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.

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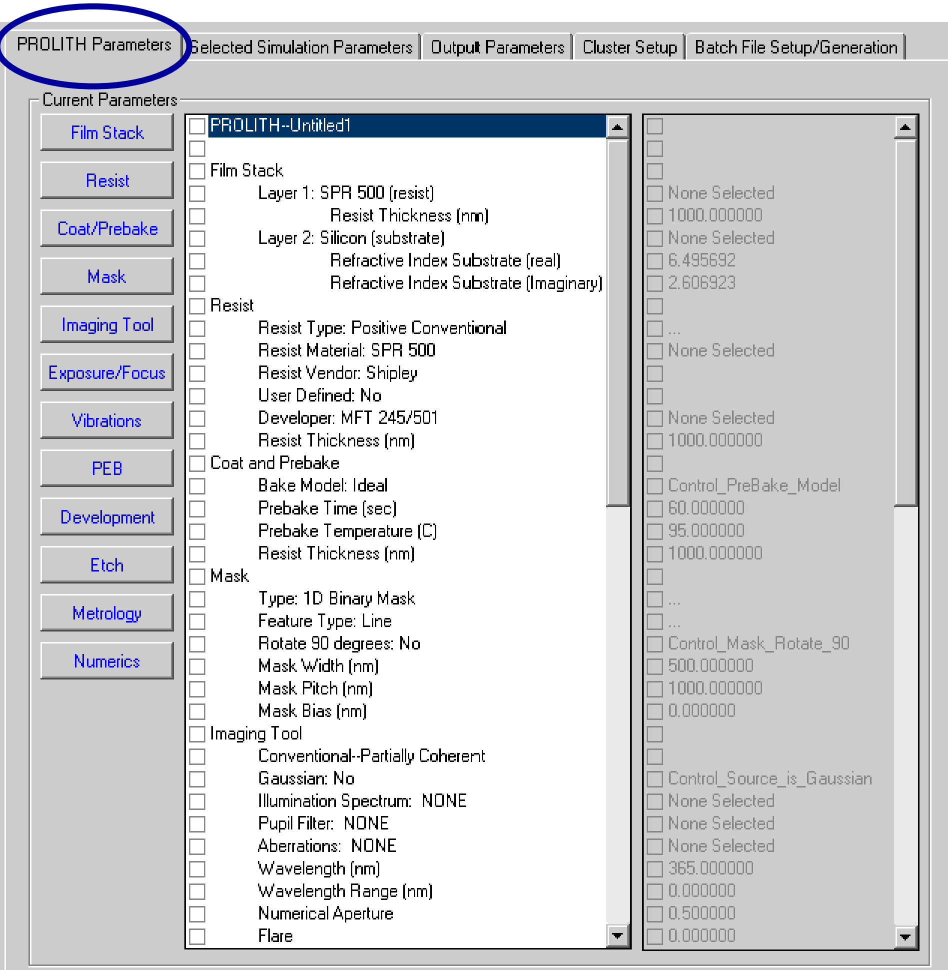
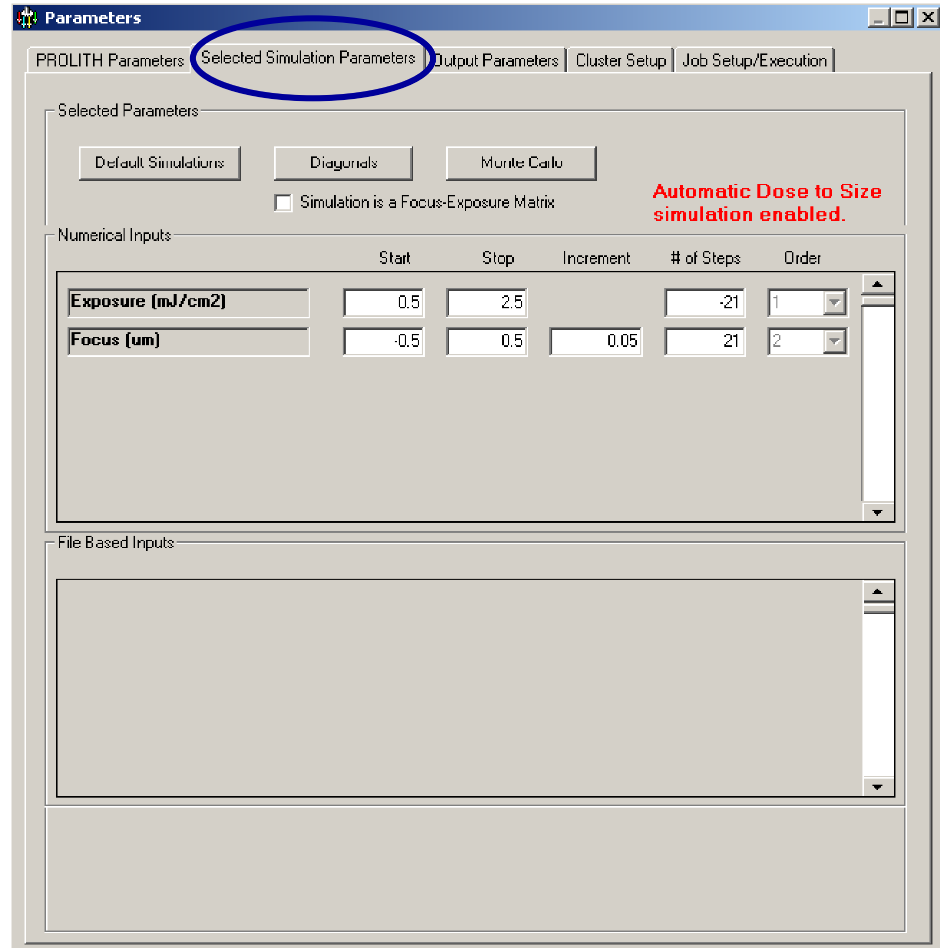
ProLE™ Workbench Menu Bar

- 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





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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

Mask Files - .MSK

1D Grayscale Masks -.GRY

Source Shape Files - .SRC

Spectrum Files - .ILL

Vibration Files - .VIB

Resist Files - .RES

Temp.(Bake)Profiles - .TPR

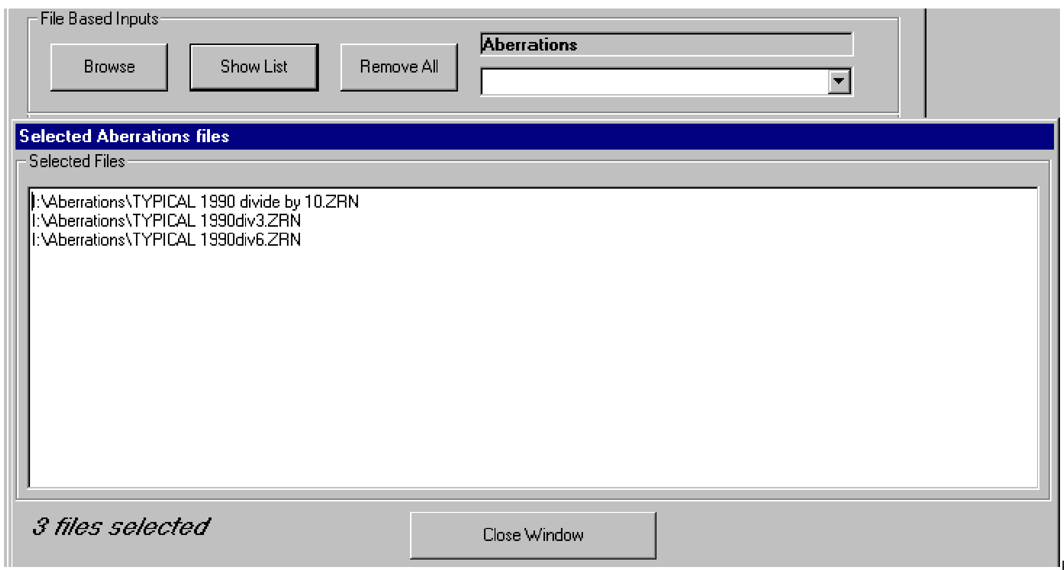
Pupil Filter Files - .FIL

CODE-V Aberrations -.INT

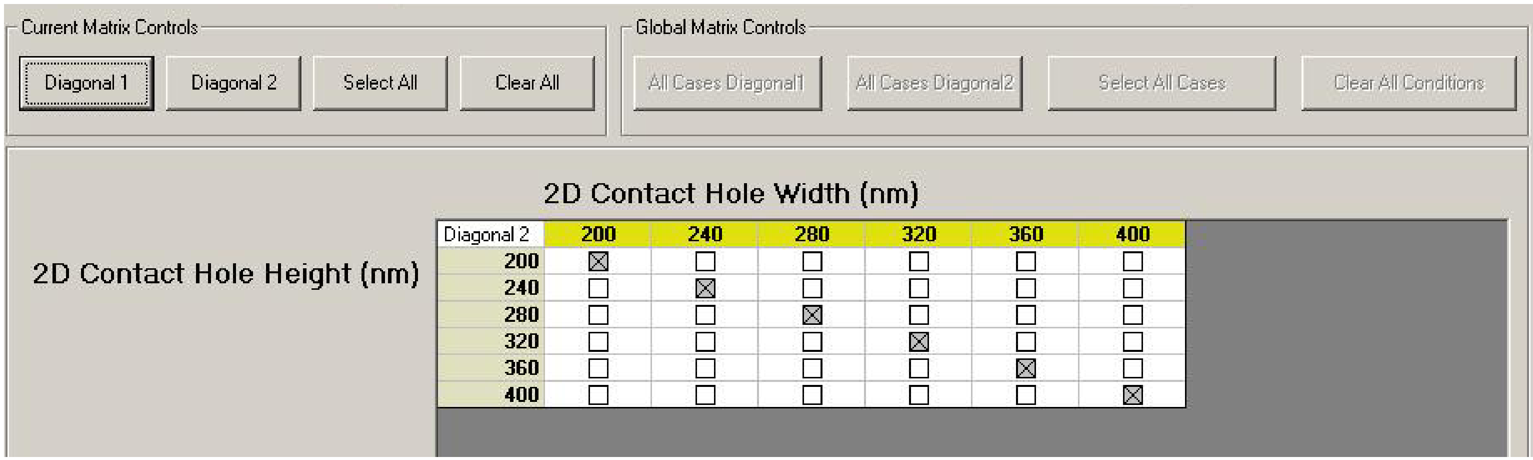
New file type:

High Order Zernikes - .HOZ

User Defined Distribution - .UDD



Simulation Matrix Combination Screen



- 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

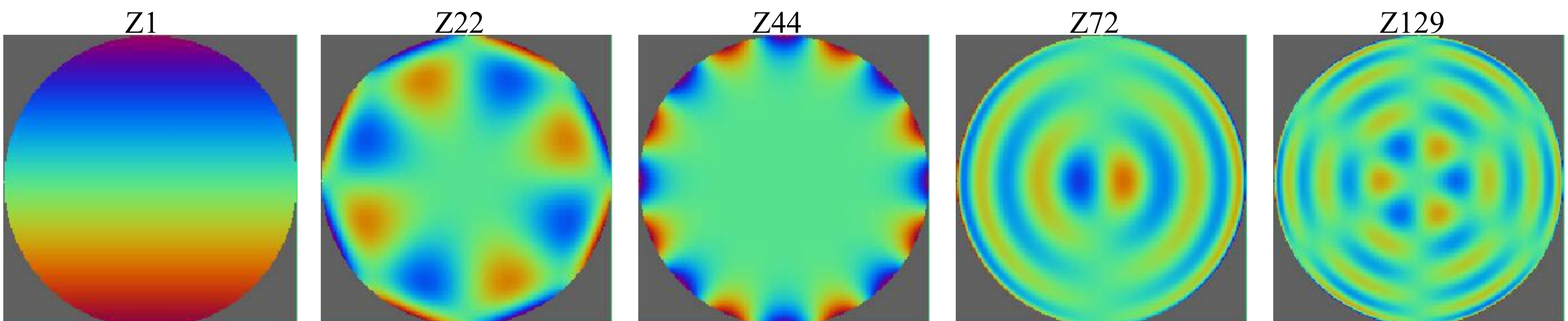
- Investigate Zernike aberrations up to Z136
- Correlate PROLITH aberrations with CODE-V™ Lens information
- Load and combine .ZRN, .INT and the new .HOZ files

Advanced Aberrations

Available Zernike Terms | Selected Zernike Terms

Please select the Zernike Terms to vary

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



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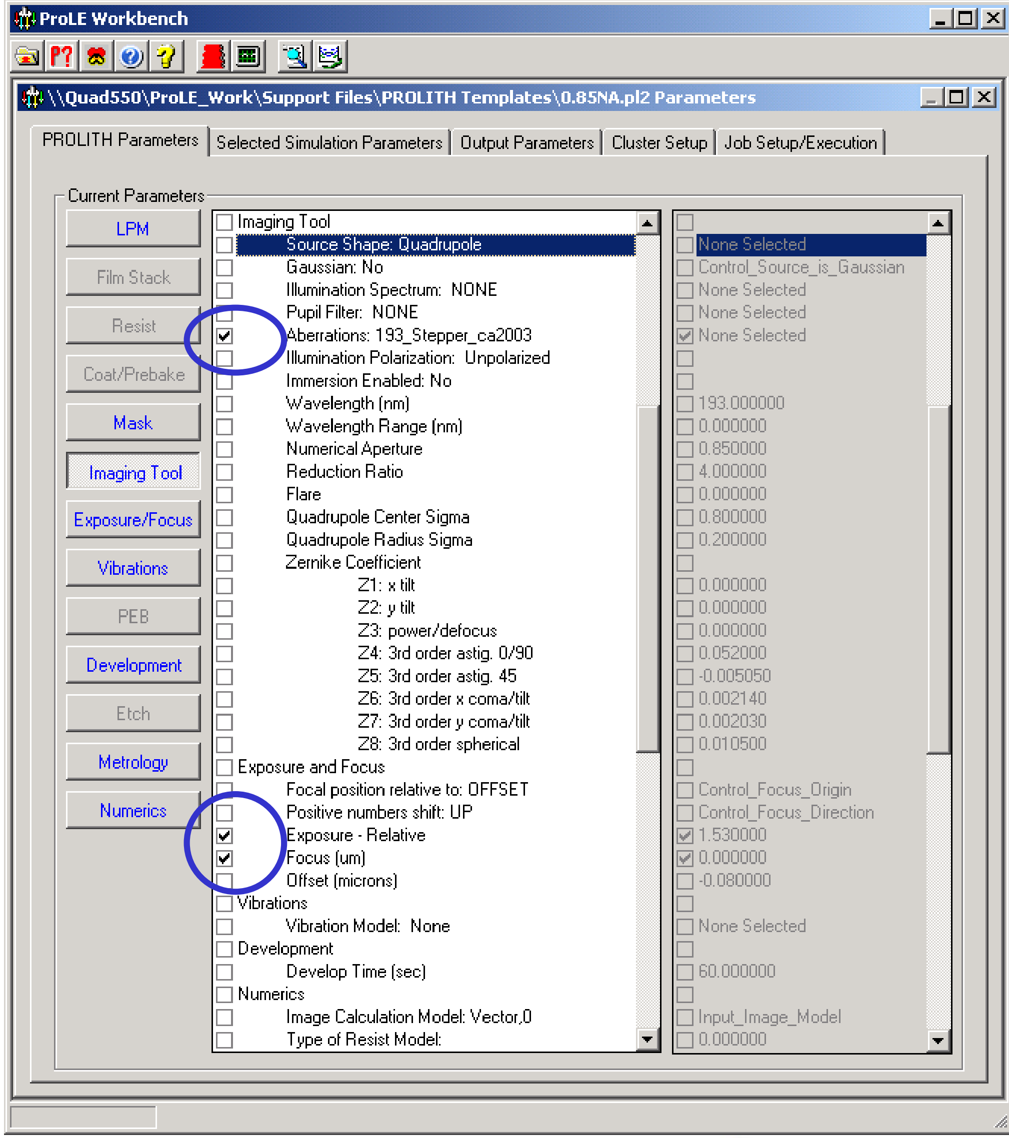
Example:
F/E with auto dose-to-size centering, and Monte Carlo generated aberrations

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)

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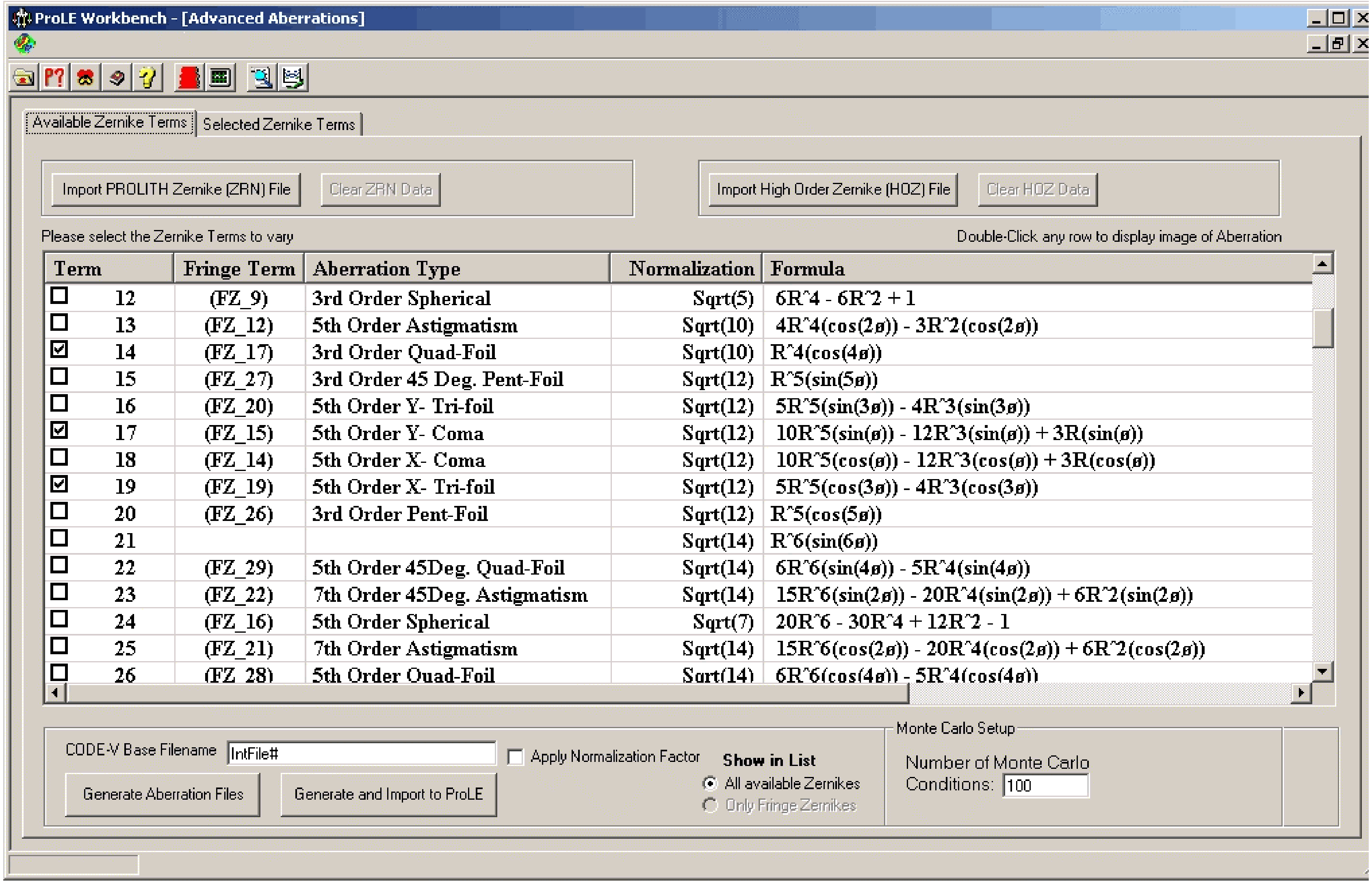
Choose aberrations to be varied



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

F/E, aberration example page 2

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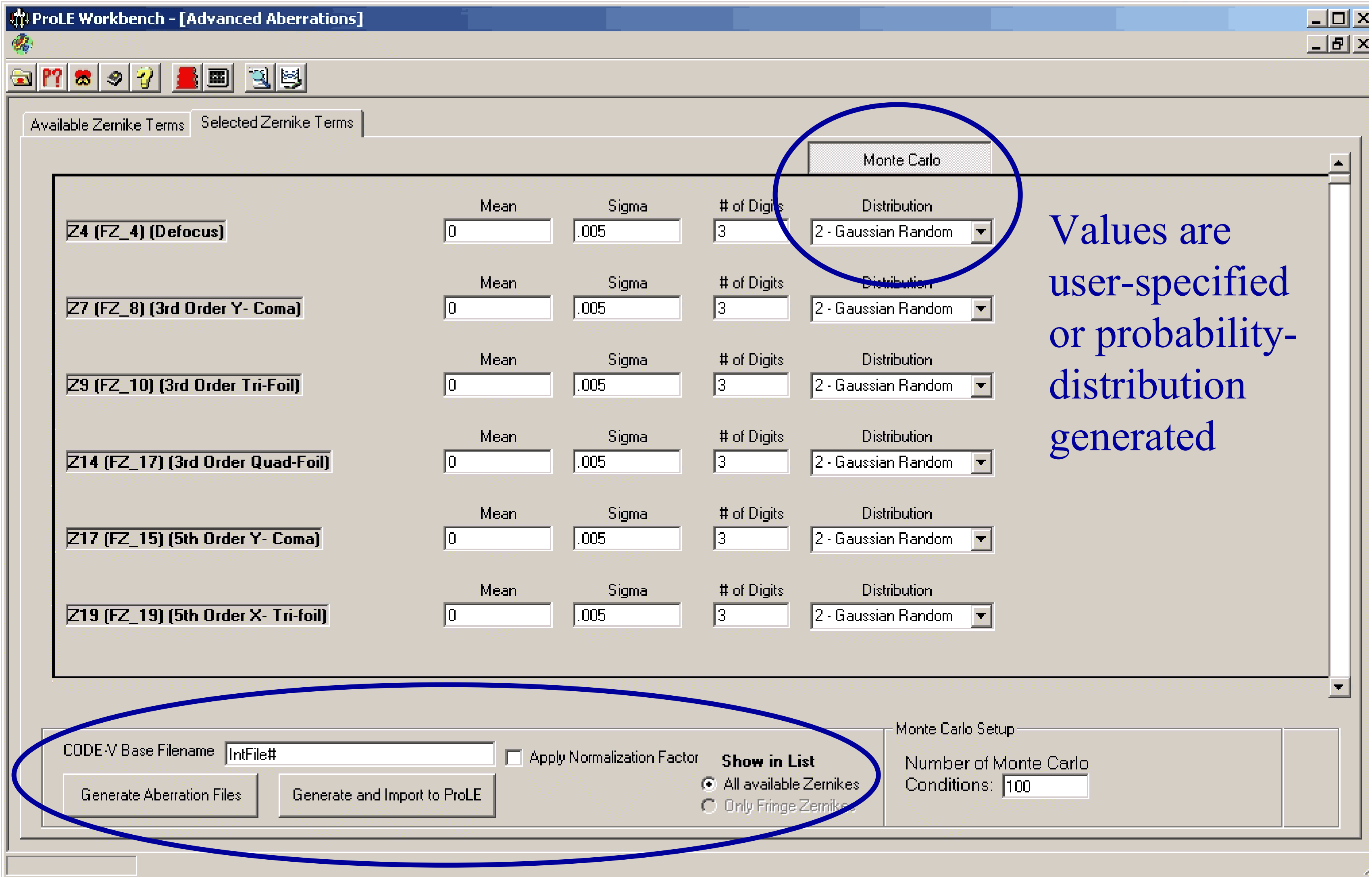
Example: Set aberration file conditions

F/E, aberration example page 3



Values are user-specified or probability-distribution generated

Generate aberration files or run directly

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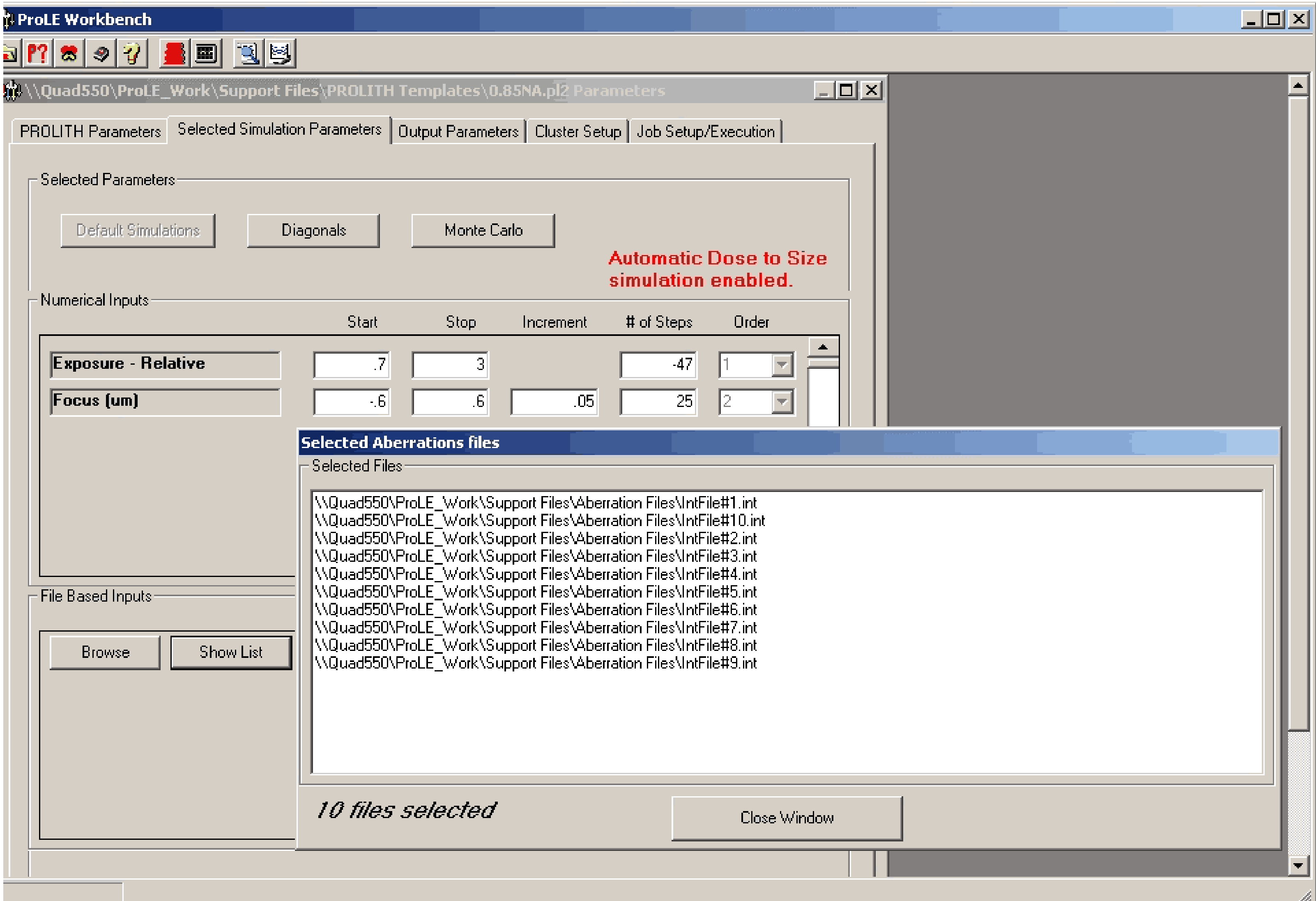
Enter values for selected parameters

F/E, aberration example page 4



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Case table showing abberation combinations

F/E, aberration example page 5

Aberration Casetable.txt - Notepad

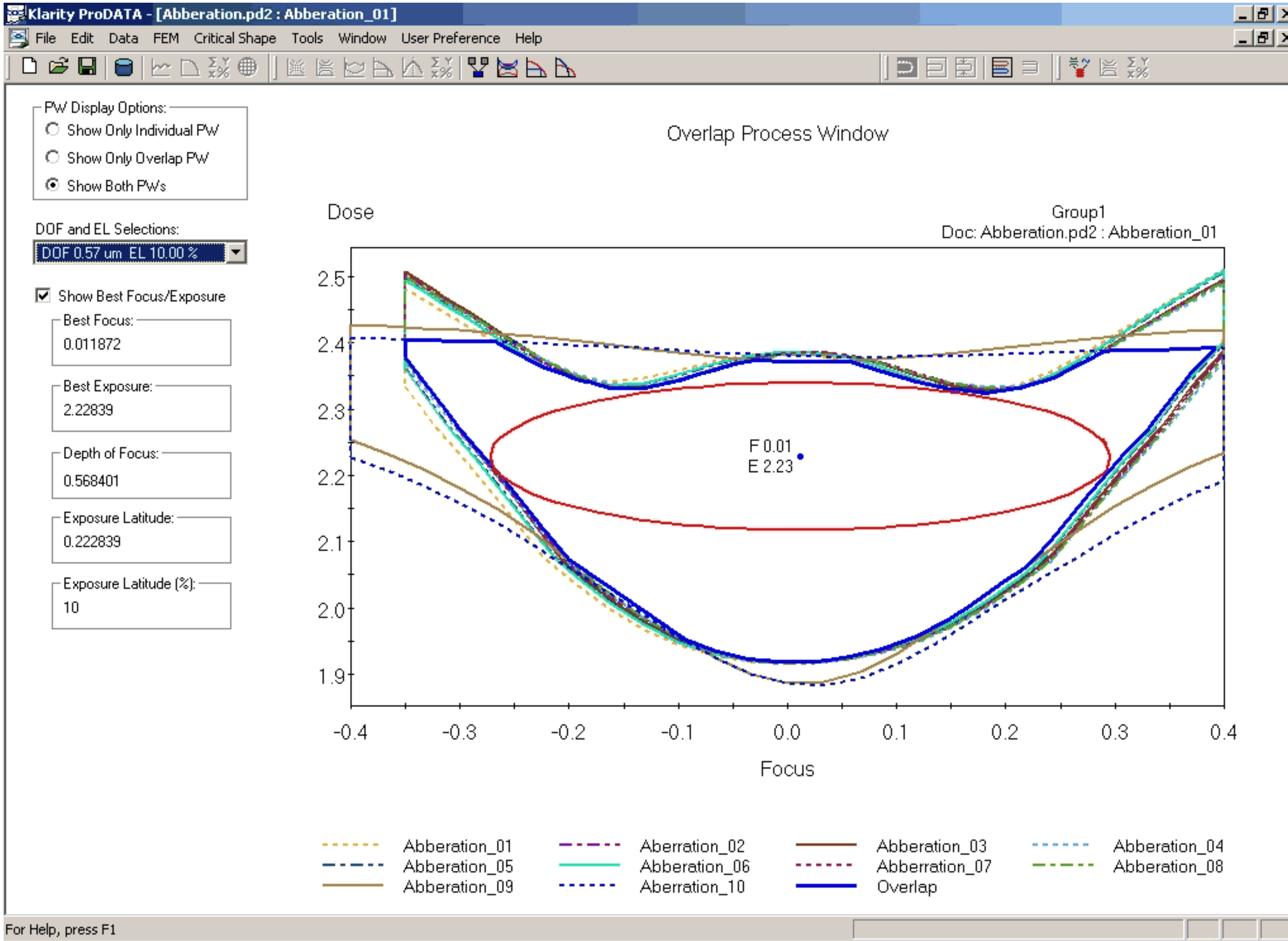
File Edit Format Help

```
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



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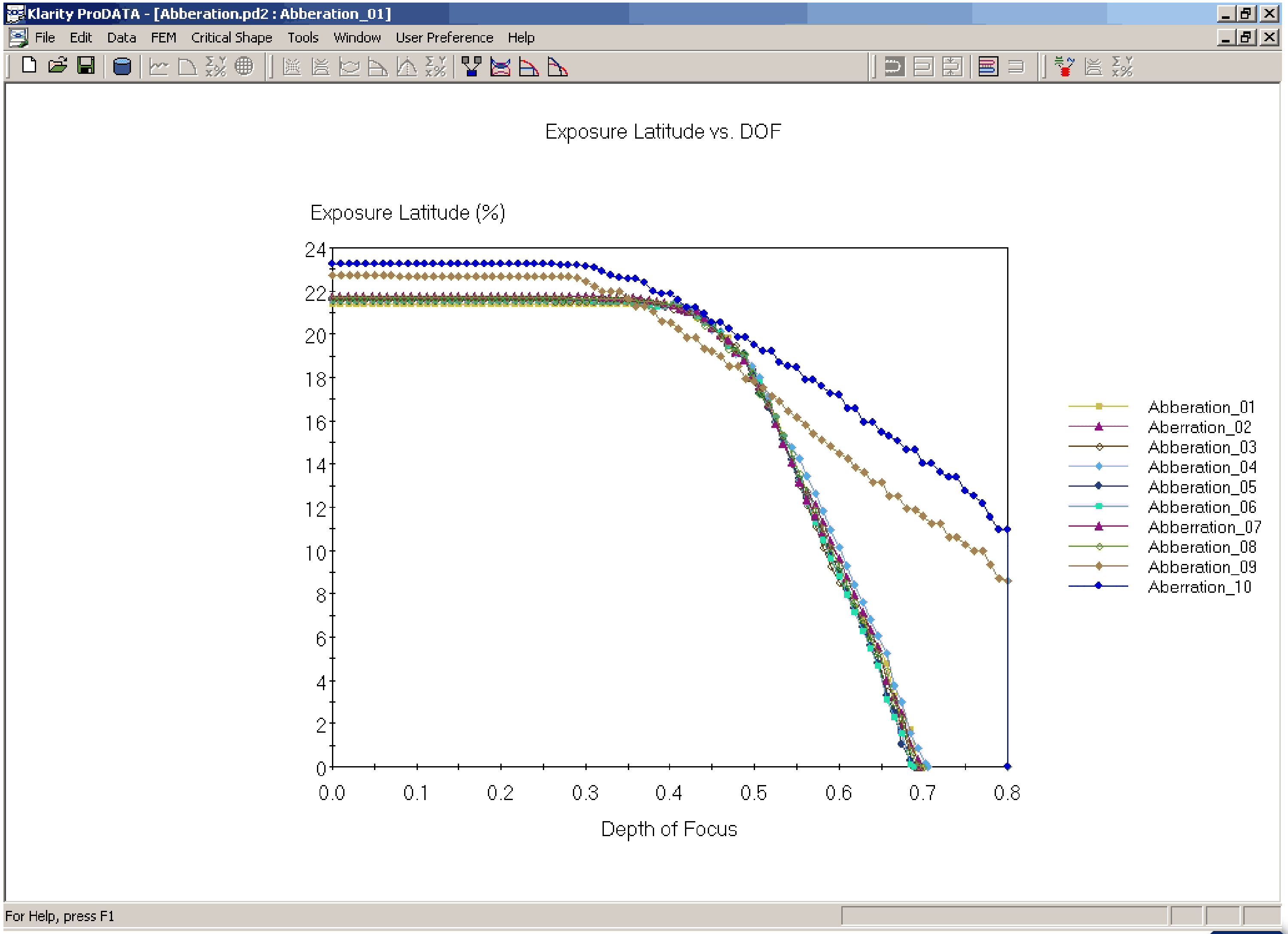
Exposure latitude vs. DoF

F/E, aberration example page 7



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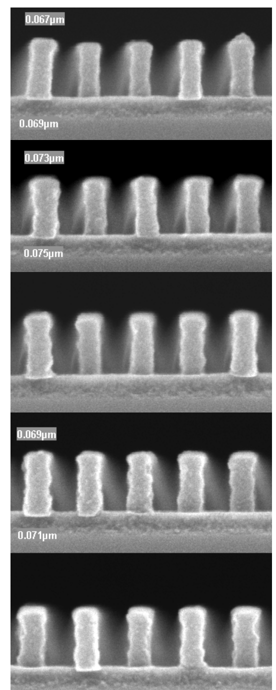
J. V. Beach, J. S. Petersen, M. J. Maslow, D. J. Gerold, D. McCafferty, **“Evaluation of SCAA Mask Technology as a Pathway to the 65 nm Node,”** SPIE paper 5040-17, 2003



-0.2 µm

-0.1 µm

0.0 µm

0.1 µm

0.2 µm

75 nm 1:1 dense lines. SCAA mask and 0.75NA, 193nm, 0.15σ

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