PURDUE UNIVERSITY SUMMER 2009 REU IN PHYSICS

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REMEMBER…?

- AMO Physics
- BEC
- Lasers & Speckle

RESEARCH

WHICH DIFFUSER?

- Small angular divergence
  - Easy
  - Lose less light
- Uncorrelated Speckle

LUMINIT .5° FWHM LIGHT-SHAPING DIFFUSER

- Used by another group for speckle
- Superior to mobile phone diffusers
  - Divergence, transmission, diameter, development

WHAT DO WE NEED TO KNOW?

- Optical setup → speckle size
- Speckle development
- Potential depth

CODE

AUTOCOVARIANCE

$$R_{xy}(m) = E[x_{n+m}y^*_n] = E[x_n y^*_{n-m}]$$

$$\hat{R}_{xy}(m) = \begin{cases} \sum_{n=0}^{N-m-1} x_{n+m}y^*_n & m \geq 0 \\ \hat{R}^*_{yx}(-m) & m < 0 \end{cases}$$

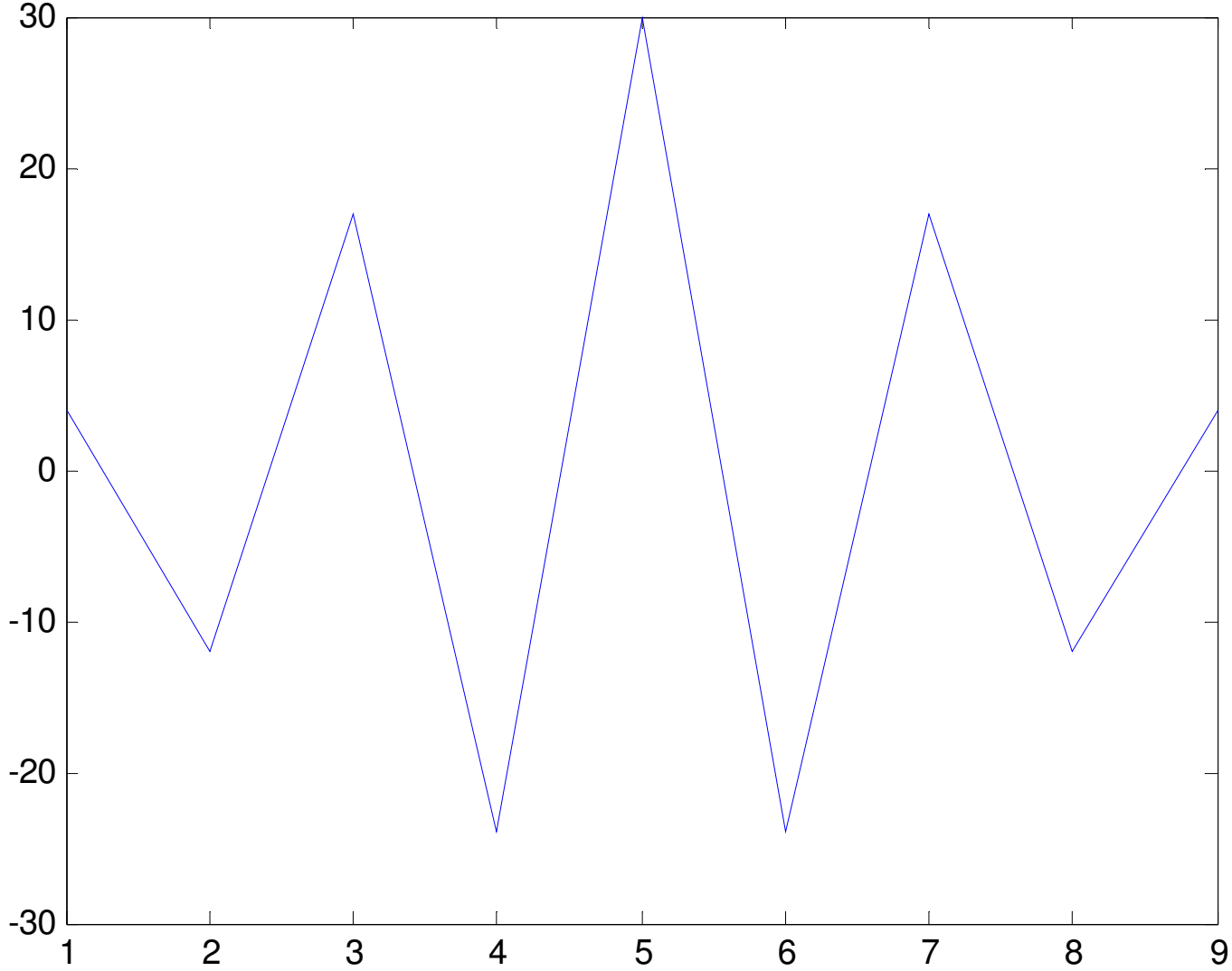
AUTOCOVARIANCE

$$R_{XX} = \begin{cases} X_0X_0 & X_1X_0 & X_2X_0 & X_3X_0 & X_4X_0 \\ +X_1X_1 & +X_2X_1 & +X_3X_1 & +X_4X_1 & \\ +X_2X_2 & +X_3X_2 & +X_4X_2 & & \\ +X_3X_3 & +X_4X_3 & & & \\ +X_4X_4 & & & & \end{cases} \begin{matrix} n=0 \\ n=1 \\ n=2 \\ n=3 \\ n=4 \end{matrix}$$

m=0 m=1 m=2 m=3 m=4

Given $X = [\ -2\ 3\ -2\ 3\ -2\ ]$ …

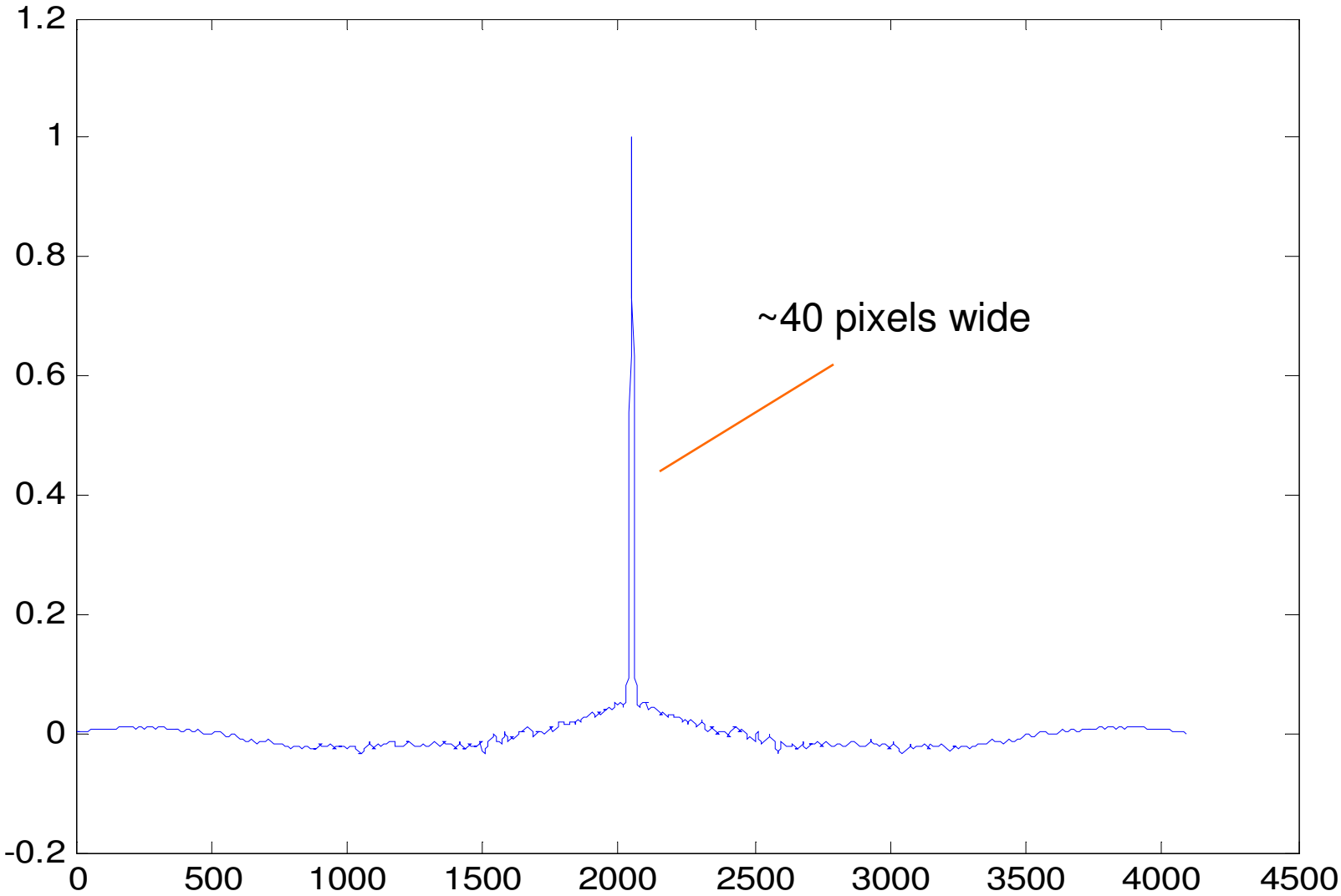
AUTOCOVARIANCE



SPECKLESIZE.M

- Normalized autocovariance of each row
- Average
- Fit Gaussian range [.2→1]
- Size of fit at .5 and $1/e^2$ values
- Goodness of fit

SPECKLESIZE.M



SPECKLESIZE.M

$$SS_{\text{tot}} = \sum_i (y_i - \bar{y})^2,$$

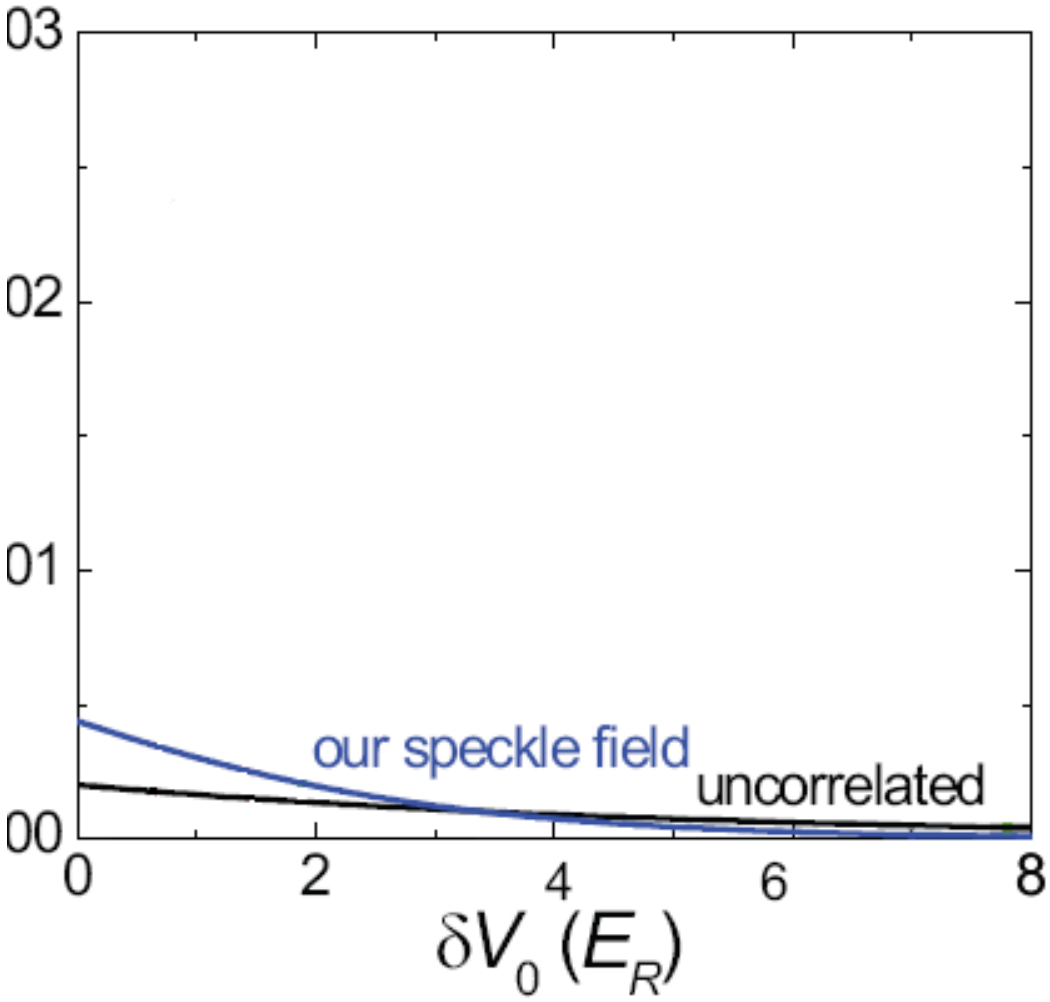
$$SS_{\text{err}} = \sum_i (y_i - f_i)^2$$

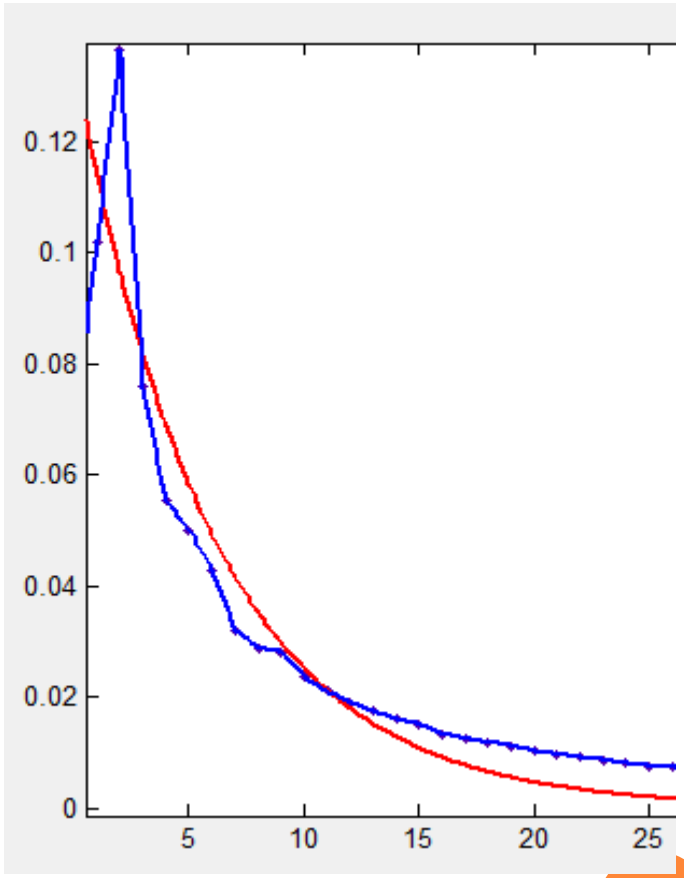
$$R^2 \equiv 1 - \frac{SS_{\text{err}}}{SS_{\text{tot}}}.$$

SPECKLEDEVELOPMEN

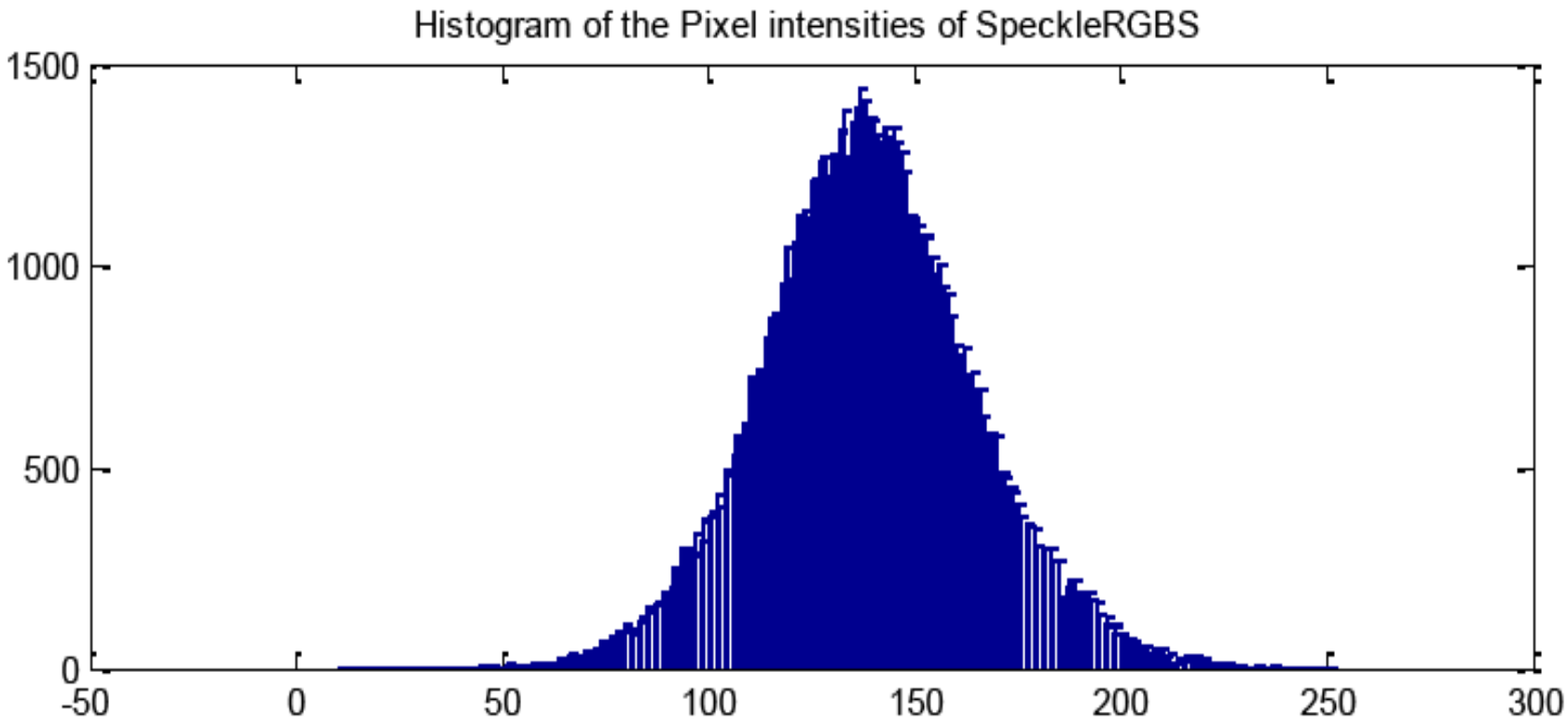
- Normalized intensity histogram
  - Intensity probability density
- Signal:Noise

SPECKLEDEVELOPMENT.M





SPECKLEDEVELOPMENT.M



Cell phone diffuser

CORRLENGTH.M

- Speckle size for a given λ, D, z
- Good agreement with SpeckleSize.m
- Accuracy limited by D
- Phasor model

$$L = \frac{2\lambda z}{\sqrt{\pi} D}$$

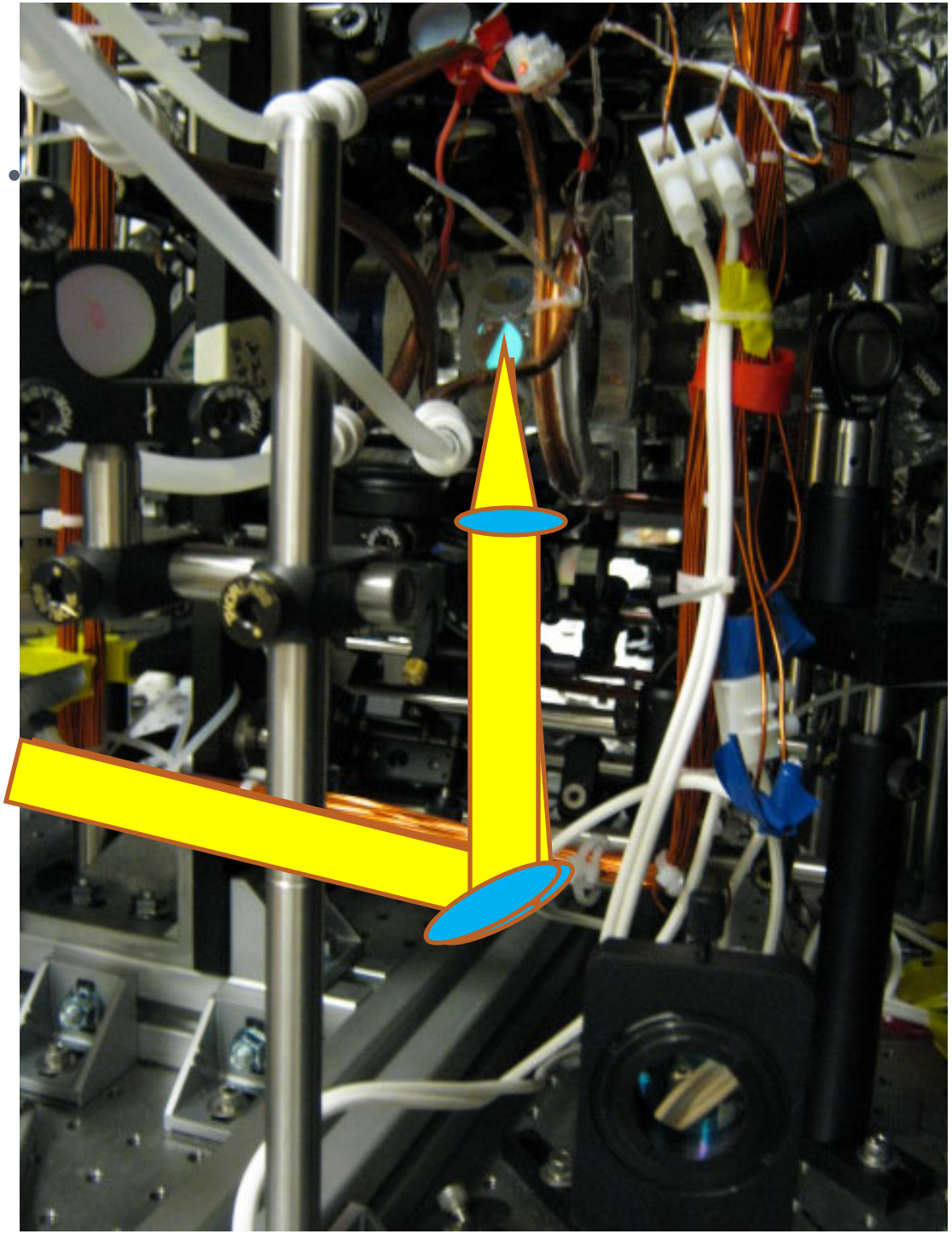
CORRLENGTH.

f=30cm

f=7cm

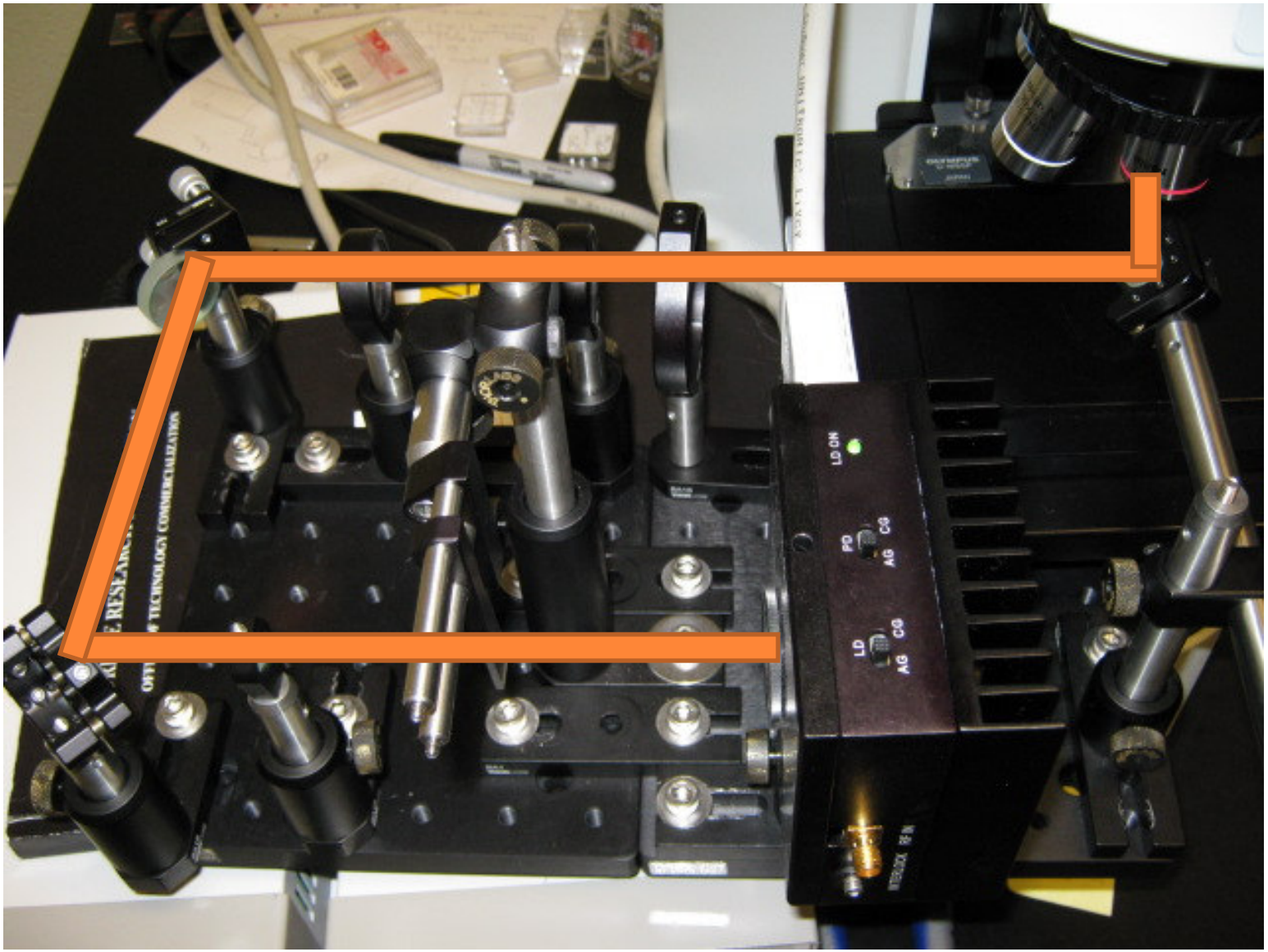
D = 21cm

D = 5cm

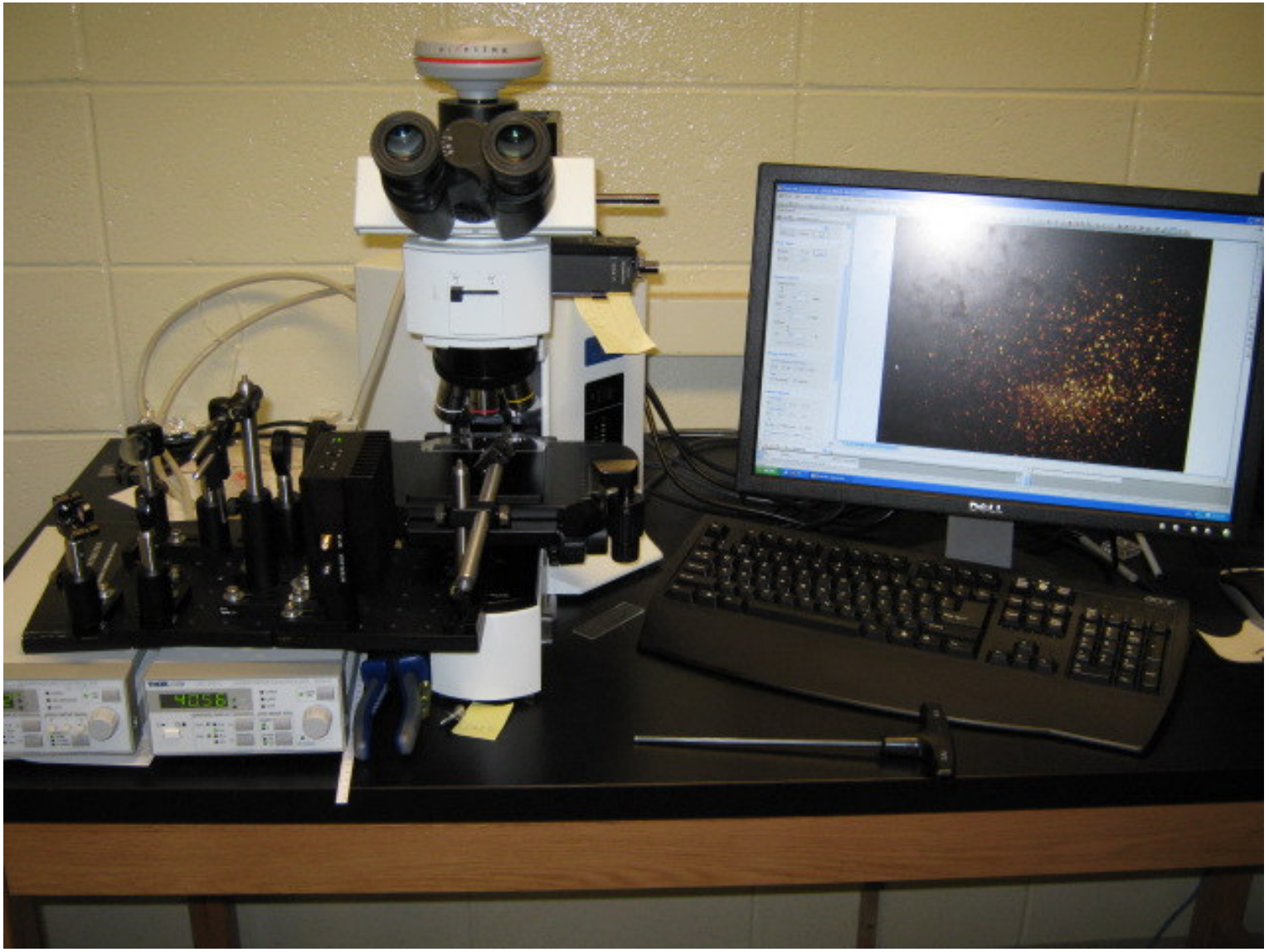


IMAGING

IMAGING SETUP



IMAGING SETUP



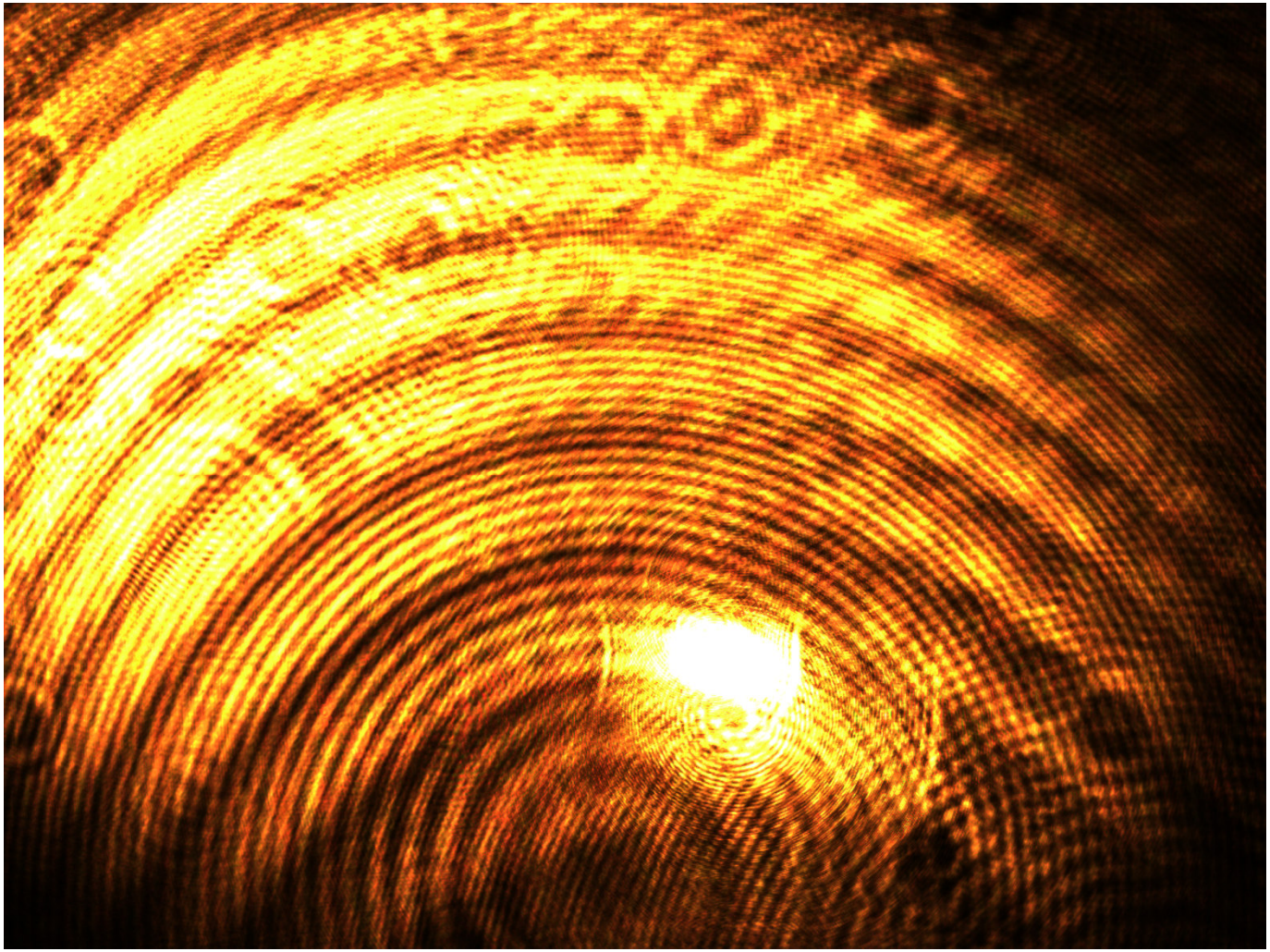
POTENTIAL DEPTH

Total Power and $1/e^2$ radius

Peak Intensity

Color-to-intensity conversion

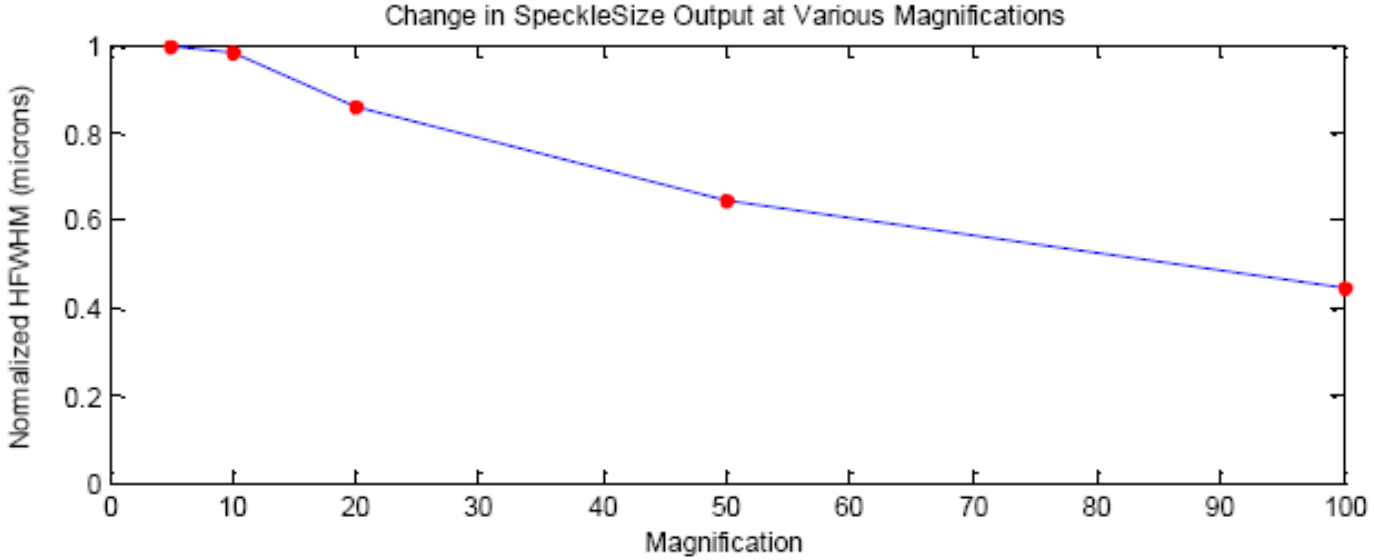
POTENTIAL DEPTH

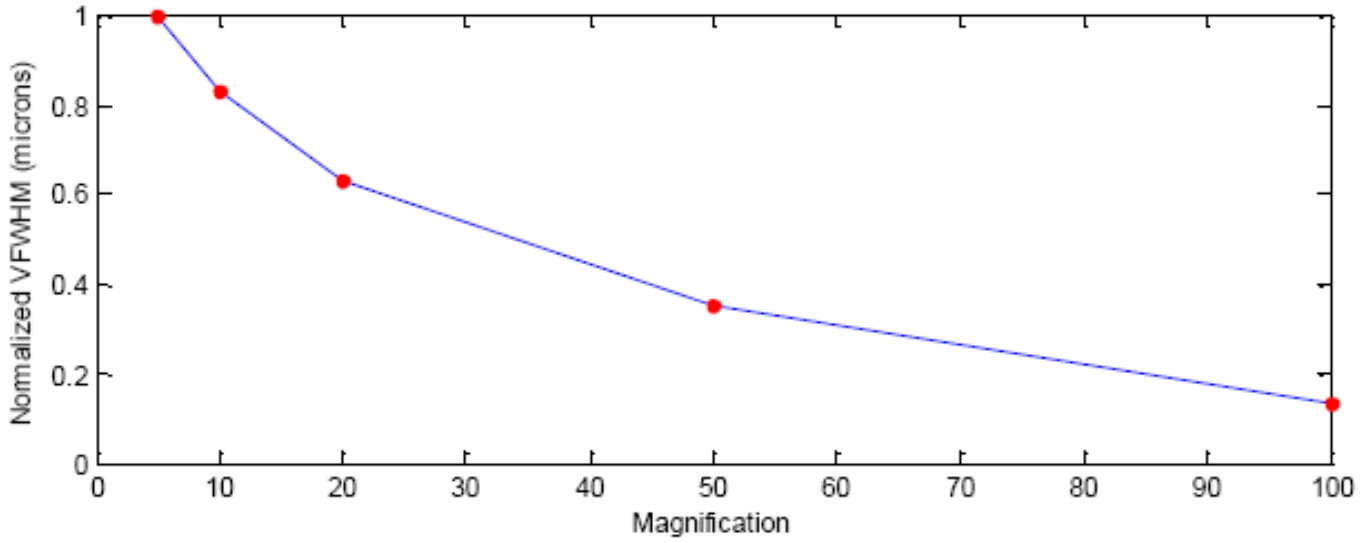


POTENTIAL DEPTH

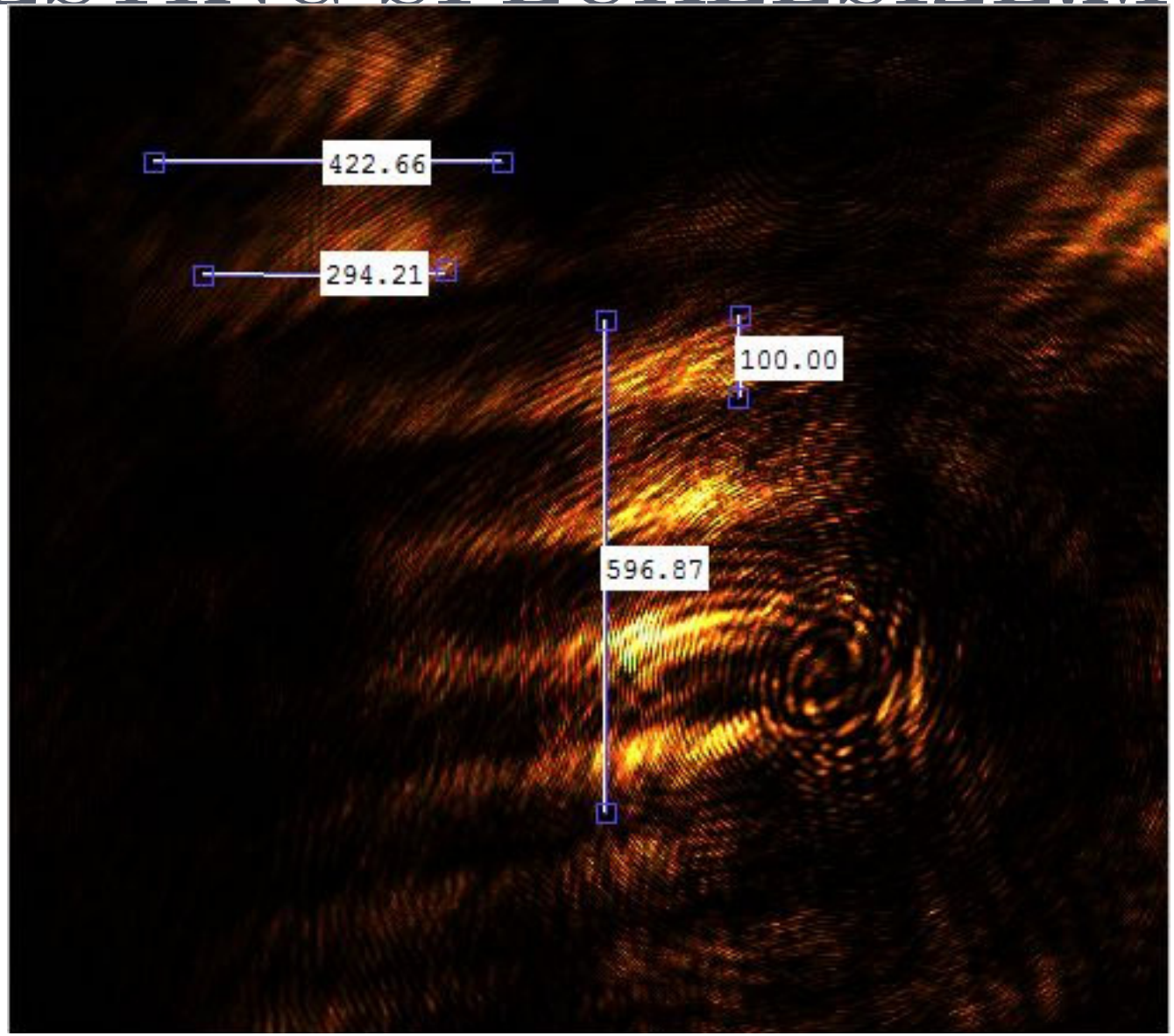
- Attribute aberration to microscope/camera
- Check with beam profiler

TESTING SPECKLESIZE.M

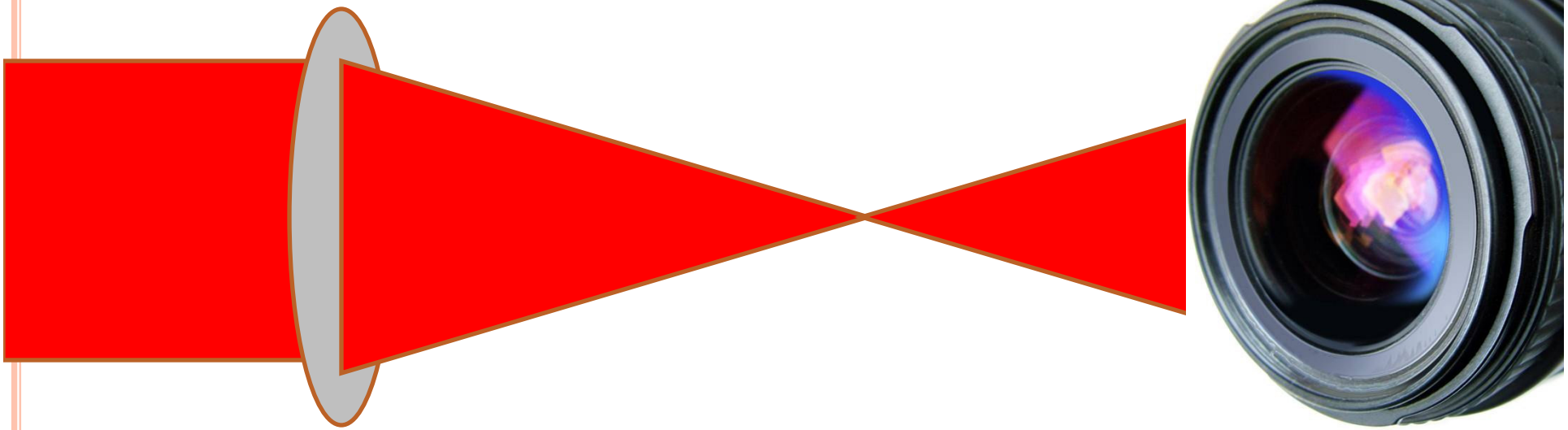




TESTING SPECKLESIZE.M

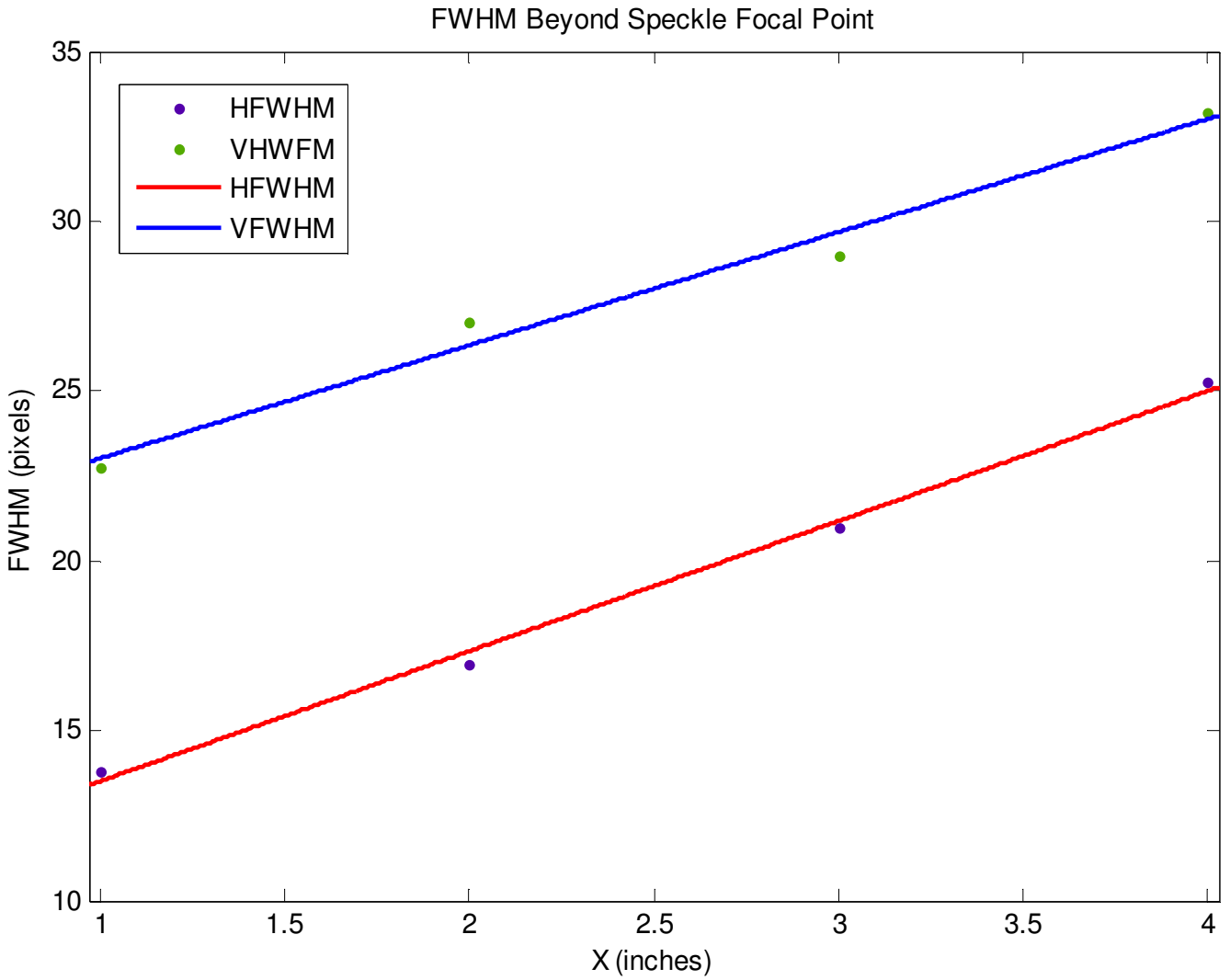


TESTING BEAM DIVERGENCE



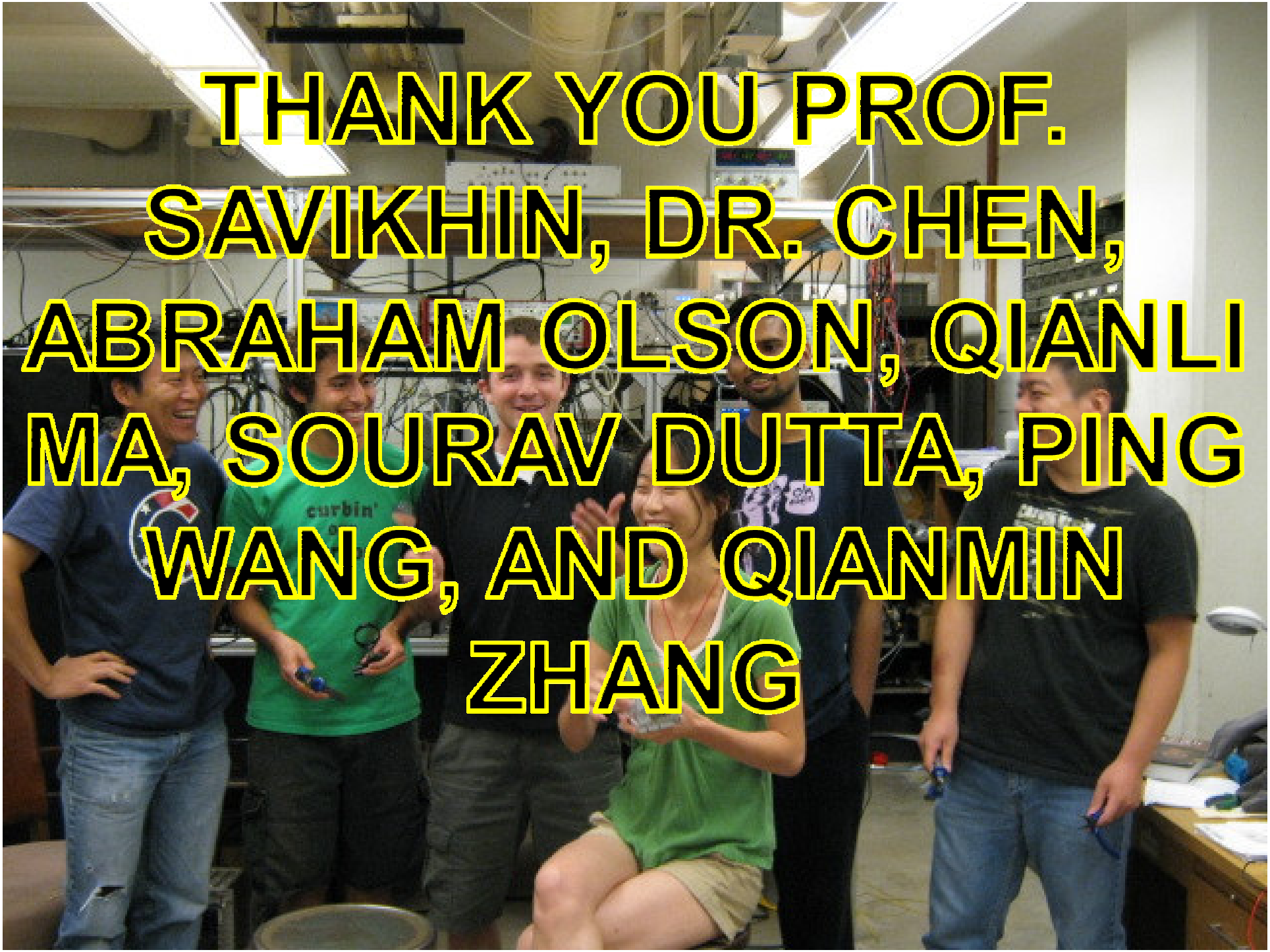
$$w(z) = w_0 \sqrt{1 + \left(\frac{z}{z_\mathrm{R}}\right)^2}\,.$$

TESTING BEAM DIVERGENCE



I LEAVE THE GROUP WITH…

- MATLAB image processing tools
- Research on speckle
- Speckle characterization
- Method for intensity mapping
- Diffuser with uncorrelated speckle
- Data tables, images


THANK YOU PROF. SAVIKHIN, DR. CHEN, ABRAHAM OLSON, QIANLI MA, SOURAV DUTTA, PING WANG, AND QIANMIN ZHANG