Heat Flow Analysis of Micro-objects Using Optical Tweezers

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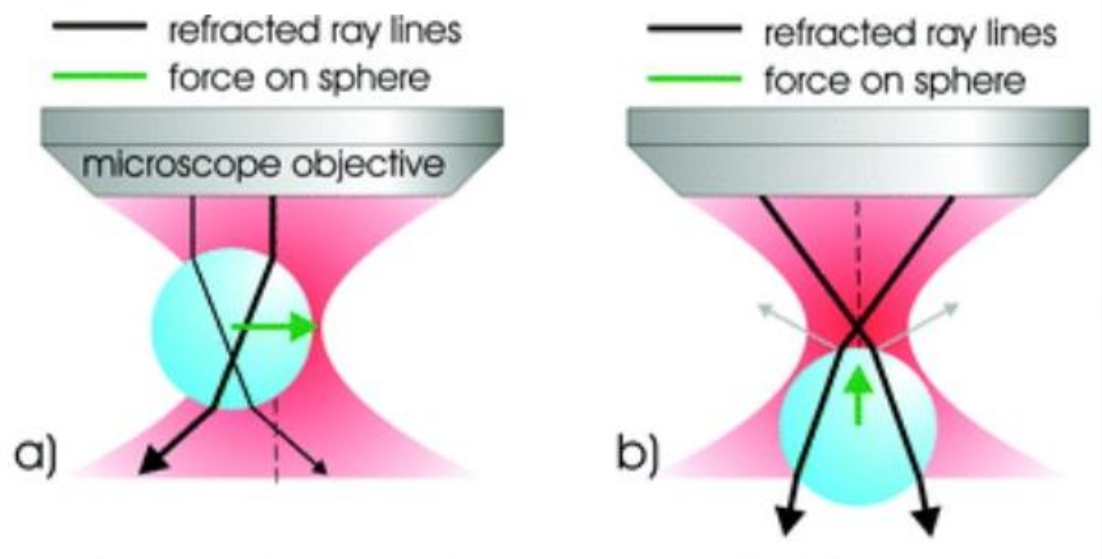
Background

- Optical traps can be modeled as Hookean springs

- Ray Optics Explanation
    - Conservation of momentum due to refraction
    - Appropriate for larger beads

- Polarization Explanation
    - Bead is polarized from the laser's electric field and acts like a dipole
    - Appropriate for smaller beads

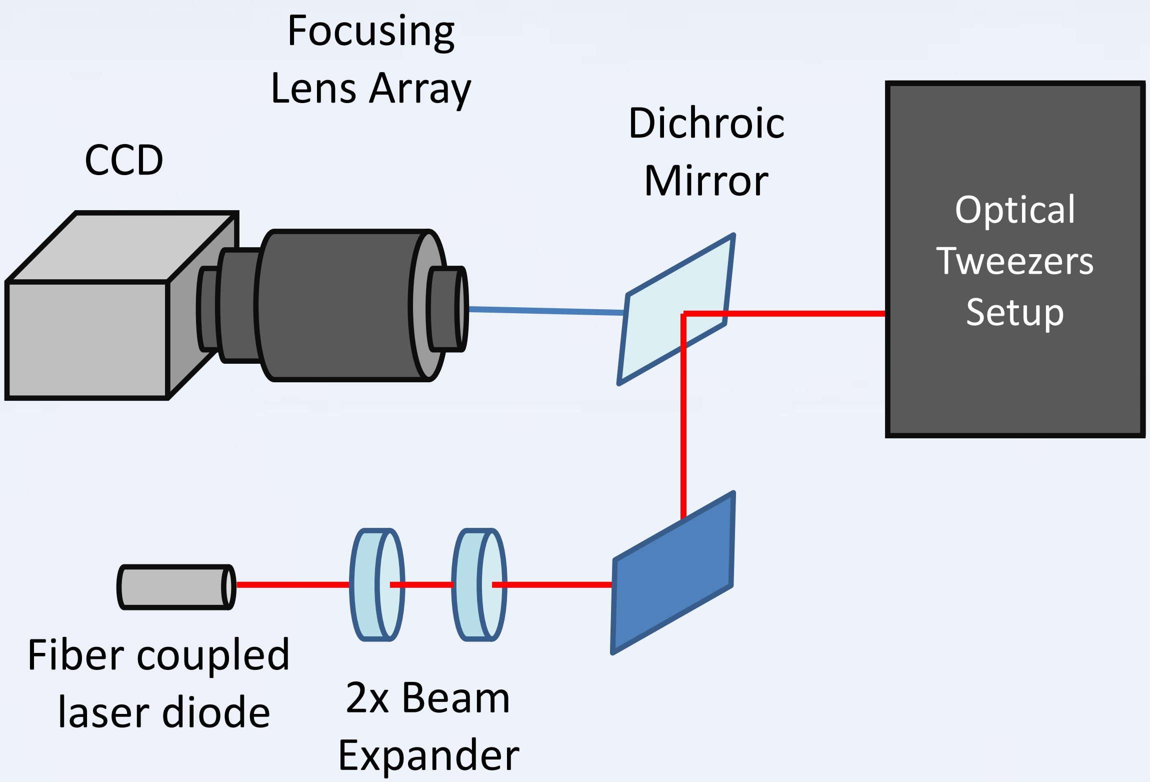


[http://pubs.rsc.org/en/content/articlehtml/2008/cs/b512471a]

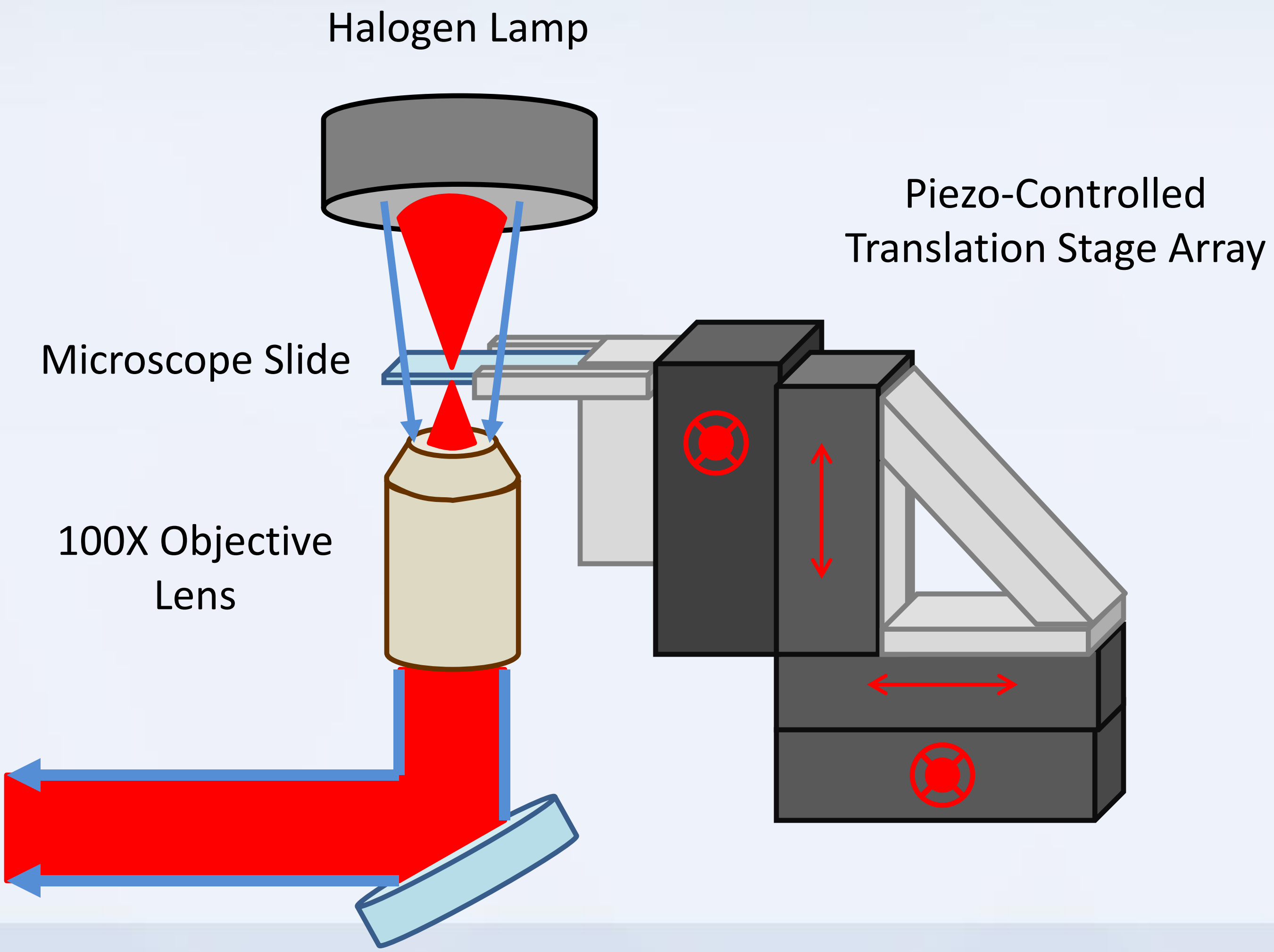
Overall Goals of the Project

- Build and align optical tweezers
- Charaterize trap strength
- Fabricate micro-objects
- Characterize transient heat flow in micro-objects dependent on object topology

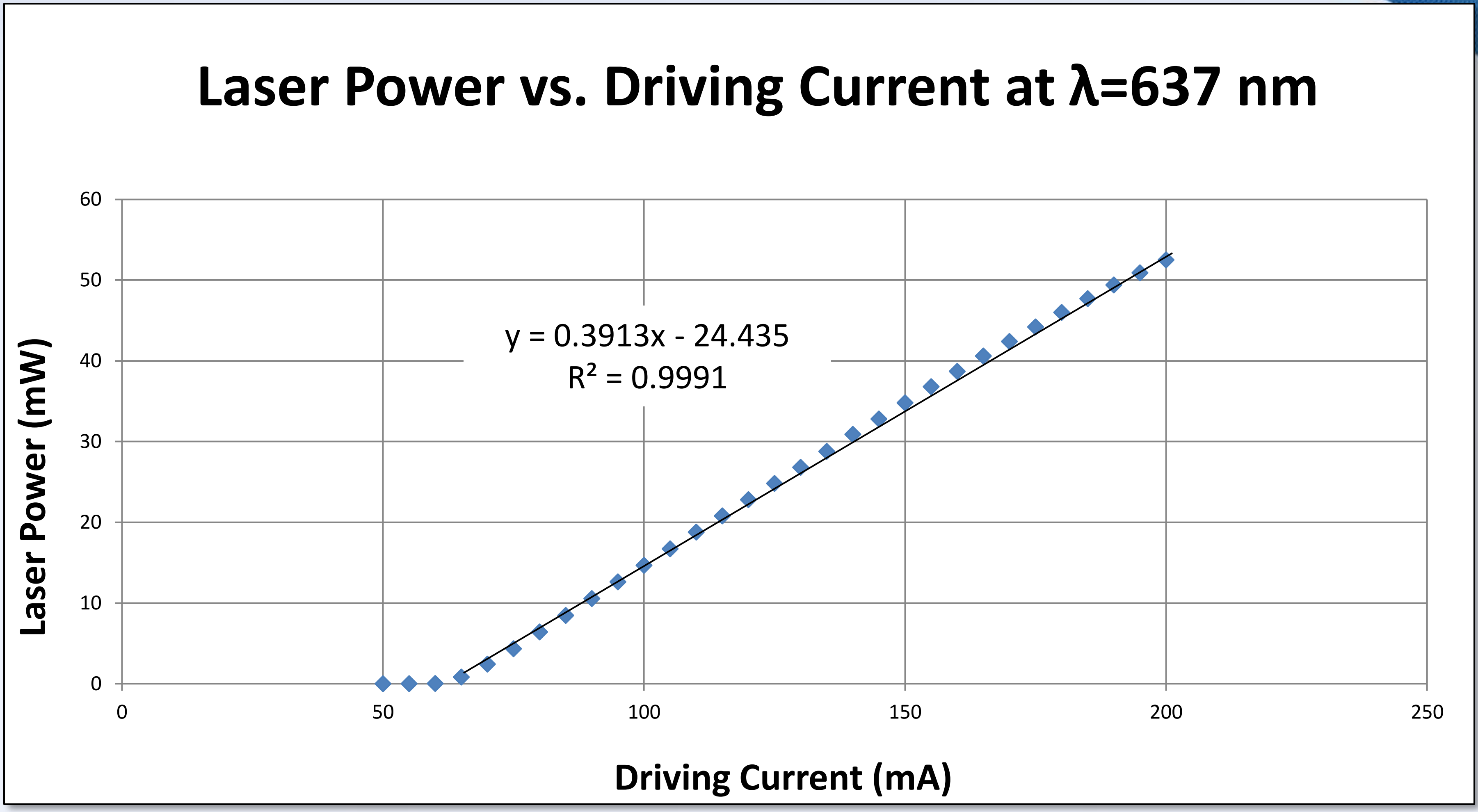
Overall Setup



Optical Tweezers Setup



Laser Characterization



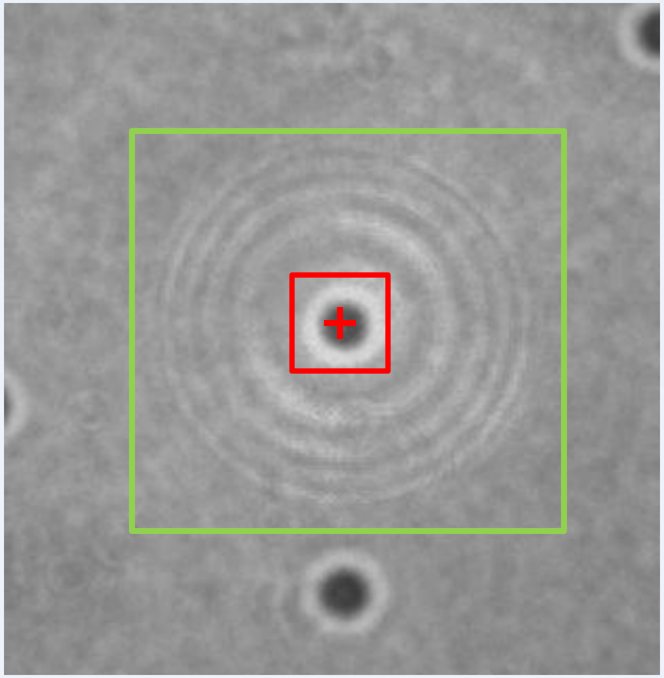
Brownian Motion Measurements

- Equipartition Theorem:

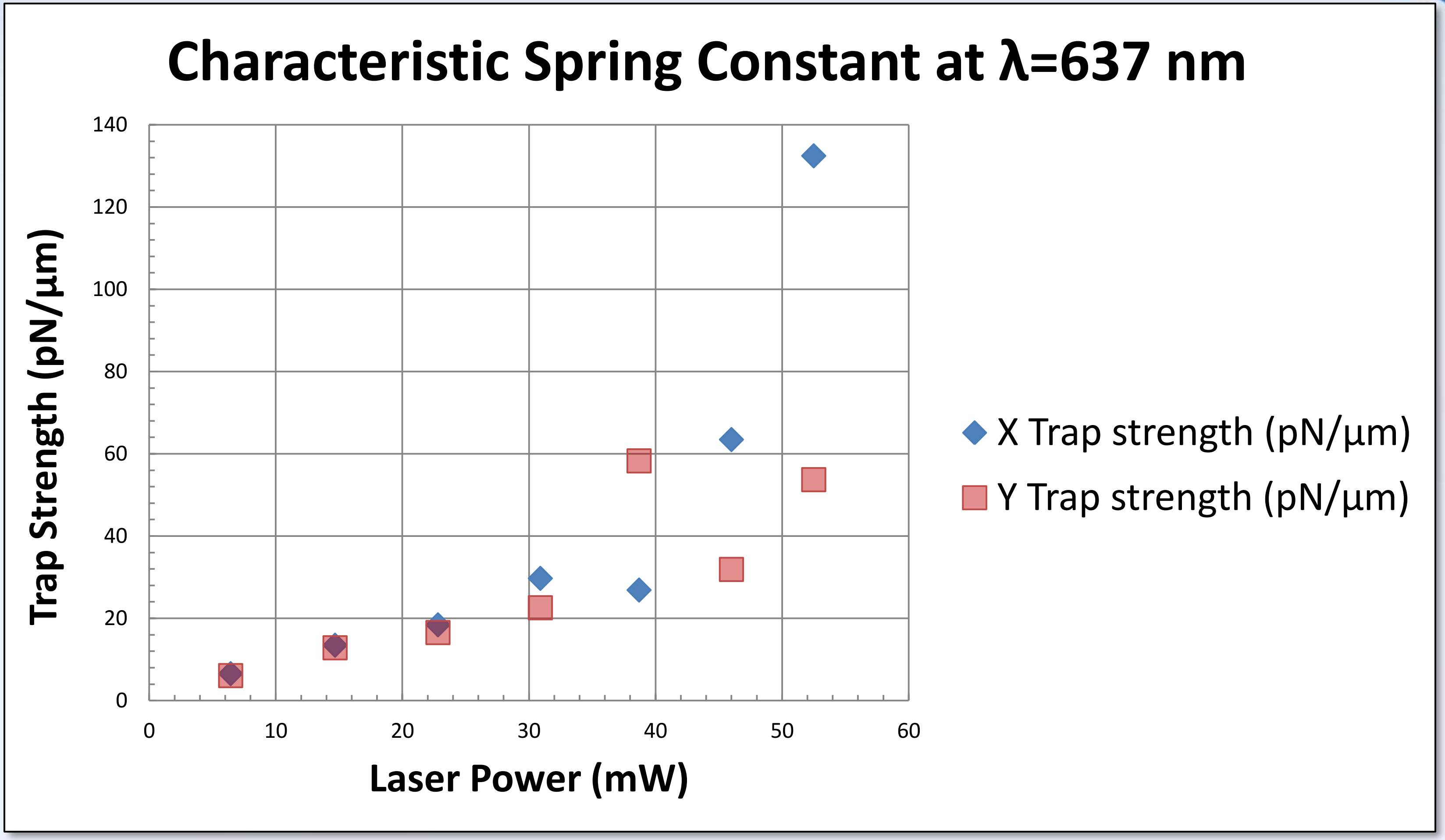
$$\frac{1}{2}k_B T = \frac{1}{2}k\langle x^2 \rangle$$

Where k_B is the Boltzman constant, T is temperature in Kelvin, k is the characteristic spring constant, and $\langle x^2 \rangle$ is the average variance where variance = $\sum_i (x_{avg} - x_i)^2$

$$k = \frac{k_b T}{\langle x^2 \rangle}$$

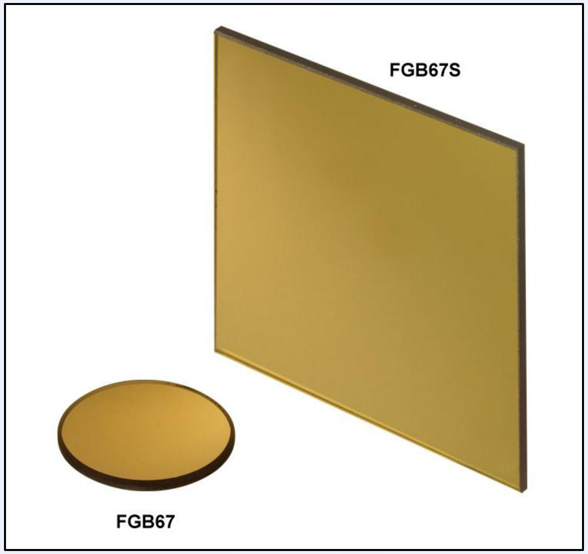


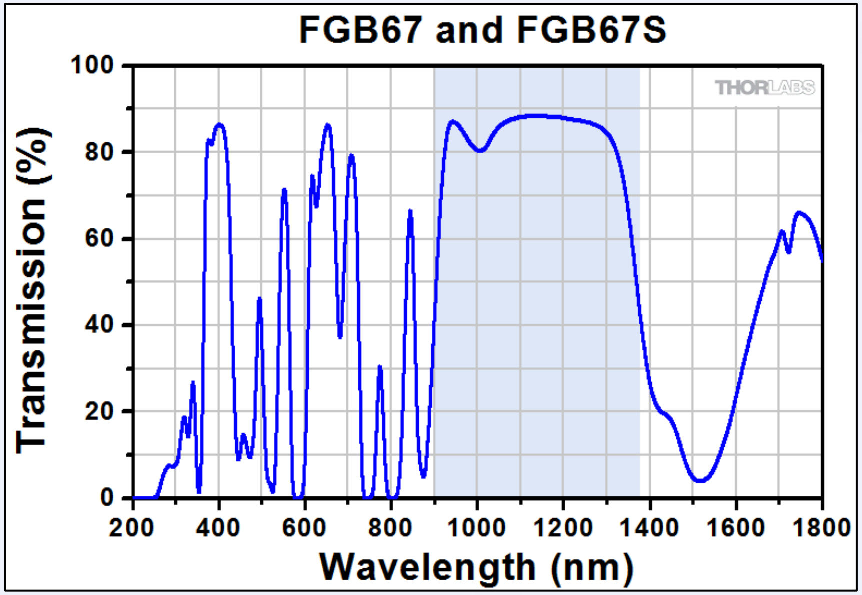
Brownian Motion Measurements



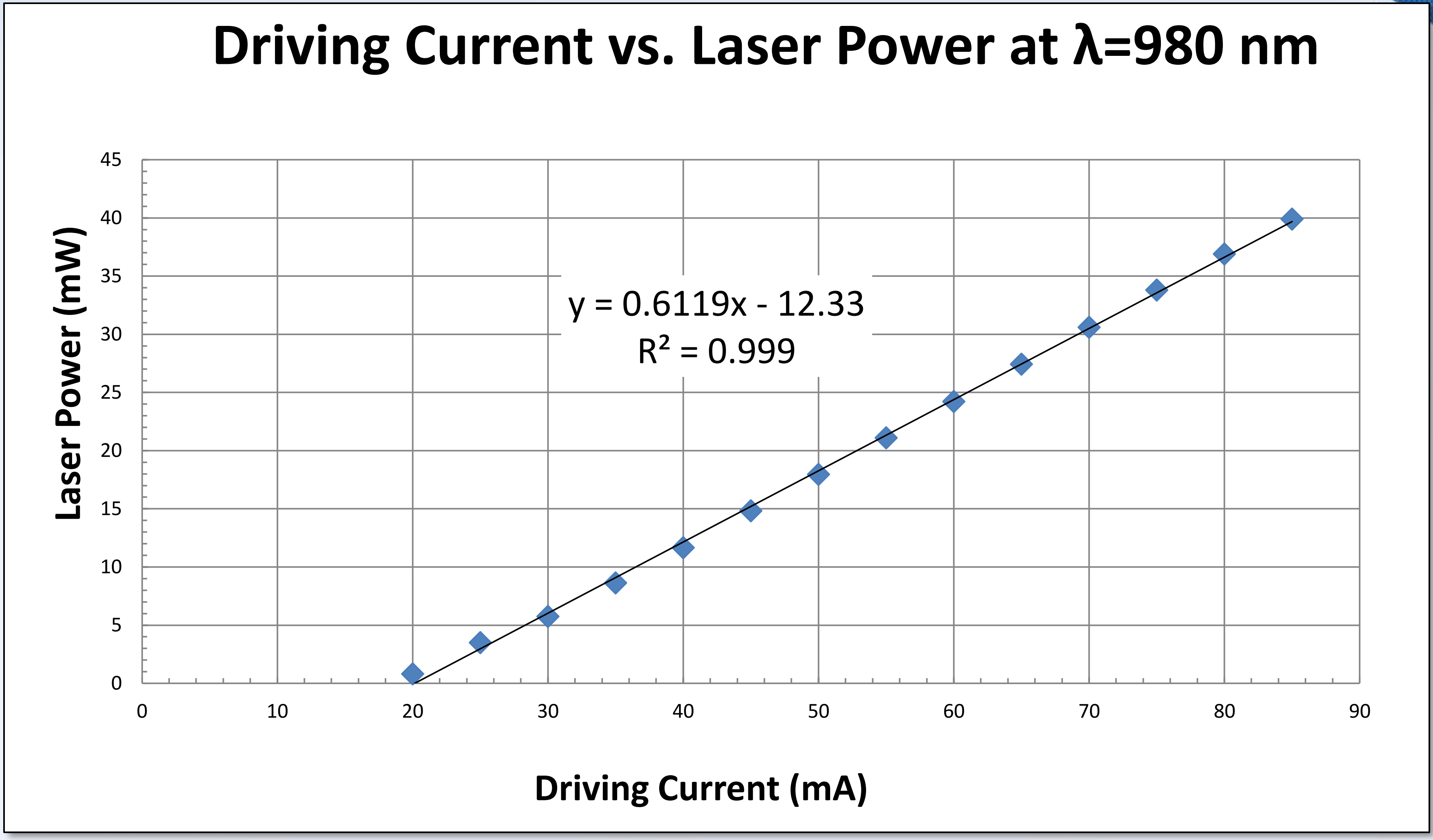
Transition to IR

- Availability of 980 nm and 1550 nm lasers
- Absorption and transmission characteristics of Thorlabs FGB67 colored glass

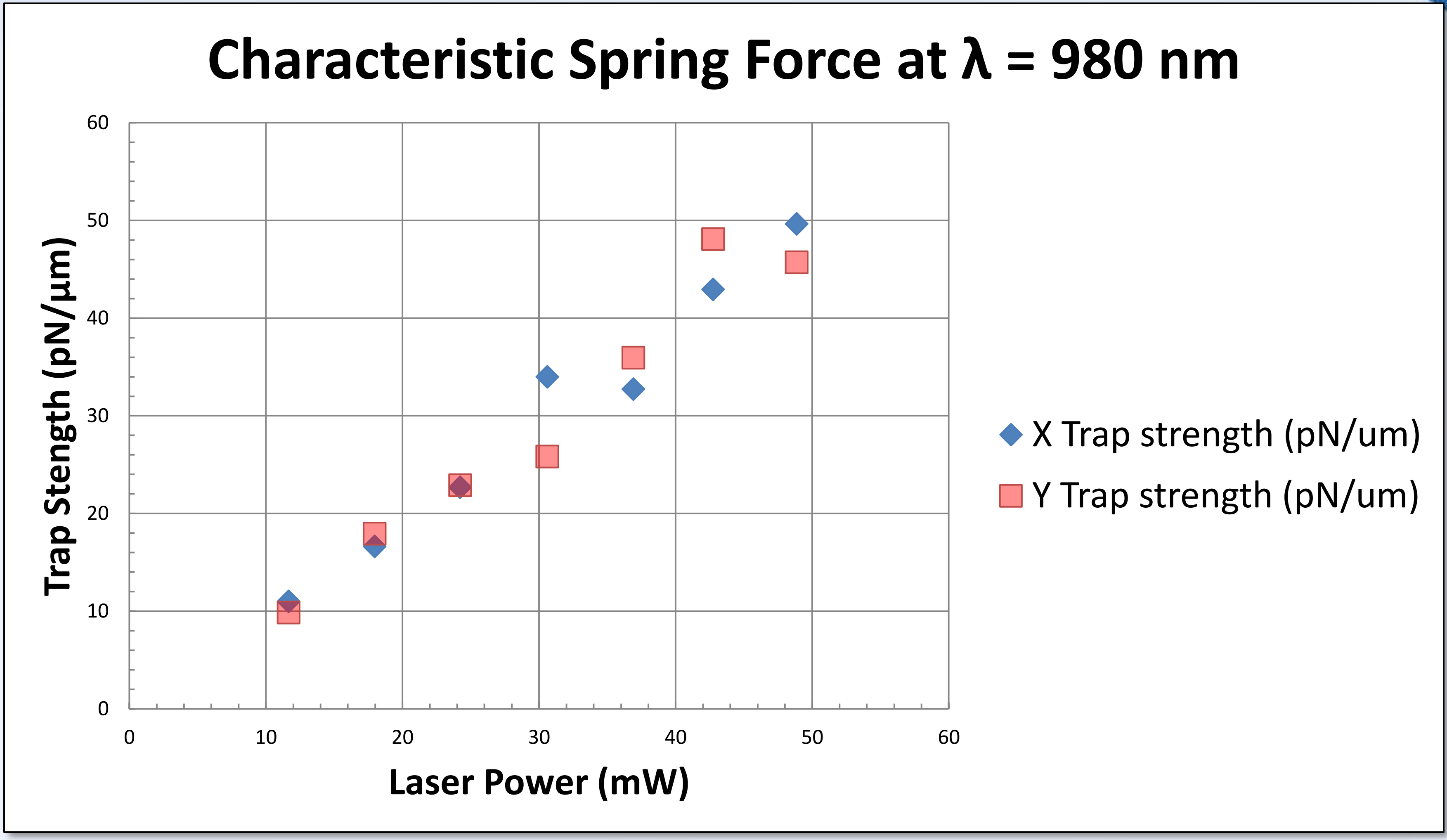




Laser Characterization



Brownian Motion Measurements



Stoke’s Drag Force Measurement

- Assuming: Spherical objects, homogeneous liquid, laminar flow, and no particle interference

$$F_d = 6\pi r \mu v$$

where r is the radius of the object, μ is the fluid viscosity, and v is the object velocity

- Determining object velocity from sinusoidally driven translation stage

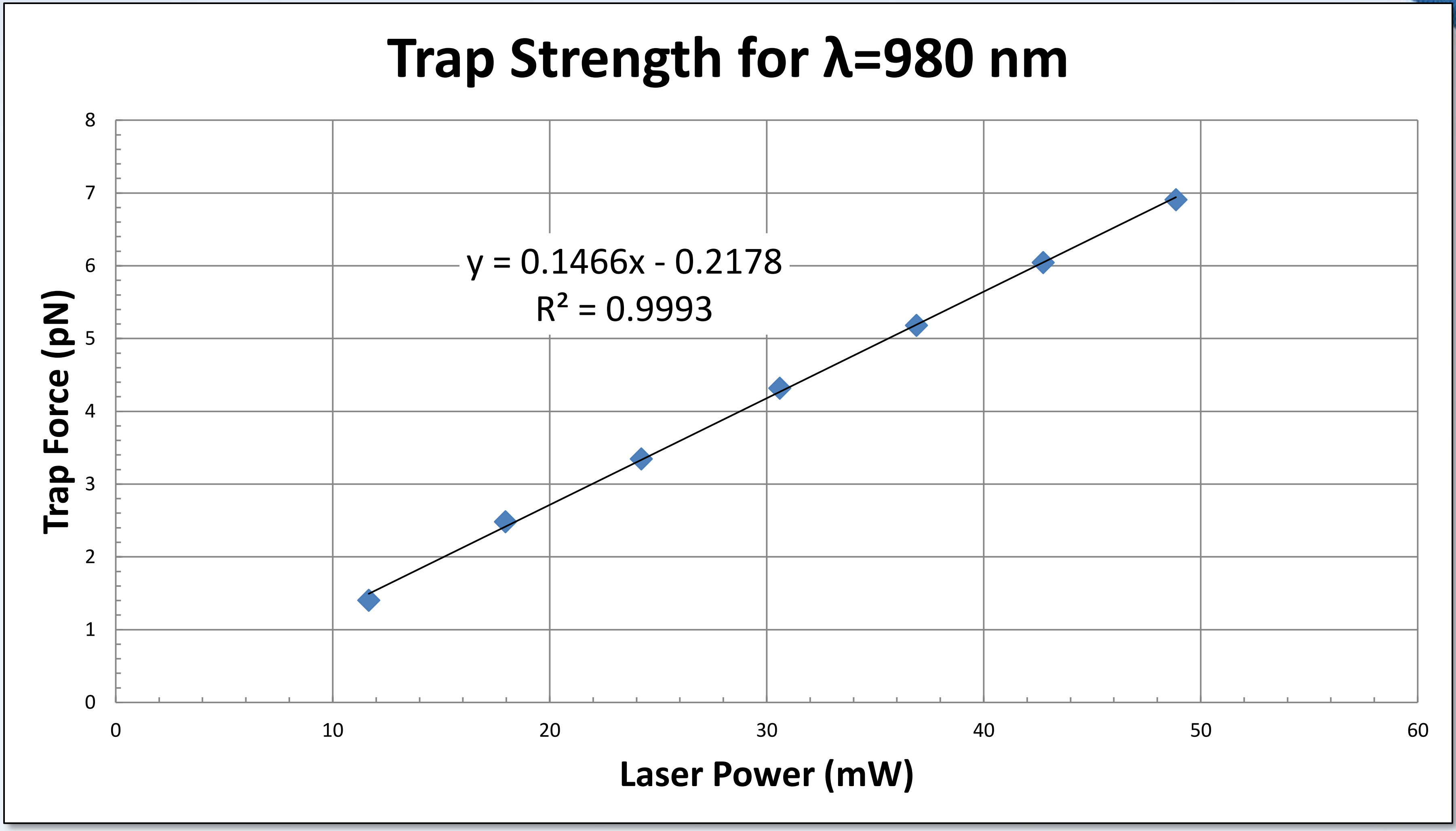
$$x = A\sin(\omega t)$$

$$v = \omega A\cos(\omega t)$$

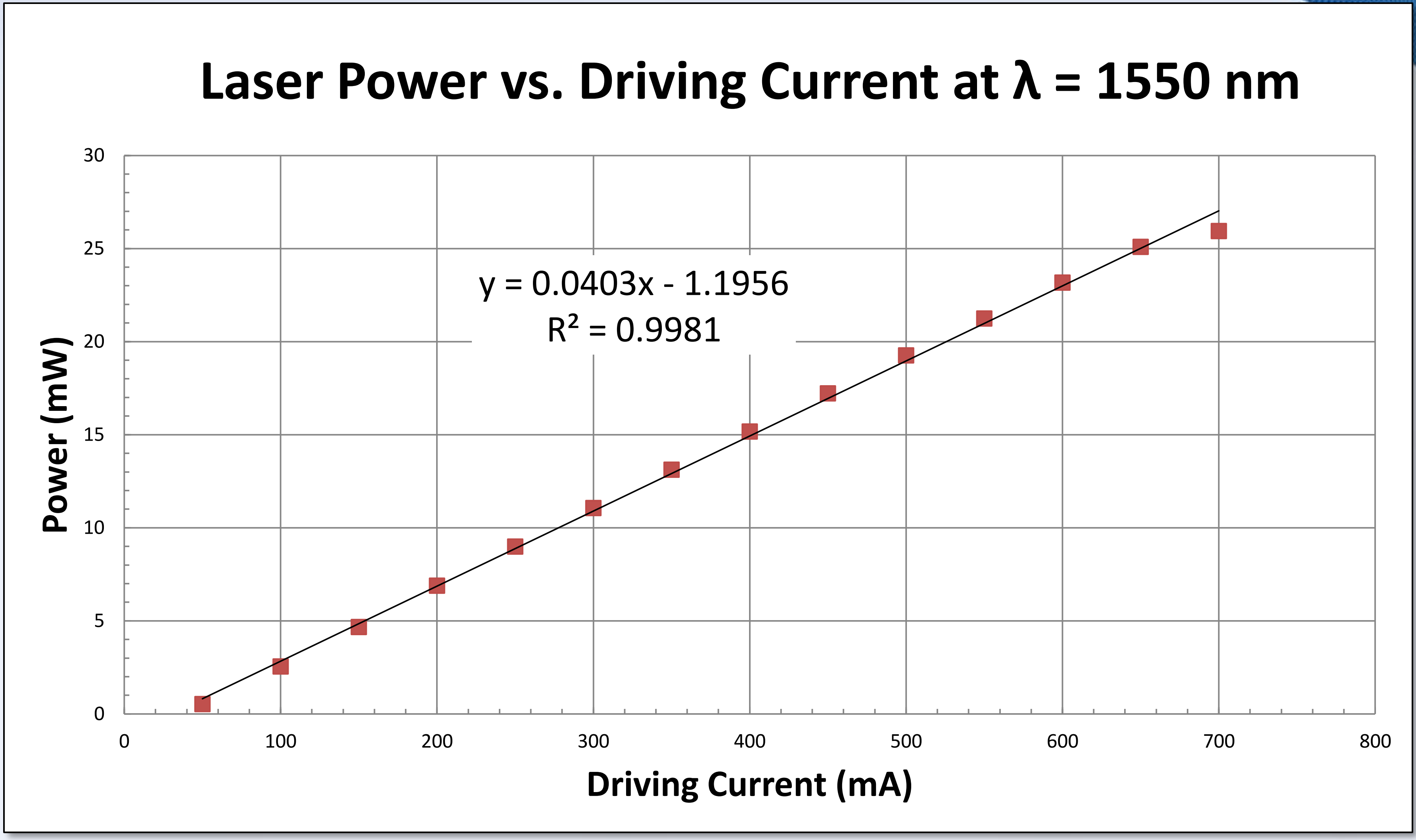
$$v_{\max} = \omega A = 2\pi f A$$

$$\Longrightarrow \boxed{F_d = 12\pi^2 r \mu f A}$$

Stoke's Drag Force Measurement



Laser Characterization



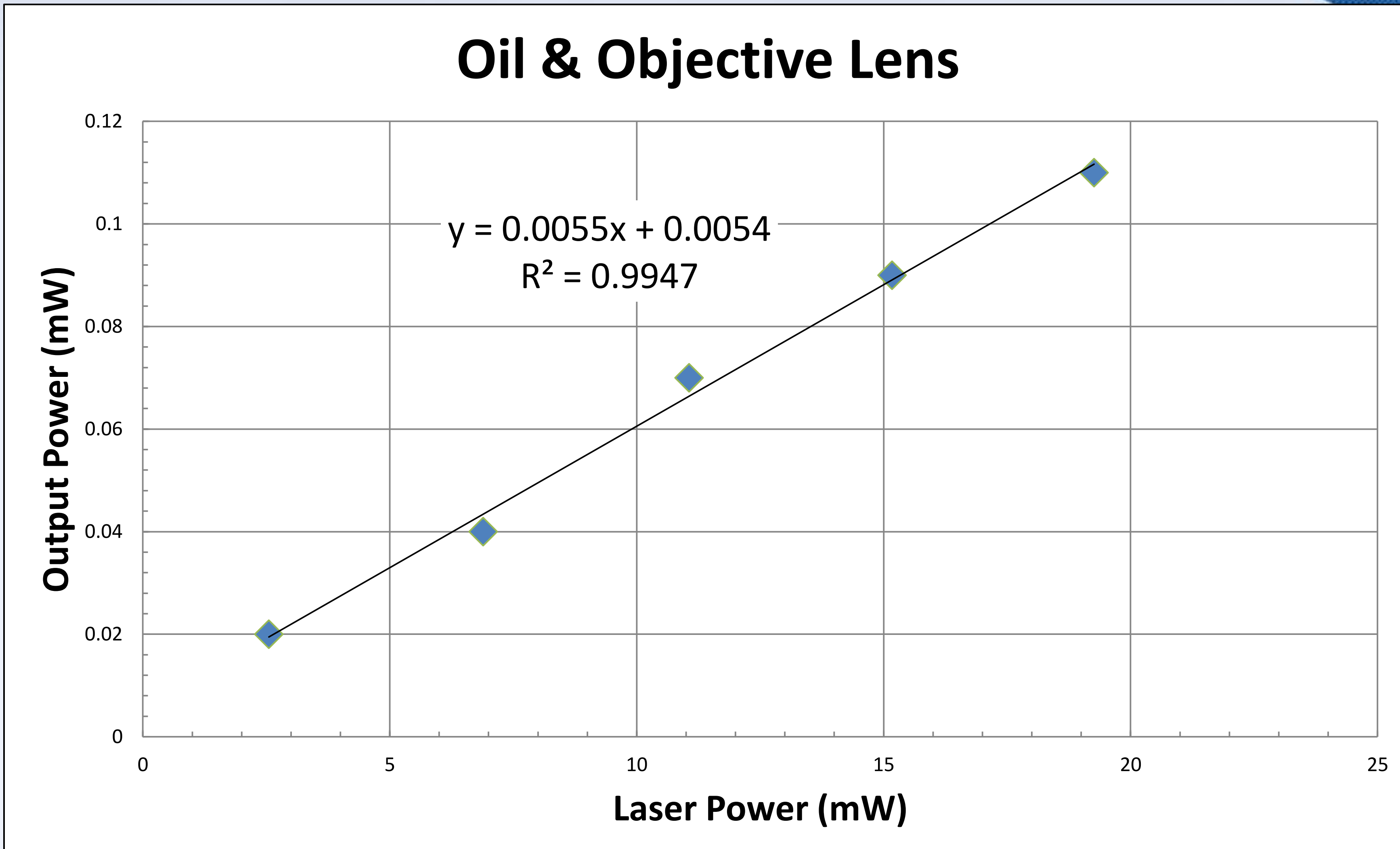
Unexpected Obstacles

- At best, objective lens will have 28% transmission at 1550 nm

- Beam expanding lenses refract 1550 nm light and 980 nm light differently

[http://www.thorlabs.us/thorproduct.cfm?partnumber=RMS100X-PFO]

Objective Lens Characterization



Success

- Thorlabs FGB67 colored glass damaged by

  ~ 850 mW of unfocused 1550 nm light

Steps for Future Groups

- Acquire usable objective lens
- Integrate a 1550 nm laser with a WDM
- Fabricate micro-objects
- Study heat flow of micro-objects