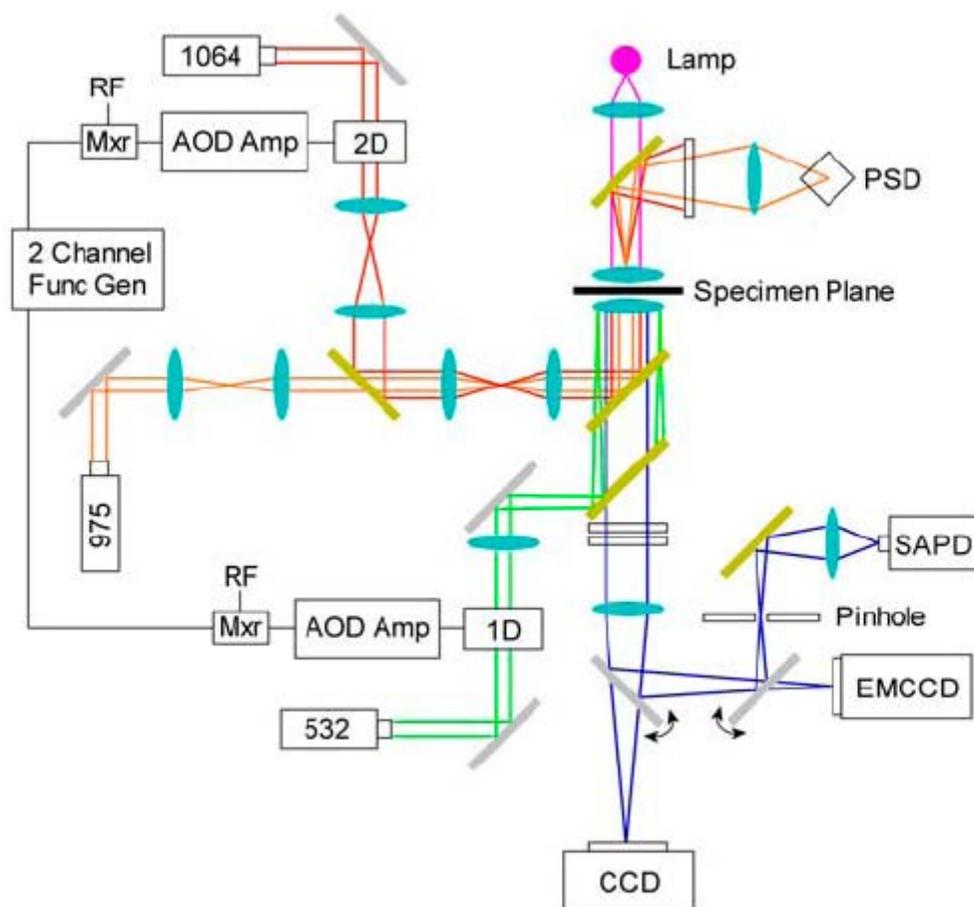


FIGURE 1. Optical layout of the instrument. All lenses, including the objective and condenser, are displayed as light-blue ovals. Filters, mirrors, and dichroics are represented as white, silver, and gold-filled rectangles, respectively. Trapping (red) and detection (orange) lasers, 1064 and 975 nm, respectively, are guided into the objective and focused on the specimen plane to form an optical trap. The position of the trapped particle is monitored by spectrally isolating and imaging the detection laser on a PSD. Total internal fluorescence excitation, supplied by a 532-nm laser (green), is focused near the back pupil of the objective. Bright-field illumination is provided by a mercury arc lamp (magenta), and images (blue) are collected by a CCD camera. Fluorescence images (blue) are collected by an electron multiplying CCD (EMCCD), and single molecule fluorescence counts are spatially filtered through a pinhole and acquired by an SAPD. The trapping and excitation lasers are modulated by AODs controlled with an electronic mixer (Mxr) that combines a preamplified radio frequency AOD drive signal with a square wave generated in a function generator.

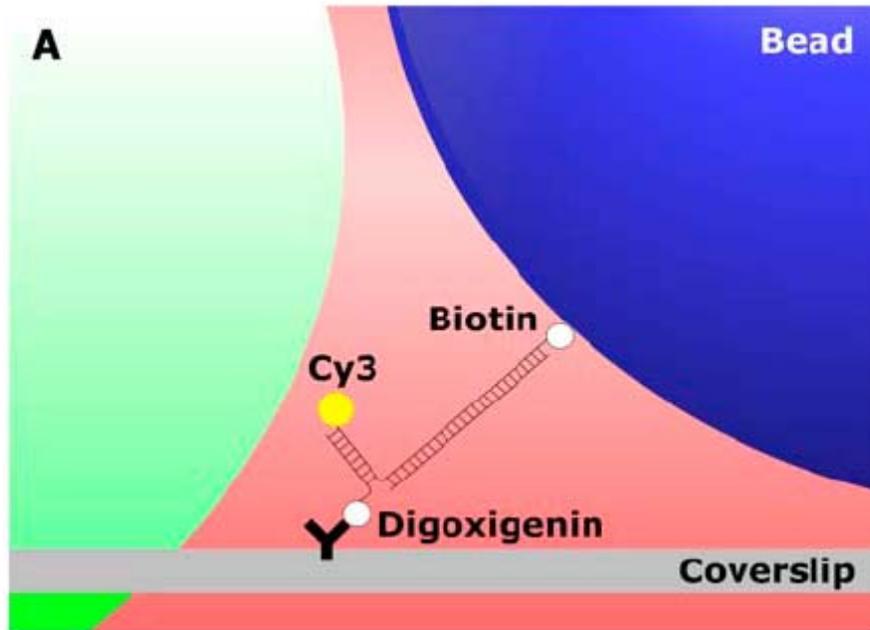


FIGURE 2. Unzipping geometry for a 15-bp dsDNA system. It is attached on one end to a trapped bead via a biotin–streptavidin interaction and immobilized on the other end by means of a digoxigenin–antibody linkage. The 15-bp region of interest is labeled with a Cy3 fluorophore to confirm the location and timing of the unzipping mechanical event.