



biobeam Documentation

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Contents

1	biobeam	2
2	Introduction	2
3	Installation	2
4	Basic Usage	2
4.1	Beam propagation	2
5	Input Beam patterns	3
5.1	Gaussian/Bessel beams	3
5.2	Cylindrical Lens	5
5.3	Bessel Lattices	7
6	Examples	8
6.1	Plane wave scattered by sphere	8
6.2	Light sheet through cell phantom	8
6.3	Computing the psf inside a cell phantom	8
6.4	Aberration from sphere	8
7	Some Examples	8
	Index	9

Biobeams is awesome. And so are you!

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

1 biobeam

A super useful tool

2 Introduction

Biobeams is awesome. And so are you!

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

3 Installation

To nicely render the 3d output it is advisable to install *Spimagine*, an OpenCL accelerated renderer [Spimagine](#)

```
pip install spimagine
```

After that you should be able to simply do

```
pip install biobeams
```

4 Basic Usage

Contents

- *Basic Usage*
 - *Beam propagation*

4.1 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, fft-
                    plan_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, n_volumes=10)
```

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

c = (cx,cy,cz) in realtive 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

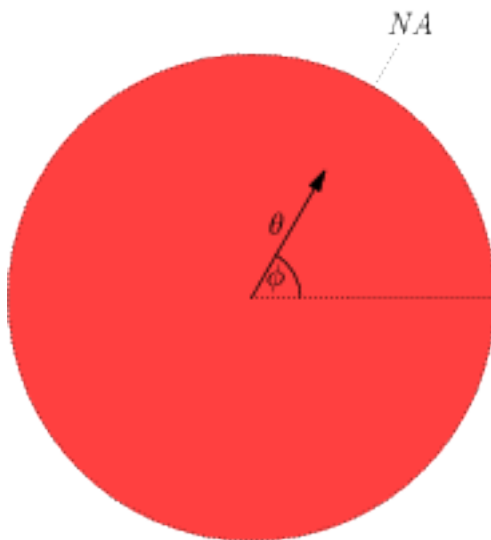
5 Input Beam patterns

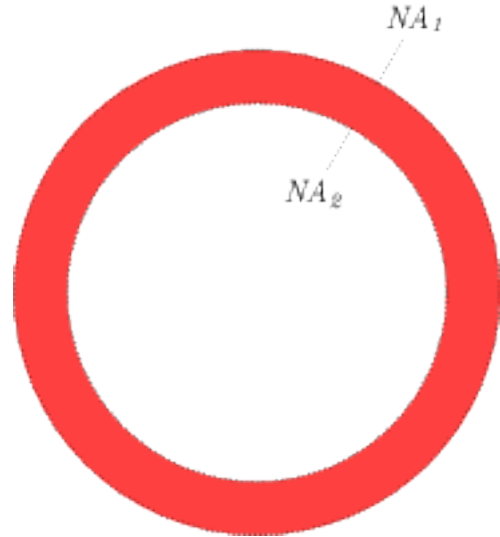
Contents

- *Input Beam patterns*
 - *Gaussian/Bessel beams*
 - *Cylindrical Lens*
 - *Bessel Lattices*

5.1 Gaussian/Bessel beams

Gaussian/Bessel beams





`biobeam.focus_field_beam(shape, units, 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 polarized 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** (N_x, N_y, N_z) – 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

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

Parameters

- **shape** (N_x, N_y) – 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 bessell beams), e.g. $NA = [0.5, 0.55]$ lets light through the annulus $0.5 < 0.55$ (making a bessell 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 bessell 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 bessell 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, units, lam=0.5, NA=0.3, n0=1.0, return_all_field=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** (N_x, N_y, N_z) – 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

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

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=0.6, 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 bessell beams), e.g. $NA = [0.5, 0.55]$ lets light through the annulus $0.5 < 0.55$ (making a bessell 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 bessell 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`

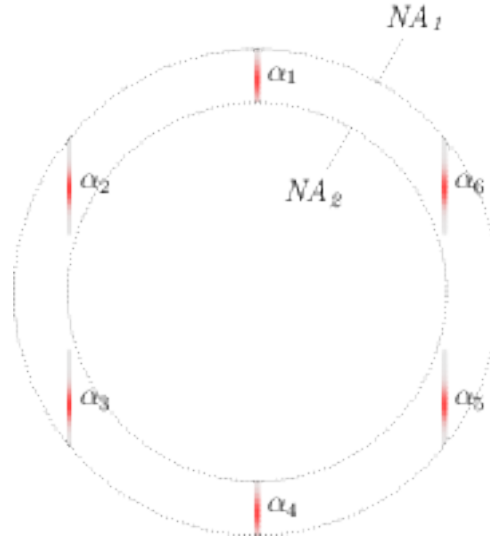
Example

```
>>> # the input pattern of a bessell 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*, *units*, *lam*=0.5, *NA1*=0.4, *NA2*=0.5, *sigma*=0.1, *kpoints*=6, *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 *i*th 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)

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

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, Npoly=6,  
                                n0=1.0, apodization_bound=10, ex_g=None,  
                                n_integration_steps=100)
```

6 Examples

6.1 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")
```

6.2 Light sheet through cell phantom

6.3 Computing the psf inside a cell phantom

6.4 Aberration from sphere

7 Some Examples

or not?

```
print "huhu"
```

```
huhu
```


Index

Symbols

`__init__()` (biobeam.Bpm3d method), 2

A

`aberr_at()` (biobeam.Bpm3d method), 3

`aberr_field_grid()` (biobeam.Bpm3d method), 3

B

Bpm3d (class in biobeam), 2

F

`focus_field_beam()` (in module biobeam), 4

`focus_field_beam_plane()` (in module biobeam), 4

`focus_field_cylindrical()` (in module biobeam), 5

`focus_field_cylindrical_plane()` (in module biobeam), 6

`focus_field_lattice()` (in module biobeam), 7

`focus_field_lattice_plane()` (in module biobeam), 8