

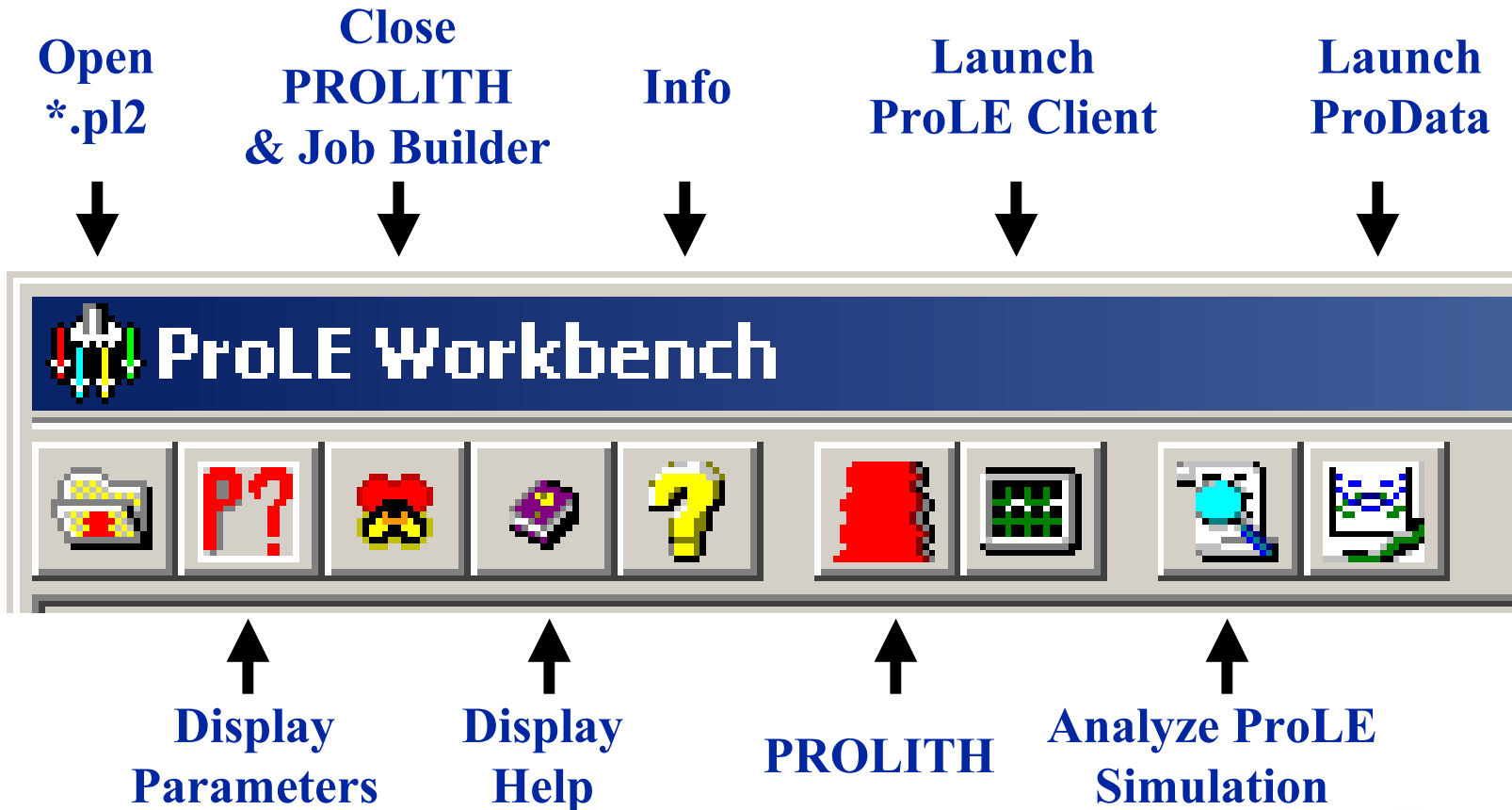
# ProLE-LE™ - the single workstation version of ProLE™ Workbench

- ◆ Efficient batching of PROLITH™ simulations
  - ❖ GUI-based. No ProBATCH commands or syntax needed
  - ❖ Perform Monte Carlo Simulations (of aberrations only)
  - ❖ Investigate Higher Order Aberrations
  - ❖ Eliminate undesired simulation matrix conditions
  - ❖ Single workstation version of distributed-computing ProLE system
- ◆ Complements and enhances your PROLITH investment

\*ProBatch is a set of commands for driving PROLITH™, from KLA-Tencor Inc.

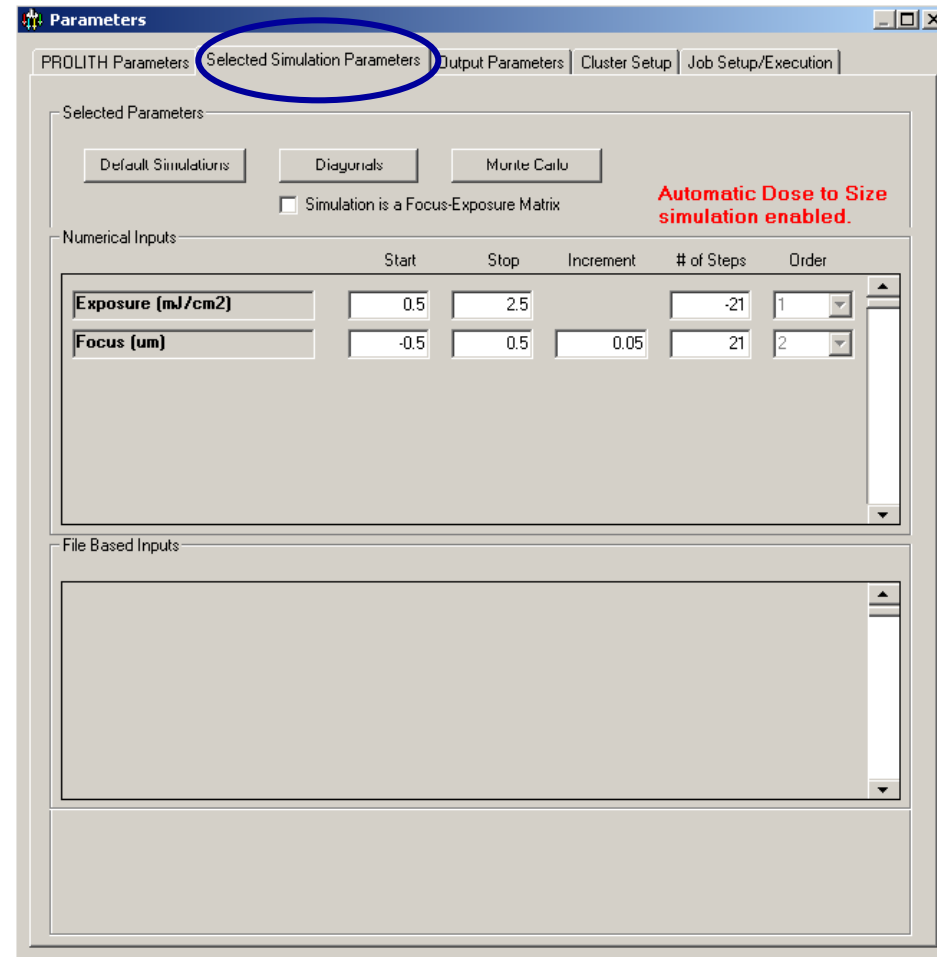
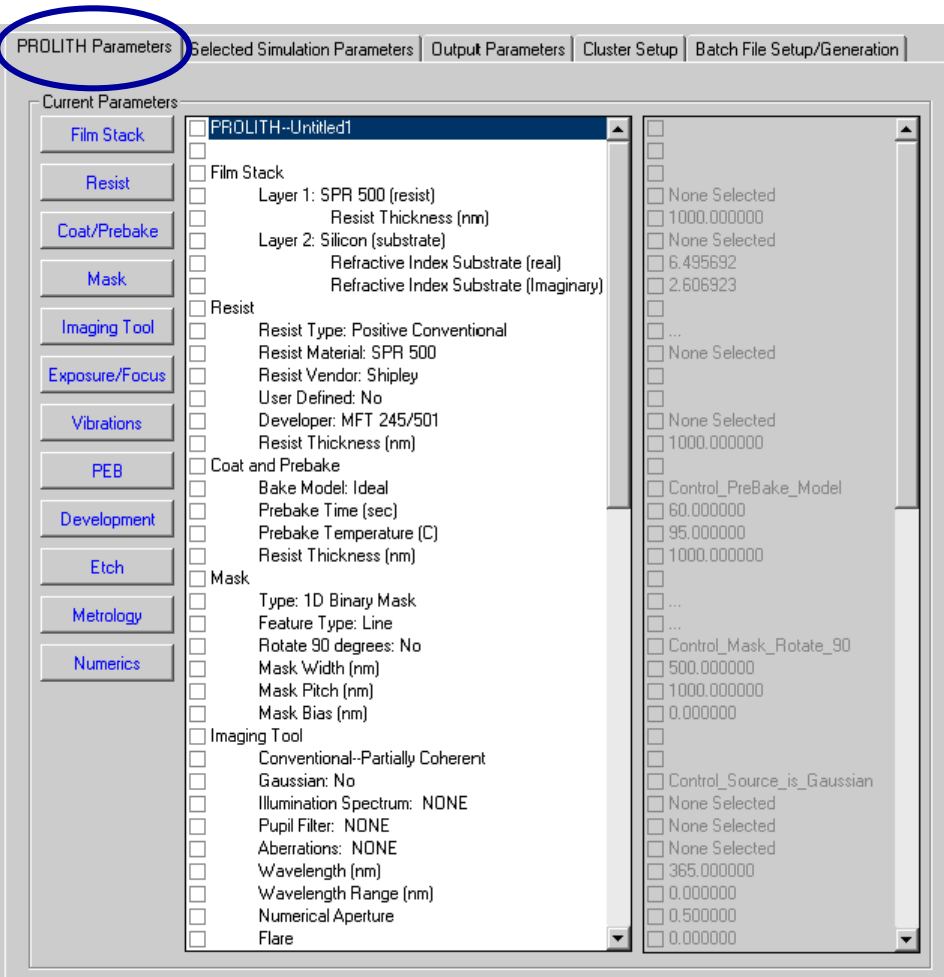
# ProLE™ Workbench Menu Bar

- Workbench embeds ProLE, PROLITH, Data sorter and Automated ProData plus other software utilities.



# ProLE™ Workbench Setup Screens

- Select any PROLITH input parameter including File Based inputs



# Input File Selection Screen

Select inputs defined by PROLITH database files and ProLE Workbench will generate simulations varying the selected files automatically.

## Available File-based Inputs

**Aberration Files - .ZRN**

**Vibration Files - .VIB**

**New file type:**

**Mask Files - .MSK**

**Resist Files - .RES**

**High Order Zernikes - .HOZ**

**1D Grayscale Masks -.GRY**

**Temp.(Bake)Profiles - .TPR**

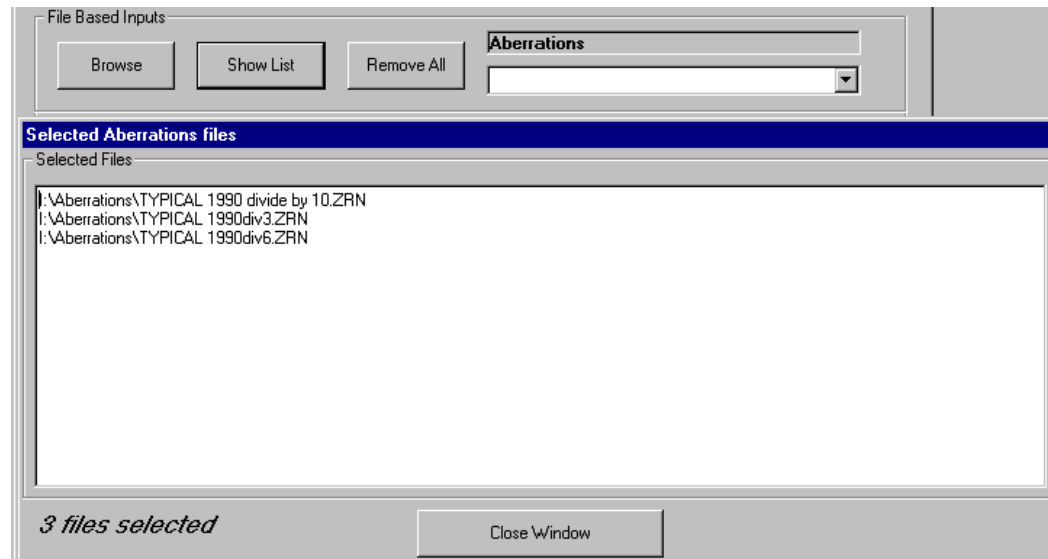
**User Defined Distribution -  
.UDD**

**Source Shape Files - .SRC**

**Pupil Filter Files - .FIL**

**Spectrum Files - .ILL**

**CODE-V Aberrations -.INT**



# Simulation Matrix Combination Screen

Current Matrix Controls: Diagonal 1, Diagonal 2, Select All, Clear All

Global Matrix Controls: All Cases Diagonal 1, All Cases Diagonal 2, Select All Cases, Clear All Conditions

2D Contact Hole Width (nm)

Diagonal 2	200	240	280	320	360	400
200	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
240	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
280	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
320	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
360	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
400	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

2D Contact Hole Height (nm)

- ◆ Eliminate unnecessary simulations by taking control of the Simulation Matrix
- ◆ Use ProLE to simulate coupled inputs such as Contact Hole Width/Height, Alt. PSM Chrome Widths, and more

# Aberrations Selection

- Investigate Zernike aberrations up to Z136
- Correlate PROLITH aberrations with CODE-V™ Lens information
- Load and combine .ZRN, .INT and the new .HOZ files

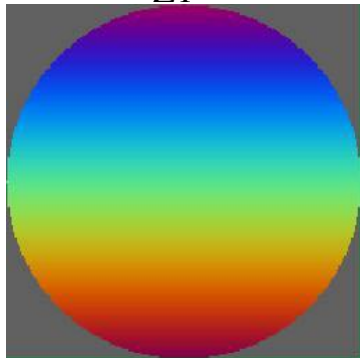
Advanced Aberrations

Available Zernike Terms | Selected Zernike Terms

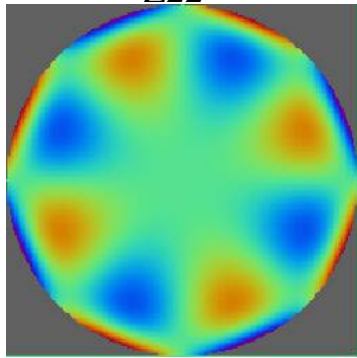
Please select the Zernike Terms to vary

Term	Fringe Term	Aberration Type	Normalization	Formula
<input type="checkbox"/> 0	(Z1)	Piston	1	1
<input type="checkbox"/> 1	(Z3)	Y- Tilt	Sqrt(4)	$R(\sin(\theta))$
<input type="checkbox"/> 2	(Z2)	X- Tilt	Sqrt(4)	$R(\cos(\theta))$
<input type="checkbox"/> 3	(Z6)	Primary 45Deg. Astigmatism	Sqrt(6)	$R^2(\sin(2\theta))$
<input type="checkbox"/> 4	(Z4)	Defocus	Sqrt(3)	$2R^2 - 1$
<input type="checkbox"/> 5	(Z5)	Primary Astigmatism	Sqrt(6)	$R^2(\cos(2\theta))$
<input type="checkbox"/> 6	(Z11)		Sqrt(8)	$R^3(\sin(3\theta))$
<input type="checkbox"/> 7	(Z8)	Primary Y- Coma	Sqrt(8)	$3R^3(\sin(\theta)) - 2R(\sin(\theta))$
<input type="checkbox"/> 8	(Z7)	Primary X- Coma	Sqrt(8)	$3R^3(\cos(\theta)) - 2R(\cos(\theta))$
<input type="checkbox"/> 9	(Z10)		Sqrt(8)	$R^3(\cos(3\theta))$
<input type="checkbox"/> 10	(Z18)		Sqrt(10)	$R^4(\sin(4\theta))$
<input type="checkbox"/> 11	(Z13)	4th Order 45Deg. Astigmatism	Sqrt(10)	$4R^4(\sin(2\theta)) - 3R^2(\sin(2\theta))$
<input type="checkbox"/> 12	(Z9)	Primary Spherical	Sqrt(5)	$6R^4 - 6R^2 + 1$
<input type="checkbox"/> 13	(Z12)	4th Order Astigmatism	Sqrt(10)	$4R^4(\cos(2\theta)) - 3R^2(\cos(2\theta))$

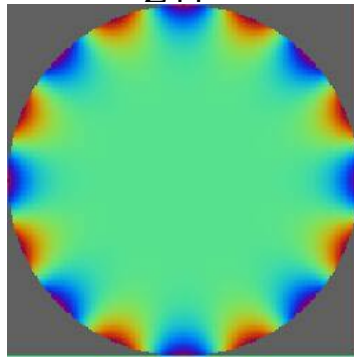
Z1



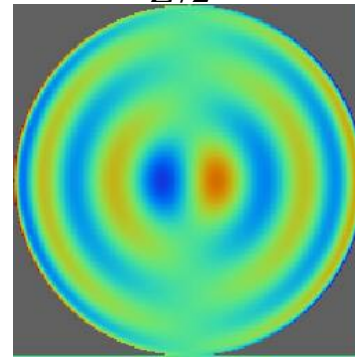
Z22



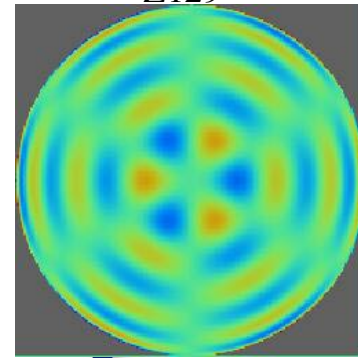
Z44



Z72



Z129

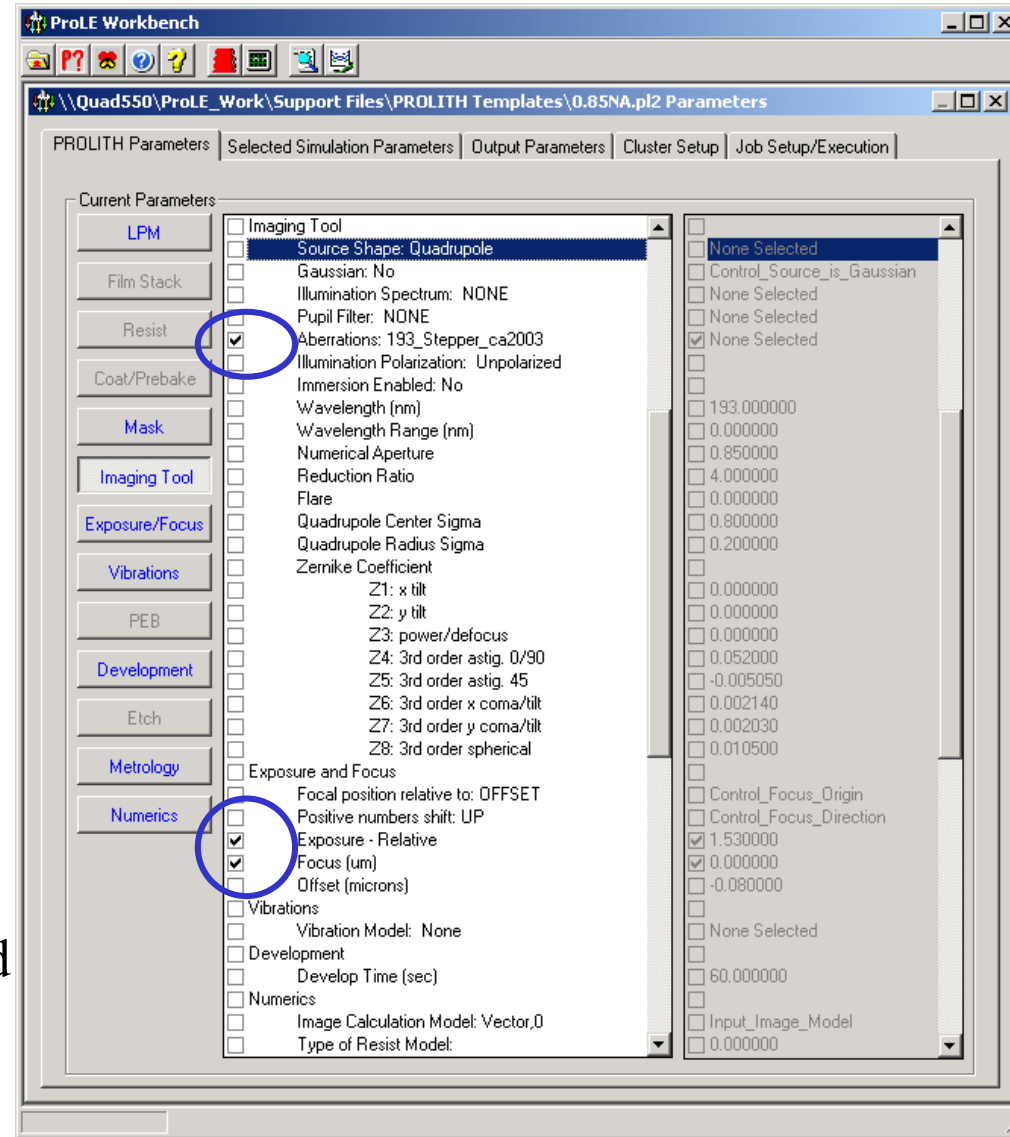


# **Example: F/E with auto dose-to-size centering, and Monte Carlo generated aberrations**

# Input parameter selection

## F/E, aberration example page 1

- Select any PROLITH input parameter including File Based inputs
- Example: F/E with file-based aberrations
  - Aberrations selected for later file based input
  - Focus and Exposure selected



(193nm, 0.85NA, 100:100nm line-space  
Quadrupole 0.8/0.2 center/radius)



# Choose aberrations to be varied

ProLE Workbench - [Advanced Aberrations]

Available Zernike Terms | Selected Zernike Terms

Import PROLITH Zernike (ZRN) File | Clear ZRN Data | Import High Order Zernike (HOZ) File | Clear HOZ Data

Please select the Zernike Terms to vary | Double-Click any row to display image of Aberration

Term	Fringe Term	Aberration Type	Normalization	Formula
<input type="checkbox"/>	12	(FZ_9) 3rd Order Spherical	Sqrt(5)	$6R^4 - 6R^2 + 1$
<input type="checkbox"/>	13	(FZ_12) 5th Order Astigmatism	Sqrt(10)	$4R^4(\cos(2\theta)) - 3R^2(\cos(2\theta))$
<input checked="" type="checkbox"/>	14	(FZ_17) 3rd Order Quad-Foil	Sqrt(10)	$R^4(\cos(4\theta))$
<input type="checkbox"/>	15	(FZ_27) 3rd Order 45 Deg. Pent-Foil	Sqrt(12)	$R^5(\sin(5\theta))$
<input type="checkbox"/>	16	(FZ_20) 5th Order Y- Tri-foil	Sqrt(12)	$5R^5(\sin(3\theta)) - 4R^3(\sin(3\theta))$
<input checked="" type="checkbox"/>	17	(FZ_15) 5th Order Y- Coma	Sqrt(12)	$10R^5(\sin(\theta)) - 12R^3(\sin(\theta)) + 3R(\sin(\theta))$
<input type="checkbox"/>	18	(FZ_14) 5th Order X- Coma	Sqrt(12)	$10R^5(\cos(\theta)) - 12R^3(\cos(\theta)) + 3R(\cos(\theta))$
<input checked="" type="checkbox"/>	19	(FZ_19) 5th Order X- Tri-foil	Sqrt(12)	$5R^5(\cos(3\theta)) - 4R^3(\cos(3\theta))$
<input type="checkbox"/>	20	(FZ_26) 3rd Order Pent-Foil	Sqrt(12)	$R^5(\cos(5\theta))$
<input type="checkbox"/>	21		Sqrt(14)	$R^6(\sin(6\theta))$
<input type="checkbox"/>	22	(FZ_29) 5th Order 45Deg. Quad-Foil	Sqrt(14)	$6R^6(\sin(4\theta)) - 5R^4(\sin(4\theta))$
<input type="checkbox"/>	23	(FZ_22) 7th Order 45Deg. Astigmatism	Sqrt(14)	$15R^6(\sin(2\theta)) - 20R^4(\sin(2\theta)) + 6R^2(\sin(2\theta))$
<input type="checkbox"/>	24	(FZ_16) 5th Order Spherical	Sqrt(7)	$20R^6 - 30R^4 + 12R^2 - 1$
<input type="checkbox"/>	25	(FZ_21) 7th Order Astigmatism	Sqrt(14)	$15R^6(\cos(2\theta)) - 20R^4(\cos(2\theta)) + 6R^2(\cos(2\theta))$
<input type="checkbox"/>	26	(FZ_28) 5th Order Quad-Foil	Sqrt(14)	$6R^6(\cos(4\theta)) - 5R^4(\cos(4\theta))$

CODE-V Base Filename: IntFile#  Apply Normalization Factor **Show in List**

All available Zernikes
  Only Fringe Zernikes

Monte Carlo Setup  
 Number of Monte Carlo Conditions:

## F/E, aberration example page 2

# Example: Set aberration file conditions

## F/E, aberration example page 3

ProLE Workbench - [Advanced Aberrations]

Available Zernike Terms Selected Zernike Terms

	Mean	Sigma	# of Digits	Distribution
Z4 (FZ_4) (Defocus)	0	.005	3	2 - Gaussian Random
Z7 (FZ_8) (3rd Order Y- Coma)	0	.005	3	2 - Gaussian Random
Z9 (FZ_10) (3rd Order Tri-Foil)	0	.005	3	2 - Gaussian Random
Z14 (FZ_17) (3rd Order Quad-Foil)	0	.005	3	2 - Gaussian Random
Z17 (FZ_15) (5th Order Y- Coma)	0	.005	3	2 - Gaussian Random
Z19 (FZ_19) (5th Order X- Tri-foil)	0	.005	3	2 - Gaussian Random

Monte Carlo Setup

Number of Monte Carlo Conditions: 100

CODE-V Base Filename: IntFile#  Apply Normalization Factor **Show in List**

All available Zernikes  
 Only Fringe Zernikes

Generate Aberration Files Generate and Import to ProLE

Values are user-specified or probability-distribution generated

Generate aberration files or run directly

# Enter values for selected parameters

## F/E, aberration example page 4

The screenshot shows the ProLE Workbench interface. The main window is titled "PROLITH Parameters" and has several tabs: "Selected Simulation Parameters", "Output Parameters", "Cluster Setup", and "Job Setup/Execution". The "Selected Simulation Parameters" tab is active, showing a "Selected Parameters" section with buttons for "Default Simulations", "Diagonals", and "Monte Carlo". A red message states "Automatic Dose to Size simulation enabled." Below this is a "Numerical Inputs" section with a table:

	Start	Stop	Increment	# of Steps	Order
Exposure - Relative	.7	3		-47	1
Focus (um)	-6	.6	.05	25	2

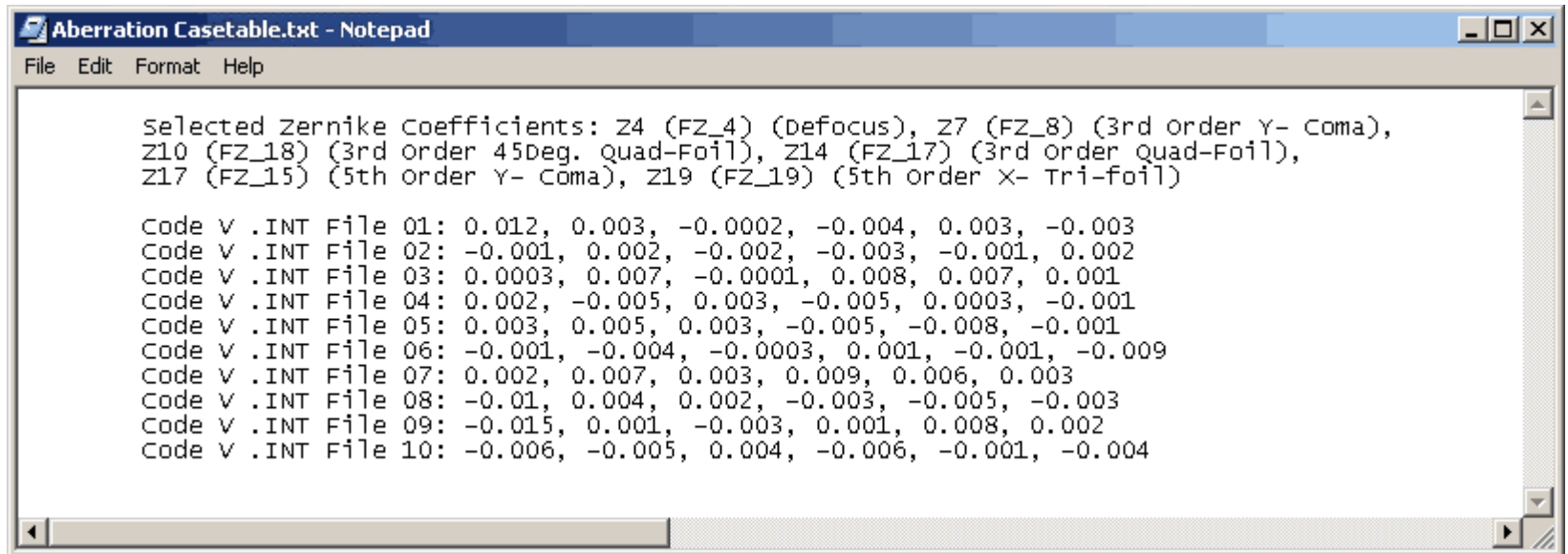
Below the table is a "File Based Inputs" section with "Browse" and "Show List" buttons. A "Selected Aberrations files" dialog box is open, showing a list of 10 files:

```
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#1.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#10.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#2.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#3.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#4.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#5.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#6.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#7.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#8.int
\\Quad550\ProLE_Work\Support Files\Aberration Files\IntFile#9.int
```

The dialog box also shows "10 files selected" and a "Close Window" button.

# Case table showing aberration combinations

## F/E, aberration example page 5



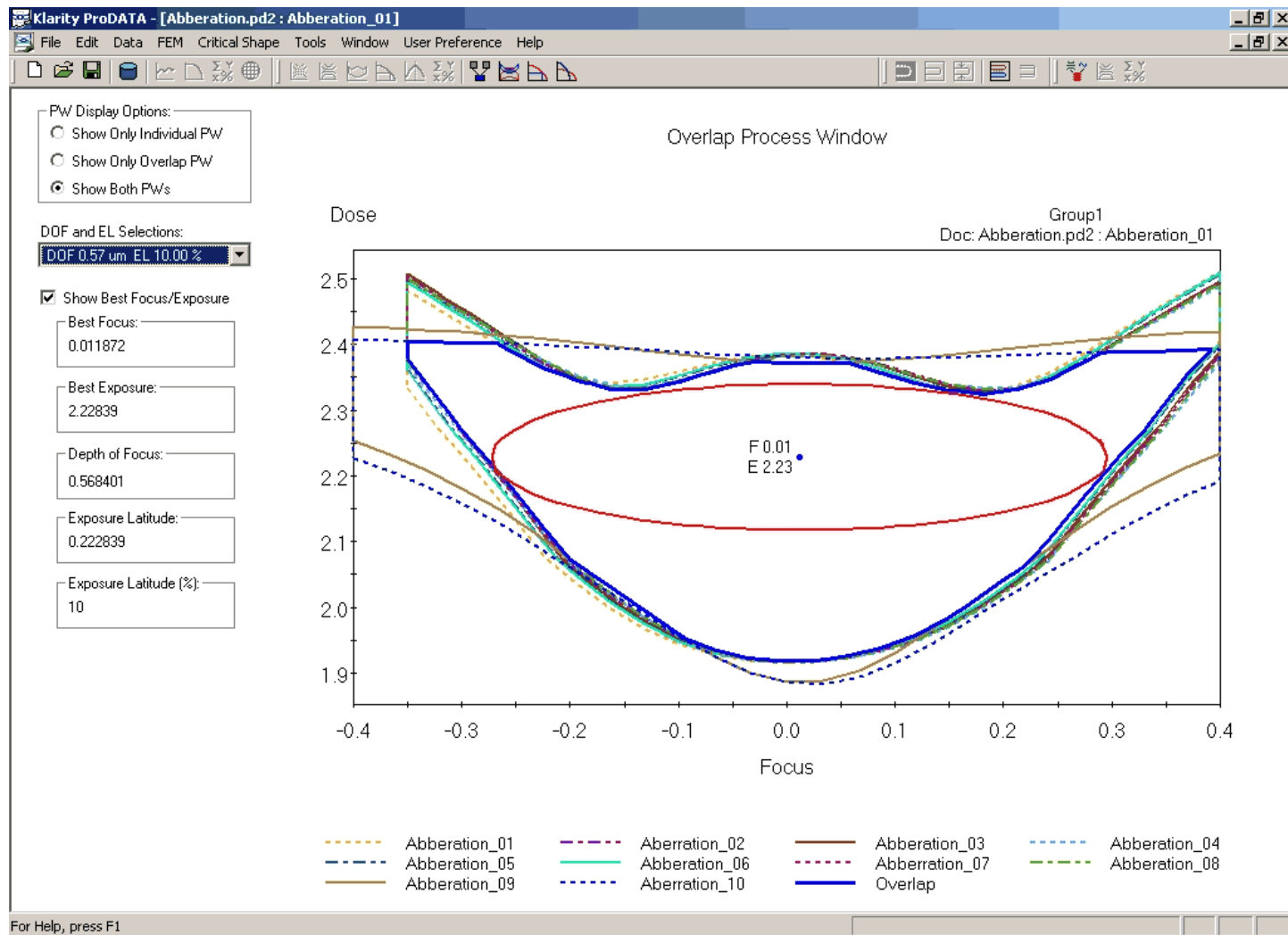
```
Aberration Casetable.txt - Notepad
File Edit Format Help

selected Zernike Coefficients: Z4 (FZ_4) (Defocus), Z7 (FZ_8) (3rd order Y- Coma),
Z10 (FZ_18) (3rd order 45Deg. Quad-Foil), Z14 (FZ_17) (3rd order Quad-Foil),
Z17 (FZ_15) (5th order Y- Coma), Z19 (FZ_19) (5th order X- Tri-foil)

Code V .INT File 01: 0.012, 0.003, -0.0002, -0.004, 0.003, -0.003
Code V .INT File 02: -0.001, 0.002, -0.002, -0.003, -0.001, 0.002
Code V .INT File 03: 0.0003, 0.007, -0.0001, 0.008, 0.007, 0.001
Code V .INT File 04: 0.002, -0.005, 0.003, -0.005, 0.0003, -0.001
Code V .INT File 05: 0.003, 0.005, 0.003, -0.005, -0.008, -0.001
Code V .INT File 06: -0.001, -0.004, -0.0003, 0.001, -0.001, -0.009
Code V .INT File 07: 0.002, 0.007, 0.003, 0.009, 0.006, 0.003
Code V .INT File 08: -0.01, 0.004, 0.002, -0.003, -0.005, -0.003
Code V .INT File 09: -0.015, 0.001, -0.003, 0.001, 0.008, 0.002
Code V .INT File 10: -0.006, -0.005, 0.004, -0.006, -0.001, -0.004
```

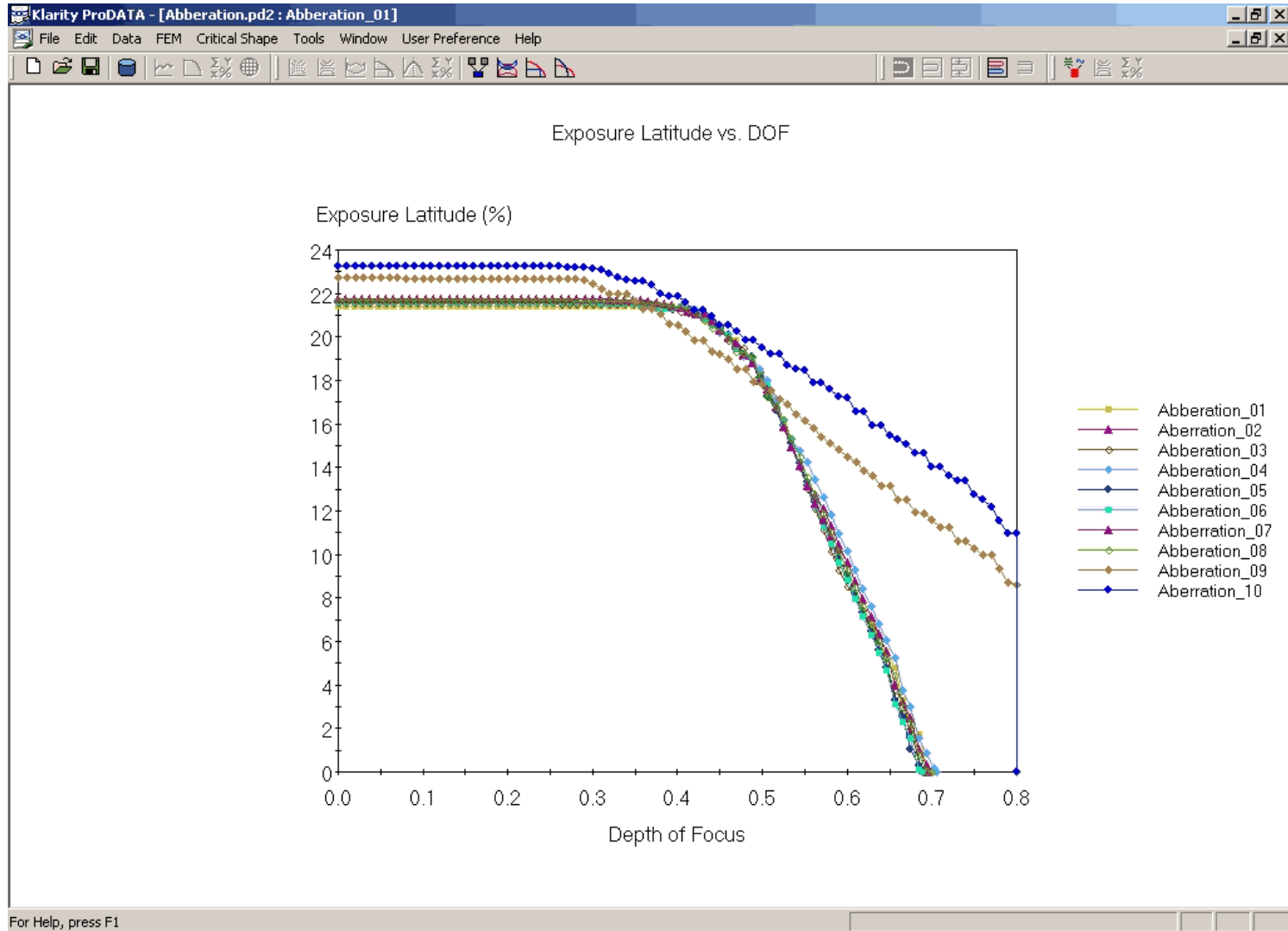
# F/E process window (with ProDATA analysis option)

## F/E, aberration example page 6



# Exposure latitude vs. DoF

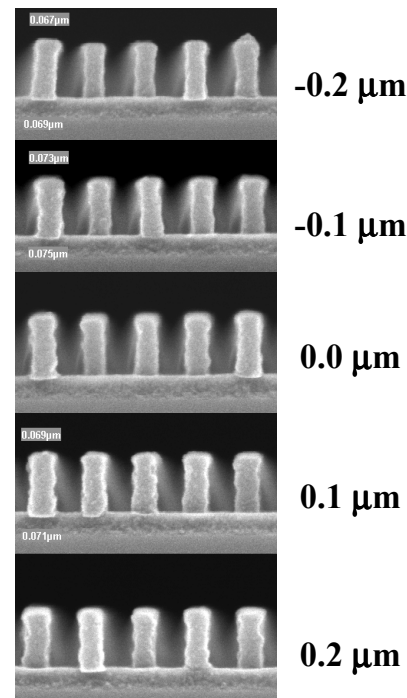
## F/E, aberration example page 7



# Lithography Drives Yield

- ◆ PAL is the lithography expert
- ◆ We embed this experience into our products
- ◆ Contact us to do the same for your products!

J. V. Beach, J. S. Petersen, M. J. Maslow, D. J. Gerold, D. McCafferty, “**Evaluation of SCAA Mask Technology as a Pathway to the 65 nm Node,**” SPIE paper 5040-17, 2003



**75 nm 1:1 dense lines.  
SCAA mask and  
0.75NA, 193nm, 0.15 $\sigma$**