biobeam Documentation

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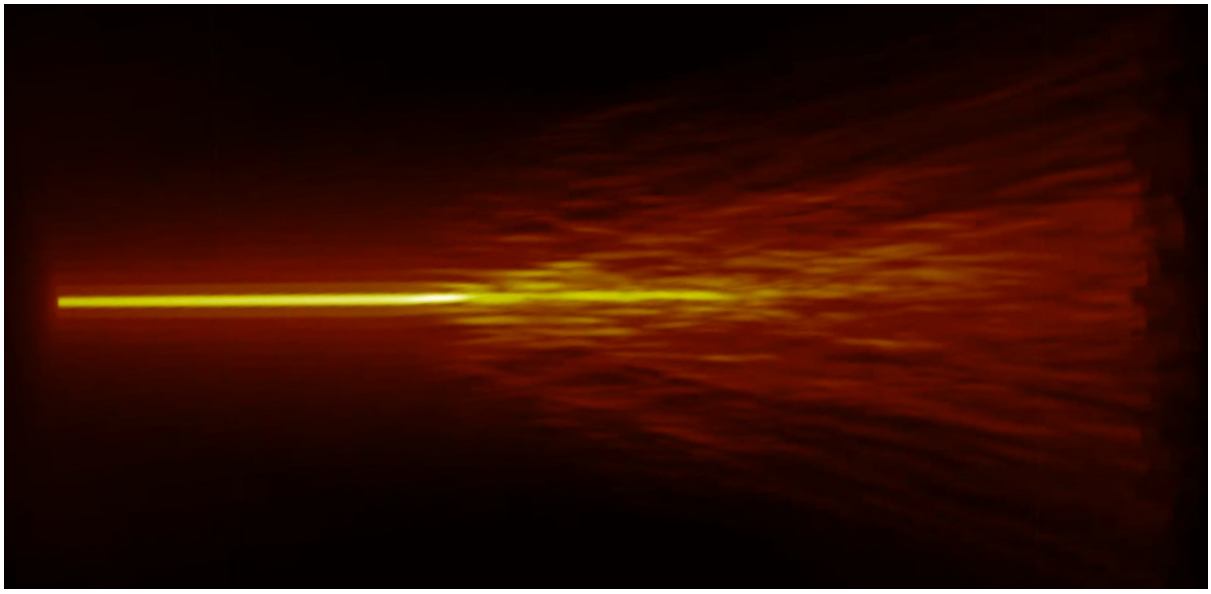
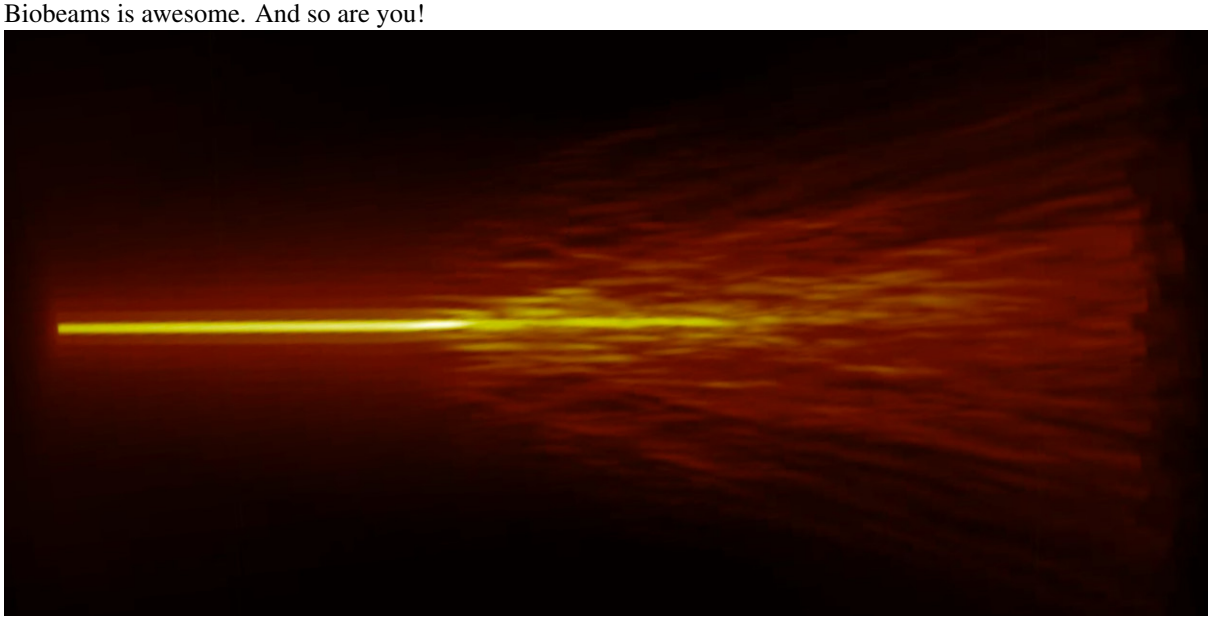


1 Introduction

Biobeams is awesome. And so are you!



This is something I want to say that is not in the docstring.

2 Installation

To nicely render the 3d output it is advisible to install *Spimagine*, an OpenCL accelerated renderer Spimagine

```
pip install spimagine
```

After that you should be able to simple do

```
pip install biobeams
```

3 Basic Usage

3.1 Beam propagation

class biobeam.**Bpm3d**(*size=None*, *shape=None*, *units=None*, *dn=None*, *lam=0.5*, *n0=1.0*, *simul_xy=None*, *simul_z=1*, *n_volumes=1*, *enforce_subsampled=False*, *fftplan_kwargs={}*)

the main class for gpu accelerated bpm propagation

__init__(*size=None*, *shape=None*, *units=None*, *dn=None*, *lam=0.5*, *n0=1.0*, *simul_xy=None*, *simul_z=1*, *n_volumes=1*, *enforce_subsampled=False*, *fftplan_kwargs={}*)

Parameters

- **size** (*(Sx,Sy,Sz)*) – the size of the geometry in microns (Sx,Sy,Sz)
- **shape** (*(Nx,Ny,Nz)*) – the shape of the geometry in pixels (Nx,Ny,Nz)
- **units** (*(dx,dy,dz)*) – the voxelsizes in microns (dx,dy,dz)
- **dn** (*ndarray (float32|complex64)*) – refractive index distribution, dn.shape != (Nz,Ny,Nx)
- **lam** (*float*) – the wavelength in microns
- **n0** (*float*) – the refractive index of the surrounding media
- **simul_xy** (*(Nx,Ny,Nz), optional*) – the shape of the 2d computational geometry in pixels (Nx,Ny) (e.g. subsampling in xy)
- **simul_z** (*int, optional*) – the subsampling factor along z
- **n_volumes** (*int*) – splits the domain into chunks if GPU memory is not large enough (will be set automatically)

Example

```
>>> m = Bpm3d(size = (10,10,10),shape = (256,256,256),units = (0.1,0.1,0.1),lam = 0.488,r
```

aberr_at(*NA=0.4*, *center=(0, 0, 0)*, *n_zern=20*, *n_integration_steps=200*)

c = (cx,cy,cz) in relative pixel coordinates wrt the center

returns phi, zern

aberr_field_grid(*NA*, *cxs*, *cys*, *cz*, *n_zern=20*, *n_integration_steps=200*)

cxs, cys are equally spaced 1d arrays defining the grid

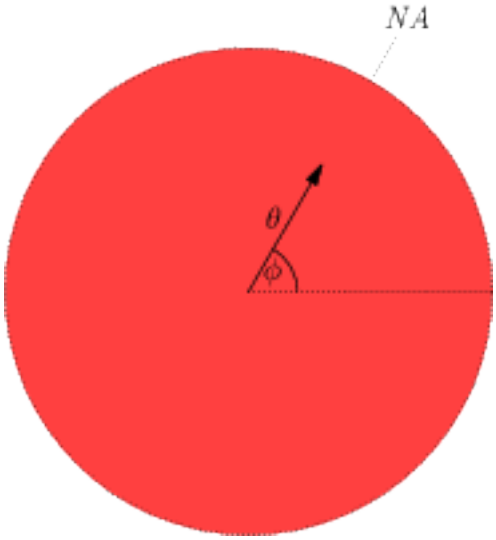
propagate(*u0=None*, *offset=0*, *return_comp='field'*, *return_shape='full'*, *free_prop=False*, *dn_mean_method='none'*, ***kwargs*)

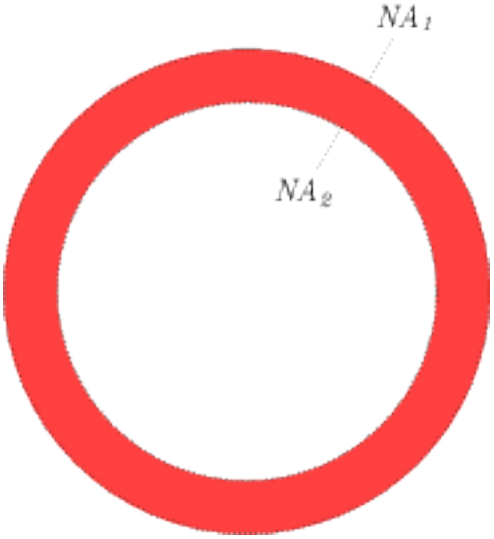
kwargs: return_comp in ["field", "intens"] return_shape in ["last", "full"] free_prop = False | True dn_mean_method = "none", "global", "local"

4 Input Beam patterns

4.1 Gaussian/Bessel beams

Gaussian/Bessel beams





biobeam.**focus_field_beam**(*shape=(128, 128, 128), units=(0.1, 0.1, 0.1), lam=0.5, NA=0.6, n0=1.0, return_all_fields=False, n_integration_steps=200*)

calculates the focus field for a perfect, aberration free optical system for x polzarized illumination via the vectorial debye diffraction integral (see [1]). The pupil function is given by numerical aperture(s) NA (that can be a list to model bessel beams, see further below)

Parameters

- **shape** (*Nx, Ny, Nz*) – the shape of the geometry
- **units** (*dx, dy, dz*) – the pixel sizes in microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA** (*float/list*) – the numerical aperture(s) of the illumination objective that is either a single number (for gaussian beams) or an even length list of NAs (for bessel beams), e.g. *NA = [0.5,0.55]* lets light through the annulus 0.5<0.55 (making a bessel beam) or *NA = [0.1,0.2,0.5,0.6]* lets light through the annulus 0.1<0.2 and 0.5<0.6 making a beating double bessel beam...
- **n0** (*float*) – the refractive index of the medium
- **n_integration_steps** (*int*) – number of integration steps to perform
- **return_all_fields** (*boolean*) – if True returns also the complex vectorial field components

[1] Matthew R. Foreman, Peter Toeroek, *Computational methods in vectorial imaging*, Journal of Modern Optics, 2011, 58, 5-6, 339

Returns

- **u** (*ndarray*) – the intensity of the focus field
- **(u,ex,ey,ez)** (*list(ndarray)*) – the intensity of the focus field and the complex field components (if return_all_fields is True)

Example

```
>>> u = focus_field_beam((128,128,128), (0.1,0.1,.1), lam=.5, NA = .4)
```

References

biobeam.**focus_field_beam_plane**(*shape=(128, 128), units=(0.1, 0.1), z=0.0, lam=0.5, NA=0.6, n0=1.0, ex_g=None, n_integration_steps=200*)

calculates the complex 2d input field at position -z of a perfect, aberration free optical system

Parameters

- **shape** (*Nx, Ny*) – the 2d shape of the geometry
- **units** (*dx, dy*) – the pixel sizes in microns
- **z** (*float*) – defocus position in microns, such that the beam would focus at z e.g. an input field with z = 10. would hav its focus spot after 10 microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA** (*float/list*) – the numerical aperture(s) of the illumination objective that is either a single number (for gaussian beams) or an even length list of NAs (for bessel beams), e.g. NA = [0.5,0.55] lets light through the annulus 0.5<0.55 (making a bessel beam) or NA = [0.1,0.2,0.5,0.6] lets light through the annulus 0.1<0.2 and 0.5<0.6 making a beating double bessel beam...
- **n0** (*float*) – the refractive index of the medium
- **n_integration_steps** (*int*) – number of integration steps to perform

Returns **ex** – the complex field

Return type ndarray

Example

```
>>> # the input pattern of a bessel beam that will focus after 4 microns
>>> ex = focus_field_beam_plane((256,256), (0.1,0.1), z = 4, lam=.5, NA = (.4,.5))
```

See also:

biobeam.focus_field_beam() the 3d function

4.2 Cylindrical Lens

biobeam.**focus_field_cylindrical**(*shape=(128, 128, 128), units=(0.1, 0.1, 0.1), lam=0.5, NA=0.3, n0=1.0, return_all_fields=False, n_integration_steps=100*)

calculates the focus field for a perfect, aberration free cylindrical lens after x polarized illumination via the vectorial debye diffraction integral (see [2]). The pupil function is given by the numerical aperture NA

Parameters

- **shape** (*Nx,Ny,Nz*) – the shape of the geometry
- **units** (*dx,dy,dz*) – the pixel sizes in microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA** (*float*) – the numerical aperture of the lens
- **n0** (*float*) – the refractive index of the medium
- **return_all_fields** (*boolean*) – if True, returns u,ex,ey,ez where ex/ey/ez are the complex field components
- **n_integration_steps** (*int*) – number of integration steps to perform
- **return_all_fields** – if True returns also the complex vectorial field components

Returns

- **u** (*ndarray*) – the intensity of the focus field
- **(u,ex,ey,ez)** (*list(ndarray)*) – the intensity of the focus field and the complex field components (if return_all_fields is True)

Example

```
>>> u, ex, ey, ez = focus_field_cylindrical((128,128,128), (0.1,0.1,.1), lam=.5, NA = .4, ret
```

References

biobeam.**focus_field_cylindrical_plane**(*shape=(128, 128), units=(0.1, 0.1), z=0.0, lam=0.5, NA=0.3, n0=1.0, ex_g=None, n_integration_steps=200*)

calculates the complex 2d input field at position -z of a perfect, aberration free optical system

Parameters

- **shape** (*Nx,Ny*) – the 2d shape of the geometry
- **units** (*dx,dy*) – the pixel sizes in microns
- **z** (*float*) – defocus position in microns, such that the beam would focus at z e.g. an input field with z = 10. would hav its focus spot after 10 microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA** (*float/list*) – the numerical aperture(s) of the illumination objective that is either a single number (for gaussian beams) or an even length list of NAs (for bessel beams), e.g. NA = [0.5,0.55] lets light through the annulus 0.5<0.55 (making a bessel beam) or NA = [0.1,0.2,0.5,0.6] lets light through the annulus 0.1<0.2 and 0.5<0.6 making a beating double bessel beam...
- **n0** (*float*) – the refractive index of the medium
- **n_integration_steps** (*int*) – number of integration steps to perform

Returns **ex** – the complex field

[2] Colin J. R. Sheppard: Cylindrical lenses—focusing and imaging: a review, Appl. Opt. 52, 538-545 (2013)

Return type ndarray

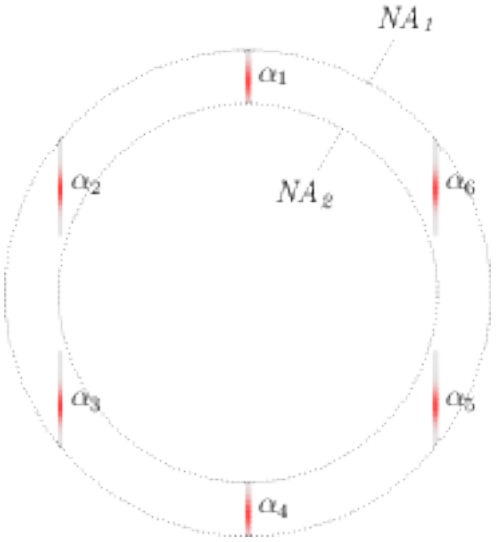
Example

```
>>> # the input pattern of a bessel beam that will focus after 4 microns
>>> ex = focus_field_cylindrical_plane((256,256), (0.1,0.1), z = 4., lam=.5, NA = (.4,.5))
```

See also:

biobeam.focus_field_cylindrical() the 3d function

4.3 Bessel Lattices



biobeam.**focus_field_lattice**(*shape=(128, 128, 128)*, *units=(0.1, 0.1, 0.1)*, *lam=0.5*, *NA1=0.4*, *NA2=0.5*, *sigma=0.1*, *kpoints=6*, *return_all_fields=False*, *n0=1.0*, *n_integration_steps=100*)

Calculates the focus field for a bessel lattice. The pupil function consists out of discrete points (kpoints) superimposed on an annulus (NA1<NA2) which are smeared out by a 1d gaussian of given sigma creating an array of bessel beams in the focal plane (see [3]).

Parameters

- **shape** (*Nx, Ny, Nz*) – the shape of the geometry
- **units** (*dx, dy, dz*) – the pixel sizes in microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA1** (*float/list*) – the numerical aperture of the inner ring
- **NA2** (*float/list*) – the numerical aperture of the outer ring
- **sigma** (*float*) – the standard deviation of the gaussian smear function applied to each point on the aperture (the bigger sigma, the tighter the sheet in y)
- **kpoints** (*int/ (2,N) array*) – defines the set of points on the aperture that create the lattice, can be - a (2,N) ndarray, such that kpoints[:,i] are the coordinates of the ith point - a single int, defining points on a regular polygon (e.g. 4 for a square lattice, 6 for a hex lattice) $k_i = \arcsin \frac{NA_1+NA_2}{2n_0} \begin{pmatrix} \cos\phi_i \\ \sin\phi_i \end{pmatrix}$, $\phi_i = \frac{\pi}{2} + \frac{2i}{N}$
- **n0** (*float*) – the refractive index of the medium

[3] Chen et al. Lattice light-sheet microscopy: imaging molecules to embryos at high spatiotemporal resolution. Science 346, (2014).

- **n_integration_steps** (*int*) – number of integration steps to perform
- **return_all_fields** (*boolean*) – if True, returns u,ex,ey,ez where ex/ey/ez are the complex vector field components

Returns

- **u** (*ndarray*) – the intensity of the focus field
- **(u,ex,ey,ez)** (*list(ndarray)*) – the intensity of the focus field and the complex field components (if return_all_fields is True)

Example

```
>>> u = focus_field_lattice((128,128,128), (0.1,0.1,.1), lam=.5, NA1 = .44, NA2 = .55, kpoint
```

References

biobeam.**focus_field_lattice_plane**(*shape=(256, 256)*, *units=(0.1, 0.1)*, *z=0.0*, *lam=0.5*, *NA1=0.4*, *NA2=0.5*, *sigma=0.1*, *kpoints=6*, *n0=1.0*, *apodization_bound=10*, *ex_g=None*, *n_integration_steps=100*)

calculates the complex 2d input field at position -z of a for a bessel lattice beam.

Parameters

- **shape** (*Nx,Ny*) – the shape of the geometry
- **units** (*dx,dy*) – the pixel sizes in microns
- **z** (*float*) – defocus position in microns, such that the beam would focus at z e.g. an input field with z = 10. would have its focal spot after 10 microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA1** (*float/list*) – the numerical aperture of the inner ring
- **NA2** (*float/list*) – the numerical aperture of the outer ring
- **sigma** (*float*) – the standard deviation of the gaussian smear function applied to each point on the aperture (the bigger sigma, the tighter the sheet in y)
- **kpoints** (*int/ (2,N) array*) – defines the set of points on the aperture that create the lattice, can be - a (2,N) ndarray, such that kpoints[:,i] are the coordinates of the ith point - a single int, defining points on a regular polygon (e.g. 4 for a square lattice, 6 for a hex lattice) $k_i = \arcsin \frac{NA_1+NA_2}{2n_0} \begin{pmatrix} \cos\phi_i \\ \sin\phi_i \end{pmatrix}$ $, \phi_i = \frac{\pi}{2} + \frac{2i}{N}$
- **n0** (*float*) – the refractive index of the medium
- **apodization_bound** (*int*) – width of the region where the input field is tapered to zero (with a hamming window) on the +/- x borders
- **n_integration_steps** (*int*) – number of integration steps to perform
- **return_all_fields** (*boolean*) – if True, returns u,ex,ey,ez where ex/ey/ez are the complex vector field components

Returns **u** – the 2d complex field

Return type ndarray

Example

```
>>> u = focus_field_lattice_plane((128,128), (0.1,0.1), z = 2., lam=.5, NA1 = .44, NA2 = .55,
```

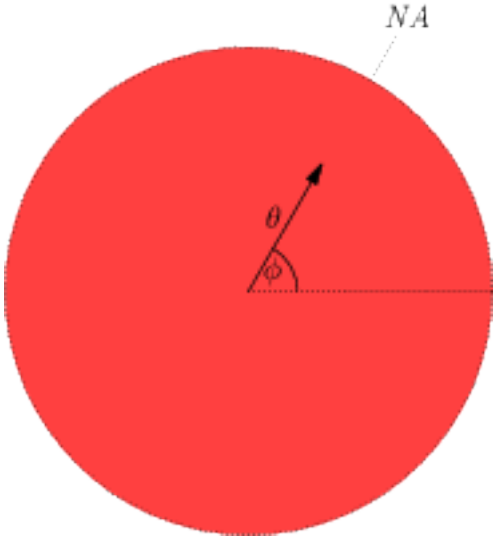
See also:

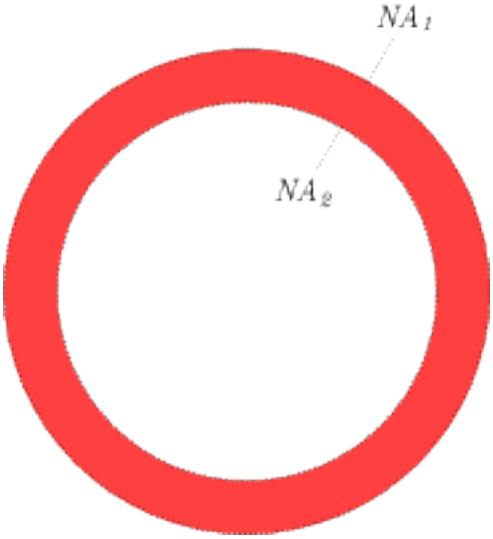
biobeam.focus_field_lattice() the corresponding 3d function

5 Focus field calculations

5.1 Gaussian/Bessel beams

Gaussian/Bessel beams





biobeam.**focus_field_beam**(*shape=(128, 128, 128), units=(0.1, 0.1, 0.1), lam=0.5, NA=0.6, n0=1.0, return_all_fields=False, n_integration_steps=200*)

calculates the focus field for a perfect, aberration free optical system for x polzarized illumination via the vectorial debye diffraction integral (see [1]). The pupil function is given by numerical aperture(s) NA (that can be a list to model bessel beams, see further below)

Parameters

[1] Matthew R. Foreman, Peter Toeroek, *Computational methods in vectorial imaging*, Journal of Modern Optics, 2011, 58, 5-6, 339

- **shape** (*Nx, Ny, Nz*) – the shape of the geometry
- **units** (*dx, dy, dz*) – the pixel sizes in microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA** (*float/list*) – the numerical aperture(s) of the illumination objective that is either a single number (for gaussian beams) or an even length list of NAs (for bessel beams), e.g. *NA = [0.5,0.55]* lets light through the annulus 0.5<0.55 (making a bessel beam) or *NA = [0.1,0.2,0.5,0.6]* lets light through the annulus 0.1<0.2 and 0.5<0.6 making a beating double bessel beam...
- **n0** (*float*) – the refractive index of the medium
- **n_integration_steps** (*int*) – number of integration steps to perform
- **return_all_fields** (*boolean*) – if True returns also the complex vectorial field components

Returns

- **u** (*ndarray*) – the intensity of the focus field
- **(u,ex,ey,ez)** (*list(ndarray)*) – the intensity of the focus field and the complex field components (if return_all_fields is True)

Example

```
>>> u = focus_field_beam((128,128,128), (0.1,0.1,.1), lam=.5, NA = .4)
```

References

biobeam.**focus_field_beam_plane**(*shape=(128, 128), units=(0.1, 0.1), z=0.0, lam=0.5, NA=0.6, n0=1.0, ex_g=None, n_integration_steps=200*)

calculates the complex 2d input field at position -z of a perfect, aberration free optical system

Parameters

- **shape** (*Nx, Ny*) – the 2d shape of the geometry
- **units** (*dx, dy*) – the pixel sizes in microns
- **z** (*float*) – defocus position in microns, such that the beam would focus at z e.g. an input field with z = 10. would hav its focus spot after 10 microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA** (*float/list*) – the numerical aperture(s) of the illumination objective that is either a single number (for gaussian beams) or an even length list of NAs (for bessel beams), e.g. NA = [0.5,0.55] lets light through the annulus 0.5<0.55 (making a bessel beam) or NA = [0.1,0.2,0.5,0.6] lets light through the annulus 0.1<0.2 and 0.5<0.6 making a beating double bessel beam...
- **n0** (*float*) – the refractive index of the medium
- **n_integration_steps** (*int*) – number of integration steps to perform

Returns **ex** – the complex field

Return type ndarray

Example

```
>>> # the input pattern of a bessel beam that will focus after 4 microns
>>> ex = focus_field_beam_plane((256,256), (0.1,0.1), z = 4, lam=.5, NA = (.4,.5))
```

See also:

biobeam.focus_field_beam() the 3d function

5.2 Cylindrical Lens

biobeam.**focus_field_cylindrical**(*shape=(128, 128, 128), units=(0.1, 0.1, 0.1), lam=0.5, NA=0.3, n0=1.0, return_all_fields=False, n_integration_steps=100*)

calculates the focus field for a perfect, aberration free cylindrical lens after x polarized illumination via the vectorial debye diffraction integral (see [2]). The pupil function is given by the numerical aperture NA

Parameters

- **shape** (*Nx,Ny,Nz*) – the shape of the geometry
- **units** (*dx,dy,dz*) – the pixel sizes in microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA** (*float*) – the numerical aperture of the lens
- **n0** (*float*) – the refractive index of the medium
- **return_all_fields** (*boolean*) – if True, returns u,ex,ey,ez where ex/ey/ez are the complex field components
- **n_integration_steps** (*int*) – number of integration steps to perform
- **return_all_fields** – if True returns also the complex vectorial field components

Returns

- **u** (*ndarray*) – the intensity of the focus field
- **(u,ex,ey,ez)** (*list(ndarray)*) – the intensity of the focus field and the complex field components (if return_all_fields is True)

Example

```
>>> u, ex, ey, ez = focus_field_cylindrical((128,128,128), (0.1,0.1,.1), lam=.5, NA = .4, ret
```

References

biobeam.**focus_field_cylindrical_plane**(*shape=(128, 128), units=(0.1, 0.1), z=0.0, lam=0.5, NA=0.3, n0=1.0, ex_g=None, n_integration_steps=200*)

calculates the complex 2d input field at position -z of a perfect, aberration free optical system

Parameters

[2] Colin J. R. Sheppard: Cylindrical lenses—focusing and imaging: a review, Appl. Opt. 52, 538-545 (2013)

- **shape** (*Nx, Ny*) – the 2d shape of the geometry
- **units** (*dx, dy*) – the pixel sizes in microns
- **z** (*float*) – defocus position in microns, such that the beam would focus at z e.g. an input field with z = 10. would hav its focus spot after 10 microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA** (*float/list*) – the numerical aperture(s) of the illumination objective that is either a single number (for gaussian beams) or an even length list of NAs (for bessel beams), e.g. NA = [0.5,0.55] lets light through the annulus 0.5<0.55 (making a bessel beam) or NA = [0.1,0.2,0.5,0.6] lets light through the annulus 0.1<0.2 and 0.5<0.6 making a beating double bessel beam...
- **n0** (*float*) – the refractive index of the medium
- **n_integration_steps** (*int*) – number of integration steps to perform

Returns **ex** – the complex field

Return type ndarray

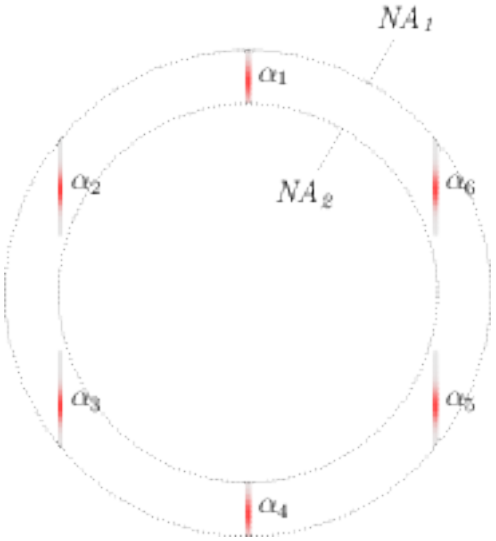
Example

```
>>> # the input pattern of a bessel beam that will focus after 4 microns
>>> ex = focus_field_cylindrical_plane((256,256), (0.1,0.1), z = 4., lam=.5, NA = (.4,.5))
```

See also:

biobeam.focus_field_cylindrical() the 3d function

5.3 Bessel Lattices



biobeam.**focus_field_lattice**(*shape=(128, 128, 128)*, *units=(0.1, 0.1, 0.1)*, *lam=0.5*, *NA1=0.4*, *NA2=0.5*, *sigma=0.1*, *kpoints=6*, *return_all_fields=False*, *n0=1.0*, *n_integration_steps=100*)

Calculates the focus field for a bessel lattice. The pupil function consists out of discrete points (kpoints) superimposed on an annulus (NA1<NA2) which are smeared out by a 1d gaussian of given sigma creating an array of bessel beams in the focal plane (see [3]).

Parameters

[3] Chen et al. Lattice light-sheet microscopy: imaging molecules to embryos at high spatiotemporal resolution. Science 346, (2014).

- **shape** (*Nx,Ny,Nz*) – the shape of the geometry
- **units** (*dx,dy,dz*) – the pixel sizes in microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA1** (*float/list*) – the numerical aperture of the inner ring
- **NA2** (*float/list*) – the numerical aperture of the outer ring
- **sigma** (*float*) – the standard deviation of the gaussian smear function applied to each point on the aperture (the bigger sigma, the tighter the sheet in y)
- **kpoints** (*int/ (2,N) array*) – defines the set of points on the aperture that create the lattice, can be - a (2,N) ndarray, such that kpoints[:,i] are the coordinates of the ith point - a single int, defining points on a regular polygon (e.g. 4 for a square lattice, 6 for a hex lattice) $k_i = \arcsin \frac{NA_1+NA_2}{2n_0} \begin{pmatrix} \cos\phi_i \\ \sin\phi_i \end{pmatrix}$ $, \phi_i = \frac{\pi}{2} + \frac{2i}{N}$
- **n0** (*float*) – the refractive index of the medium
- **n_integration_steps** (*int*) – number of integration steps to perform
- **return_all_fields** (*boolean*) – if True, returns u,ex,ey,ez where ex/ey/ez are the complex vector field components

Returns

- **u** (*ndarray*) – the intensity of the focus field
- **(u,ex,ey,ez)** (*list(ndarray)*) – the intensity of the focus field and the complex field components (if return_all_fields is True)

Example

```
>>> u = focus_field_lattice((128,128,128), (0.1,0.1,.1), lam=.5, NA1 = .44, NA2 = .55, kpoint
```

References

biobeam.**focus_field_lattice_plane**(*shape=(256, 256), units=(0.1, 0.1), z=0.0, lam=0.5, NA1=0.4, NA2=0.5, sigma=0.1, kpoints=6, n0=1.0, apodization_bound=10, ex_g=None, n_integration_steps=100*)

calculates the complex 2d input field at position -z of a for a bessel lattice beam.

Parameters

- **shape** (*Nx,Ny*) – the shape of the geometry
- **units** (*dx,dy*) – the pixel sizes in microns
- **z** (*float*) – defocus position in microns, such that the beam would focus at z e.g. an input field with z = 10. would have its focal spot after 10 microns
- **lam** (*float*) – the wavelength of light used in microns
- **NA1** (*float/list*) – the numerical aperture of the inner ring
- **NA2** (*float/list*) – the numerical aperture of the outer ring
- **sigma** (*float*) – the standard deviation of the gaussian smear function applied to each point on the aperture (the bigger sigma, the tighter the sheet in y)
- **kpoints** (*int/ (2,N) array*) – defines the set of points on the aperture that create the lattice, can be - a (2,N) ndarray, such that kpoints[:,i] are the coordinates of

the ith point - a single int, defining points on a regular polygon (e.g. 4 for a square lattice, 6 for a hex lattice) $k_i = \arcsin \frac{NA_1+NA_2}{2n_0} \begin{pmatrix} \cos\phi_i \\ \sin\phi_i \end{pmatrix}$ $, \phi_i = \frac{\pi}{2} + \frac{2i}{N}$

- **n0** (*float*) – the refractive index of the medium
- **apodization_bound** (*int*) – width of the region where the input field is tapered to zero (with a hamming window) on the +/- x borders
- **n_integration_steps** (*int*) – number of integration steps to perform
- **return_all_fields** (*boolean*) – if True, returns u,ex,ey,ez where ex/ey/ez are the complex vector field components

Returns **u** – the 2d complex field

Return type ndarray

Example

```
>>> u = focus_field_lattice_plane((128,128), (0.1,0.1), z = 2., lam=.5, NA1 = .44, NA2 = .55,
```

See also:

biobeam.focus_field_lattice() the corresponding 3d function

6 Simulating light sheet microscopy

7 Aberrations

8 Examples

8.1 Plane wave scattered by sphere

```
# create the refractive index difference
x = 0.1 * np.arange(-128,128)
Z, Y, X = np.meshgrid(x,x,x,indexing = "ij")
R = np.sqrt(X**1+Y**2+Z**2)
dn = 0.05*(R<2.)

# create the computational geometry
m = Bpm3d(dn = dn, units = (0.1,0.1,0.1), lam = 0.5)

# propagate a plane wave and return the intensity
u = m._propagate()

# vizualize
import matplotlib.pyplot as plt
plt.subplot(1,2,1)
plt.imshow(u[...,128], cmap = "hot")
plt.title("zy slice")
plt.subplot(1,2,2)
plt.imshow(u[128,...], cmap = "hot")
plt.title("xy slice")
```

8.2 Light sheet through cell phantom

8.3 Computing the psf inside a cell phantom

8.4 Aberration from sphere

9 Some Examples

or not?

```
print "huhu"
```

```
huhu
```

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