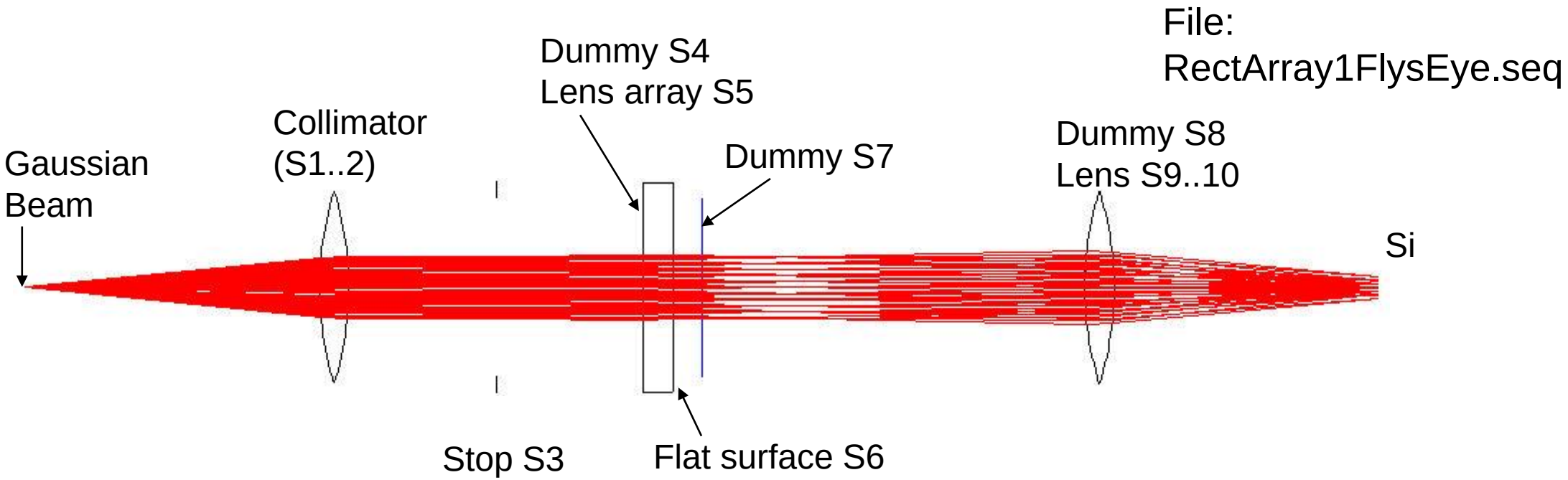
Example: System with Lenslet Array



- This example model has a Gaussian source at 1300 nm = 1.3 μm, a collimating lens, an array lens with a UDS array on the front surface, a focusing lens, and several dummy surfaces
- Due to the array, this lens is NOT well corrected for imaging – it has a geometrical RMS spot size of ~0.5 mm – with sufficient sampling, **BSP** can still be used to analyze this system

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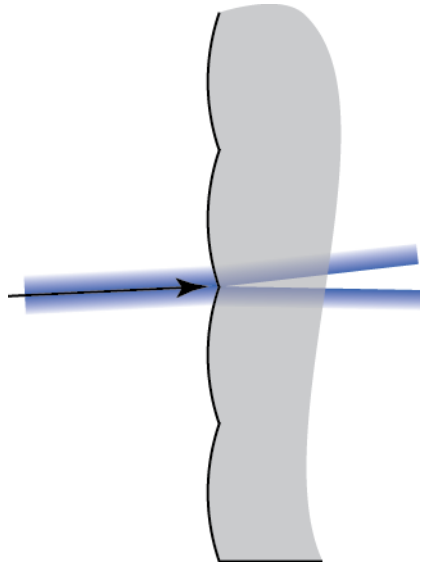
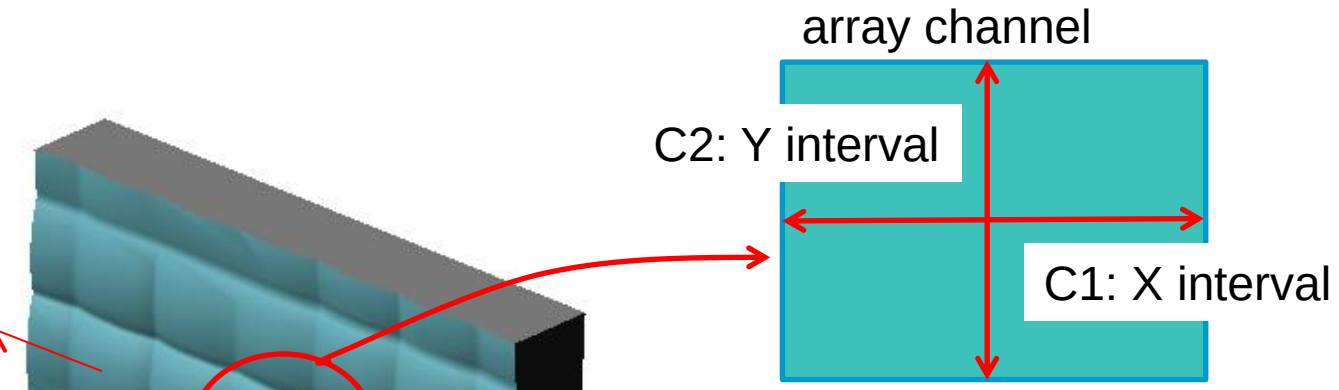
BSP and Arrays – What Is the Main Issue?

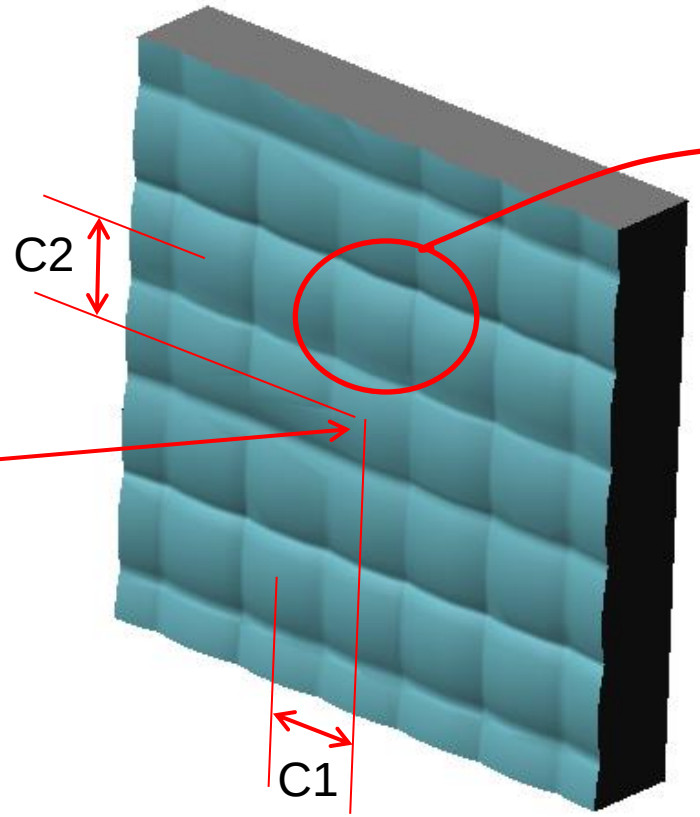
- In **BSP**, all of the energy in a beamlet propagates in the direction of the beamlet's base ray

- A beamlet that spans two or more lenslets has its energy sent in multiple directions
  - The energy following a facet boundary can no longer be represented by a single beamlet
  - Use of smaller beamlets through resampling can mitigate this



CV_UDS_FLYSEYE.dll: Rectangular Array UDS





No offset
Array element is centered on surface vertex

CV_UDS_FLYSEYE.dll

Parameter	Value
Y Radius	2.0000
C1: X interval in array	0.2000
C2: Y interval in array	0.2000
C3: Conic constant	0.0000
C4: A (4th degree coeff)	0.0000
C5: B (6th degree coeff)	0.0000
C6: C (8th degree coeff)	0.0000
C7: D (10th degree coeff)	0.0000
C8: Unused	0.0000

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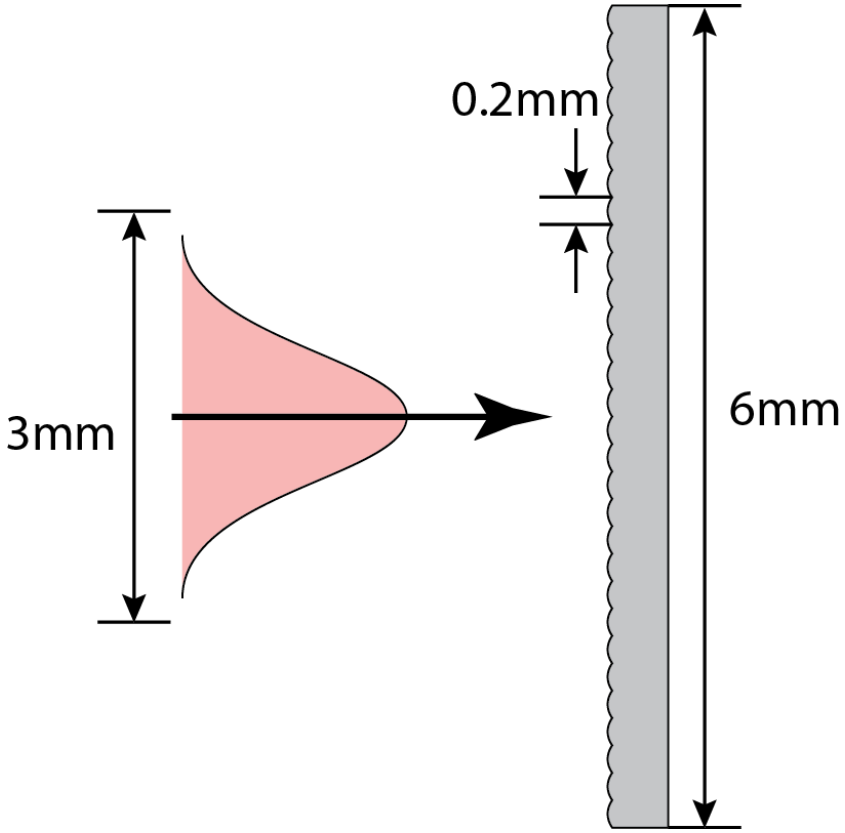
BSP Issues for Array System

- Arrays of microlenses have small features so resampling is typically needed before each array (and maybe elsewhere)
  - Array lens surface (s5) is 6 mm square, the lenslets are 0.2 mm in full width, so there are 30 lenslets across the diameter
  - In this example, Gaussian Beam Trace shows that the Gaussian beam size is much smaller than lenslet element aperture so we can resample over smaller beam "footprint" of 3 mm x 3 mm
  - Beamlets should be small enough to adequately sample features, but for the sake of efficiency, no smaller
  - Resampling with 300 points across 3 mm: starting beamlet size of 0.01 mm (8λ), 20 beamlets across each lenslet
  - Even though we can resample on any surface, slope-discontinuities (at the boundary between lenslets) could cause resampling problems, so we resample on dummy surface (s4) in contact with lens array



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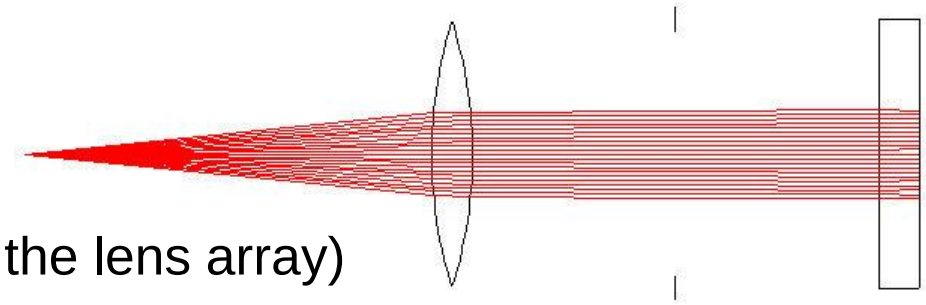
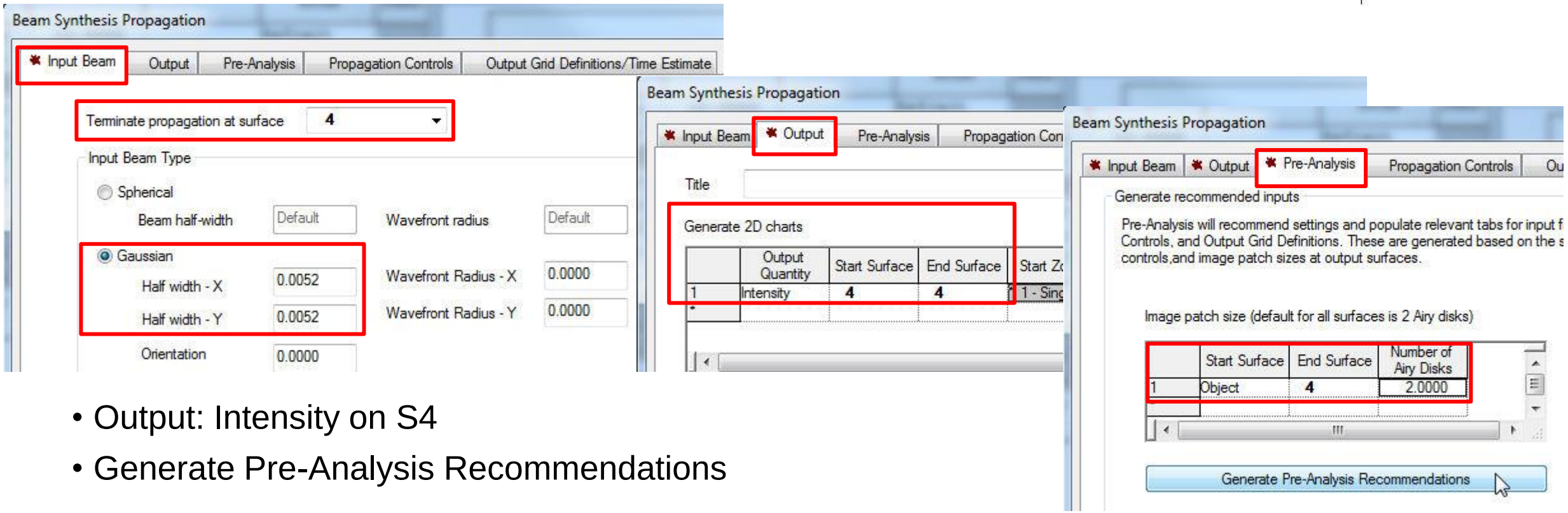
Example: Determining Settings for BSP (1)

- Open supplied lens RectArray1FlysEye.seq
- Input: 0.0052 mm Gaussian beam at object surface
- Pre-analysis can determine **BSP** controls to S4 (prior to the lens array)





- Output: Intensity on S4
- Generate Pre-Analysis Recommendations

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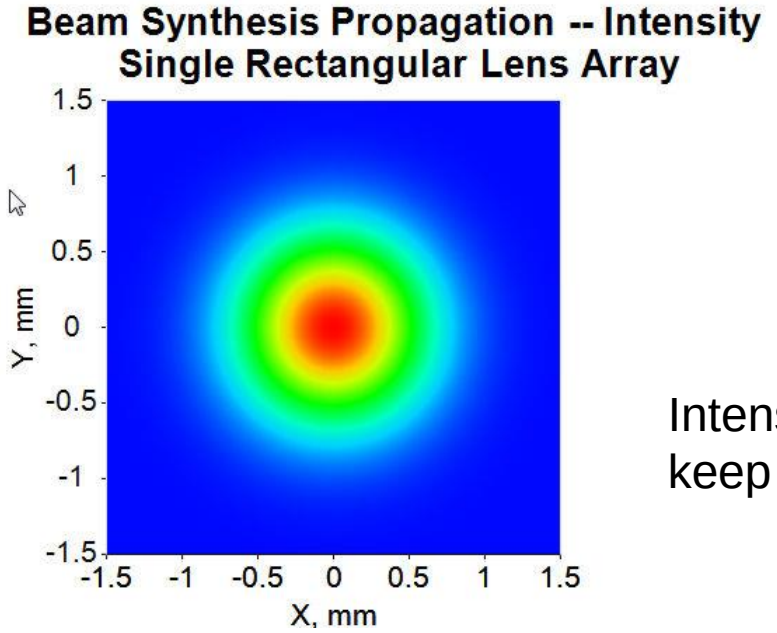
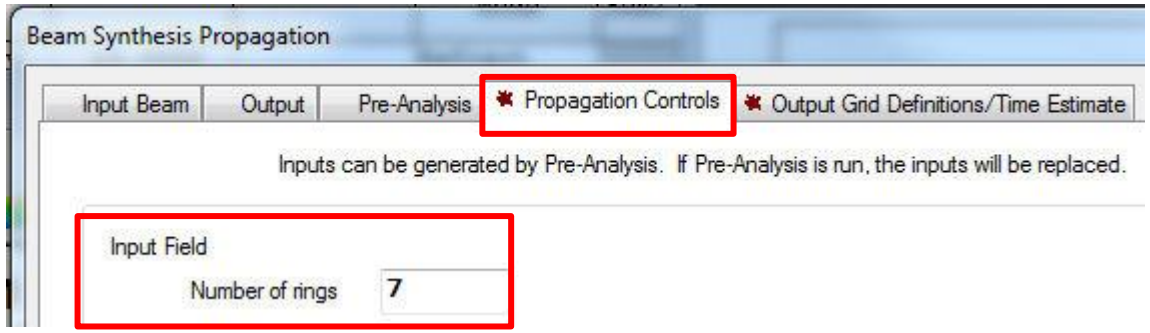
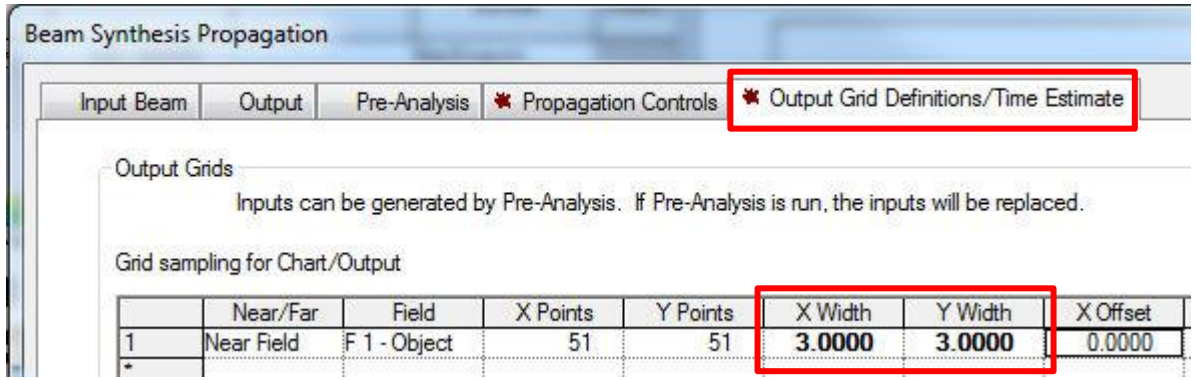
Example: Determining Settings for BSP (2)

- Review Pre-analysis recommendations:
  - Input Field: NRI 7
  - Output Grid, S4: GWX 5
    Larger than expected; reduce to GWX/GWY 3, assess output
  - Press OK to run **BSP**







Intensity at chart extents is sufficiently small; keep area of interest to 3 mm x 3 mm

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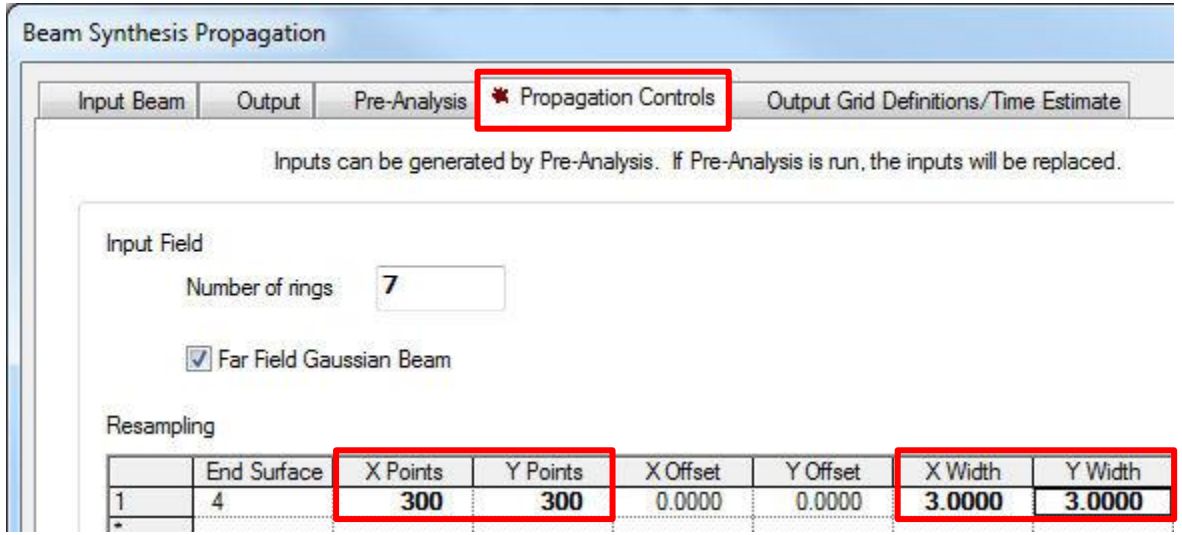
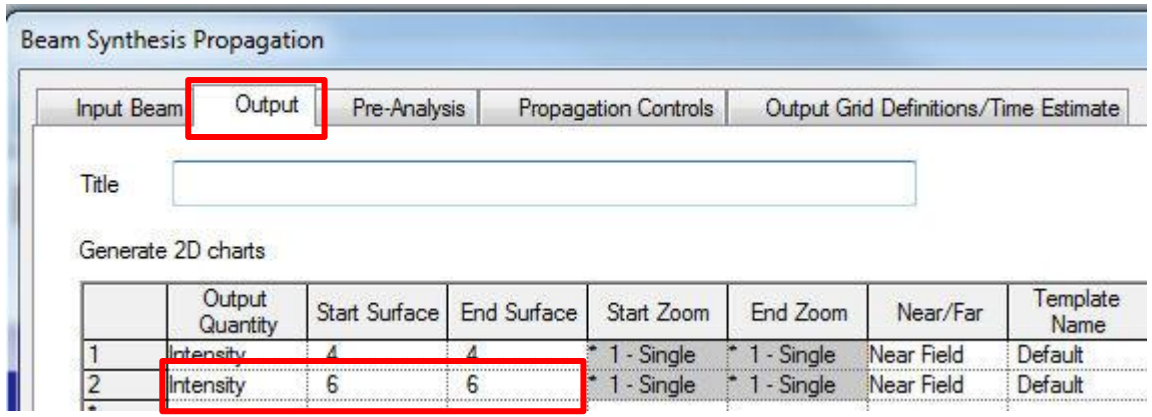
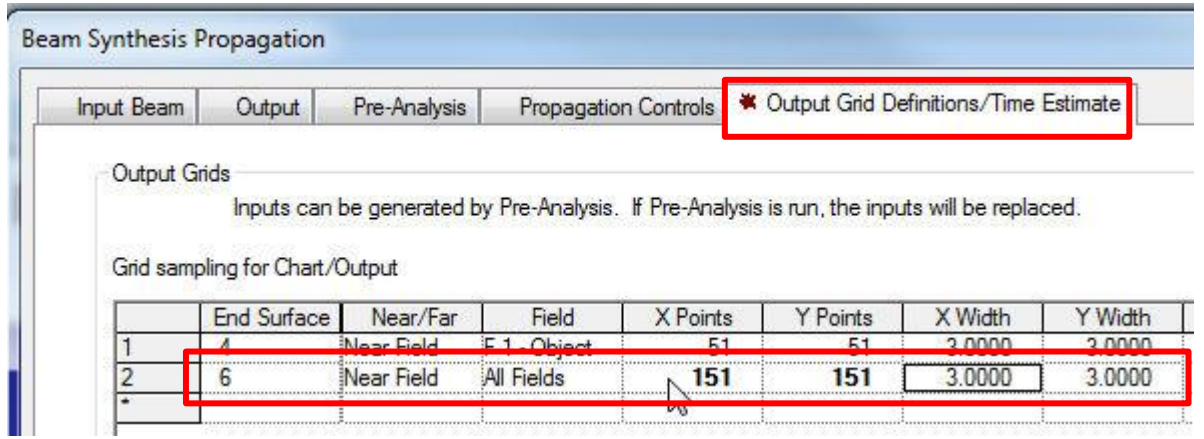
Example: Determining Settings for BSP (3)

- On Propagation Controls tab, resample at S4 to propagate small beamlets through array
  - Want ~300 beamlets over 3 mm; how does the output vary when 299 or 301 beamlets are used?
- On Output tab, request intensity at S6 (flat back surface of array element)
  - Adjust sampling on Output Grid… tab







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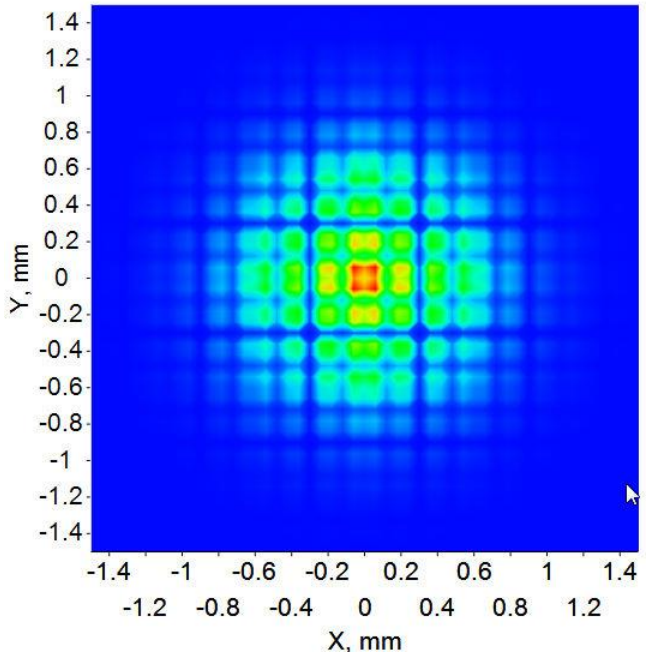
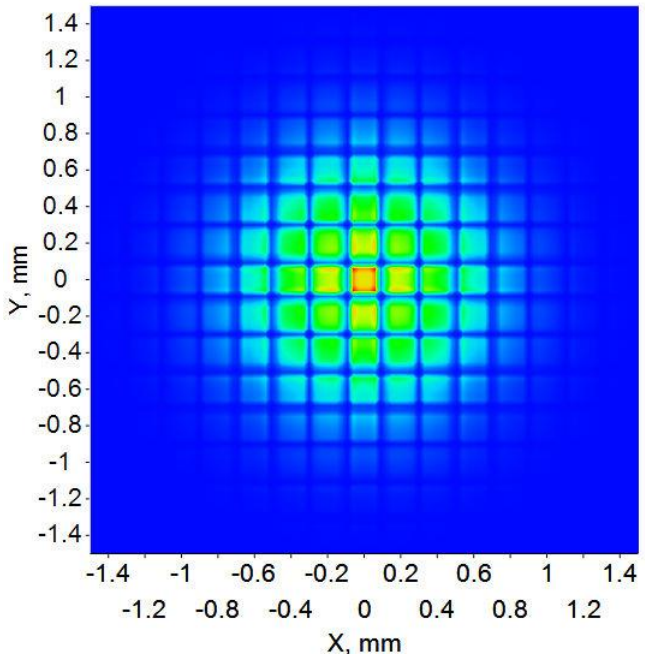
Example: Determining Settings for BSP (4)

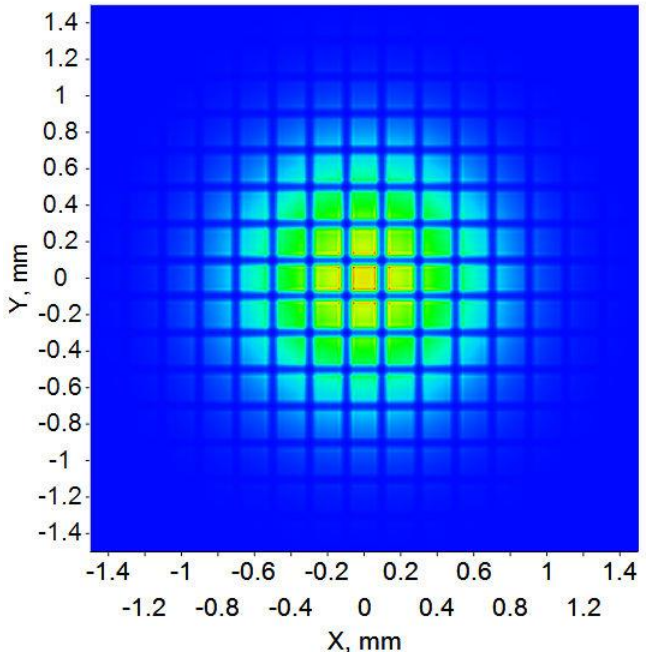
- Output grids (sampling) for charts do not alter the propagated field, but can be very important when assessing if resampling parameters are accurate.
- Reconstructing the field for display can be time-consuming; use slice plots if feasible



GPX S6 51



GPX S6 101



GPX S6 201

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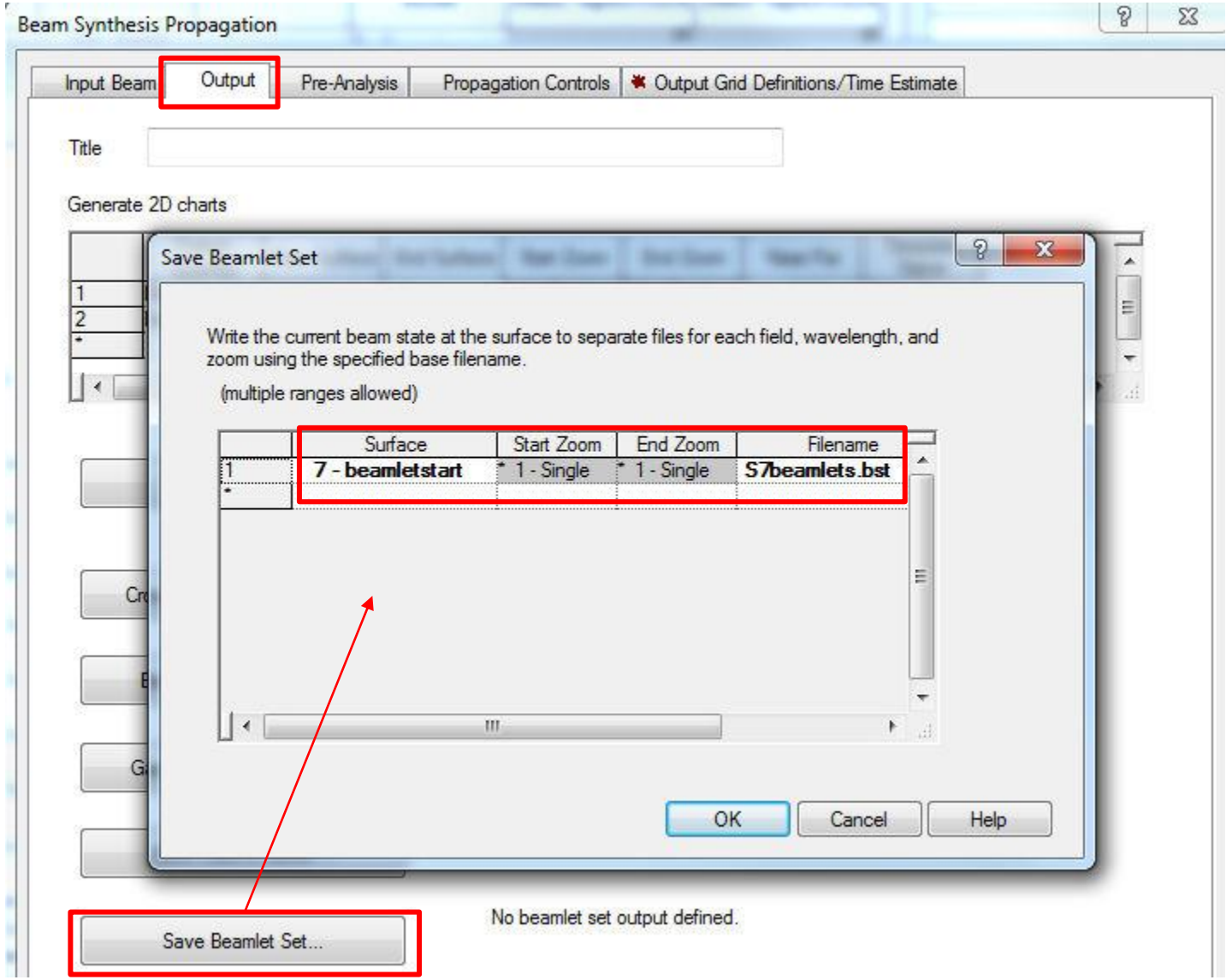
Example: Determining Settings for BSP (5)

- After you're satisfied with the resampling parameters, save the beamlet set at S7
  - Output tab, click on "Save Beamlet Set", enter surface 7 and filename S7beamlets.bst



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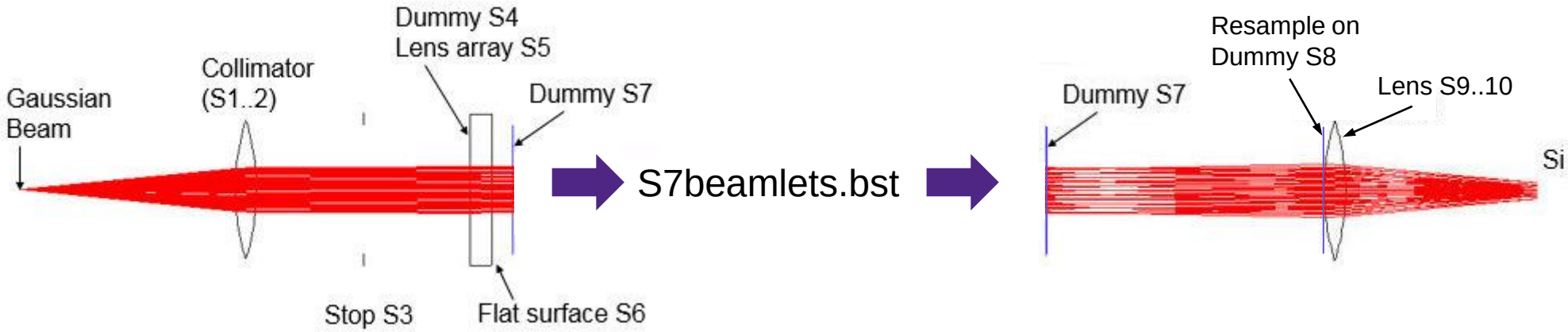
Example: Determining Settings for BSP (6)

- By the time they reach the lens, beamlets from the array will have spread to the point where the “aberrations” seen by individual beamlets are too large, so we also resample on a dummy surface (s8) in contact with the focusing lens (s9..10), and compare field at s8 and s9
- Determining resampling parameters may require several attempts; use beamlet sets to work efficiently. (Even with the input beamlet sets, calculations take ~ 10 minutes.)
  - Write out the beamlet set at dummy surface (S7) after the array element
  - Use the beamlet set as input field while determining resampling parameters for S8



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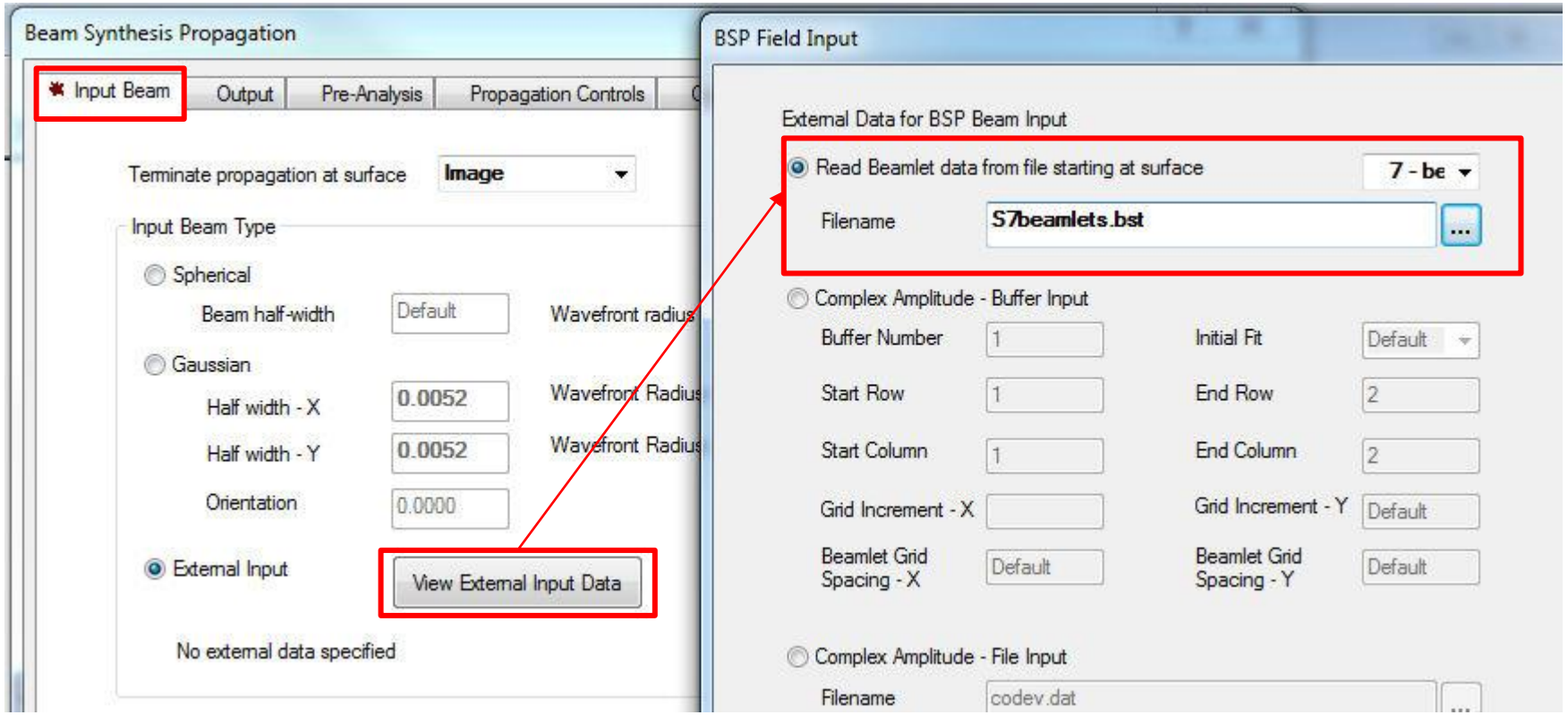
Example: Determining Settings for BSP (7)

- For the next stage of propagation, change Input Beam to External Input and enter the saved beamlet set starting at S7



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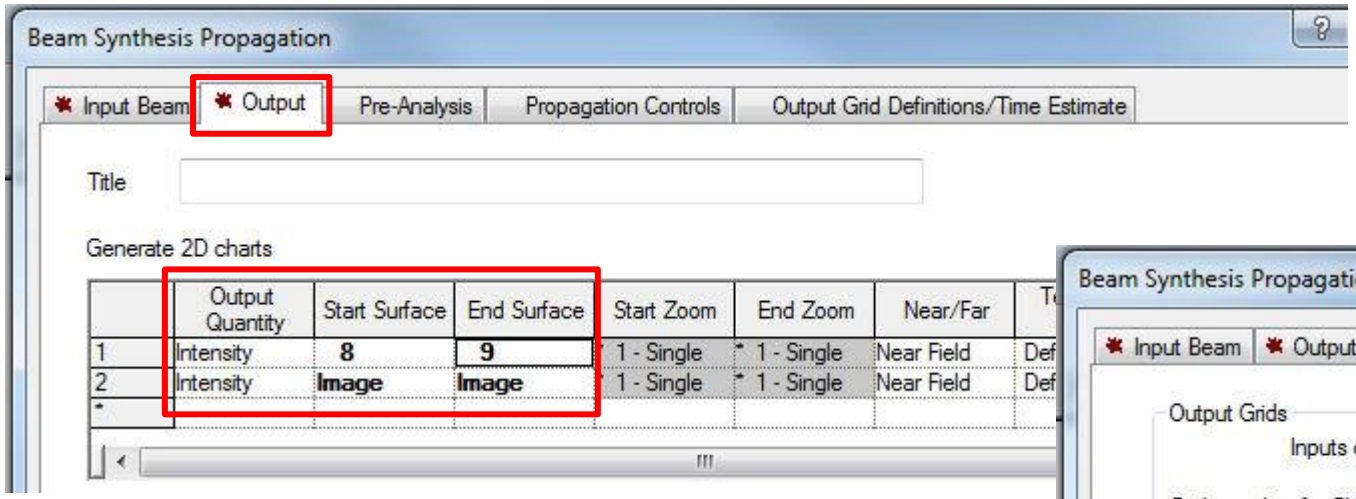
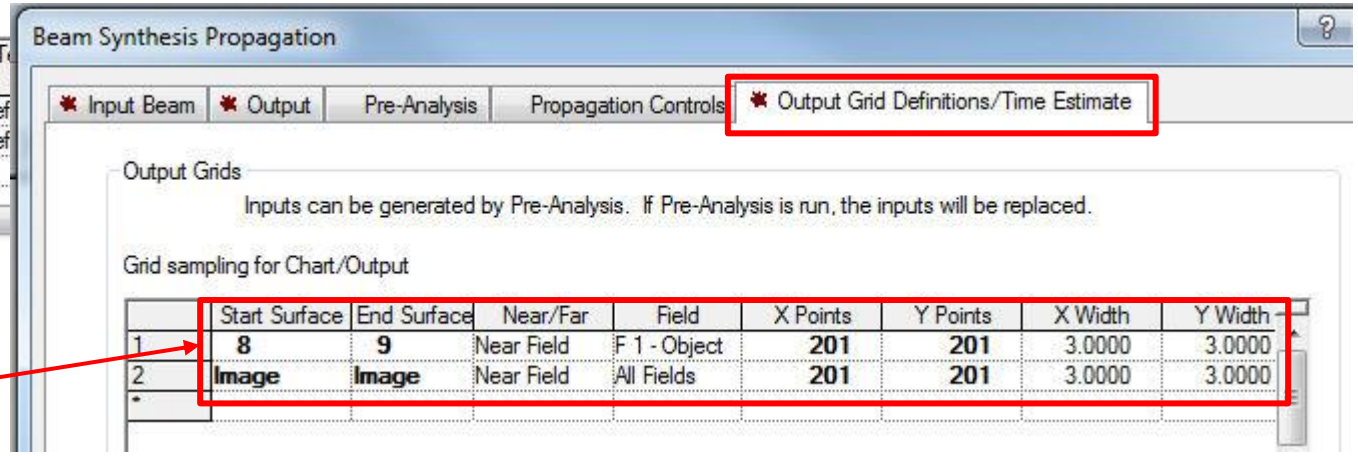
Example: Determining Settings for BSP (8)

- Output: Intensity at S8, S9, and Image
- Output Grids: Try 201 points in X and Y; X, Y Width = 3





Start with values used for "good" intensity chart on S6

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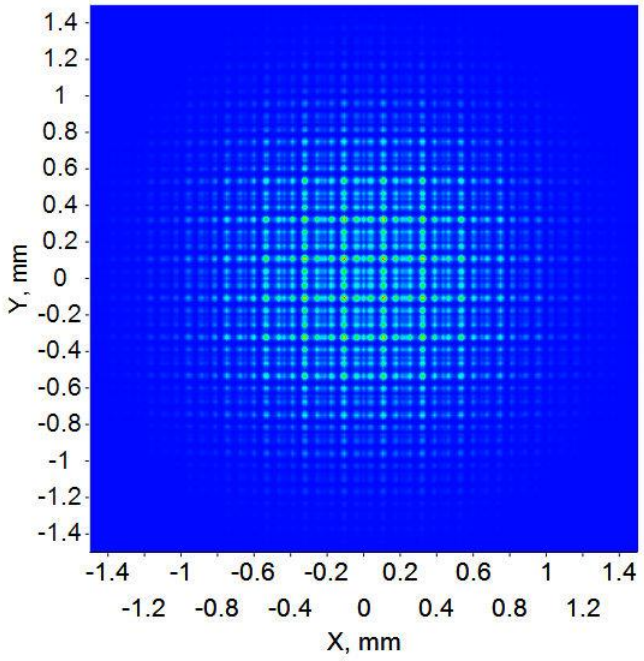
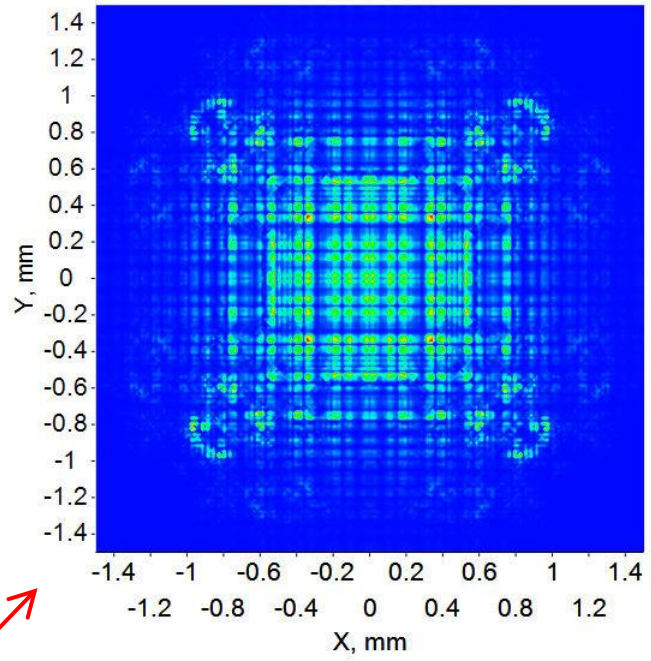
Example: Determining Settings for BSP (9)

- Intensity charts after resample on S8 with 101 points in X and Y

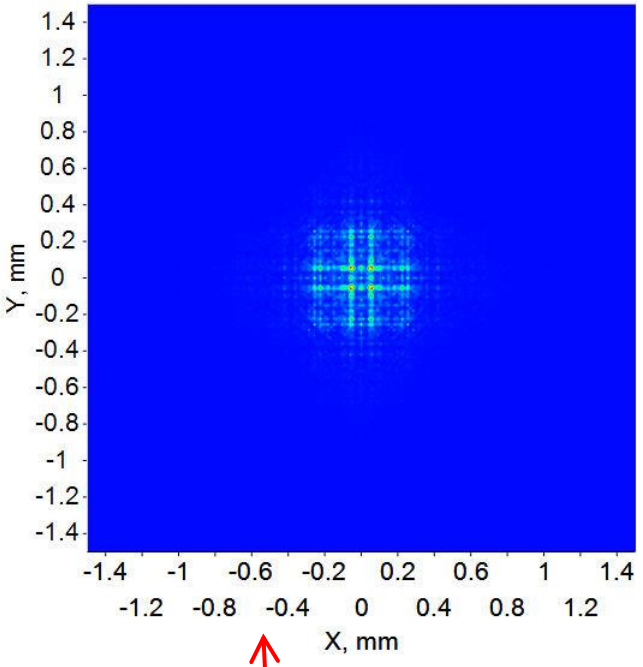
S8



S9



Image



Should match;
Increase sampling on S8

Reduce area used for chart of Image intensity

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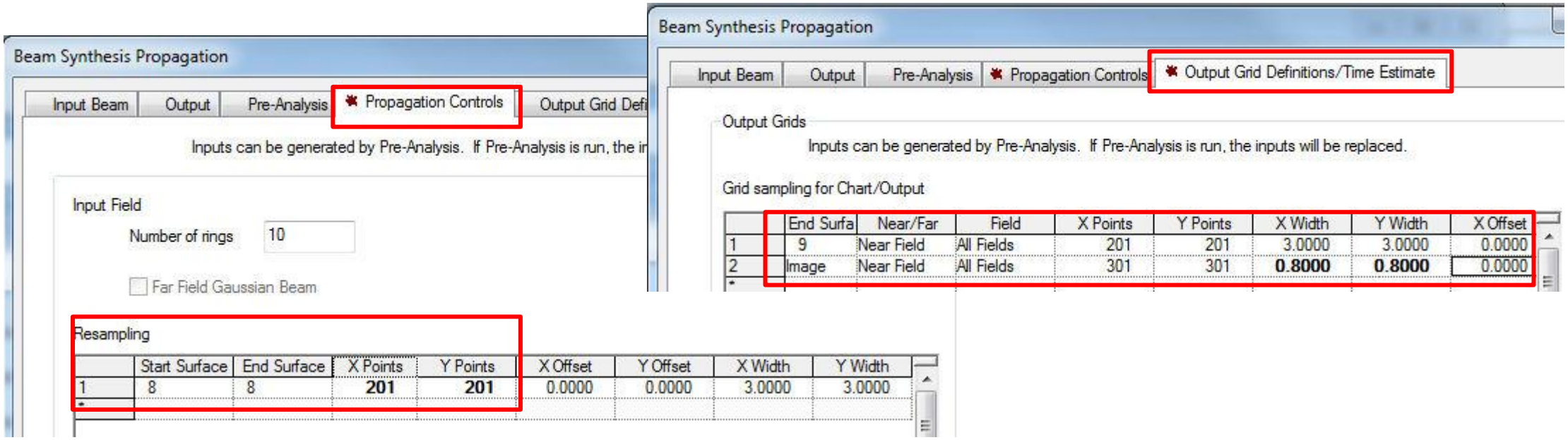
Example: Determining Settings for BSP (10)

- Resampling on S8: 201 points in X and Y; X, Y Width = 3
- Output Grid on Image: 301 points in X and Y; Width = 0.8



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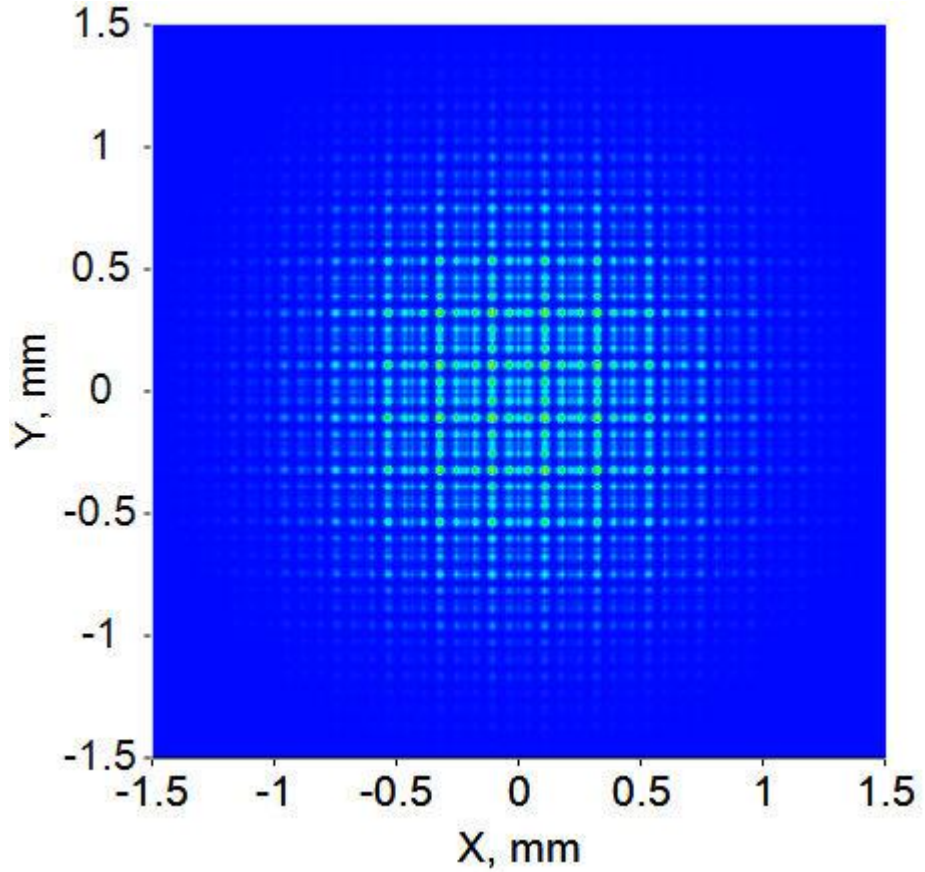
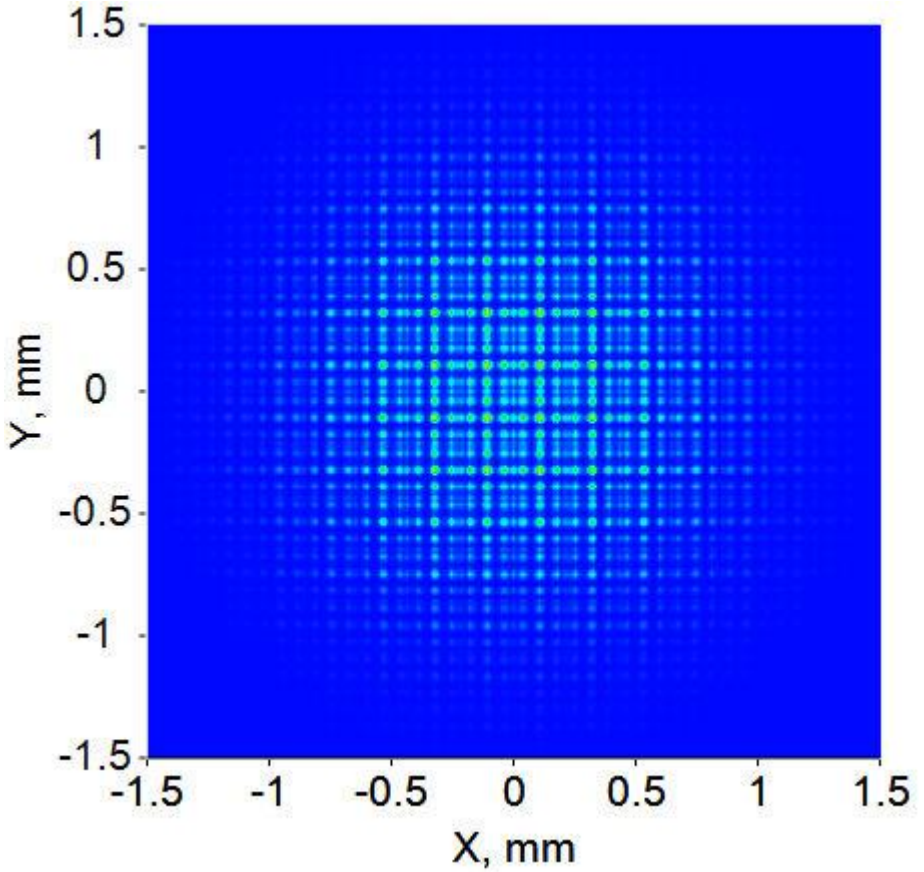
Example: Determining Settings for BSP (11)

- Increased resampling on S8 produces matching intensity charts at S8 and S9

S8



S9



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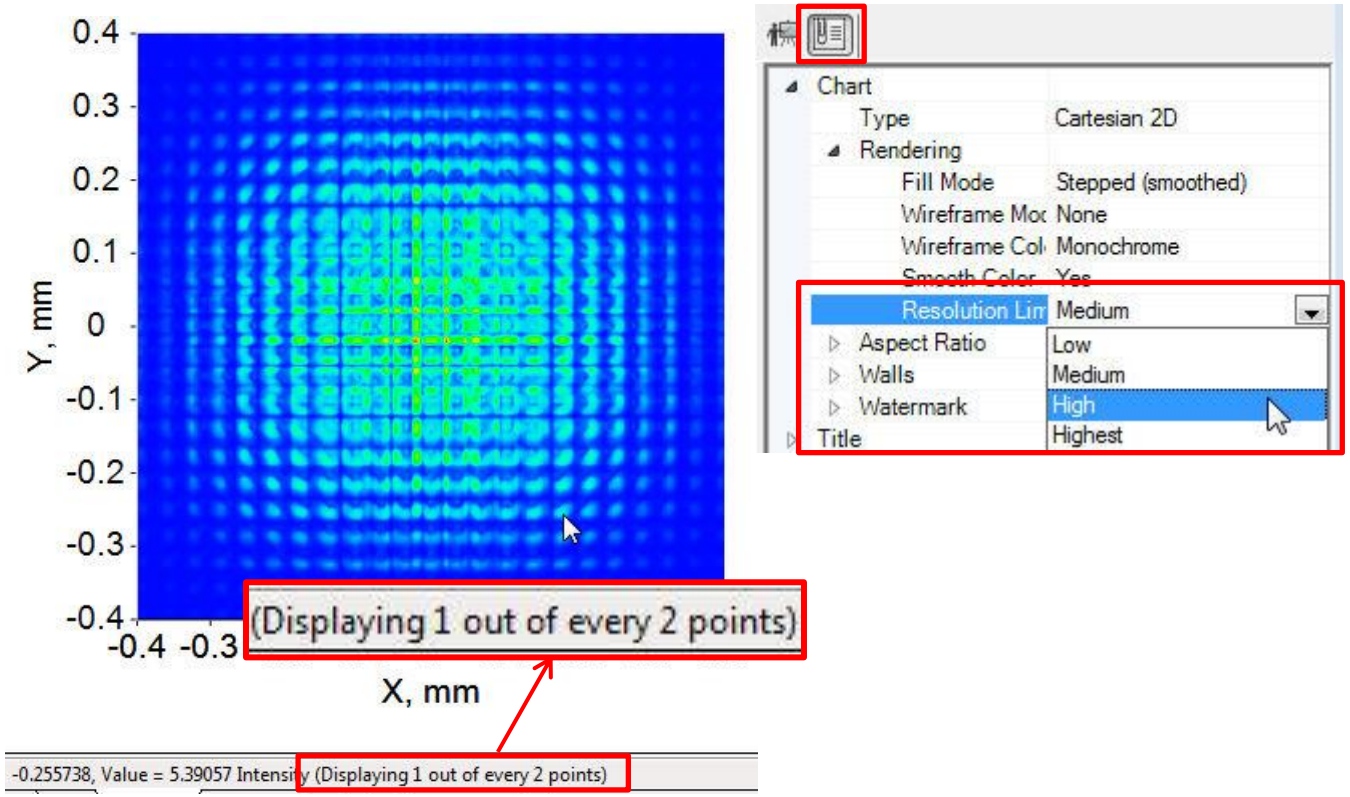
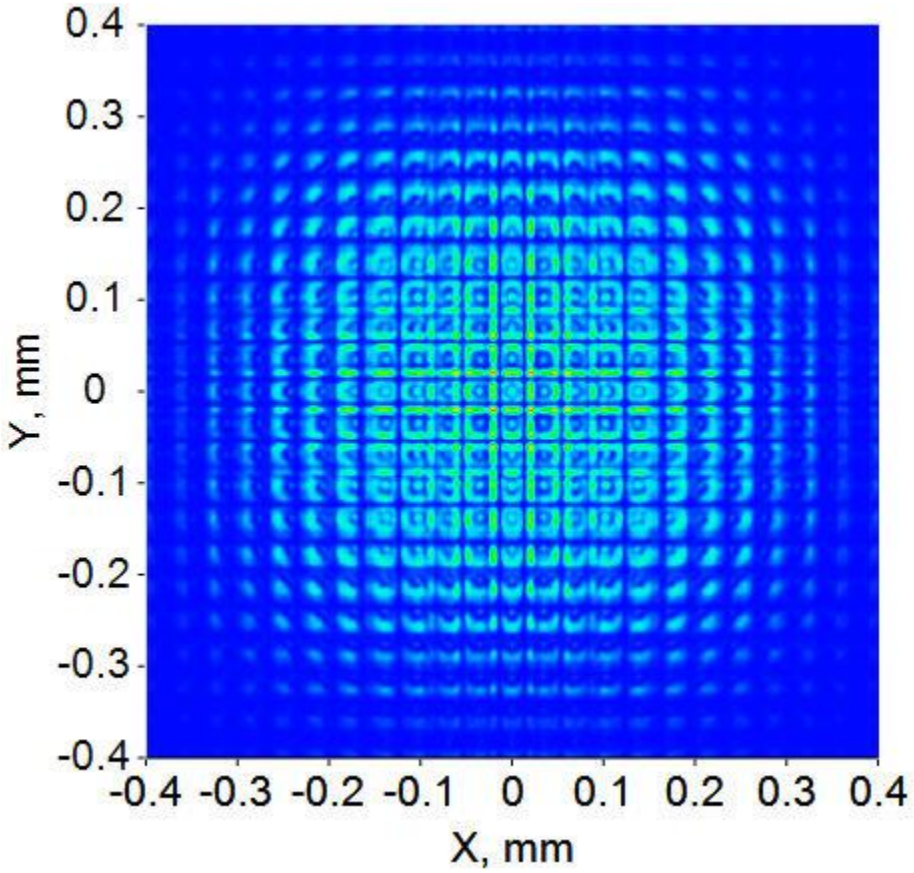
Example: Determining Settings for BSP (12)

- Aliasing in output at image is a charting artifact; use chart properties to adjust Resolution Limit





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Example: Determining Settings for BSP (13)

!Stage 1

```
BSP
  esn s7
  nri 7
  wrx  0.0052  ;  wry  0.0052
  cht int s4
  gwx s4 3.0   ! display width 3.0 mm
  rsf s4 ! Resample field
  rwx s4 3.0; rwy s4 3.0  ! Full width in mm
  rpx s4 299; rpy s4 299 ! Number of points
  cht int s6  ! chart intensity after array
    gwx s6 3.0; gpx s6 201 ! width, # of points
 wbs s7 S7beamlets  ! Save beamlets at S7
go
```

!Stage 2

```
BSP
 rbs s7 S7incoming
 rsf s8  ! Resample field
    rwx s8 3.0; rwy s8 3.0  ! width
    rpx s8 199 ; rpy s8 199 ! points
  cht int s8..9  ! chart intensity on s8 and s9
    gwx s8..9 3.0  ! width
    gpx s8..9 201  ! points
  cht int si  ! Chart intensity at image
    gwx si 0.8  ! display width 0.8 mm
    gpx si 301  ! dense grid to avoid aliasing
go
```


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