qpformat Documentation

Release 0.3.5

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Contents:

Qpformat is a Python3 library for opening quantitative phase imaging data file formats. This is the documentation of qpformat version 0.3.5.

CHAPTER 1

Introduction

1.1 Why qpformat?

There is a multitude of phase-imaging techniques that inevitably comes with a broad range of quantitative phase imaging (QPI) file formats. In addition, raw data, such as digital holographic microscopy (DHM) images, must be preprocessed to access the phase encoded in the interference pattern. Qpformat provides a unified and user-friendly interface for loading QPI data. It is based on the qpimage library and thus benefits from its hdf5-based data structure (e.g. elaborate background correction, meta data management, and transparent data storage). Furthermore, qpformat can manage large datasets (e.g. many holograms in one folder) without running out of memory by means of its lazily-evaluated `SeriesData` class.

1.2 Supported file formats

Class	Storage type	Description
`SeriesFolder`	*multiple*	Folder-based wrapper file format
`SeriesHdf5HyperSpy`	hologram	HyperSpy hologram series (HDF5 format)
`SeriesHdf5Qpimage`	phase,amplitude	Qpimage series (HDF5 format)
`SeriesZipTifHolo`	hologram	Off-axis hologram series (zipped TIFF files)
`SeriesZipTifPhasics`	phase,intensity	Phasics series data (zipped "SID PHA*.tif" files)
`SingleHdf5Qpimage`	phase,amplitude	Qpimage single (HDF5 format)
`SingleNpyNumpy`	*multiple*	Numpy complex field or phase data (numpy binary format)
`SingleTifHolo`	hologram	Off-axis hologram image (TIFF format)
`SingleTifPhasics`	phase,intensity	Phasics image ("SID PHA*.tif")

CHAPTER 2

Getting started

2.1 Installing qpformat

qpformat is written in pure Python and supports Python version 3.5 and higher. qpformat depends on several other scientific Python packages, including:

- numpy,
- scipy,
- qpimage (phase data manipulation),

To install qpformat, use one of the following methods (package dependencies will be installed automatically):

- **from PyPI:** `pip install qpformat`
- **from sources:** `pip install .` or `python setup.py install`

2.2 User API

Qpformat supports *several file formats* that are categorized into *qpformat.file_formats.SingleData* (the experimental data file format contains only one phase image) and *qpformat.file_formats.SeriesData* (the experimental data file format supports multiple phase images). From these base classes, all data file formats are derived. The idea is that experimental data is not loaded into memory until the *get_qpimage* method is called which returns a `qpimage.QPImage` object.

2.2.1 Basic Usage

To extract the (unwrapped) phase from a DHM image, use the *qpformat.load_data()* method. The file format type is determined automatically by qpformat.

```
import qpformat
# The data are not loaded into memory, only the meta data is read
dataset = qpformat.load_data("/path/to/hologram_image.tif")
# Get the quantitative phase data (a qpimage.QPImage is returned)
qpi = dataset.get_qpimage()
# Get the 2D phase image data as a numpy array
phase = qpi.pha
```

The object `qpi` is an instance of `qpimage.QPImage` which comes with an elaborate set of background correction methods. Note that *`qpformat.load_data()`* accepts keyword arguments that allow to define the setup metadata as well as the hologram reconstruction parameters.

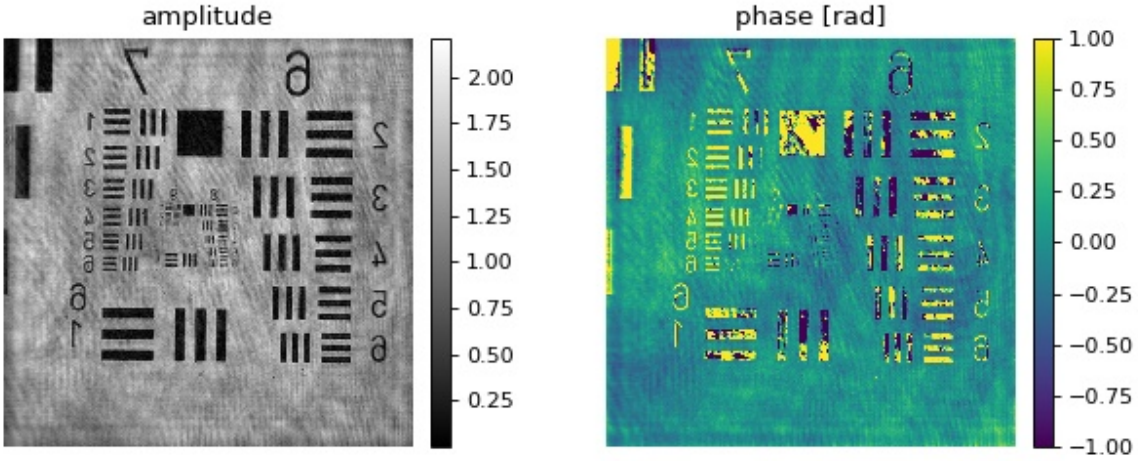
CHAPTER 3

Examples

3.1 Hologram from tif file

This example illustrates how to retrieve phase and amplitude from a hologram stored as a tif file. The experimental hologram is a U.S. Air Force test target downloaded from the Submersible Holographic Astrobiology Microscope with Ultraresolution (SHAMU) project *[BBL+17]*. The values for pixel resolution, wavelength, and reconstruction distance are taken from the corresponding Python example.

The object returned by the `get_qpimage <qpformat.file_formats.dataset.SingleData.get_qpimage()` function is an instance of `qpimage.QPImage` which allows for field refocusing. The refocused QPImage is background-corrected using a polynomial fit to the phase data at locations where the amplitude data is not attenuated (bright regions in the amplitude image).

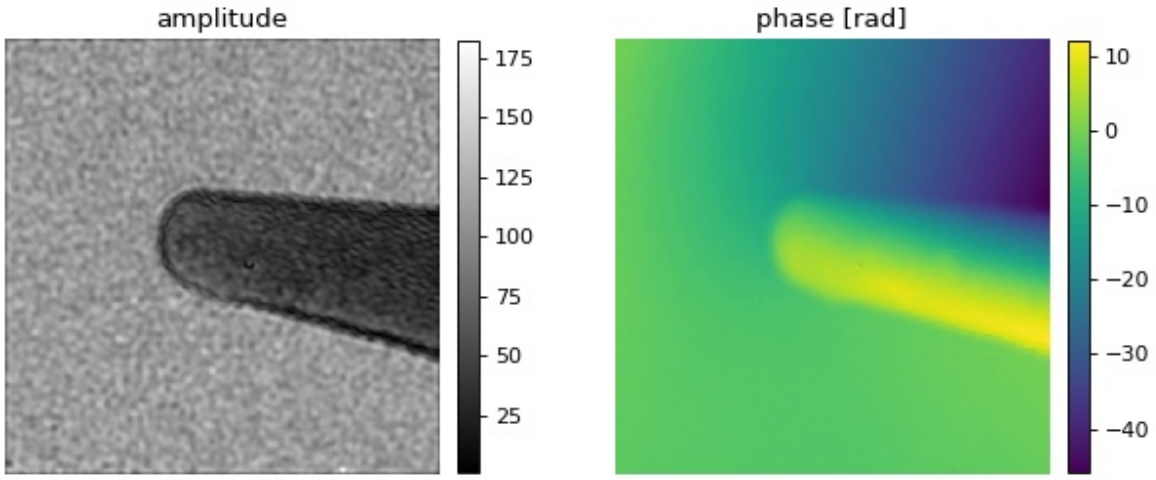


`tif_hologram.py`

```python
import urllib.request
import os

import matplotlib.pylab as plt
import qpformat


# load the experimental data
dl_loc = "https://github.com/bmorris3/shampoo/raw/master/data/"
dl_name = "USAF_test.tif"
if not os.path.exists(dl_name):
    print("Downloading {} ...".format(dl_name))
    urllib.request.urlretrieve(dl_loc + dl_name, dl_name)


ds = qpformat.load_data(dl_name,
                        # manually set meta data
                        meta_data={"pixel size": 3.45e-6,
                                   "wavelength": 405e-9,
                                   "medium index": 1},
                        # set filter size to 1/2 (defaults to 1/3)
                        # which increases the image resolution
                        holo_kw={"filter_size": .5})

# retrieve the qpimage.QPImage instance
qpi = ds.get_qpimage()
# refocus `qpi` to 0.03685m
qpi_foc = qpi.refocus(0.03685)
# perform an offset-based amplitude correction
qpi_foc.compute_bg(which_data="amplitude",
                   fit_profile="offset",
                   fit_offset="mode",
                   border_px=10,
                   )
# perform a phase correction using
# - those pixels that are not dark in the amplitude image (amp_bin) and
# - a 2D second order polynomial fit to the phase data
amp_bin = qpi_foc.amp > 1  # bright regions
qpi_foc.compute_bg(which_data="phase",
                   fit_profile="poly2o",
                   from_mask=amp_bin,
                   )

# plot results
plt.figure(figsize=(8, 3.5))
# ampltitude
ax1 = plt.subplot(121, title="amplitude")
map1 = plt.imshow(qpi_foc.amp, cmap="gray")
plt.colorbar(map1, ax=ax1, fraction=.0455, pad=0.04)
# phase in interval [-1rad, 1rad]
ax2 = plt.subplot(122, title="phase [rad]")
map2 = plt.imshow(qpi_foc.pha, vmin=-1, vmax=1)
plt.colorbar(map2, ax=ax2, fraction=.0455, pad=0.04)
# disable axes
[ax.axis("off") for ax in [ax1, ax2]]
plt.tight_layout()
plt.show()
```

3.2 HyperSpy hologram file format

This example demonstrates the import of hologram images in the HyperSpy hdf5 file format. The off-axis electron hologram shows an electrically biased Fe needle *[MLFDB15]*. The corresponding HyperSpy demo can be found here.



hyperspy_hologram.py

```
import urllib.request
import os

import matplotlib.pylab as plt
import qpformat

# load the experimental data
dl_loc = "https://github.com/hyperspy/hyperspy/raw/RELEASE_next_major/" \
         + "hyperspy/misc/holography/example_signals/"
dl_name = "01_holo_Vbp_130V_0V_bin2_crop.hdf5"
if not os.path.exists(dl_name):
    print("Downloading {} ...".format(dl_name))
    urllib.request.urlretrieve(dl_loc + dl_name, dl_name)

ds = qpformat.load_data(dl_name,
                        holo_kw={
                            # reduces ringing artifacts in the amplitude image
                            "filter_name": "smooth disk",
                            # select correct sideband
                            "sideband": -1,
                            })

# retrieve the qpimage.QPImage instance
qpi = ds.get_qpimage(0)

# plot results
plt.figure(figsize=(8, 3.5))
# ampltitude
ax1 = plt.subplot(121, title="amplitude")
map1 = plt.imshow(qpi.amp, cmap="gray")
```

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```
plt.colorbar(map1, ax=ax1, fraction=.0455, pad=0.04)
# phase in interval [-1rad, 1rad]
ax2 = plt.subplot(122, title="phase [rad]")
map2 = plt.imshow(qpi.pha)
plt.colorbar(map2, ax=ax2, fraction=.0455, pad=0.04)
# disable axes
[ax.axis("off") for ax in [ax1, ax2]]
plt.tight_layout()
plt.show()
```

3.3 Conversion of external file formats to .npy files

Sometimes the data recorded are not in a file format supported by qpformat or it is not feasible to implement a reader class for a very unique data set. In this example, QPI data, stored as a tuple of files ("*_intensity.txt" and "*_phase.txt") with commas as decimal separators, are converted to the numpy file format which is supported by qpformat.

This example must be executed with a directory as an command line argument, i.e. `python convert_txt2npy.py /path/to/folder/`

`convert_txt2npy.py`

```
import pathlib
import sys

import numpy as np


def get_paths(folder):
    '''Return *_phase.txt files in `folder`'''
    folder = pathlib.Path(folder).resolve()
    files = folder.rglob("*_phase.txt")
    return sorted(files)


def load_file(path):
    '''Load a txt data file'''
    path = pathlib.Path(path)
    data = path.open().readlines()
    # remove comments and empty lines
    data = [l for l in data if len(l.strip()) and not l.startswith("#")]
    # determine data shape
    n = len(data)
    m = len(data[0].strip().split())
    res = np.zeros((n, m), dtype=np.dtype(float))
    # write data to array, replacing comma with point decimal separator
    for ii in range(n):
        res[ii] = np.array(data[ii].strip().replace(",", ".").split(),
                           dtype=float)
    return res


def load_field(path):
    '''Load QPI data using *_phase.txt files'''
    path = pathlib.Path(path)
```

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```
    phase = load_file(path)
    inten = load_file(path.parent / (path.name[:-10] + "_intensity.txt"))
    ampli = np.sqrt(inten)
    return ampli * np.exp(1j * phase)


if __name__ == "__main__":
    path = pathlib.Path(sys.argv[-1])
    if not path.is_dir():
        raise ValueError("Command line argument must be directory!")
    # output directory
    pout = path.parent / (path.name + "_npy")
    pout.mkdir(exist_ok=True)
    # get input *_phase.txt files
    files = get_paths(path)
    # conversion
    for ff in files:
        field = load_field(ff)
        np.save(str(pout / (ff.name[:-10] + ".npy")), field)
```

3.4 Conversion of external holograms to .tif files

Qpformat can load hologram data from .tif image files. If your experimental hologram data are stored in a different file format, you can either request its implementation in qpformat by creating an issue or you can modify this example script to your needs.

This example must be executed with a directory as an command line argument, i.e. `python convert_txt2tif.py /path/to/folder/`

convert_txt2tif.py

```
import pathlib
import sys

import numpy as np
from skimage.external import tifffile

# File names ending with these strings are ignored
ignore_endswith = ['.bmp', '.npy', '.opj', '.png', '.pptx', '.py', '.svg',
                   '.tif', '.txt', '_RIdist', '_parameter', '_parameter_old',
                   '_phase', 'n_array', 'n_array_real', '~']
# uncomment this line to keep background hologram files
ignore_endswith += ['_bg']


def get_paths(folder, ignore_endswith=ignore_endswith):
    '''Return hologram file paths

    Parameters
    ----------
    folder: str or pathlib.Path
        Path to search folder
    ignore_endswith: list
        List of filename ending strings indicating which
```

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```
        files should be ignored.
    '''
    folder = pathlib.Path(folder).resolve()
    files = folder.rglob("*")
    for ie in ignore_endswith:
        files = [ff for ff in files if not ff.name.endswith(ie)]
    return sorted(files)


if __name__ == "__main__":
    path = pathlib.Path(sys.argv[-1])
    if not path.is_dir():
        raise ValueError("Command line argument must be directory!")
    # output directory
    pout = path.parent / (path.name + "_tif")
    pout.mkdir(exist_ok=True)
    # get input hologram files
    files = get_paths(path)
    # conversion
    for ff in files:
        # convert image data to uint8 (most image sensors)
        hol = np.loadtxt(str(ff), dtype=np.uint8)
        tifout = str(pout / (ff.name + ".tif"))
        # compress image data
        tifffile.imsave(tifout, hol, compress=9)
```

CHAPTER 4

Code reference

4.1 module-level

qpformat.**load_data**(*path*, *fmt=None*, *bg_data=None*, *bg_fmt=None*, *meta_data={}*, *holo_kw={}*, *as_type='float32'*)

Load experimental data

Parameters

- **path** (*str*) – Path to experimental data file or folder
- **fmt** (*str*) – The file format to use (see *file_formats.formats*). If set to *None*, the file format is be guessed.
- **bg_data** (*str*) – Path to background data file or *qpimage.QPImage*
- **bg_fmt** (*str*) – The file format to use (see *file_formats.formats*) for the background. If set to *None*, the file format is be guessed.
- **meta_data** (*dict*) – Meta data (see *qpimage.meta.DATA_KEYS*)
- **as_type** (*str*) – Defines the data type that the input data is casted to. The default is "float32" which saves memory. If high numerical accuracy is required (does not apply for a simple 2D phase analysis), set this to double precision ("float64").

Returns **dataobj** – Object that gives lazy access to the experimental data.

Return type *SeriesData* or *SingleData*

4.2 file format base classes

4.2.1 SeriesData

class qpformat.file_formats.**SeriesData**(*path*, *meta_data={}*, *holo_kw={}*, *as_type='float32'*)

Series data file format base class

Parameters

- **path** (*str or pathlib.Path*) – Path to the experimental data file.
- **meta_data** (*dict*) – Dictionary containing meta data. see qpimage.META_KEYS.
- **as_type** (*str*) – Defines the data type that the input data is casted to. The default is "float32" which saves memory. If high numerical accuracy is required (does not apply for a simple 2D phase analysis), set this to double precision ("float64").

as_type = None
Enforced dtype via keyword arguments

path = None
pathlib.Path to data file or BytesIO

meta_data = None
Enforced metadata via keyword arguments

holo_kw = None
Hologram retrieval; keyword arguments for qpimage.holo.get_field().

background_identifier = None
Unique string that identifies the background data that was set using *set_bg*.

identifier
Return a unique identifier for the given data set

get_identifier(*idx*)
Return an identifier for the data at index *idx*

get_name(*idx*)
Return name of data at index *idx*

get_qpimage(*idx*)
Return background-corrected QPImage of data at index *idx*

get_qpimage_raw(*idx*)
Return QPImage without background correction

get_time(*idx*)
Return time of data at index *idx*

saveh5(*h5file*)
Save the data set as an hdf5 file (qpimage.QPSeries format)

set_bg(*dataset*)
Set background data

Parameters **dataset** (*DataSet*, *qpimage.QPImage*, or int) – If the len(dataset) matches len(self), then background correction is performed element-wise. Otherwise, len(dataset) must be one and is used for all data of self.

See also:

get_qpimage() obtain the background corrected QPImage

static verify(*path*)
Verify that *path* has this file format

Returns *True* if the file format matches. The implementation of this method should be fast and memory efficient, because e.g. the "GroupFolder" file format depends on it.

4.2.2 SingleData

class qpformat.file_formats.**SingleData**(*path*, *meta_data={}*, *holo_kw={}*, *as_type='float32'*)
Single data file format base class

Parameters

- **path** (*str or pathlib.Path*) – Path to the experimental data file.
- **meta_data** (*dict*) – Dictionary containing meta data. see qpimage.META_KEYS.
- **as_type** (*str*) – Defines the data type that the input data is casted to. The default is "float32" which saves memory. If high numerical accuracy is required (does not apply for a simple 2D phase analysis), set this to double precision ("float64").

get_identifier(*idx=0*)
Return an identifier for the data at index *idx*

get_name(*idx=0*)
Return name of data at index *idx*

get_qpimage(*idx=0*)
Return background-corrected QPImage of data at index *idx*

get_qpimage_raw(*idx=0*)
QPImage without background correction

get_time(*idx=0*)
Time of QPImage

identifier
Return a unique identifier for the given data set

saveh5(*h5file*)
Save the data set as an hdf5 file (qpimage.QPSeries format)

set_bg(*dataset*)
Set background data

Parameters **dataset** (*DataSet*, *qpimage.QPImage*, or int) – If the len(dataset) matches len(self), then background correction is performed element-wise. Otherwise, len(dataset) must be one and is used for all data of self.

See also:

get_qpimage() obtain the background corrected QPImage

static verify(*path*)
Verify that *path* has this file format

Returns *True* if the file format matches. The implementation of this method should be fast and memory efficient, because e.g. the "GroupFolder" file format depends on it.

4.3 file format readers

All file formats inherit from *qpformat.file_formats.SeriesData* (and/or *qpformat.file_formats.SingleData*).

4.3.1 SeriesFolder

class qpformat.file_formats.**SeriesFolder**(**args*, ***kwargs*)

Folder-based wrapper file format

is_series = True

storage_type

The storage type depends on the wrapped file format

files

List of files (only supported file formats)

4.3.2 SeriesHdf5HyperSpy

class qpformat.file_formats.**SeriesHdf5HyperSpy**(*path*, *meta_data={}*, *holo_kw={}*, *as_type='float32'*)

HyperSpy hologram series (HDF5 format)

HyperSpy has its own implementation to read this file format.

is_series = True

storage_type = 'hologram'

4.3.3 SeriesHdf5Qpimage

class qpformat.file_formats.**SeriesHdf5Qpimage**(**args*, ***kwargs*)

Qpimage series (HDF5 format)

is_series = True

storage_type = 'phase,amplitude'

4.3.4 SeriesZipTifHolo

class qpformat.file_formats.**SeriesZipTifHolo**(**args*, ***kwargs*)

Off-axis hologram series (zipped TIFF files)

The data are stored as multiple TIFF files (*qpformat.file_formats.SingleTifHolo*) in a zip file.

is_series = True

storage_type = 'hologram'

files

List of hologram data file names in the input zip file

4.3.5 SeriesZipTifPhasics

class qpformat.file_formats.**SeriesZipTifPhasics**(**args*, ***kwargs*)
Phasics series data (zipped "SID PHA*.tif" files)

The data are stored as multiple TIFF files (*qpformat.file_formats.SingleTifPhasics*) in a zip file.

is_series = True

storage_type = 'phase,intensity'

files
List of Phasics tif file names in the input zip file

4.3.6 SingleHdf5Qpimage

class qpformat.file_formats.**SingleHdf5Qpimage**(*path*, *meta_data={}*, *holo_kw={}*, *as_type='float32'*)
Qpimage single (HDF5 format)

See the documentation of qpimage for more information.

is_series = False

storage_type = 'phase,amplitude'

4.3.7 SingleNpyNumpy

class qpformat.file_formats.**SingleNpyNumpy**(*path*, *meta_data={}*, *holo_kw={}*, *as_type='float32'*)
Numpy complex field or phase data (numpy binary format)

The experimental data given in *path* consist of a single 2D ndarray (no pickled objects). The ndarray is either complex-valued (scattered field) or real-valued (phase).

is_series = False

storage_type
Depending on input data type, the storage type is either "field" (complex) or "phase" (real).

4.3.8 SingleTifHolo

class qpformat.file_formats.**SingleTifHolo**(*path*, *meta_data={}*, *holo_kw={}*, *as_type='float32'*)
Off-axis hologram image (TIFF format)

is_series = False

storage_type = 'hologram'

4.3.9 SingleTifPhasics

class qpformat.file_formats.**SingleTifPhasics**(*path*, *meta_data={}*, **args*, ***kwargs*)
Phasics image ("SID PHA*.tif")

Notes

- Only the processed phase data files are supported, i.e. TIFF file names starting with "SID PHA" exported by the commercial Phasics software.
- If the "wavelength" key in *meta_data* is not set (units: [m]), then the wavelength is extracted from the xml data stored in tag "61238" of the tif file.

is_series = False

storage_type = 'phase,intensity'

4.4 exceptions

exception qpformat.file_formats.**MultipleFormatsNotSupportedError**
Used when a folder contains series file formats

(see GitHub issue #1)

exception qpformat.file_formats.**UnknownFileFormatError**
Used when a file format could not be detected

CHAPTER 5

Bilbliography

CHAPTER 6

Indices and tables

- genindex
- modindex
- search

Bibliography

[BBL+17] Manuel Bedrossian, Casey Barr, Chris A. Lindensmith, Kenneth Nealson, and Jay L. Nadeau. Quantifying microorganisms at low concentrations using digital holographic microscopy (DHM). *Journal of Visualized Experiments*, nov 2017. doi:10.3791/56343.

[MLFDB15] V. Migunov, A. London, M. Farle, and R. E. Dunin-Borkowski. Model-independent measurement of the charge density distribution along an fe atom probe needle using off-axis electron holography without mean inner potential effects. *Journal of Applied Physics*, 117(13):134301, apr 2015. doi:10.1063/1.4916609.

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