recon_PUP_FF_SOFC_hires3_S2

February 8, 2019

1 Overview

This notebook provides detailed steps for the reconstruction (including data reduction and morphology reconstruction) of proejct PUP_FF_SOFC_hires3_S2, which was taken place back in 2015.

> NOTE:
> * Currently, only the first layer (out of seven valid layers) is analyzed. * The choice of the first layer is based on the fact that it contains the tip, the poristy of which has significant impact on the FC performance.

1.1 Prepation

Import modules and define user define functions.

In [1]:
```
# -- import modules
import tomopy
import gc
import numpy   as np
import scipy   as sp
import numexpr as ne

import matplotlib.pyplot as plt

from tqdm import tnrange, tqdm_notebook
from tqdm import trange

from dxchange.reader   import read_aps_1id_metafile
from dxchange.reader   import read_tiff_stack
from dxchange.writer   import write_aps_1id_report
from dxchange.writer   import write_tiff_stack
from dxchange.writer   import write_vtr

from tomopy.prep.alignment import find_slits_corners_aps_1id
from tomopy.prep.alignment import detector_drift_adjust_aps_1id
from tomopy.prep.alignment import remove_slits_aps_1id
from tomopy.prep.normalize import minus_log
from tomopy.misc.npmath    import discrete_cdf
from tomopy.misc.npmath    import gauss1d
```

```
from scipy.signal   import medfilt
from scipy.signal   import medfilt2d
# from scipy.signal   import convolve
from scipy.optimize import curve_fit

from scipy.ndimage import gaussian_filter
from scipy.ndimage import shift
from scipy.ndimage import convolve

from scipy.special import erf, erfc

# --
import ipywidgets as widgets
from ipywidgets import interact, interactive, fixed, interact_manual, IntProgress
from IPython.display import display

# --
from matplotlib import animation, rc
from IPython.display import HTML, Image
```

```
/home/chenz3/.pyenv/versions/anaconda3-5.2.0/lib/python3.6/site-packages/skimage/transform/_wa
  warn("The default mode, 'constant', will be changed to 'reflect' in "
```

In [2]:
```
# -- svd function
def svd_enhance(img, eigen_cut=20):
    U, S, V = np.linalg.svd(img, full_matrices=True)
    eigen_cut = min(eigen_cut, U.shape[1], V.shape[0])
    return np.dot(U[:,:eigen_cut]*S[:eigen_cut], V[:eigen_cut,:])
```

In [3]:
```
# -- quick lambda function
val_atPercent = lambda ar, p: np.sort(ar.flatten())[int(np.prod(ar.shape)*p)]
wgt_histequal = lambda ar: (np.sort(ar.flatten()).searchsorted(ar) + 1)/np.prod(ar.sha
wgts_binned   = lambda wgts, bins: np.int64(np.floor(wgts * bins)).astype(wgts.dtype) 
```

1.2 Metadata processing

Process/Parse the metadata (auto-generated during scan) to extract

- beam status (various stability)
- frame quality
- connectivity bewteen rotation angle (ω) and the image sequence number
- group layers into dataframes

In [4]:
```
# ----- CONFIG BLOCK ----- #
# -- change the following based on the sample
metaf1        = "PUP_FF_SOFC_hires3_S2_TomoStillScan.dat"
sampleImgName = "PUP_FF_SOFC_hires3_S2/PUP_FF_SOFC_hires3_S2_000008.tif"
```

```
write_base    = "PUP_FF_SOFC_hires3_S2_results/PUP_FF_SOFC_hires3_S2"
reportfn      = "PUP_FF_SOFC_hires3_S2_report/scanSummary.pdf"

# -- reconstruction config
recon_config = {'algorithm': 'gridrec',
                'filter'   : 'hann',
               }

# -- build data frame and generate report
df_layers = write_aps_1id_report(read_aps_1id_metafile(metaf1), reportfn)

layerIDs = df_layers['layerID'].unique()

print(f"Unique layers are: {layerIDs}")
```

```
Unique layers are: [ 6  7  8  9 10 11 12]
```

manual select the first layer, which contains the tip

```
In [5]: layerID = 6

        df_layern = df_layers[df_layers['layerID'] == layerID]

        df_layern.describe()
```

```
Out[5]:               num         nSeq           exp       fOmega        Omega  \
        count  3631.000000  3631.000000  3.631000e+03  3631.000000  3631.000000
        mean   1786.165244  1816.000000  1.500000e-01    -1.487194    -1.487225
        std    1048.041119  1048.323741  1.015994e-14   104.810435   104.810434
        min       1.000000     1.000000  1.500000e-01  -180.000000  -180.000000
        25%     878.500000   908.500000  1.500000e-01   -92.250000   -92.250050
        50%    1786.000000  1816.000000  1.500000e-01    -1.500000    -1.500080
        75%    2693.500000  2723.500000  1.500000e-01    89.250000    89.249900
        max    3601.000000  3631.000000  1.500000e-01   180.000000   180.000000

                      ICint         IC-E1         IC-E2         IC-E3        IC-E4  \
        count  3.631000e+03   3631.000000   3631.000000   3631.000000  3631.000000
        mean   6.500000e-01  76380.527403  78185.773891  73212.141283   321.169375
        std    4.441504e-14   4045.376572   4142.571960   3879.211524    15.836482
        min    6.500000e-01      0.000000      0.000000    419.000000   284.000000
        25%    6.500000e-01  76262.000000  78056.000000  72992.000000   309.000000
        50%    6.500000e-01  76515.000000  78320.000000  73298.000000   320.000000
        75%    6.500000e-01  76965.000000  78796.000000  73905.000000   334.000000
        max    6.500000e-01  78201.000000  81453.000000  75524.000000   363.000000

               ...       bpEds      LN2temp    SRcurrent  encoderX       seqNum  \
        count  ...  3631.000000  3631.000000  3631.000000    3631.0  3631.000000
        mean   ...   -13.517194    84.220476   102.049297       0.0  1815.026990
```

```
std     ...      1.058316     0.003734     0.174000       0.0  1048.324049
min     ...    -13.574900    84.211000   101.639000       0.0     1.000000
25%     ...    -13.573100    84.218000   101.927000       0.0   907.500000
50%     ...    -13.572800    84.221000   102.052000       0.0  1815.000000
75%     ...    -13.572400    84.223000   102.170000       0.0  2722.500000
max     ...      7.125490    84.230000   102.508000       0.0  3631.000000

       layerID          TBS          VBS          BLS          BLT
count   3631.0  3631.000000  3622.000000  3631.000000  3631.000000
mean       6.0     0.987991          inf     2.105510     0.006412
std        0.0     0.052350          NaN     0.110042     0.039903
min        6.0     0.005654     0.949812     0.000000     0.004191
25%        6.0     0.985021     0.976874     2.107535     0.004288
50%        6.0     0.989150     0.977052     2.112055     0.004315
75%        6.0     0.997342     0.977191     2.114556     0.004344
max        6.0     1.019190          inf     2.147057     0.768496

[8 rows x 23 columns]
```

```
In [9]: # rotation related quantity (useful for reconstruction)
        thetas = np.radians(df_layern.loc[df_layern['type']=='still', 'Omega'].values)
        dn = int(np.pi/(thetas[1] - thetas[0]))  # assuming eaqual spacing along omega
```

1.3 Data reduction

The raw data is way to large for regular computer server to handle, therefore data reduction is necessary before further analysis.

first, generate necessary folders for subsequent analysis

```
In [8]: %%bash

        mkdir -p PUP_FF_SOFC_hires3_S2_report
        mkdir -p PUP_FF_SOFC_hires3_S2_results
        mkdir -p PUP_FF_SOFC_hires3_S2_runtime
```

second, background normalization using collected dark and white field images

```
In [9]: print(f"Reading in tiff images")
        flat_pre = read_tiff_stack(sampleImgName, df_layern.loc[df_layern['type'] == 'pre_white
        flat_pst = read_tiff_stack(sampleImgName, df_layern.loc[df_layern['type'] == 'post_whi
        dark_pst = read_tiff_stack(sampleImgName, df_layern.loc[df_layern['type'] == 'post_dar
        print(f"=> quick summary of background images for layer_{layerID}:")
        print(f"\tPre-flat  image:{flat_pre.shape} as {flat_pre.dtype}")
        print(f"\tPost-flat image:{flat_pst.shape} as {flat_pst.dtype}")
        print(f"\tPost-dark image:{dark_pst.shape} as {dark_pst.dtype}")
```

```
Reading in tiff images
=> quick summary of background images for layer_6:
        Pre-flat  image:(10, 2048, 2048) as uint16
```

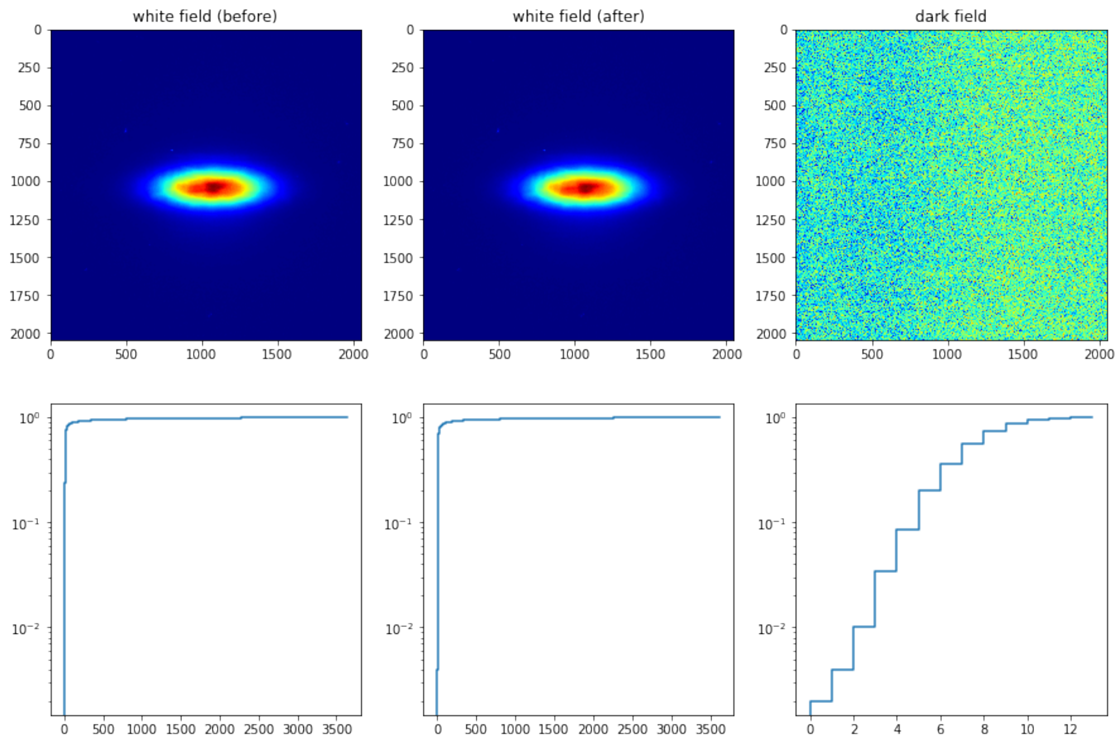
```
Post-flat image:(10, 2048, 2048) as uint16
Post-dark image:(10, 2048, 2048) as uint16
```

```
In [10]: # interactively view the flat field image
         # 10 dark, 10 white_pre, 10_white_post

         def viz_flat(n):
             fig, axes = plt.subplots(2, 3, figsize=(15, 10),)

             axes[0,0].imshow(flat_pre[n,:,:], 'jet')
             axes[0,0].set_title("white field (before)")
             xx,yy = discrete_cdf(flat_pre[n,:,:].flatten(), steps=500)
             axes[1,0].plot(xx,yy)
             axes[1,0].set_yscale('log')

             axes[0,1].imshow(flat_pst[n,:,:], 'jet')
             axes[0,1].set_title("white field (after)")
             xx,yy = discrete_cdf(flat_pst[n,:,:].flatten(), steps=500)
             axes[1,1].plot(xx,yy)
             axes[1,1].set_yscale('log')

             axes[0,2].imshow(dark_pst[n,:,:], 'jet')
             axes[0,2].set_title("dark field")
             xx,yy = discrete_cdf(dark_pst[n,:,:].flatten(), steps=500)
             axes[1,2].plot(xx,yy)
             axes[1,2].set_yscale('log')

         # -- use the template
         interactive_plot = interactive(viz_flat, n=(0, flat_pre.shape[0]-1))  # still field

         output = interactive_plot.children[-1]
         interactive_plot
```

```
interactive(children=(IntSlider(value=4, description='n', max=9), Output()), _dom_classes=('wi
```

Static view (for non-interacitve notebook mode)

```
In [11]: viz_flat(4)
```



now, it is time to read in the raw projections

NOTE: careful with the memory usage (about **30.0G** per layer).

```
In [12]: projs = read_tiff_stack(sampleImgName, df_layern.loc[df_layern['type'] == 'still',  'r
         print(f"=> quick summary of projection images for layer_{layerID}:")
         print(f"\tprojections image:{projs.shape} as {projs.dtype}")
```

```
=> quick summary of projection images for layer_6:
        projections image:(3601, 2048, 2048) as uint16
```

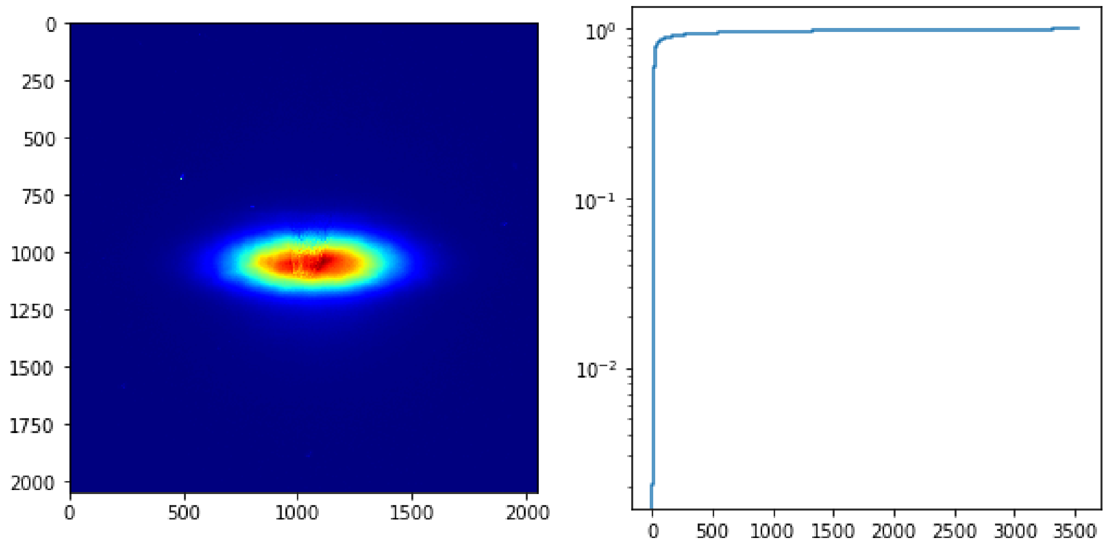
```
In [13]: # Interactive view of the projection images

         def viz_proj(n):

             fig, axes = plt.subplots(1, 2, figsize=(10, 5))

             axes[0].imshow(projs[n,:,:], 'jet')

             xx,yy = discrete_cdf(projs[n,:,:].flatten(), steps=500)
             axes[1].plot(xx,yy)
             axes[1].set_yscale('log')

         # -- use the template
```

```
interactive_plot = interactive(viz_proj, n=(0, projs.shape[0]-1))  # still field

output = interactive_plot.children[-1]
interactive_plot
```

```
interactive(children=(IntSlider(value=1800, description='n', max=3600), Output()), _dom_classes
```

static view of proejctio images (for non-interactive notebook session)

In [14]:
```
viz_proj(1800)
```



since the majority of the image is empty, it is better to isolate the region with sample to reduce total data size.

After several interactive visual inspections, the following cropping limit is selected for this layer.

- Layer_6: `img[750:1150, 800:1300]`

1.3.1 Crop down images

In [16]:
```
# get the background
bg_white = np.median(flat_pre, axis=0).astype(float)
bg_dark  = np.median(dark_pst, axis=0).astype(float)
```

In [17]:
```
bg_white = bg_white[750:1150, 800:1300]
bg_dark  = bg_dark[ 750:1150, 800:1300]
projs    = projs[:, 750:1150, 800:1300]
```

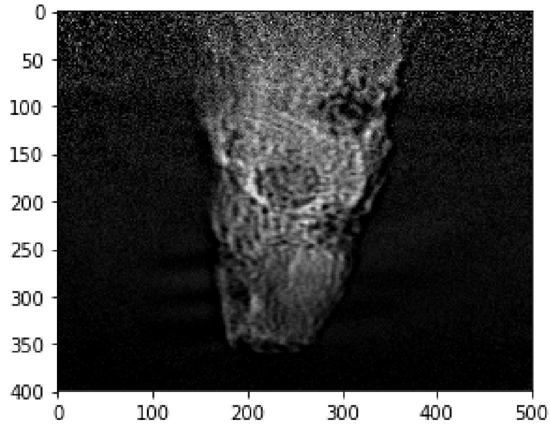
In [20]:
```
# remove the background using both white field and dark field

projs_clean = np.zeros(projs.shape)

for n in tqdm_notebook(range(projs.shape[0])):
    img = np.copy(projs[n,:,:]).astype(float)
    img = np.where(img-bg_dark>0, img-bg_dark, 0)
    bg  = np.where(bg_white-bg_dark>0, bg_white-bg_dark, 1)
    img = img/bg
    img = -np.log(np.where(img>0, img, 1))
    projs_clean[n,:,:] = np.where(img>0, img, 0)
```

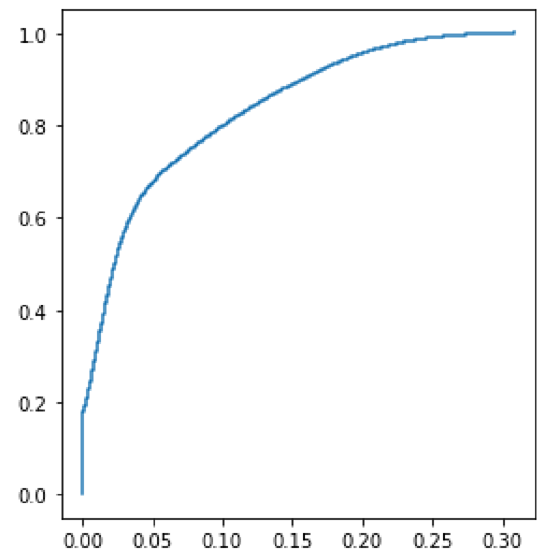
```
HBox(children=(IntProgress(value=0, max=3601), HTML(value='')))
```

In [21]:
```
# Interactive view of the projection images

def viz_proj(n):

    fig, axes = plt.subplots(1, 2, figsize=(10, 5))

    axes[0].imshow(projs_clean[n,:,:], 'gray')

    xx,yy = discrete_cdf(projs_clean[n,:,:].flatten(), steps=500)
    axes[1].plot(xx,yy)

# -- use the template
interactive_plot = interactive(viz_proj, n=(0, projs.shape[0]-1))  # still field

output = interactive_plot.children[-1]
interactive_plot
```

```
interactive(children=(IntSlider(value=1800, description='n', max=3600), Output()), _dom_classes
```

In [22]:
```
# static view
viz_proj(1800)
```





save the reduced projections and **restart kernel (manual)**

```
In [23]: np.save('PUP_FF_SOFC_hires3_S2_runtime/layer6_projs_reduced', projs_clean)
```

1.4 Tomography reconstruction

With the reduced data set, it is now possible to perform the reconstruction.

1.4.1 Counter sample jittering

Due to the experiment setup, significant sample jittering (particularly horizontal one) is present in the data set. This poses a huge issue to the tomography reconstruction process which requires a common rotation axis for all image. Consequelty, a phase correlation based correction process, termed "iterative pair-wise adjustment", is used here to counter the **horizontal** sample jittering by forcing the rotation axis of all iamge to the center of the image.

> Note: Although visible vertical sample jittering is also observed, there is currently no reliable way to counter its impact due to lack of common reference feature.

```
In [7]: # load the reduced data set

        projs = np.load('PUP_FF_SOFC_hires3_S2_runtime/layer6_projs_reduced.npy')

        for n in tqdm_notebook(range(projs.shape[0])):
            projs[n,:,:] /= projs[n,:,:].max()

        print(projs.shape)
```

```
HBox(children=(IntProgress(value=0, max=3601), HTML(value='')))
```

```
(3601, 400, 500)
```

```
In [10]: # -- center the data using iterative pairwise adjustment
         n_iters     = 10
         rot_centers = []

         for i in tqdm_notebook(range(n_iters), desc='iter'):
             # adjust the images
             for n_img in tqdm_notebook(range(int(dn)), desc='adjust'):
                 # locate the pair-wise center through PC
                 _cnt = tomopy.find_center_pc(projs[n_img,:,:],
                                              projs[n_img+dn,:,:],
                                              rotc_guess=projs.shape[2]/2,
                                             )
                 # adjust the pair images
                 # NOTE:
                 #   make sure have order=1 to force using linear interpolation to avoid negat
                 val_shift = np.array([0, projs.shape[2]/2 - _cnt])
                 projs[n_img,:,:]    = shift(projs[n_img,:,:],    val_shift, mode='constant', c
                 projs[n_img+dn,:,:] = shift(projs[n_img+dn,:,:], val_shift, mode='constant', c

             # calculate the average rotation center
             tmp = []
             for n_img in tqdm_notebook(range(int(dn)), desc='calcAvg'):
                 tmp.append(tomopy.find_center_pc(projs[n_img,:,:],
                                                  projs[n_img+dn,:,:],
                                                  rotc_guess=projs.shape[2]/2,
                                                 )
                           )
             # get the average rotation center
             _cnt = np.average(tmp)
             # if the average rotation center has been adjusted to middle, stop
             if abs(_cnt - projs.shape[2]/2)<0.1:
                 break
```

```
HBox(children=(IntProgress(value=0, description='iter', max=10, style=ProgressStyle(descriptio

HBox(children=(IntProgress(value=0, description='adjust', max=1800, style=ProgressStyle(descri

HBox(children=(IntProgress(value=0, description='calcAvg', max=1800, style=ProgressStyle(descr
```

During the analysis, it was noiticed that there are three corrupted frames, which will add necessary noise to the reconstruction results. Therefore, the pairs containing corrupted frames are excluded from the reconstruction process.

In [11]:
```
# -- gather the horizontal jitter profile (rotation center distribution)
dict_rotcnts = {}

thetas = np.radians(df_layern.loc[df_layern['type']=='still', 'Omega'].values)
dn = int(np.pi/(thetas[1] - thetas[0]))  # assuming eaqual spacing along omega

rot_centers = []
for n_img in tqdm_notebook(range(0, int(dn))):
    rot_centers.append(tomopy.find_center_pc(projs[n_img,   :,:], projs[n_img+dn,:,:]

dict_rotcnts['iterPairWiseAdjust'] = rot_centers + rot_centers

# -- find the good/bad frames
rot_cnts = np.array(dict_rotcnts['iterPairWiseAdjust'])

idx_goodimg = np.where(abs(rot_cnts -250)< 1)[0]
idx_badimg  = np.where(abs(rot_cnts -250)>=1)[0]

projs_good  = projs[idx_goodimg,:,:]
thetas_good = thetas[idx_goodimg]
rot_cnt = np.average(rot_cnts[idx_goodimg])

print(projs_good.shape, thetas_good.shape, rot_cnt, np.average(rot_cnts))
```

```
HBox(children=(IntProgress(value=0, max=1800), HTML(value='')))


(3594, 400, 500) (3594,) 249.99763494713412 249.98625
```

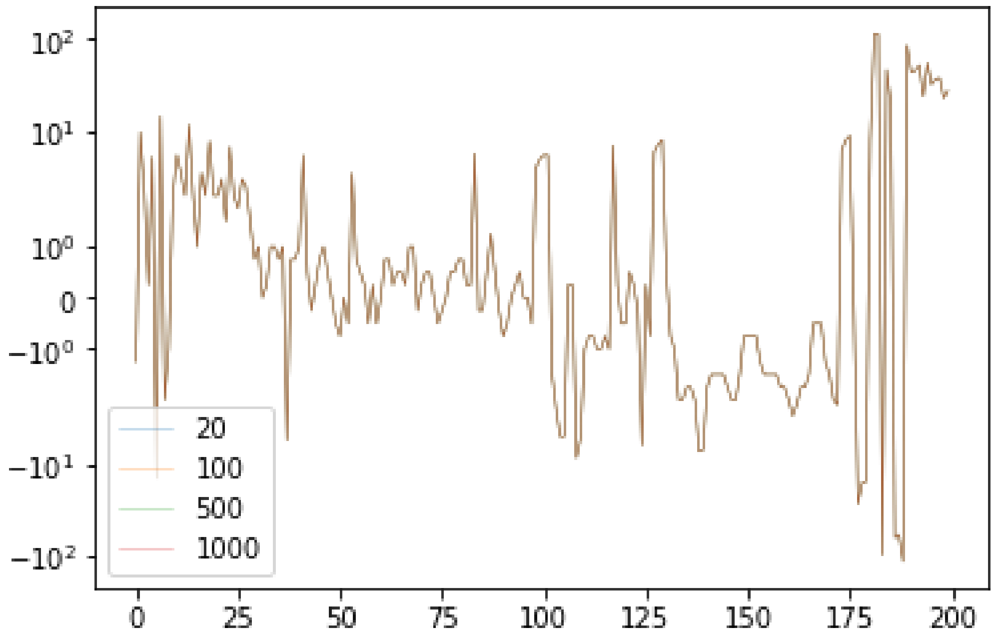
1.4.2 counter rotation axis tilt

Prelimenary analysis (see below) indicate that the rotation axis is tilted, which is most likely caused by the mis-alignment between FF detector and the sample rotation stage. In theory, the most accurate correction would be in-plane rotation to bring the 180^o-pair into a leveled position. However, due to lack of reference points, the exact rotation cannot be deterministically located. Therefore, an finite steps apprixmation is used where different rotation center is used for thin slice of data (two sinograms at a time).

In [12]:
```
# testing for single pair


nimgs = [20, 100, 500, 1000]
for nimg in nimgs:
    cnts = []
    for nrow in range(0, projs.shape[1], 2):
        cnts.append(tomopy.find_center_pc(projs[n_img,   nrow:nrow+2,:],
                                          projs[n_img+dn,nrow:nrow+2,:],
                                          rotc_guess=projs.shape[2]/2,
                                         ) - 250
```

```
                    )
        plt.plot(cnts, label=f"{nimg}", linewidth=0.5, alpha=0.5)

    plt.yscale('symlog')
    plt.legend()
```

Out[12]: <matplotlib.legend.Legend at 0x7f4718c83940>



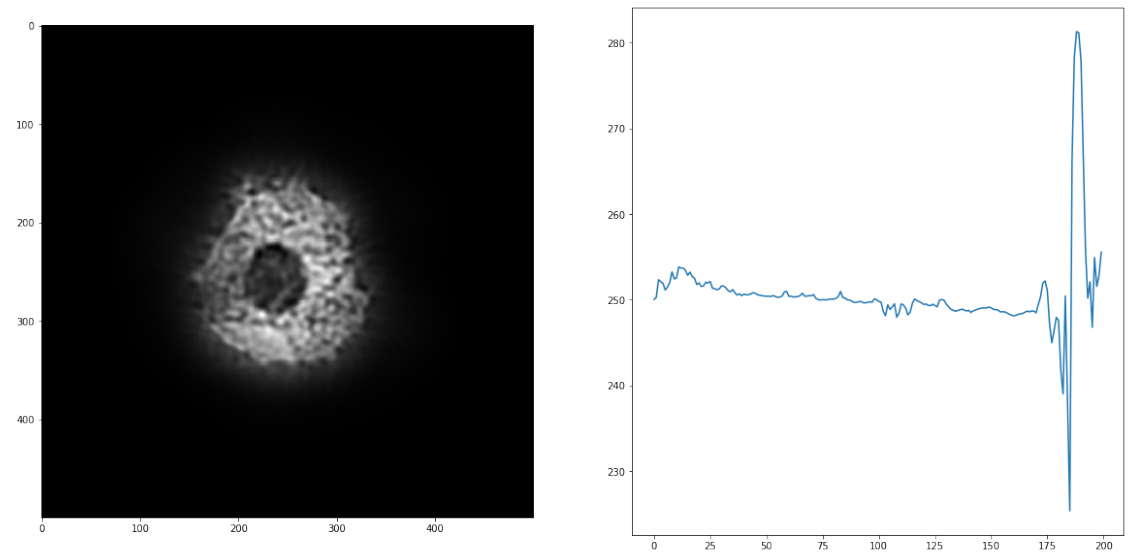
In [ ]:
```
# use slab of 16 pixels
# [32, 16, 8, 4, 2,]

size_slab = 2
recon     = np.zeros((projs.shape[1], projs.shape[2], projs.shape[2]))
rotcnts   = []

for nrow in tqdm_notebook(range(0, projs.shape[1], size_slab), desc='slab'):
    # locate the rotation center
    _projs  = projs[:,nrow:nrow+size_slab,:]
    _rotcnt = []
    for nimg in tqdm_notebook(range(dn), desc=f'r{nrow}_omega'):
        _rotcnt.append(tomopy.find_center_pc(_projs[nimg,   :,:],
                                              _projs[nimg+dn,:,:],
                                              rotc_guess=projs.shape[2]/2,
                                             ),
                      )
    _rotcnt = np.array(_rotcnt + _rotcnt)  # 180 -> 360
```

```
            # perform the reconstruction
            recon[nrow:nrow+size_slab,:,:] = tomopy.recon(projs_good[:,nrow:nrow+size_slab,:],
                                                          thetas_good,
                                                          center=np.average(_rotcnt[idx_goodimg
                                                          algorithm='gridrec', filter_name='har
                                                         )
            rotcnts.append(np.average(_rotcnt[idx_goodimg]))

        # removal phase artifacts
        recon = tomopy.circ_mask(recon, axis=0, ratio=0.6)

        phase_recon = tomopy.retrieve_phase(recon,
                                            pixel_size=2e-5,   # 200 nm pixel size on the dete
                                            dist=10,           # the notes said 36m !?
                                            energy=50,         # 45-50 keV, according to exist
                                            )

        # output to disk
        for n in tqdm_notebook(range(recon.shape[0])):

            img  = np.copy(recon[n,:,:])
            pha  = np.absolute(np.copy(phase_recon[n,:,:]))
            pha /= pha.max()

            img -= img.min()
            img /= img.max()

            msk  = gaussian_filter(pha, sigma=20)

            recon[n,:,:] = img*msk*255

        # -- write to disk
        write_tiff_stack(recon,
                         overwrite=True,
                         fname=write_base,
                         start=0,
                        )
```

In [ ]:
```
# quick sanity check
def peekrecon(n):
    fig, axes = plt.subplots(1, 2, figsize=(20,10))

    img = np.copy(recon[n,:,:])

    axes[0].imshow(img, 'gray')

    # plot the discrete rotation center
```

```
        axes[1].plot(rotcnts)


    # -- use the template
    interactive_plot = interactive(peekrecon, n=(0, recon.shape[0]-1))  # still field

    output = interactive_plot.children[-1]
    interactive_plot
```

```
In [15]: # static view
         peekrecon(199)
```



1.5 Appendix

List versions of all the modules used in this notebook environment.

> Note: Ensure reproducability of the reconstruction results.

```
In [13]: # %load https://gist.github.com/kinverarity1/6038316/raw/loaded_modules.py
         '''List loaded modules and packages, and show their version numbers
         and/or Git repository's HEAD commit SHA.

         '''
         # Standard library modules
         import types

         # Third-party packages
         import git      # GitPython
         import os
```

```python
def module_path(mod):
    '''Returns path to the file that module *mod* comes from.
    If it doesn't come from a file, return None.'''
    if hasattr(mod, '__file__'):
        return os.path.abspath(os.path.dirname(mod.__file__))
    else:
        return None


def from_git_repo(mod):
    '''Does the module *mod* reside in a Git repository?'''
    path = module_path(mod)
    if path:
        try:
            repo = git.Repo(path)
        except:
            return False
        else:
            return True
    else:
        return False


def git_path_sha(mod, slice=slice(0, 8, 1)):
    '''Return SHA hash for the HEAD commit for the repository
    that the module *mod* resides in.'''
    repo = git.Repo(module_path(mod))
    return repo.git_dir, repo.head.commit.hexsha[:8]


def module_version(mod):
    '''Return version string for module *mod*, or nothing if
    it doesn't have a "version" or "__version__" attribute.'''
    version = []
    if hasattr(mod, '__dict__'):
        keys = []
        for key in mod.__dict__.keys():
            if key.lower() == 'version' or key.lower() == '__version__':
                v = mod.__dict__[key]
                if isinstance(v, str):
                    version.append(v)
        if keys:
            print(mod, keys)
    if version:
        return ', '.join(version)
    else:
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        return ''


def find_loaded_modules(only_versioned_modules=True):
    '''Return list of loaded modules for which there is a version
    number or a Git repository commit SHA.

    Return a list of *(name, version, path_to_git_repo, git_head_sha)*,
    which has an HTML property for pretty display in IPython Notebooks.

    '''
    def list_of_lists_to_HTML(lists, header_row=None):
        '''Convert a list of a list of strings to a HTML table.'''
        s = '<table>'
        if header_row:
            s += '\n\t<tr>\n\t\t'
            s += ''.join(['<th>%s</th>' % item for item in header_row])
            s += '\n\t</tr>'
        for inner_list in lists:
            s += '\n\t<tr>\n\t\t'
            s += ''.join(['<td>%s</td>' % item for item in inner_list])
            s += '\n\t</tr>'
        s += '\n</table>'
        return s

    class LoadedModules(list):
        '''Very simple wrapper for a list of lists of strings, with an attribute
        for display in IPython Notebooks.'''
        def __init__(self, *args, **kwargs):
            list.__init__(self, *args, **kwargs)

        @property
        def HTML(self):
            from IPython.display import HTML
            return HTML(
                    list_of_lists_to_HTML(
                            self, header_row=['Name', 'Version', 'Path', 'SHA']))

    objs = LoadedModules()
    for i, mod in enumerate(globals().values()):
        if isinstance(mod, types.ModuleType):
            if hasattr(mod, '__name__'):
                name = mod.__name__
            else:
                name = ''

            if from_git_repo(mod):
                path, sha = git_path_sha(mod)
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                else:
                    path = ''
                    sha = ''

                version = module_version(mod)

                if only_versioned_modules:
                    flag = version or (path and sha)
                else:
                    flag = True

                if flag:
                    objs.append([mod.__name__, version, path, sha])
        objs.sort(key=lambda r: r[0])
        return objs
```

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In [14]: find_loaded_modules().HTML
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Out[14]: <IPython.core.display.HTML object>
```