# pyPhase

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# CONTENTS

**pyPhase** is an open-source Python package for phase retrieval from phase contrast images in the Fresnel regime. For an overview, check out the pyPhase manuscript: https://arxiv.org/abs/2012.07942

- Phase retrieval algorithms
- Wave propagation.
- Handling of different image sources and formats
- Tools for pre-processing such as registration of phase contrast images and motion estimation

CHAPTER

ONE

# INSTALLATION

Installation is currently through PyPI. Create a virtual environment using your favourite virtual environment manager, verify that pip is installed, then:

```
pip install pyphase
```

PyPhase currently requires Elastix 4.9 installed for registration. To manually install elastix 4.9 go to https://elastix.lumc.nl/download.php

- Unzip the archive.
- Add the path for elastix/bin to your .bashrc: add YOUR_PATH_TO_elastix/bin to your environment variable PATH.
- Add the path for elastix/lib to your .bashrc: add YOUR_PATH_TO_elastix/lib to your environment variable LD_LIBRARY_PATH.

Test your installation:

```
python3 import pyphase
```

CHAPTER

TWO

# INDICES AND TABLES

- genindex
- modindex
- search

## 2.1 About

**pyPhase** is an open source phase retrieval package created by *Max Langer*. X-ray propagation-based imaging techniques are well-established at synchrotron radiation and laboratory sources. However, most reconstruction algorithms for such image modalities, also known as phase retrieval algorithms, have been developed specifically for one instrument by and for experts, making the development and spreading of the use of such techniques difficult. Here, we present PyPhase, a free and open-source package for propagation-based near-field phase reconstructions, which is distributed under the CeCILL license. PyPhase implements some of the most popular phase-retrieval algorithms in a highly-modular framework supporting the deployment on large-scale computing facilities. This makes the integration, the development of new phase-retrieval algorithms, and the deployment on different computing infrastructures straight-forward. To demonstrate its capabilities and simplicity, we present its application to data acquired at synchrotron MAX~IV (Lund, Sweden). For more information, read the manuscript describing the package: https://arxiv.org/abs/2012.07942

## 2.2 Examples

A simple example of usage is given, illustrating the use of the dataset module as well as using directly phase contrast images as input.

```
import pyphase
from pyphase import *
import numpy as np
```

```
#%% Choose image display to use
displayer = utilities.PyplotImageDisplayer()
```

```
#%% Load dataset
data = dataset.NanomaxPreprocessed2D('cpr', version='test')
```

```
#%% Align images using default registrator
# Increase number of resolutions and
pyphase.registrator.parameters.NumberOfResolutions = 8
```

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```
pyphase.registrator.parameters.MaximumNumberOfIterations = 3000

data.align_projection()
```

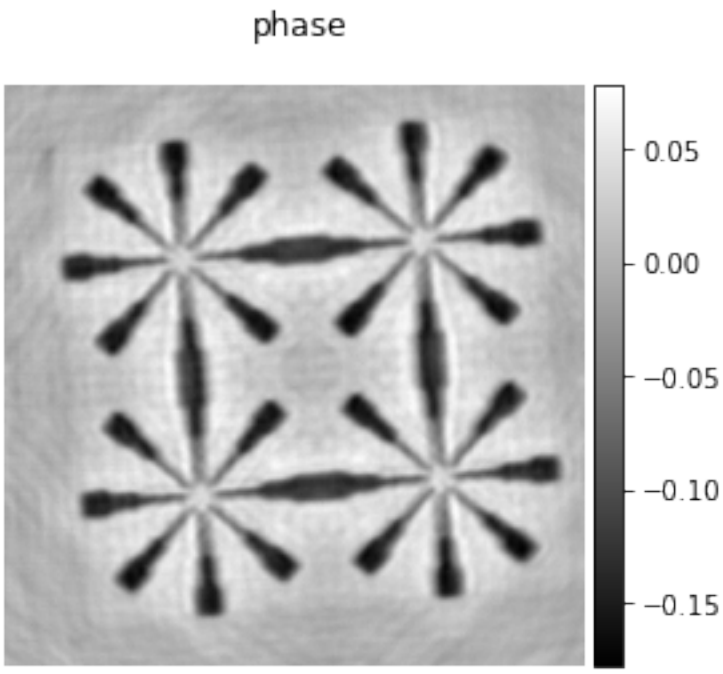
```
Aligning position 1
Found elastix version: 4.900 in '/home/ext-maxlan/elastix/bin/elastix'
Aligning position 2
Aligning position 3
Aligning position 4
```

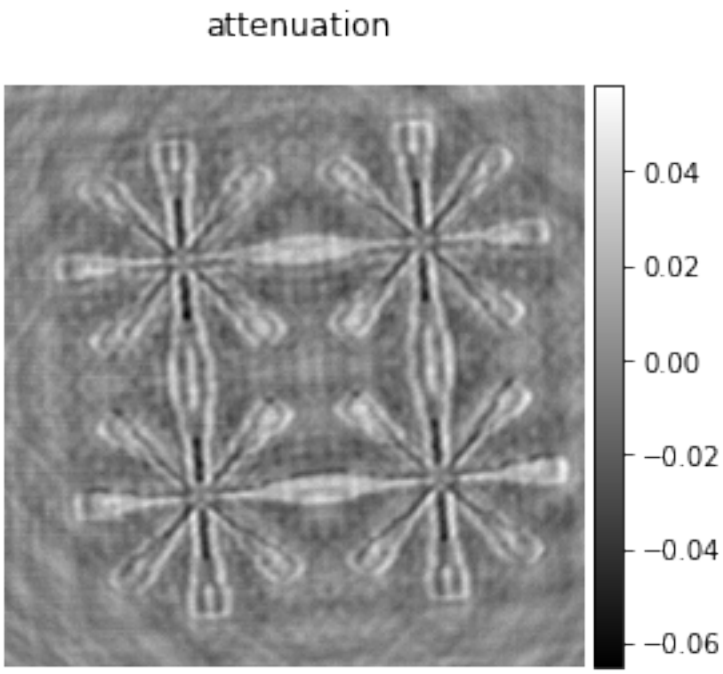
```
#%% Phase retrieval from a dataset using CTF
retriever = phaseretrieval.CTF(data)

# Modify regularisation parameter
retriever.alpha = [1e-3, 1e-8] # [LF, HF]
```

```
#%% Reconstruct
phase, attenuation = retriever.reconstruct_projection(dataset=data, projection=0)
```

```
#%% Display reconstruction
displayer.close_all()
displayer.display(data.get_image(projection=0), title='phase')
displayer.display(data.get_image(projection=0, image_type='attenuation'), title=
↪'attenuation')
```






```
#%% Phase retrieval from images
# Acquisition parameters
energy=13 #keV
effective_distance=np.array([0.010054, 0.0155, 0.0178, 0.019, 0.0203])
pixel_size = np.array([0.005924, 0.006043])*1e-6

nyp = nxp = 4096
ny = nx = 2048
```

```
#%% Load images
ID = np.zeros((len(effective_distance), nyp, nxp))
for N in range(len(effective_distance)):
    ID[N] = data.get_projection(projection=0, position=N, pad=True)
```

```
#%% Phase retrieval from images using HIO_ER
retriever = phaseretrieval.HIO_ER(shape=ID[0].shape, pixel_size=[pixel_size[0], pixel_
↪size[1]], distance=effective_distance, energy=energy, pad=1)

# Modify some parameters
retriever.alpha = [1e-3, 1e-8] # Regularisation parameter used for initialisation
retriever.iterations_hio = 2 # Number of HIO iterations
retriever.iterations_er = 2 # Number of ER iterations
retriever.iterations = 2 # Change number of global iterations
```

```
#%% Reconstruct
phase, attenuation = retriever.reconstruct_image(ID)
```

```
========== processing distance 1 ==========
Iteration 0001, error: 1.1e-05
Iteration 0002, error: 7.9e-06
Iteration 0003, error: 6.3e-06
Iteration 0004, error: 5.3e-06
```

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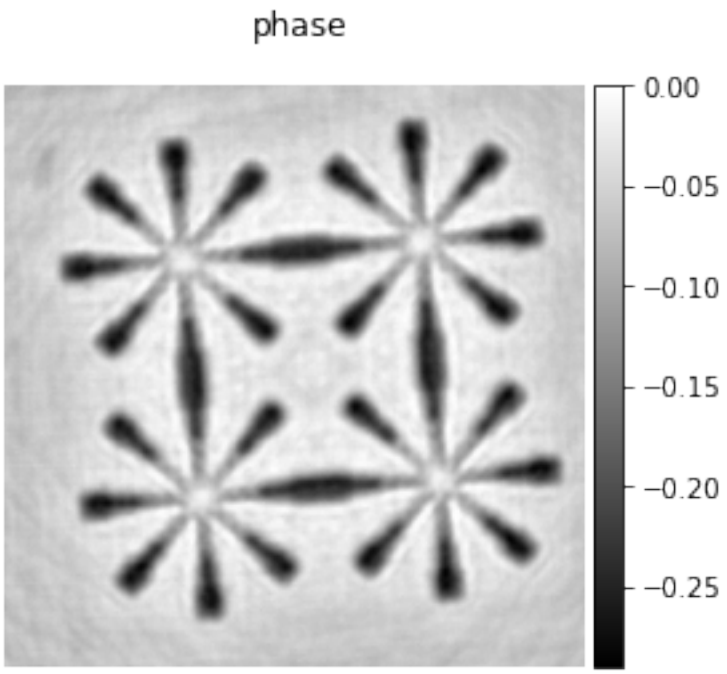
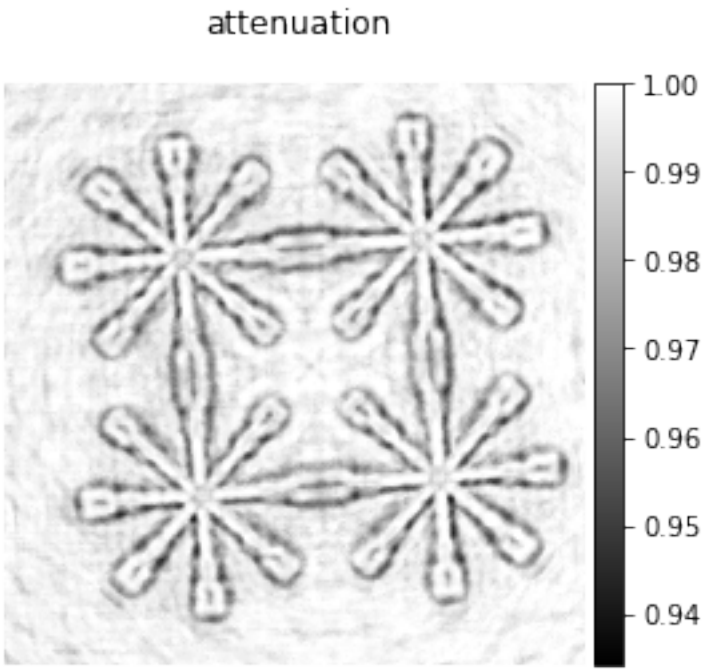
```
Iteration 0005, error: 4.7e-06
Iteration 0006, error: 4.2e-06
Iteration 0007, error: 3.8e-06
Iteration 0008, error: 3.5e-06
========== processing distance 2 ==========
Iteration 0001, error: 8.4e-05
Iteration 0002, error: 7e-05
Iteration 0003, error: 6.4e-05
Iteration 0004, error: 6e-05
Iteration 0005, error: 5.7e-05
Iteration 0006, error: 5.4e-05
Iteration 0007, error: 5.2e-05
Iteration 0008, error: 5.1e-05
========== processing distance 3 ==========
Iteration 0001, error: 1.7e-05
Iteration 0002, error: 9.8e-06
Iteration 0003, error: 7e-06
Iteration 0004, error: 5.1e-06
Iteration 0005, error: 4e-06
Iteration 0006, error: 3.3e-06
Iteration 0007, error: 2.8e-06
Iteration 0008, error: 2.4e-06
========== processing distance 4 ==========
Iteration 0001, error: 2.8e-05
Iteration 0002, error: 1.9e-05
Iteration 0003, error: 1.5e-05
Iteration 0004, error: 1.2e-05
Iteration 0005, error: 1.1e-05
Iteration 0006, error: 9.4e-06
Iteration 0007, error: 8.7e-06
Iteration 0008, error: 8e-06
========== processing distance 5 ==========
Iteration 0001, error: 1.8e-05
Iteration 0002, error: 1.2e-05
Iteration 0003, error: 1e-05
Iteration 0004, error: 8.3e-06
Iteration 0005, error: 6.9e-06
Iteration 0006, error: 6e-06
Iteration 0007, error: 5.6e-06
Iteration 0008, error: 5e-06
```

```
#%% Display reconstruction
displayer.close_all()
displayer.display(utilities.resize(phase, [ny, nx]), 'phase')
displayer.display(utilities.resize(attenuation, [ny, nx]), 'attenuation')
```


phase
0.00
−0.05
−0.10
−0.15
−0.20
−0.25


attenuation
1.00
0.99
0.98
0.97
0.96
0.95
0.94

## 2.3 API reference

This section contains the API reference and usage information for pyPhase.

### pyPhase Modules:

### 2.3.1 pyPhase

#### pyPhase package

#### dataset module

**class** dataset.**Dataset**(*name: str*, *path: str = '.'*, *version: str = 'master'*)

Bases: object

Abstract class representing a set of recorded images, acquisition parameters, reconstructed images and any intermediary images.

**align_projection**(*, *projection=0*, *save_projection=False*)

Aligns images at different positions at one projection angle

Aligns (registers) images taken at different positions using the default registration algorithm (pyphase.registrator).

**Parameters**

- **projection** (*int, optional*) – Number of projection to register.
- **save_projection** (*bool, optional*) – Save aligned images to file (creates new data files)

**align_projections**(*, *projections*)

Align a series of projections.

**Parameters** **projections** (*tuple of ints*) – In the form [start, end]

**get_alignment**(*, *projection*, *position*)

Get transform parameters for alignment.

**Returns** **transform_parameters** (*numpy array*) – Array of transform parameters. Size depends on transform used.

**get_image**(*, *projection*, *image_type='phase'*, *Fourier=False*, *pad=False*)

Get reconstructed images (phase by default)

**Parameters**

- **projection** (*int*) – Number of the projection.
- **image_type** (*str, optional*) – Can be phase or attenuation.
- **Fourier** (*bool*) – Return Fourier transform of image.
- **pad** (*bool*) – Return padded image.

**Returns** **image** (*ndarray*)

**write_image**(*, *image*, *projection*, *projection_type='phase'*)

Saves images into file.

**Parameters**

- **image** (*ndarray*) – An ndarray of the image to save.

- **projection** (*int*) – The number of the projection to be saved.
- **proj_type** (*str*) – A string containing the prefix for the name of the file to be saved.
- **position** (*int*) – Number of the position of the projection (for propagation).

**Returns** *None* – Saves the images into the file `[prefix]_[projection_number].edf` or `[prefix]_[distance]_[projection_number].edf` into the `name_` directory.

**class** `dataset.`**ESRF**(*name: str*, *path: str = '.'*, *version: str = 'master'*)
Bases: `object`

Legacy code for ESRF datasets.

---

**Note:** Will be aligned with Nanomax functionality.

---

**GetSinogram**(*distance=1*)
Return projections as sinogram

**Parameters** **distance** (*int*) – Number of the distance of the projection.

**Returns** *sinogram* – Returns projections stacked as sinogram

**align**(*interval=100*)
Align(self, RA, interval=100) Align complete data set.

TODO: Should probably check for the last projection also so that it is always included

**align_projection**(*projection*)
projection = number of projection to register

**calculate_axis_position**(*distance*)
Calculates the axis position at one position

**calculate_axis_positions**()
Calculates all axis positions.

**calculate_motion**()
Estimates motion in the scans based on supplementary images.

**calculate_reference_position**()
Calculates and sets reference position based on motion

**display_alignment**(*projection=0*)
Displays alignment and fit.

**fit_alignment**()
Fits measured alignment parameters with polynomials

**get_alignment**(*projection*, *distance*)
Returns the transform parameters for alignment at one projection and position

**get_image**(*, *projection*, *image_type='phase'*, *Fourier=False*, *pad=False*)
Get reconstructed images (phase by default)

**Parameters**

- **projection** (*int*) – Number of the projection.
- **image_type** (*str, optional*) – Can be phase or attenuation.
- **Fourier** (*bool*) – Return Fourier transform of image.

- **pad** (*bool*) – Return padded image.

**Returns** **image** (*ndarray*)

**get_motion**(*projection*, *distance*)
Returns estimation motion at one projection and position.

**get_projection**(*, *projection*, *position*, *pad=True*, *Fourier=False*, *aligned=True*, *magnification=True*)

**property nfx**

**property nfy**

**populate**()
Tries to find the dataset parameters in the accompanying *.info* and *xml* files. It is called when a parameter file `pyphase_parameter.yml` is not found.

**Returns** *self* – Returns *self* with the updated attributes.

**preprocess**()
Runs all preprocessing on the dataset: axis positions, motion, reference position, alignment

**write_image**(*, *image*, *projection*, *projection_type='phase'*)
Saves images into file.

**Parameters**

- **data** (*ndarray*) – An ndarray of the image to save.
- **projection_number** (*int*) – The number of the projection to be saved.
- **proj_type** (*str*) – A string containing the prefix for the name of the file to be saved.
- **args** (*int*) – Number of the distance of the projection.

**Returns** *None* – Saves the images into the file `[prefix]_[projection_number].edf` or `[prefix]_[distance]_[projection_number].edf` into the `name_` directory.

**class** dataset.**Nanomax**(*name: str*, *path: str = '.'*, *version: str = 'aster'*)
Bases: *dataset.Dataset*

Class for raw Nanomax data sets.

**Variables**

- **ztot** (*float*) – Focus to detector distance in m.
- **path** (*str*) – Path to dataset.
- **version** (*str*) – Version of Dataset backend structure, e.g. 'TIEHOM'
- **name** (*str*) – Name of dataset
- **frames_per_position** (*int*) – Number of frames per position.
- **initial_frame** (*int*) – Number of the initial frame.
- **projection_prefix** (*str*) – HDF5 path to projection data.
- **reference_position** (*int*) – Position number as reference for alignment (usually highest resolution)
- **diode_name** (*str*) – Name of diode (HDF path) for normalisation
- **darkfield_prefix** (*str*) – HDF5 path prefix to darkfields
- **flatfield_prefix** (*str*) – HDF5 path prefix to flatfields

- **cpr_prefix** (*str*) – HDF5 path prefix to flatfield corrected images
- **phase_prefix** (*str*) – HDF5 path prefix to phase maps
- **attenuation_prefix** (*str*) – HDF5 path prefix to attenuation images
- **aligned** (*int*) – Flag if dataset is aligned or not.

**get_projection**(*, *projection*, *position*, *pad=True*, *magnification=True*, *aligned=True*, *Fourier=False*)

Read one recorded image.

**Parameters**

- **projection** (*int*) – Number of projection to read.
- **position** (*int*) – Number of positiion ("distance") to read.
- **pad** (*bool, optional*) – Pads the image.
- **magnification** (*bool, optional*) – Brings the image to the magnification of reference_position.
- **aligned** (*bool, optional*) – Corrects alignment (requires alignment of projections).
- **Fourier** (*bool*) – Returns the Fourier transform of the image.

**property nfx**

**property nfy**

**class** dataset.**NanomaxPreprocessed**(*name: str*, *path: str = '.'*, *version: str = 'master'*)

Bases: *dataset.Dataset*

Class for preprocessed Nanomax datasets.

**Variables**

- **ztot** (*float*) – Focus to detector distance in m.
- **path** (*str*) – Path to dataset.
- **version** (*str*) – Version of Dataset backend structure, e.g. 'TIEHOM'
- **name** (*str*) – Name of dataset
- **correct_alignent** (*int*) – Flag to correct alignment.
- **aligned** (*int*) – Flag for dataset aligned.
- **phase_prefix** (*str*) – HDF5 path prefix to phase maps
- **attenuation_prefix** (*str*) – HDF5 path prefix to attenuation images
- **projection_prefix** (*str*) – HDF5 path to corrected projections
- **reference_position** (*int*) – Position number as reference for alignment (usually highest resolution)
- **energy** (*float*) – Energy in keV
- **ny** (*nx,*) – Number of pixels, horizontal, vertical
- **padding** (*int*) – Padding factor
- **detector_pixel_size** (*float*) – The detector pixel size in µm
- **alpha** (*tuple of floats*) – Regularization parameter in the form [LF, HF]

**property Lambda**
Wavelength in m, calculated from energy.

**property nfx**
Number of pixels in Fourier domain, horizontal, calculated from nx and padding

**property nfy**
Number of pixels in Fourier domain, vertical, calculated from ny and padding

**class** dataset.**NanomaxPreprocessed2D**(*name: str*, *path: str = '.'*, *version: str = 'master'*)
Bases: *dataset.NanomaxPreprocessed*

Class for single projection Nanomax data.

**get_projection**(*, *projection*, *position*, *pad=True*, *magnification=True*, *aligned=True*, *Fourier=False*)
Read one recorded image.

**Parameters**

- **projection** (*int*) – Number of projection to read.
- **position** (*int*) – Number of positiion ("distance") to read.
- **pad** (*bool, optional*) – Pads the image.
- **magnification** (*bool, optional*) – Brings the image to the magnification of reference_position.
- **aligned** (*bool, optional*) – Corrects alignment (requires alignment of projections).
- **Fourier** (*bool*) – Returns the Fourier transform of the image.

**class** dataset.**NanomaxPreprocessedTomo**(*name: str*, *path: str = '.'*, *version: str = 'master'*)
Bases: *dataset.NanomaxPreprocessed*

Class for preprocessed Nanomax tomographic datasets.

**Variables**

- **data_basename** (*str*) – File prefix to projection data files.
- **magnification_x,y** (*numpy array*) – Magnification factors for each position, horizontal, vertical
- **pixel_size_x,y** (*numpy array*) – Effective pixel size for each position
- **pixel_size** (*numpy array*) – Effective pixel size at reconstruction position

**get_projection**(*, *projection*, *position*, *pad=True*, *magnification=True*, *aligned=True*, *Fourier=False*)
Read one recorded image.

**Parameters**

- **projection** (*int*) – Number of projection to read.
- **position** (*int*) – Number of positiion ("distance") to read.
- **pad** (*bool, optional*) – Pads the image.
- **magnification** (*bool, optional*) – Brings the image to the magnification of reference_position.
- **aligned** (*bool, optional*) – Corrects alignment (requires alignment of projections).
- **Fourier** (*bool*) – Returns the Fourier transform of the image.

### parallelizer module

**class** parallelizer.**OAR**
Bases: object

Legacy class for parallellisation on OAR. Will be reimplemented as decorator

**Launch**(*dataset*, *operator*, ***kwargs*)

**WriteOarFiles**(*DS*)

parallelizer.**SLURM**(*func*)
Decorator for parallellisation on SLURM

parallelizer.**Serial**(*func*)
Decorator for serial processing. Parallelisation decorators work on functions with signature (self, *, dataset, projections)

### phaseretrieval module

### Functions:

---

**class** phaseretrieval.**CTF**(*dataset=None*, ***kwargs*)
Bases: *phaseretrieval.PhaseRetrievalAlgorithm2D*

Contrast Transfer Function [1].

#### References

[1] Cloetens et al. Appl. Phys. Lett. 75 (1999) 2912

**class** phaseretrieval.**CTFPurePhase**(*dataset=None*, ***kwargs*)
Bases: *phaseretrieval.PhaseRetrievalAlgorithm2D*

Contrast Transfer Function for pure phase objects [1].

#### References

[1] Cloetens et al. J. Phys. D: Appl. Phys 29 (1996) 133

**class** phaseretrieval.**GradientDescent**(*dataset=None*, *PSF=[]*, ***kwargs*)
Bases: *phaseretrieval.PhaseRetrievalAlgorithm2D*

Gradient descent algorithm.

**Parameters** **PSF** (*ndarray with the same shape as images*) – Point spread function (optional)

**property alpha**

**property retriever**

**class** phaseretrieval.**HIO_ER**(*dataset=None*, ***kwargs*)
Bases: *phaseretrieval.PhaseRetrievalAlgorithm2D*

Sequence of Hybrid Input Output [1] and Error Reduction [2].

**Variables**

- ***retriever*** (PhaseRetrievalAlgorithm2D) – Algorithm for initialisation
- **iterations** (*int*) – Number of global iterations
- **iterations_hio** (*int*) – Number of HIO iterations per iteration
- **iterations_er** (*int*) – Number of ER iterations per iteration
- **step_size_phase** (*float*) – Update step size for the phase
- **step_size_attenuation** (*float*) – Update step size for the attenuation

### References

[1] Fienup Appl. Opt. 21 (1982) 2758 [2] Gerchberg & Saxton Optik 35 (1972) 237

**property alpha**

**amplitude_constraint**(*wavefront*, *amplitude*, *propagator*, *mask=[]*)
Apply amplitude constraint.

**Parameters**

- **wavefront** (*complex np.array*) – Wavefront to constrain.
- **amplitude** (*np.array*) – Amplitude to impose.
- **propagator** (*complex np.array*) – Propagator corresponding to effective distance of amplitude.
- **mask** (*np.array, optional*) – Zone to apply constraint.

**Returns** **wavefront_constrained** (*complex np.array*) – Wavefront after applied constraint.

**error_estimate**(*wavefront*, *amplitude*, *propagator*, *mask=[]*)
Estimate fit to data.

**Parameters**

- **wavefront** (*complex np.array*) – Wavefront for estimation.
- **amplitude** (*np.array*) – Amplitude from measured image.
- **propagator** (*complex np.array*) – Fresnel propagator corresponding to effective propagation distance in measured image.
- **mask** (*np.array*) – Restrict estimate to a region of interest.

**Returns** **error** (*float*) – MSE calculated and measured amplitude.

**error_reduction**(*wavefront*, *support*)
One iteration of Error Reduction.

**Parameters**

- **wavefront** (*complex np.array*) – wavefront to update.
- **support** (*np.array*) – Support constraint.

**Returns** **wavefront_updated** (*complex np.array*) – Updated wavefront.

**hybrid_input_output**(*wavefront*, *initial_wavefront*, *support*, *step_size_attenuation*, *step_size_phase*)
One iteration of the Hybrid Input Output algorithm.

**Parameters**

- **wavefront** (*complex np.array*) – Constrained wavefront.
- **initial_wavefront** (*complex np.array*) – Wavefront to update.
- **support** (*np.array*) – Support of object.
- **step_size_attenuation** (*float*) – Step size for attenuation update.
- **step_size_phase** (*float*) – Step size for phase update.

**Returns** **wavefront_updated** (*complex np.array*) – Updated wavefront.

**reconstruct_projection**(*dataset*, *projection=0*, *positions=None*, *pad=False*)
Reconstruct one projection from a Dataset object and saves the result.

**Parameters**

- **dataset** (*Dataset*) – Dataset object to use (not necessarily the same as initialised).
- **projection** (*int, optional*) – Number of projection to reconstruct.
- **positions** (*int or list of ints, optional*) – Subset of positions to use for reconstruction

**Returns**

- **phase** (*np.array*) – Reconstructed phase.
- **attenuation** (*np.array*) – Reconstructed attenuation.

**property retriever**

**class** phaseretrieval.**Mixed**(*dataset*)
Bases: *phaseretrieval.PhaseRetrievalAlgorithm2D*

Mixed approach phase retrieval

---

**Note:** Legacy code to be aligned with current APIxs

---

**Lcurve**(*dataset*, *projection*)
Calculate the L-curve (for finding regularisation parameter)

**create_multimaterial_prior**(*data*)
Generate a multi-material prior from a tomographic reconstruction of a contact plane scan

---

**Note:** Legacy code to be refactored.

---

**display_Lcurve**(*dataset*)
Displays the L-curve

**get_prior**(*projection*)
Generates a prior estimate of the phase

**class** phaseretrieval.**PhaseRetrievalAlgorithm2D**(*dataset=None*, ***kwargs*)
Bases: object

Base class for 2D phase retrieval algorithms.

**Parameters**

- **dataset** (*pyphase.Dataset, optional*) – A Dataset type object.
- **shape** (*tuple of ints, optional*) – Size of images (ny, nx) for creation of frequency variables etc.

- **pixel_size** (*float, optional*) – In m.
- **distance** (*list of floats, optional*) – Effective propagation distances in m.
- **energy** (*float, optional*) – Effective energy in keV.
- **alpha** (*tuple of floats, optional*) – Regularisation parameters. First entry for LF, second for HF. Typically [1e-8, 1e-10].
- **pad** (*int*) – Padding factor (default 2).

**Variables**

- **nx** (*int*) – Number of pixels in horizontal direction.
- **ny** (*int*) – Number of pixels in horizontal direction.
- **pixel_size** (*tuple of floats*) – Pixel size [x, y] in µm.
- **ND** (*int*) – Number of positions.
- **energy** (*float*) – Energy in keV.
- **alpha** (*tuple of floats*) – First entry for LF, second for HF. Tyically [1e-8, 1e-10].
- **distance** (*numpy array*) – Effective propagation distances in m.
- **padding** (*int*) – Padding factor.
- **sample_frequency** (*float*) – Reciprocal of pixel size in lengthscale.
- ***nfx*** (*int*) – Number of samples in Fourier domain (horizontal).
- ***nfy*** (*int*) – Number of samples in Fourier domain (vertical).
- **fx** (*numpy array*) – Frequency variable (horizontal), calculated by frequency_variable.
- **fy** (*numpy array*) – Freuency variable (vertical).
- **alpha_cutoff** (*float*) – Cutoff frequency for regularization parameter in normalized frequency.
- **alpha_slope** (*float*) – Slope in regularization parameter.

### Notes

Takes either a Dataset type object with keyword dataset (which contains all necessary parameters), or parameters as above.

**property Alpha**
Image implementation of regularisation parameter (np.array)

**property Fresnel_number**
Fresnel number at each position, calculated from energy and distance (float)

**property Lambda**
Wavelength based on energy (float)

**frequency_variable**(*nfx*, *nfy*, *sample_frequency*)
Calculate frequency variables.

**Parameters**

- **nfx** (*int*) – Number of samples in x direction
- **nfy** (*int*) – Number of samples in y direction

- **sample_frequency** (*float*) – Reciprocal of pixel size in 1/m

**Returns** *nparray* – Frequency variables as an array of size [nfy, nfx, 2]

### Notes

Follows numpy FFT convention. Zero frequency at [0,0], [1:n//2] contain the positive frequencies, [n//2 + 1:] n the negative frequencies in increasing order starting from the most negative frequency.

**property nfx**

**property nfy**

**reconstruct_image**(*image*, *positions=None*, *pad=False*)
Template for reconstructing an image given as argument.

**Parameters**

- **image** (*numpy.array*) – A phase contrast image or an ndarray of images stacked along the first dimension.
- **positions** (*int or list of ints, optional*) – Subset of positions to use for reconstruction.

---

**Note:** Calls _algorithm (container purely for algorithm part).

---

**Returns**

- **phase** (*numpy.array*)
- **attenuation** (*numpy.array*)

**reconstruct_projection**(*dataset*, *projection=0*, *positions=None*, *pad=True*)
Reconstruct one projection from a Dataset object and saves the result.

**Parameters**

- **dataset** (*Dataset*) – Dataset object to use (not necessarily the same as initialised).
- **projection** (*int, optional*) – Number of projection to reconstruct.
- **positions** (*int or list of ints, optional*) – Subset of positions to use for reconstruction

**Returns**

- **phase** (*np.array*) – Reconstructed phase.
- **attenuation** (*np.array*) – Reconstructed attenuation.

**reconstruct_projections**(*, *dataset*, *projections*)
Reconstruct a range of projections (parallelized function).

**Parameters**

- **dataset** (*pyphase.Dataset*) – Dataset to reconstruct.
- **projections** (*list of int*) – In the form [start, end]

**simple_propagator**(*pxs*, *Lambda*, *z*)
Creates a Fresnel propagator.

**Parameters**

- **pxs** (*float*) – Pixel size in µm.

- **Lambda** (*float*) – Wavelength in m.
- **z** (*float*) – Effective propagation distance in m.

**Returns** **H** (*nparray*) – Fresnel propagator.

#### Notes

Temporary implementation by Y. Zhang. Will be integrated with the propagator module.

**class** phaseretrieval.**TIEHOM**(*dataset=None*, *delta_beta=500*, ***kwargs*)
Bases: *phaseretrieval.PhaseRetrievalAlgorithm2D*

Transport of Intensity Equation for homogeneous objects (or "Paganin's algorithm") [1]

**Parameters** **delta_beta** (*float, optional*) – Material dependent ratio delta over beta.

#### References

[1] Paganin et al. J. Microsc. 206 (2002) 33

**property delta_beta**
Material dependent ratio delta over beta (float).

### propagator module

**class** propagator.**CTF**(***, *dataset=None*, *shape=None*, *energy=None*, *pixel_size=None*, *pad=2*, *oversampling=4*)
Bases: *propagator.Propagator*

Propagates using the CTF. Legacy code to be aligned with Fresnel.

**PropagateProjection**(*dataset*, *projection*, *distance*)

**class** propagator.**Fresnel**(***, *dataset=None*, *shape=None*, *energy=None*, *pixel_size=None*, *pad=2*, *oversampling=4*)
Bases: *propagator.Propagator*

Propagator using Fresnel transform

**PropagateProjection**(***, *dataset=None*, *position_number=None*, *projection=None*, *phase=None*, *attenuation=None*, *position=None*, *oversampled=False*)
Propagate one projection.

**Parameters**

- **dataset** (*pyphase.Dataset, optional*) – Datset with projection data.
- **position_number** (*int, optional*) – Which position to propagate to
- **projection** (*int, optional*) – Which projection to propagate
- **phase** (*ndarray, optional*) – Phase of wave to propagate
- **attenuation** (*ndarray, optional*) – Amplitude of wave to propagate
- **position** (*float*) – Effective propagation distance
- **oversampled** (*bool*) – True if imput images are already oversampled

**class** propagator.**Propagator**(*, *dataset=None*, *shape=None*, *energy=None*, *pixel_size=None*, *pad=2*, *oversampling=4*)

Bases: object

### pyphase module

### tomography module

**class** tomography.**PyHST**

Bases: object

Tomographic operations with PyHST

**ForwardProject**(*DS*, *volume='phase'*)

Generate projections from a reconstructed dataset

**reconstruct**(*DS*, *volume='phase'*)

Tomographic reconstruction

**class** tomography.**Tomography**

Bases: object

Class for tomographic operations, for use with 3D iterative methods

**Note:** Legacy code to be aligned with current API

### utilities module

**class** utilities.**ElastixAffine**

Bases: *utilities.RegistrationAlgorithm*

Affine registration algorithm using Elastix.

**Variables**

- **parameters** (*Parameters*) – Elastix standard parameters
- **number_of_parameters** (*int, default=6*) – Number of parameters in the transform

**class** utilities.**ElastixRigid**

Bases: *utilities.RegistrationAlgorithm*

Rigid registration algorithm using Elastix.

**Variables**

- **parameters** (*Parameters*) – Elastix standard parameters
- **number_of_parameters** (*int, default=3*) – Number of parameters in the transform

**class** utilities.**ElastixSimilar**

Bases: *utilities.RegistrationAlgorithm*

Similarity transform registration algorithm using Elastix

**Variables**

- **parameters** (*Parameters*) – Elastix standard parameters
- **number_of_parameters** (*int, default=4*) – Number of parameters in the transform

**class** utilities.**ImageDisplayer**
Bases: object

Wrapper class for image display.

**class** utilities.**PyplotImageDisplayer**
Bases: *utilities.ImageDisplayer*

Interface to Pyplot for image display.

### Notes

With the idea to make the choice of display package flexible.

**close_all**()

**display**(*image*, *title=''*, *vmin=None*, *vmax=None*)
Display an image

**Parameters**

- **image** (*nparray*) – The image to be displayed.
- **title** (*str, optional*) – Title of figure.
- **vmin** (*optional*) – Lower limit of contrast range.
- **vmax** (*optional*) – Upper limit of contrast range.

**display_stack**(*stack*)

**class** utilities.**RegistrationAlgorithm**
Bases: object

Abstract class for registration algorithms

**apply_transformation**(*image*, *transform_parameters*, ***kwargs*)
Apply an image transform from image registration.

**Parameters**

- **image** (*ndarray*) – The image to transform.
- **transform_parameters** (*array*) – Parameters of the transform (length depends on registration algorithm used (number_of_parameters))

**Returns** *transformed_image* – The transformed image.

**register**(*moving_image*, *stationary_image*)
Register moving_image to stationary_image.

**Parameters**

- **moving_image** (*ndarray*) – The image to register.
- **stationary_image** (*ndarray*) – The image to register to.

**Returns**

- **field** (*ndarray*) – The calculated deformation field.
- **transformed_moving_image** (*ndarray*) – The deformed moving image.

- **transform_parameters** (*array*) – The calculated transform parameters. Lenght varies with the number of parameters in the chosen algorithm (number_of_parameters)

**class** utilities.**StackViewer**(*X*, *ax*)
Bases: object

Functionality to browse stacks.

utilities.**resize**(*image*, *shape*)
Resizes an image by either cutting out the centre or padding.

Assumes images are stored along fist dimension.

utilities.**update**(*title*, *position*, *target*)

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