Z-SCAN

Instrument presentations 2019

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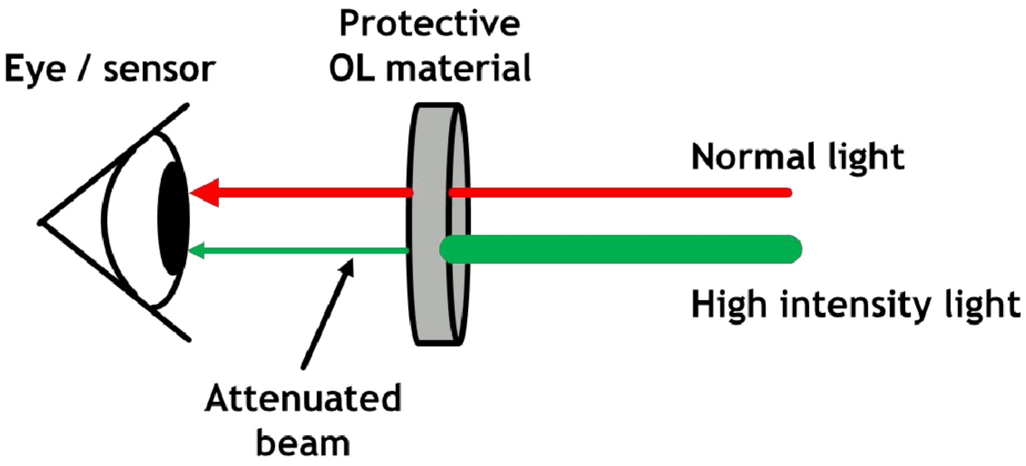
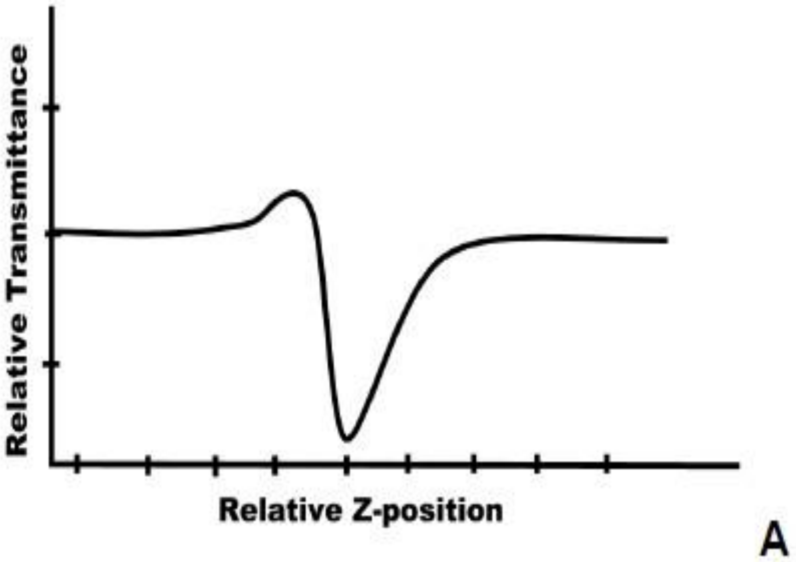
Why do we do z-scan?

- ✓ **Determine nonlinear absorption properties**
- ✓ **Optical limiting**

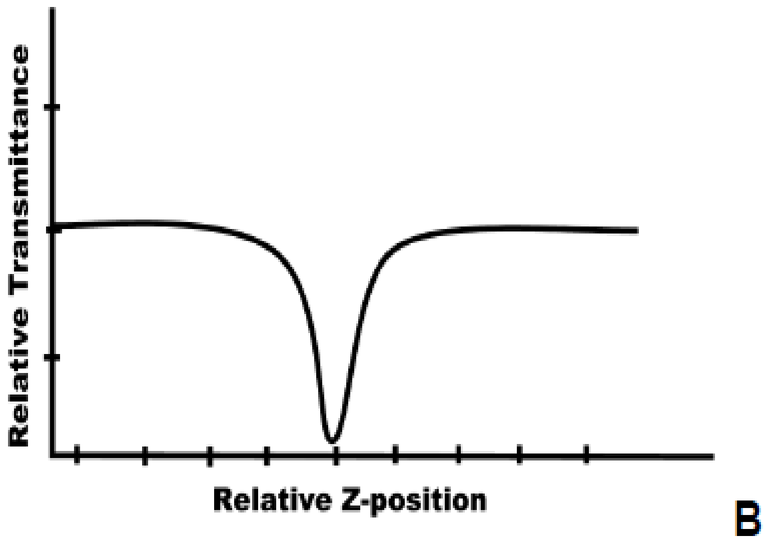


http://edition.cnn.com/videos/us/2015/07/22/laser-new-jersey-york-flights-plane-faa-marsh-nr.cnn

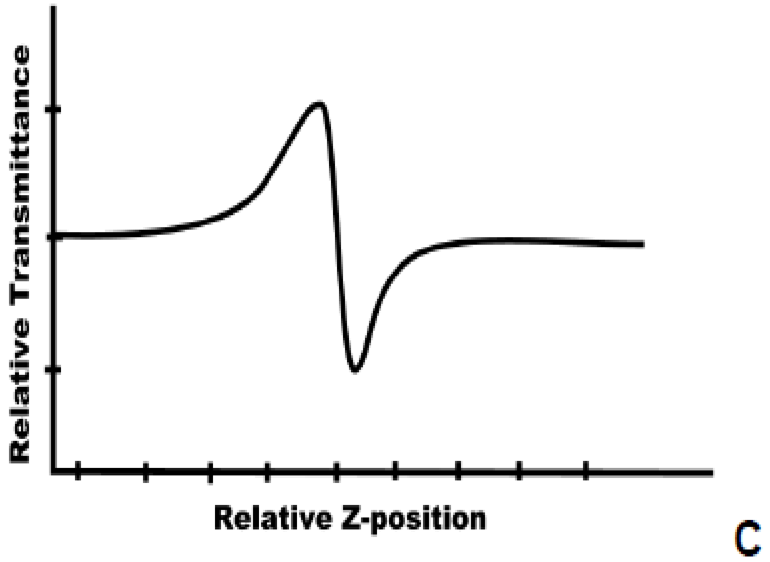
Information you can get from z-scan



Closed aperture



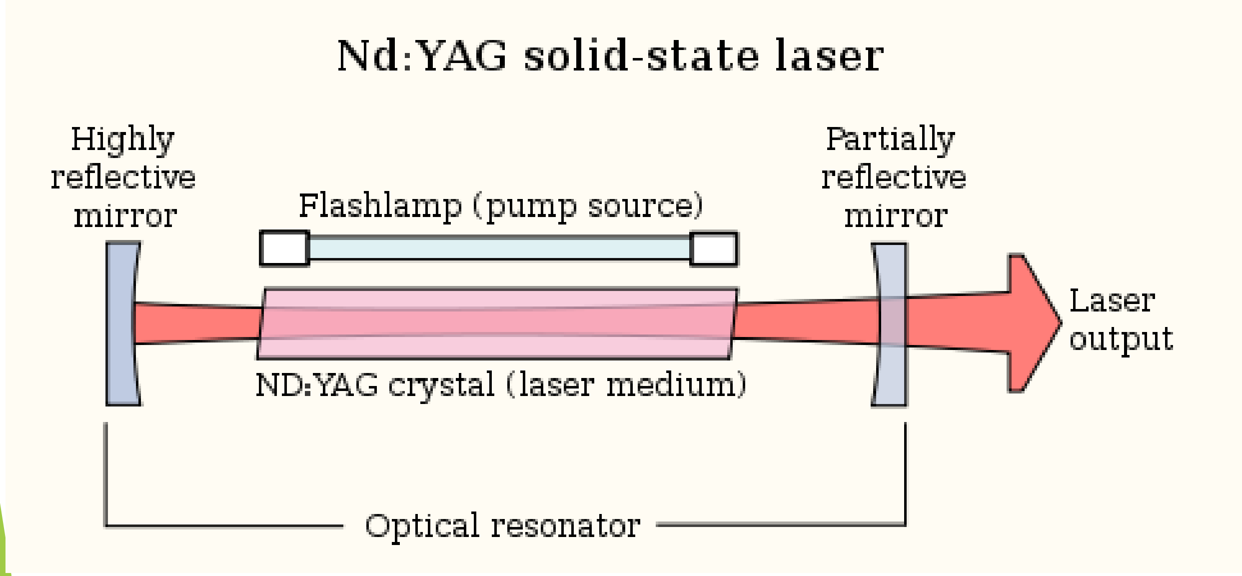
Open aperture



Closed aperture / open aperture

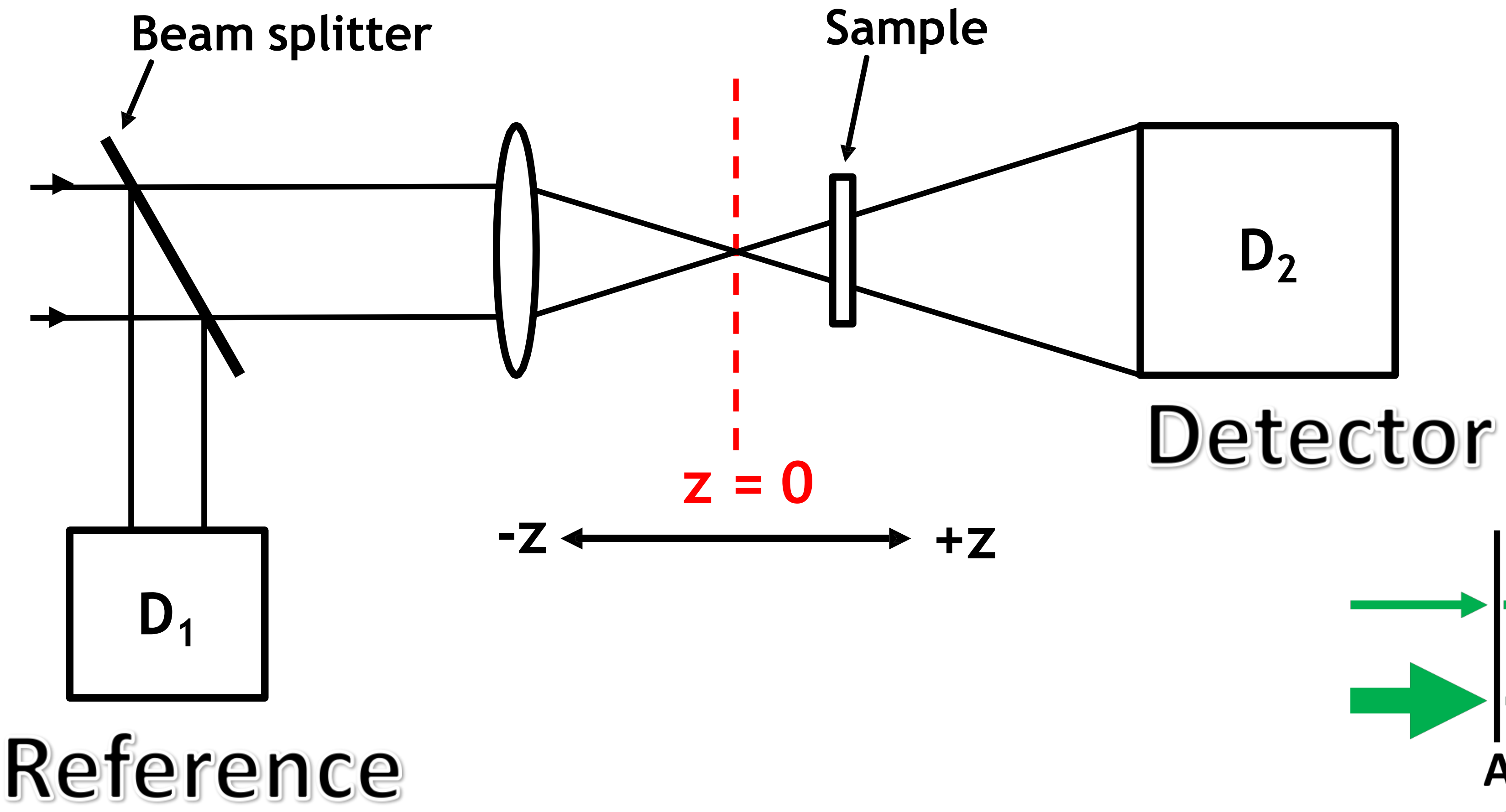
The laser

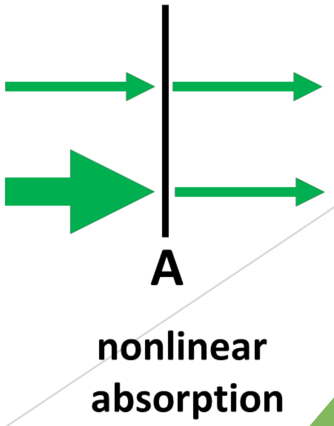
- ✓ Nd-YAG (neodymium-doped yttrium aluminium garnet)
- ✓ Emits light of wavelength 1064 nm
- ✓ Widely used to excite dye lasers, mainly via their second and third harmonics



https://osuwomeninphysics.wordpress.com/2013/11/12/fire-a-laser-at-it/

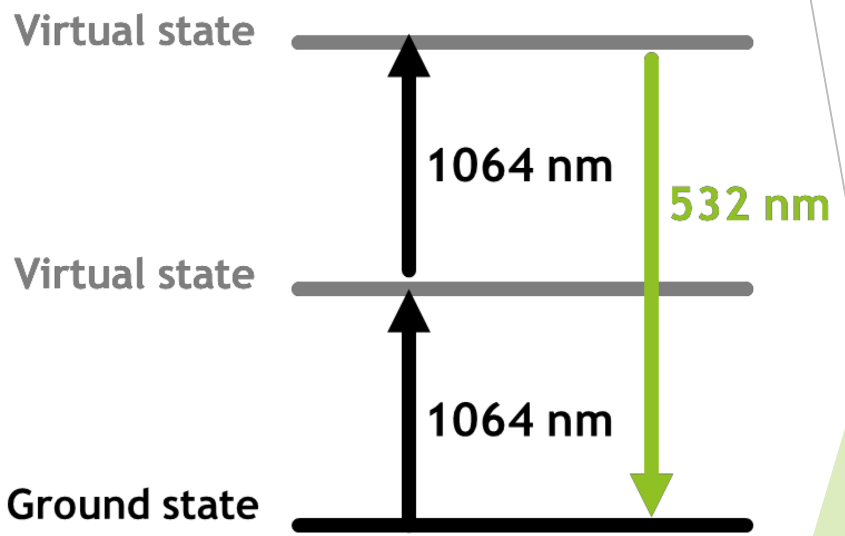
So, what's in the box?





The laser

- ✓ **Pulsed laser, Q - switching mode**
- ✓ **In Q-switched mode, Nd:YAG produces 2 wavelengths, one in the IR range (1064 nm) and a second beam of 532 nm wavelength**
- ✓ **For Z-Scan, we divert around the dye laser and use the 532 nm second harmonic as is.**



Laser power

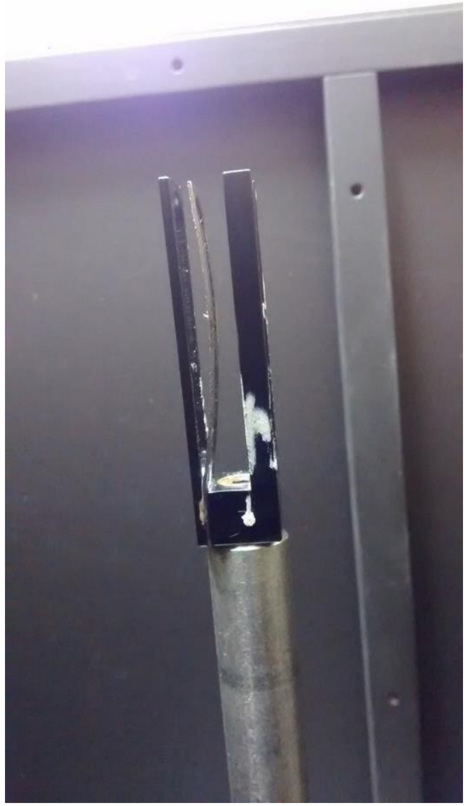
- ✓ Must know laser power
- ✓ Adjust power using the dial

- ✓ Record
- ✓ Should be saved in Results file as well

Set to:

- ✓ 5- 20 µJ for getting Z-scan absorbance or
- ✓ Crank it up to get I_m values

Loading the sample



- ✓ Place z-scan sample holder when prompted
- ✓ Avoid bumping any of the components inside the box
- ✓ Thin films: Prestik to one side of the sample holder

What you need to know about your sample before you start:

- ✓ **Extinction coefficient at 532 nm**

$$A = \varepsilon l c$$

$$\frac{\varepsilon_{Qband}}{A_{Qband}} = \frac{\varepsilon_{532nm}}{A_{532nm}}$$

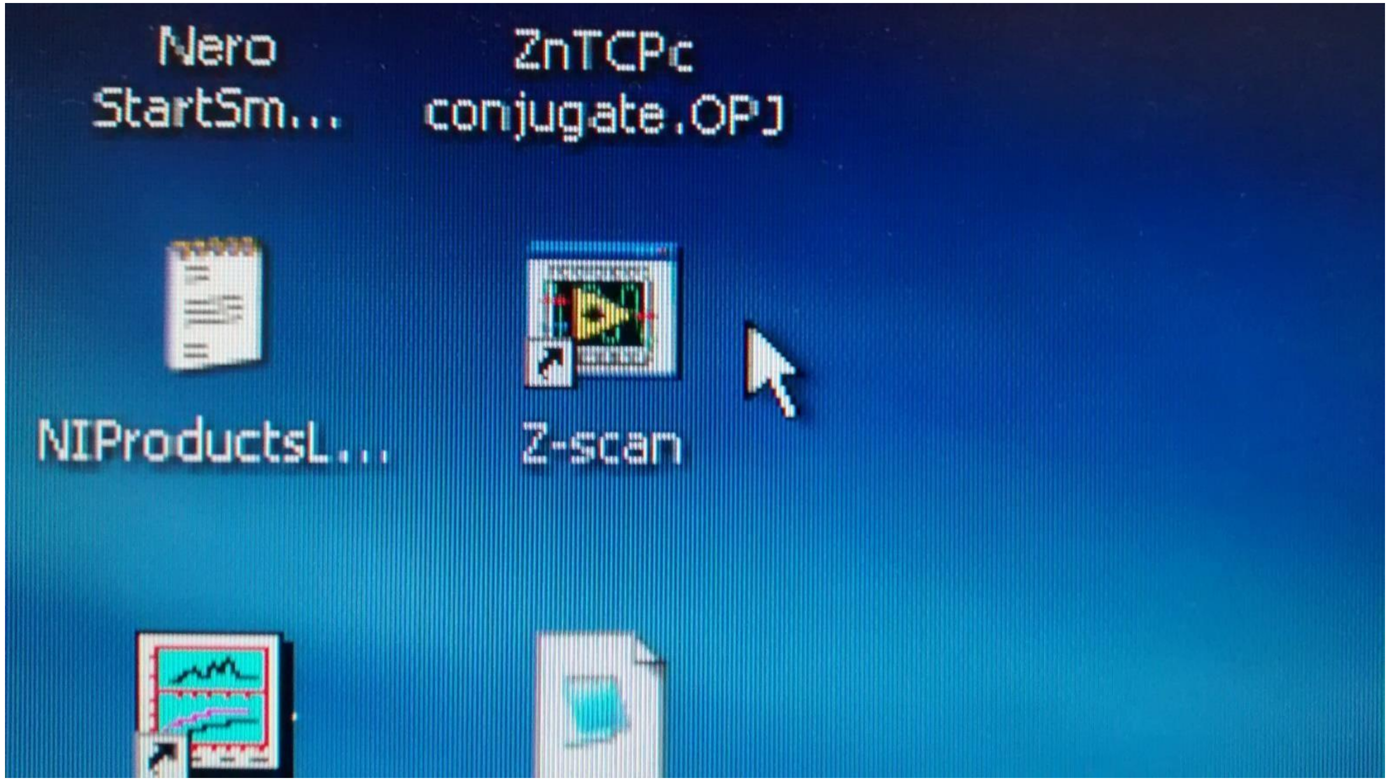
Why at 532 nm?

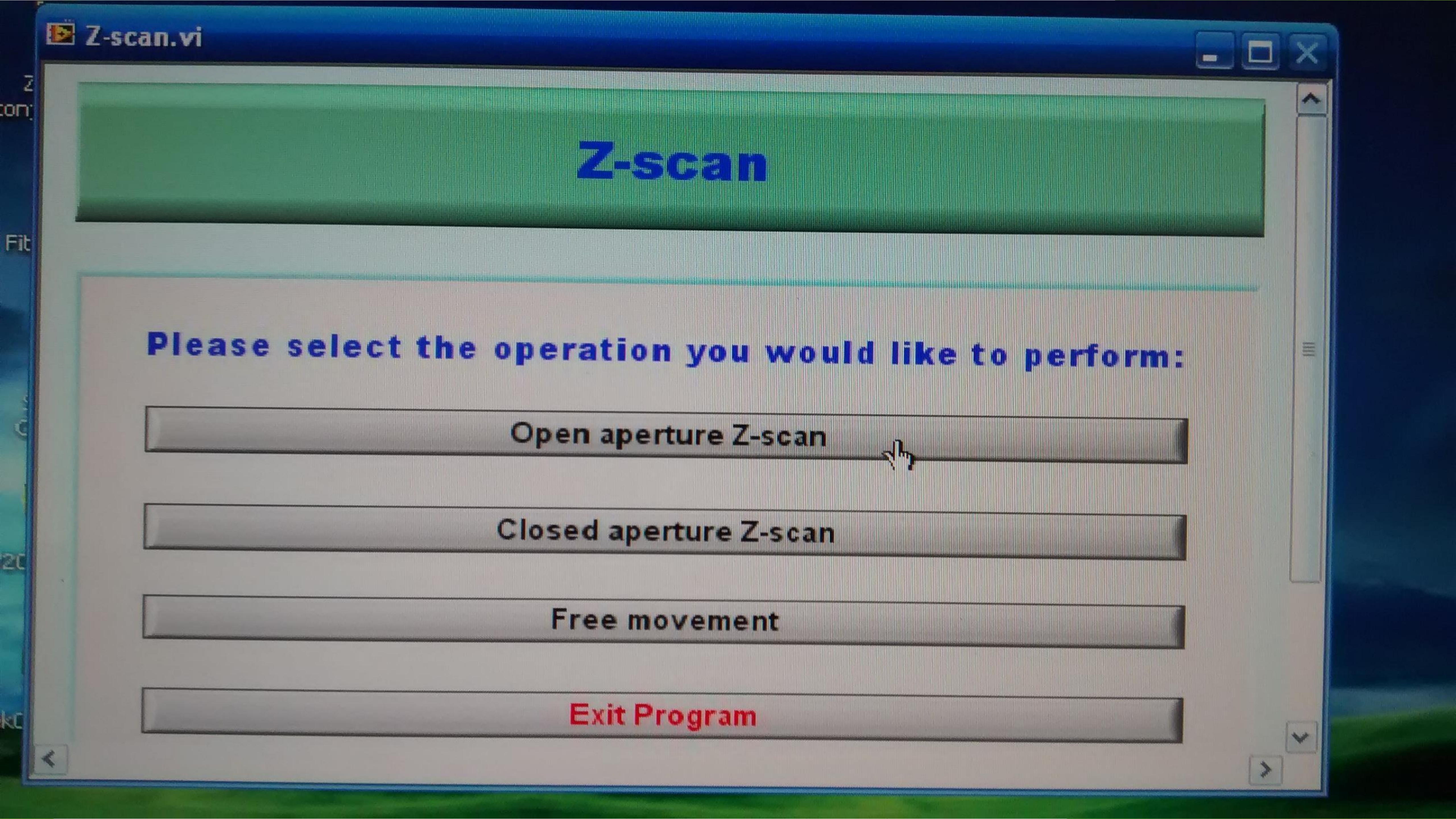
- ✓ **Linear absorption coefficient α should be measured at the wavelength of interest [Sutherland]**

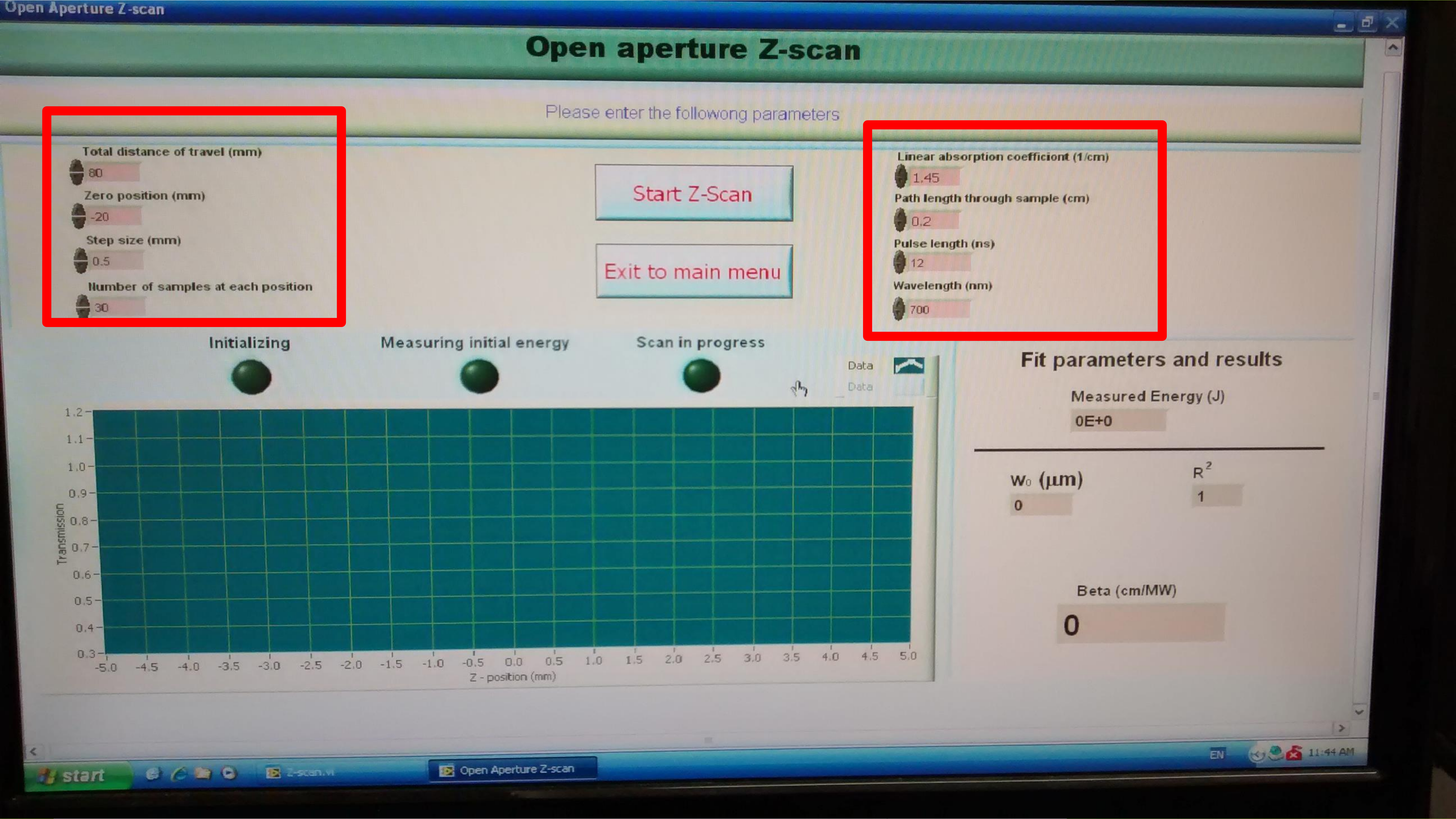
Sample prep

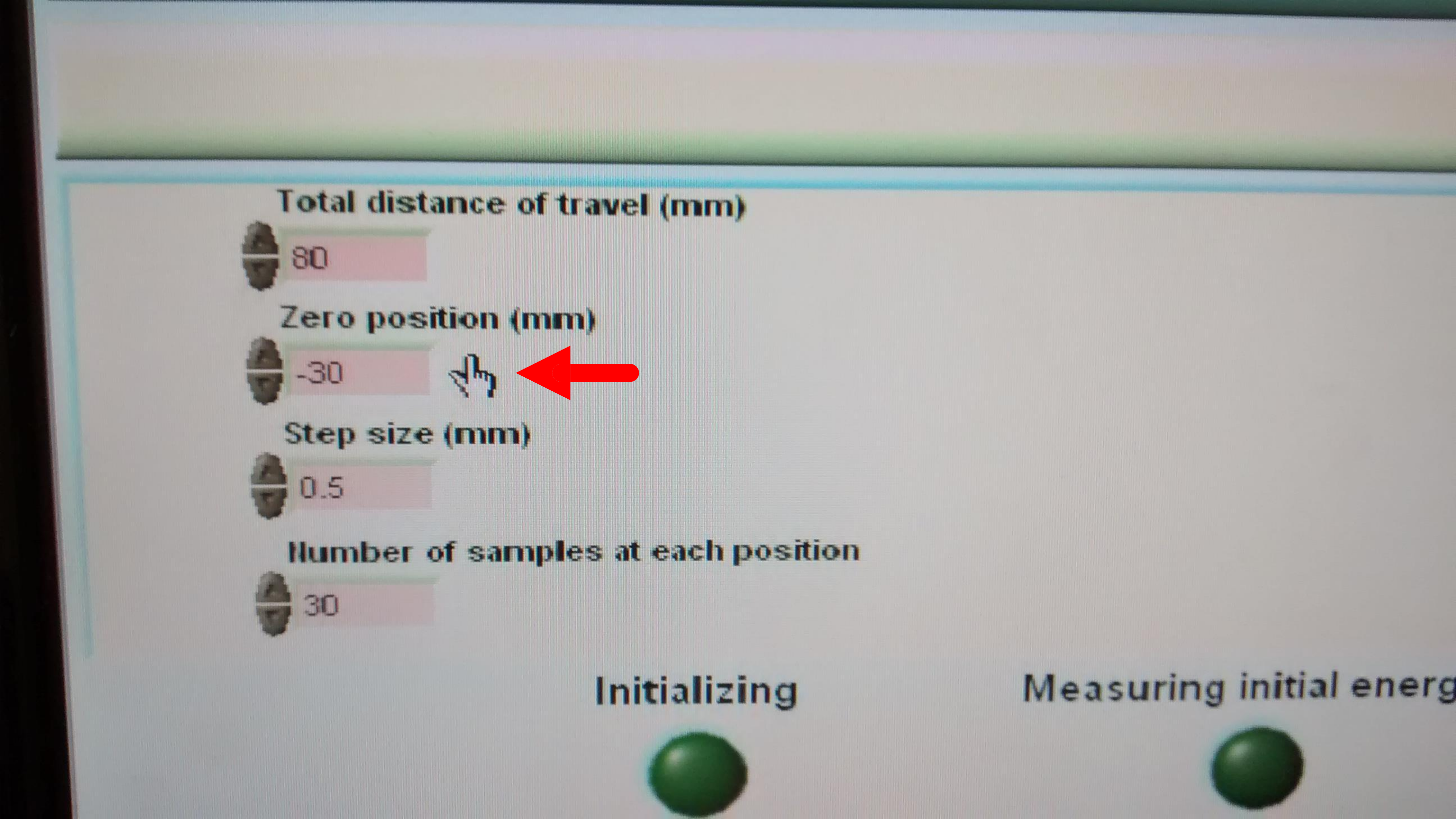
- ✓ **Solutions should be prepared with A<1 in z-scan cell to prevent intermolecular interactions**

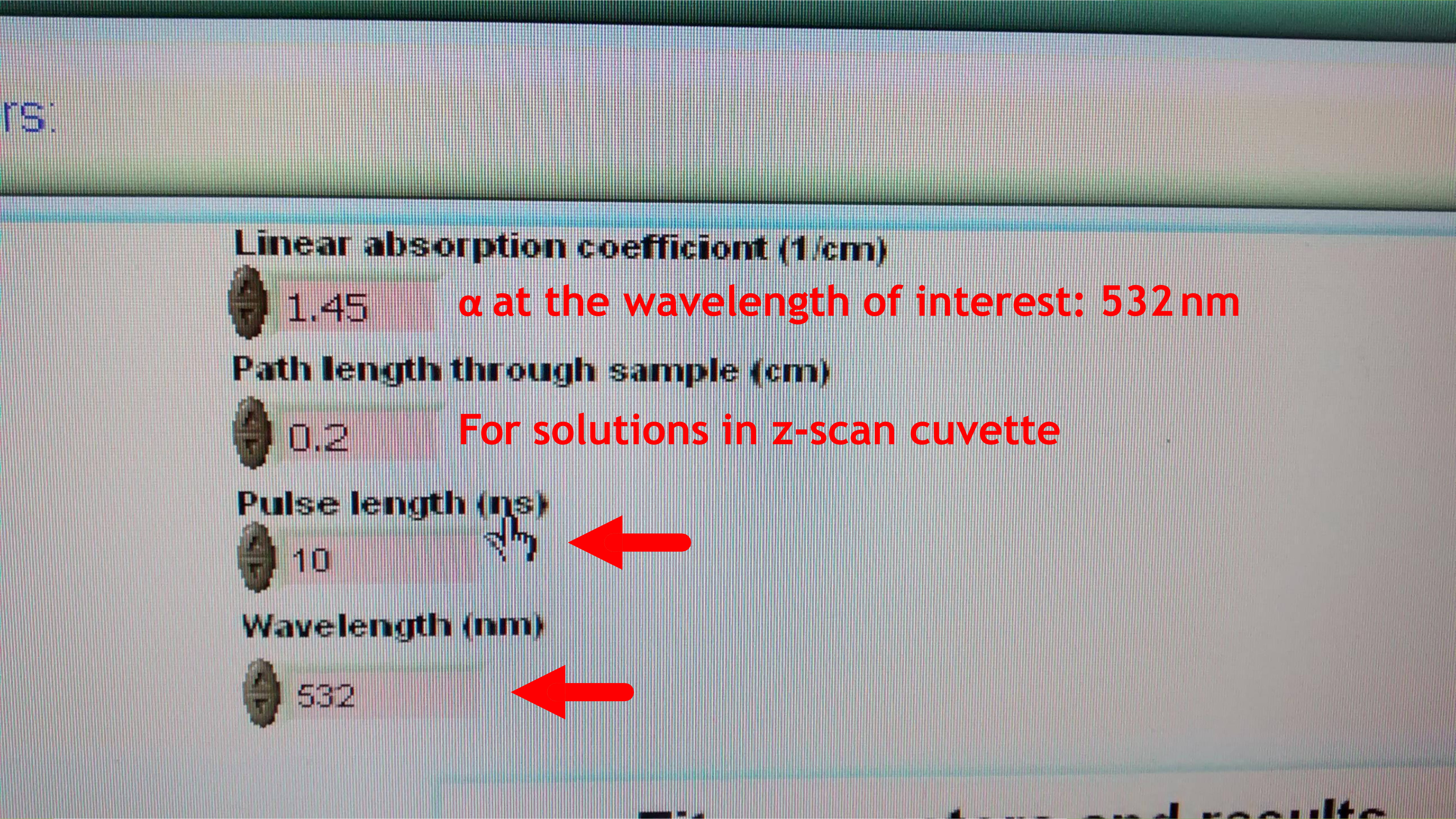
Using the software

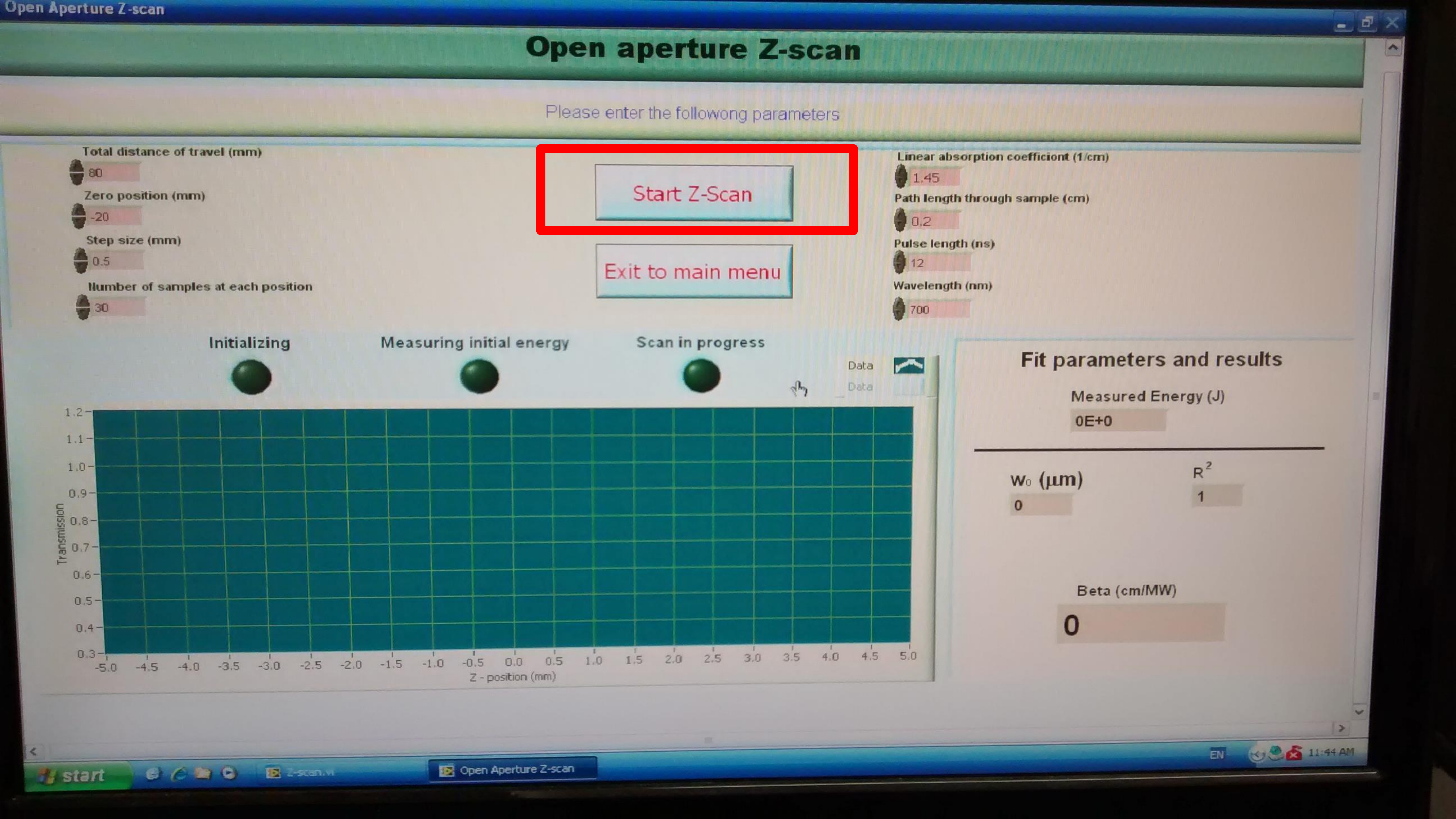


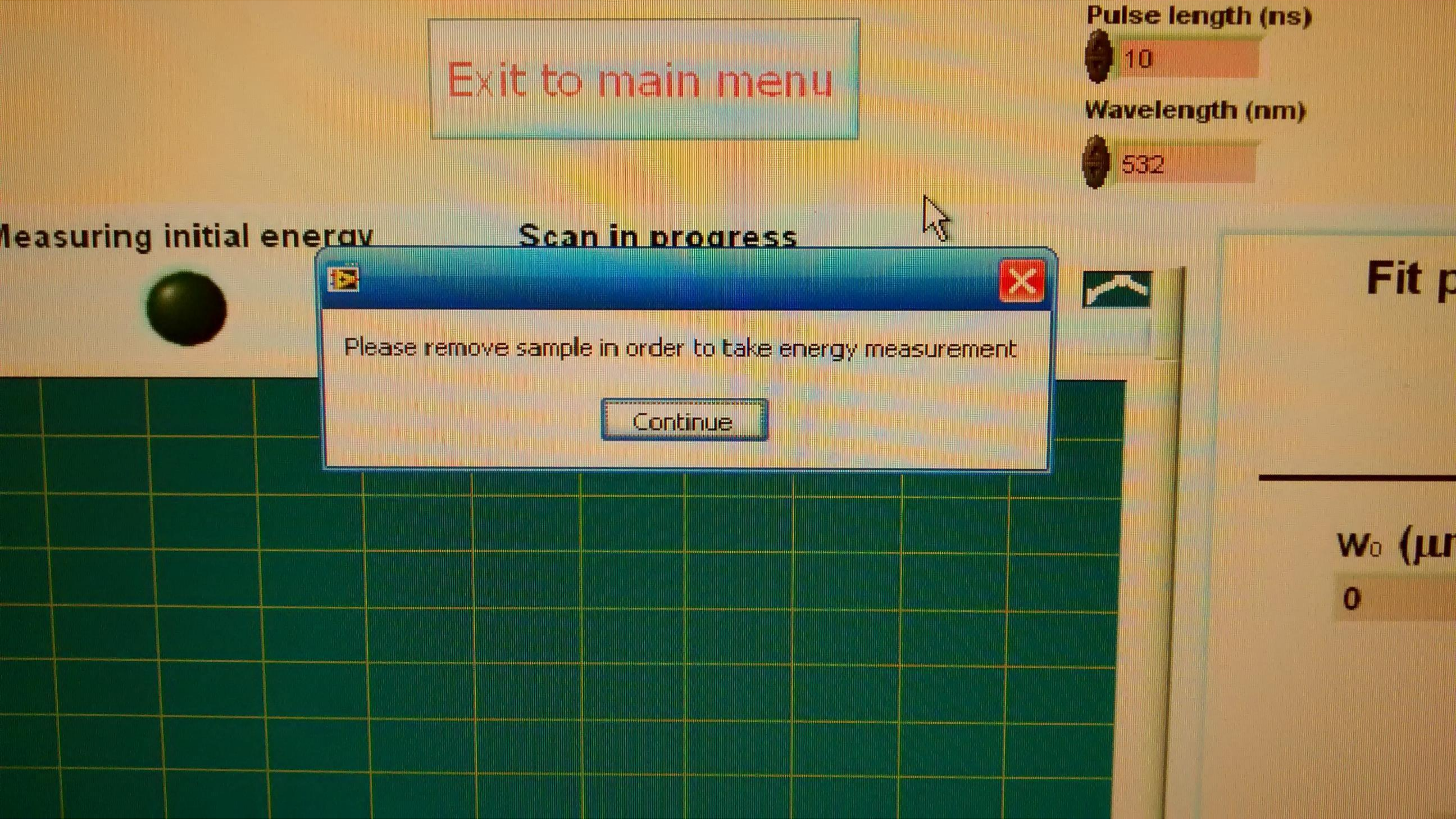

Z-scan.vi
Z-scan
Please select the operation you would like to perform:
Open aperture Z-scan
Closed aperture Z-scan
Free movement
Exit Program

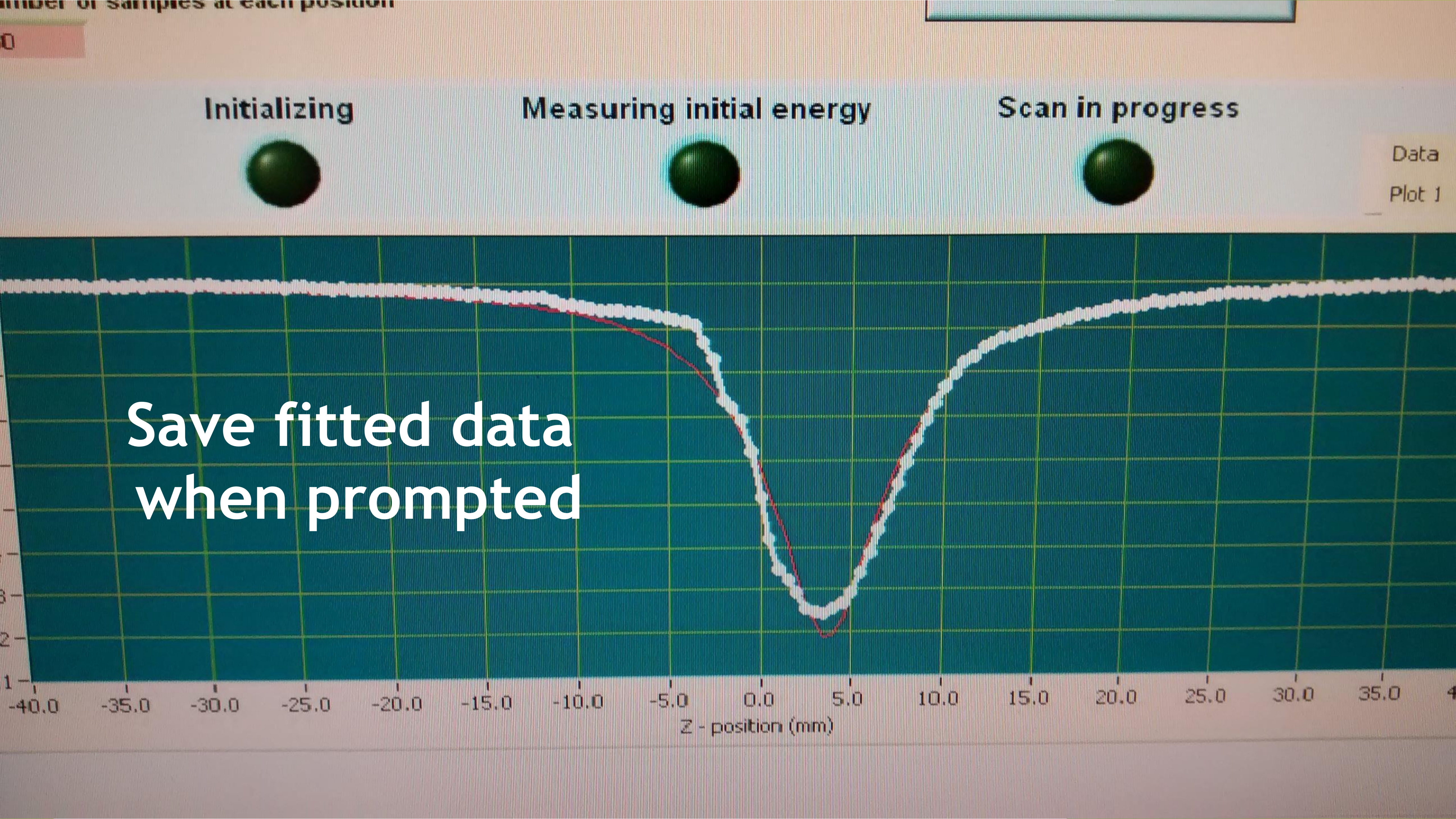

Open Aperture Z-scan
Open aperture Z-scan
Please enter the followong parameters
Total distance of travel (mm)
80
Zero position (mm)
-20
Step size (mm)
0.5
Number of samples at each position
30
Start Z-Scan
Exit to main menu
Linear absorption coefficiont (1/cm)
1.45
Path length through sample (cm)
0.2
Pulse length (ns)
12
Wavelength (nm)
700
Initializing
Measuring initial energy
Scan in progress
Data
Data
Transmission
Z - position (mm)
Fit parameters and results
Measured Energy (J)
0E+0
W0 (µm)
0
R2
1
Beta (cm/MW)
0
start
Z-scan.vi
Open Aperture Z-scan
EN
11:44 AM


Total distance of travel (mm)
80
Zero position (mm)
-30
Step size (mm)
0.5
Number of samples at each position
30
Initializing
Measuring initial energ


Linear absorption coefficient (1/cm)
1.45
α at the wavelength of interest: 532 nm
Path length through sample (cm)
0.2
For solutions in z-scan cuvette
Pulse length (ns)
10
Wavelength (nm)
532


Open Aperture Z-scan
Open aperture Z-scan
Please enter the followong parameters
Total distance of travel (mm)
80
Zero position (mm)
-20
Step size (mm)
0.5
Number of samples at each position
30
Start Z-Scan
Exit to main menu
Linear absorption coefficiont (1/cm)
1.45
Path length through sample (cm)
0.2
Pulse length (ns)
12
Wavelength (nm)
700
Initializing
Measuring initial energy
Scan in progress
Data
Transmission
Z - position (mm)
Fit parameters and results
Measured Energy (J)
0E+0
W0 (µm)
0
R2
1
Beta (cm/MW)
0
start
Open Aperture Z-scan

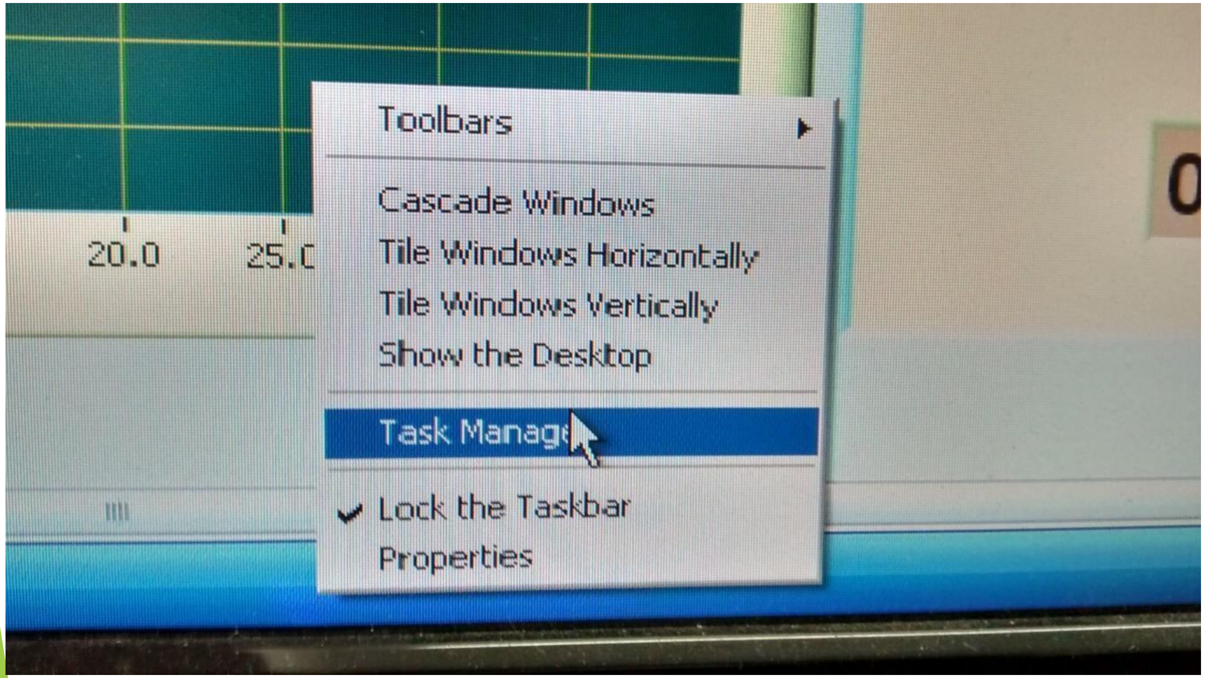

Exit to main menu
Pulse length (ns)
10
Wavelength (nm)
532
Measuring initial energy
Scan in progress
Please remove sample in order to take energy measurement
Continue
Fit p
W0 (µ
0

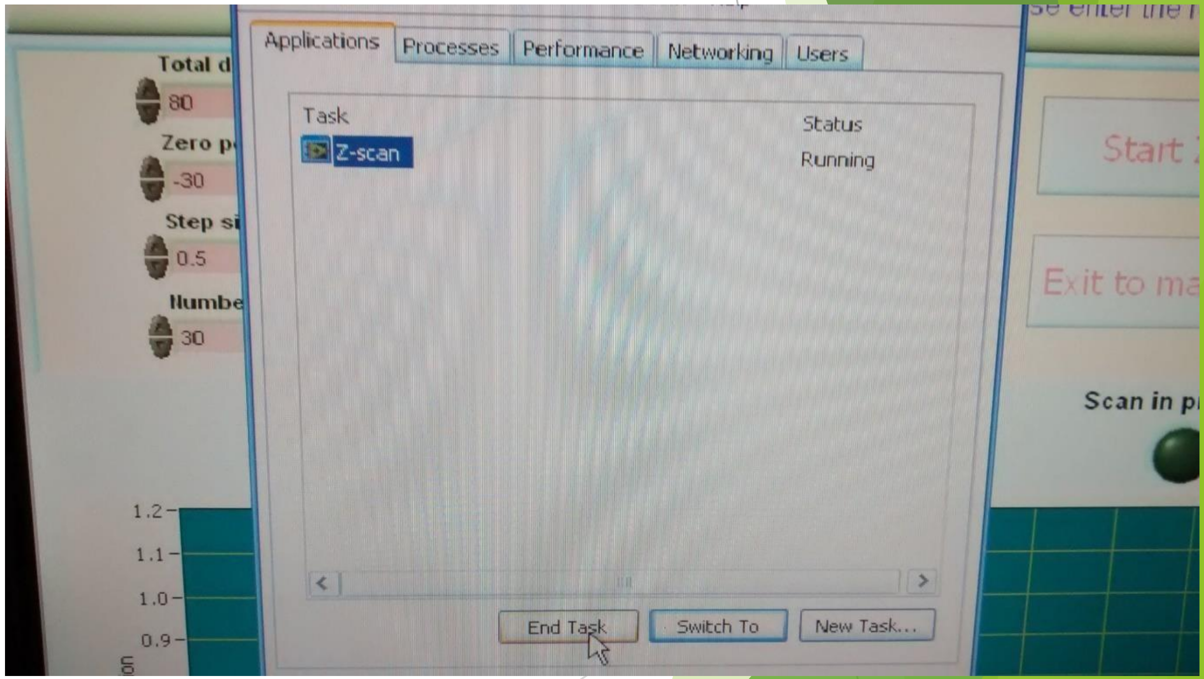


Initializing
Measuring initial energy
Scan in progress
Data
Plot 1
Save fitted data when prompted
-40.0
-35.0
-30.0
-25.0
-20.0
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Z - position (mm)

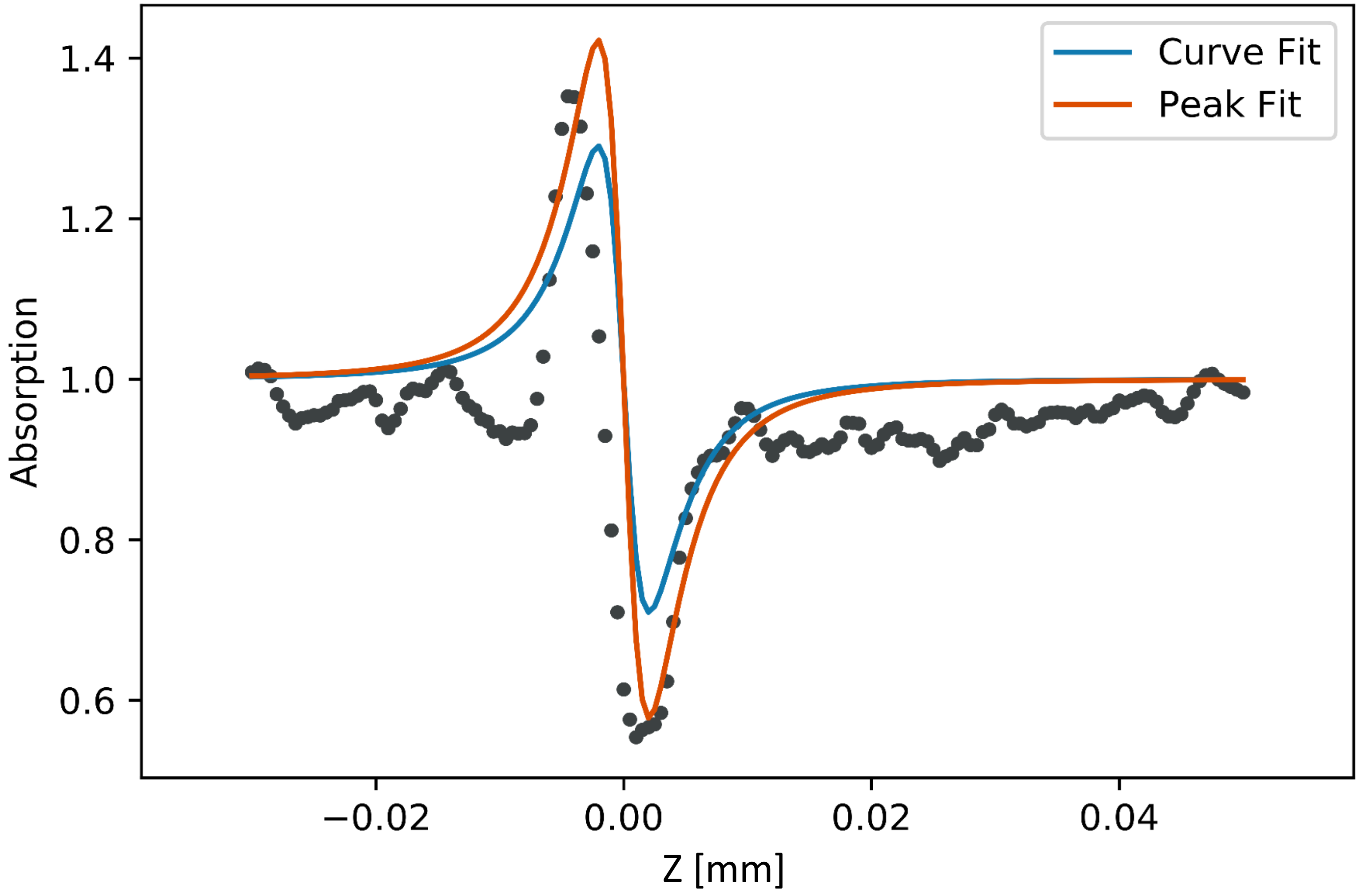
Exiting the program

- ✓ Need to use Task Manager to exit the program
- ✓ Right click on Taskbar > Task Manager > End Task





Open Aperture Z- Scan



Z – scan calculations

Non linear Absorption

$$T(z) = 1 - \frac{\Delta\psi_0}{\left(\left(\frac{z}{zr}\right)^2 + 1\right)}$$

$$\Delta\psi_0 = \frac{I_0 L_{eff}}{2\sqrt{2}}\beta$$

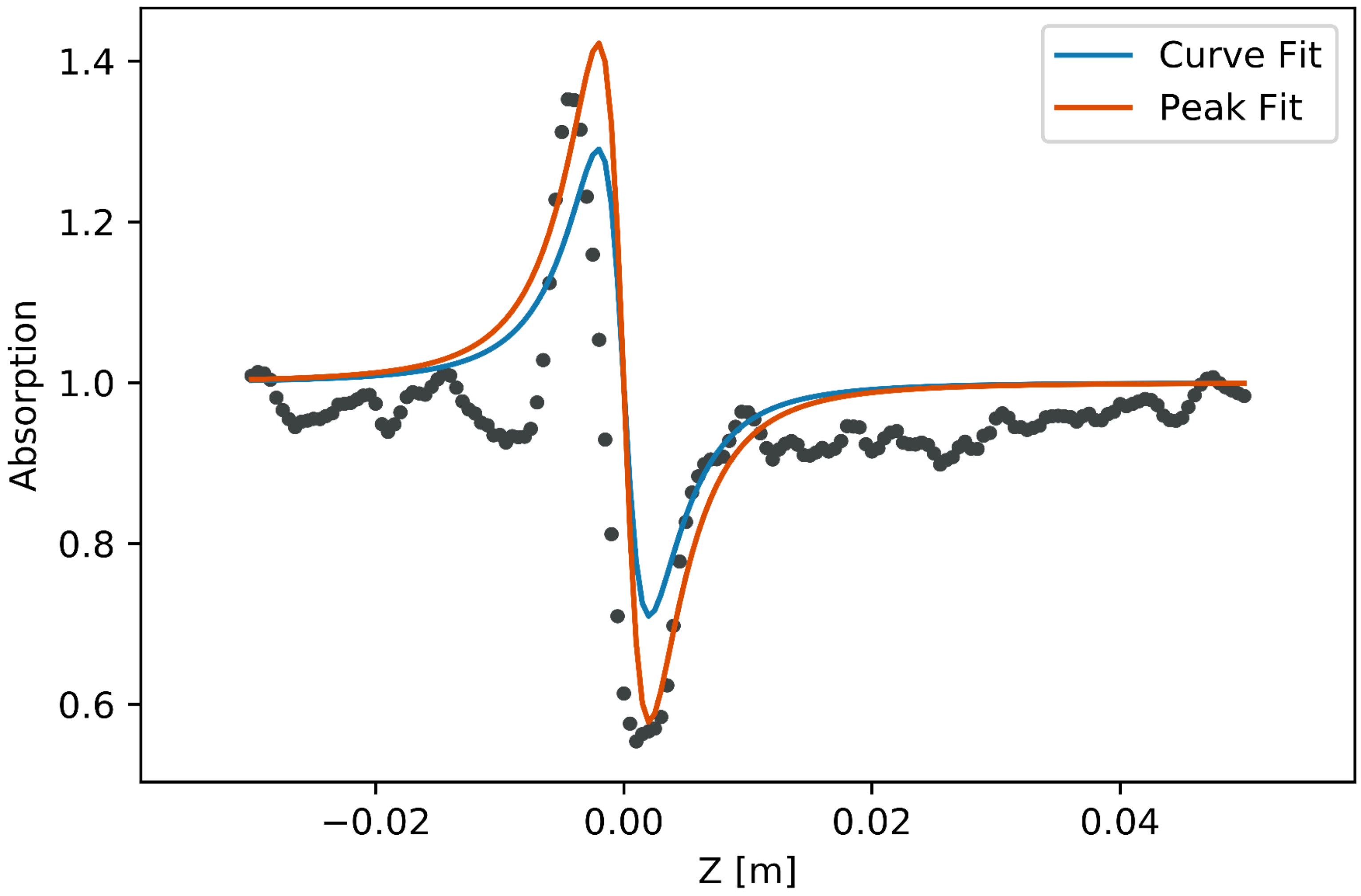
Closed Aperture equations

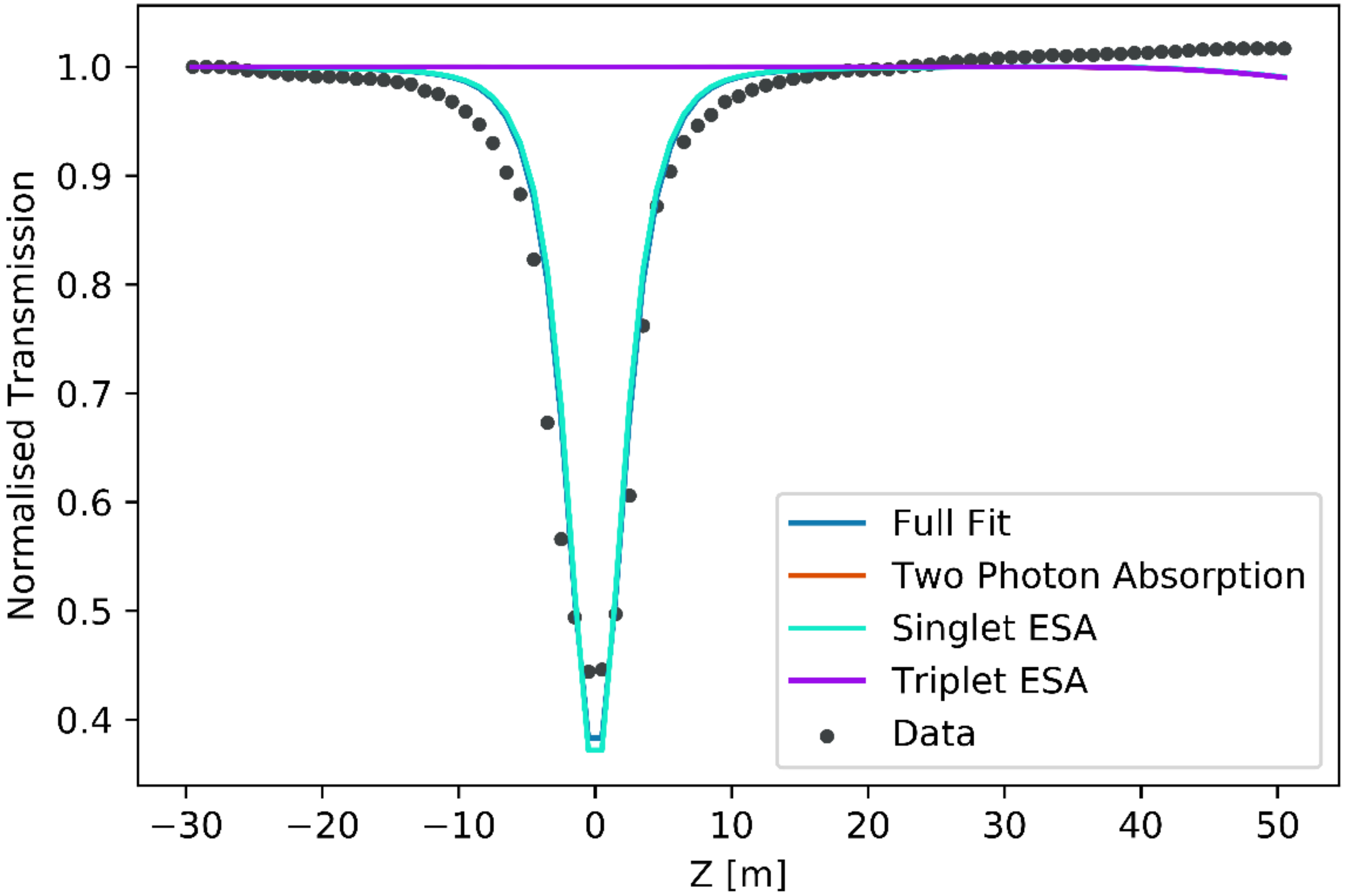
$$T(z) = 1 + \frac{4x\Delta\Phi_0}{[(x^2+9)(x^2+1)]}$$

$$\Delta T_{\mathrm{PV}} = 0.406(1-S)^{0.27}|\Delta\Phi_0|$$

$$\Delta\Phi_0 = kn_2I_0L_{\mathrm{eff}}$$

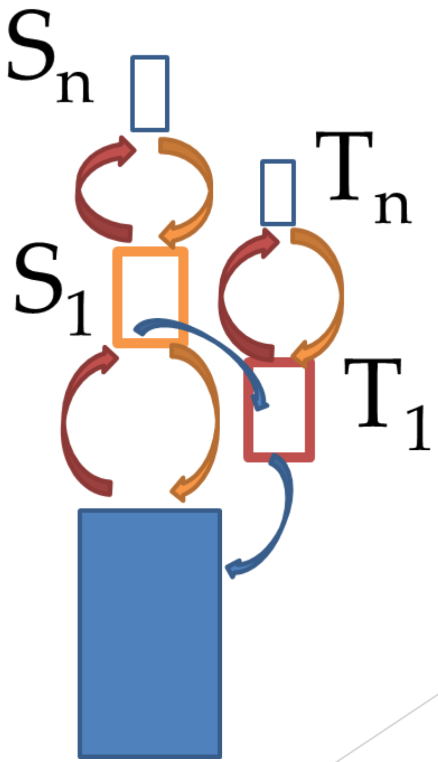
Open Aperture Z-Scan




Normalised Transmission
1.0
0.9
0.8
0.7
0.6
0.5
0.4
−30
−20
−10
0
10
20
30
40
50
Z [m]
Full Fit
Two Photon Absorption
Singlet ESA
Triplet ESA
Data

Five Level Orbital Rate Equations

- $\frac{dN_{S_0}}{dt} = -\frac{I^2\sigma_{S01}^{(2)}N_{S_0}}{2(\hbar\omega)^2} - \frac{\boldsymbol{\sigma_{01}}IN_{S_0}}{\hbar\omega} + \frac{N_{S_1}}{\tau_{10}} + \frac{N_{T_1}}{\tau_{30}}$
- $\frac{dN_{S_1}}{dt} = \frac{I^2\sigma_{S01}^{(2)}N_{S_0}}{2(\hbar\omega)^2} - \frac{N_{S_1}}{\tau_{10}} + \frac{N_{S_n}}{\tau_{21}} - \frac{\sigma_{12}IN_{S_1}}{\hbar\omega} - \frac{N_{S_1}}{\tau_{13}}$
- $\frac{dN_{T_1}}{dt} = \frac{\sigma_{34}IN_{T_1}}{\hbar\omega} - \frac{N_{T_n}}{\tau_{43}} + \frac{N_{S_1}}{\tau_{13}} - \frac{N_{T_1}}{\tau_{30}}$
- $\frac{dN_{T_n}}{dt} = \frac{\sigma_{34}IN_{T_1}}{\hbar\omega} - \frac{N_{T_n}}{\tau_{43}}$
- $\frac{dN_{S_n}}{dt} = \frac{\sigma_{12}IN_{S_1}}{\hbar\omega} - \frac{N_{S_n}}{\tau_{21}}$



Booking

- Dr. Mack
- Sign up sheet on S22 whiteboard

Acknowledgements

Dr J.Mack
Marcel Loudza