**Espec data acquisition and analysis procedure**

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**Revisions required:**

**Mark clearly if the step should be executed before or after.**

**Package this procedure with codes needed into**

**General Comments:**

**Only use 32 bit for tilt analysis**

**The only time we use an increment of 10 is when doing tilt analysis.**

**Data Acquisition**

1. Mount the sample on top of the mirror in espec chamber and run “CTE and dndT acquisition code” using Matlab 2015a (64 bit) to initialize camera and piezo.
   1. Make sure the dividing line of reflecting and transmission is parallel to the edge of image.
   2. Make sure the reflecting, transmission and background regions have roughly equal amount of fringes (not too dense).
   3. Write down which part of image corresponds to each region.
   4. Wait patiently for first section to complete the run before starting the next section. Otherwise the program will crash.
   5. If piezo crashes, restart the stage by unplugging.
2. Wrap the shroud around the athermalized stage and screw it to hold in position. Clip the shroud.
   1. **Do not close the door yet.**
   2. Set the starting temperature on espec chamber by “setpoint” button.
   3. Crop the region in program. The middle marks of the cropping window should be on the edge of sample and on dividing line.
   4. In line 63, the background pixel is defined as (100, 100). Check value by typing figure; imagesc(getsnapshot(vidobj)); axis equal to make sure the select pixel represents background.
3. Calibrate the stage. Voltage of calibration should be ~1.47.
   1. The calibration should be done several times to make sure the value converges to 1.47. When redo calibration, run the section starting from line 34 again and the section of line 52.
4. Make a new folder, create a subfolder *PhaseMaps* in it. Save workspace.
5. Do a quick test to ensure phasemaps can be recorded. Run RecordPhaseMap for a few seconds and check if files are generated.
   1. Run line 219 to check if the fringe is good.
   2. If everything works well, delete those generated files.
   3. Cd to phasemap folder.
6. Set up the chamber. Open program **Watview. If error occurs, just keep going.**
   1. Go to **Tools –F4 profile editor.**
   2. Typically start from an old file and change time and ramp. Time means how long you are gonna run this step, and ramp means the final temperature of this step. Only change **set point channel 1**, which means temperature. Remember set point channel 2 means humidity, and we should not change that.
   3. Change profile name and save the ramp by **file-change profile name**.
   4. Go to **Controller -> send profile to controller**
   5. Use the green button on the bottom of espec chamber to check and make sure the profile is correct. Use directional keys to start the profile.
   6. Use a screw driver to manually start the fan.

18 degree

8 degree

4h

1min

A typical phasemap looks like this.

1. It may take some time for the chamber to go to a specific starting temperature and soak, so be patient. The time might be several hours.
2. Scroll the acquisition program to record phasemap section in preparation. Log temperature using thermometer. Hold rec button until “rec” pop up on screen, then press logger to start recording. Once the thermometer is logging, immediately start phasemap recording.
3. Press the green button on espec chamber and follow the directional keys on the screen to start the ramp.
4. The screen of espec chamber should no longer display “step\_x” when the whole ramp is executed.
   1. Bring up the Matlab window showing “stop data acquisition” in preparation.
   2. Stop temperature recording. Press the logger so the “rec” does not flash on screen. Then hold the green “rec” button until the word “rec” disappear on the screen.
   3. Immediately hit “stop recording phasemap” button in program.
   4. It might take a few minutes for the program to settle down. Don’t do anything to the program in the while.
   5. Shut off the chamber.

**Data Analysis**

1. After data requisition, save the Matlab workspace. We can use save([filename](https://www.mathworks.com/help/matlab/ref/save.html#inputarg_filename))  command.
2. Use “Analyze\_CTE\_dndt\_...” to do analysis. Starting from line 28 and executing the section.
3. Comment region 4 and 5 and do not use them. Normally we should just use three regions: background, transmission and reflection.
4. **Pick Points:** This step selects regions of background, transmission and reflection. Run the section to see the current region. Adjust the ranges of rows and columns in line 57/58, 93/94, 123/125 to be same size, rerun the section and make sure the regions are within the boundary and correct. The size of regions can be arbitrary but cannot be too small for accurate calculations.
5. In line 236, change f2 to number of phasemaps acquired and round to let it ends with a “3” on last digit.
   1. Comment line 245-249;
   2. Make sure lines 251-258 (tilt extraction) are commented.
   3. Change step size to 1 to do interpolation to all data and run.
6. Uncomment line 289-302, comment line 240-249. Cd to phasemap folder and run section. This section extracts pixels from three regions.
7. Excel manipulation:
   1. Use the old excel file (typically excel\_mm\_dd\_year) as a template.
   2. Clean up the data from previous measurements.
   3. Retrieve SD card from thermometer. Copy only the temperature readings of the probes used (usually place, date, time, probe value 1-4) into the corresponding columns in the old excel file.
   4. Clean up unused columns of the old excel file, drag the “time” column down to have same size of temperature column, and see if the temperature plot makes sense.
8. Copy the saved workspace, temperature data and analysis code to the same folder.
9. Make a new variable in matlab (i.e. excel\_5\_8\_2017).
   1. Set excel\_5\_8\_2017 = 1.
   2. Open up the variable in matlab.
   3. Copy and paste time column + 4 temperature columns from excel into the variable.
10. In line 1-18, use ctrl+F to replace the old variable name by excel\_5\_8\_2017.
    1. Run section starting from line 19 to see if the temperature plot is correct. Magenta is the air temperature and might be slightly higher, but the other three colors should look the same.
    2. Save workspace.
11. Tilt extraction: using **32 bit** matlab (2014b)
    1. Load the saved workspace. Copy all pumaho files into phasemap folder. The files can be found by dragging down to the bottom of old folders.
    2. Uncomment line 251-258 (puma code).
    3. Change step size to 10.
    4. Comment line 289-302 and run.
    5. Save workspace again
12. Line up time stamps:
    1. Comment line 241 to 249.
    2. Uncomment line 243.
    3. Change step size to 1 and run the section.
    4. Type time = 24.\*(time-time(1)) in command line. Check max(time) should approximately equal to max(timetab). Time is the creation time of phasemaps (accurate to seconds), and timetab is the time when temperature is recorded by Omega thermocouple.
13. Interpolation the temperature
    1. Comment line 243
    2. Uncomment line 245-249 and run the program.
    3. Check figure; plot (time, TSmease); hold on; plot(time,TAmeas); hold off; to make sure the temperature is interpolated.
14. Interpolating tilt (it is taken every 10th phasemap to save storage space):
    1. In line 331, change the upper limit to match number of phasemaps.
    2. Uncomment line 339.
    3. Run line 330-339.
    4. Run line 325-329. This section scales interpolated tilt by 1/2nk.
    5. Save workspace.
15. In line 413, change the number of bbb to a number close to the number of phasemap and run. This section plot the unwrapped phase per pixel as the temperature changes. Notice all pixels in select regions are plotted, and each pixel corresponds to a single line in plot. Ideally, the plot should be relatively smooth (no abrupt change in phase) and looks the same (homogeneity). If there is an abrupt change in phase, something might be wrong with the pixel on CCD.
    1. Save workspace.
16. Make sure the folder contains checkderiv.m and MakeCTE.m files.
17. This section selects the smoothest phase.
    1. In line 42-44 of **checkderiv.m**, change ofst (lower bound) and stopshft (upper bound). The good pixels are shown in black.
    2. In line 42-44 of checkderiv.m, change threshold values. A lower threshold value means more selective.
18. In line 45, 47, 48 of “**Analyze\_CTE\_and\_dndT.m**”, replace the values of variables **bg\_ww, trans\_ww** and **ref\_ww** by **what\_bg\_pxls, what\_trans\_pxls** and **what\_ref\_pxls** and run the section. The phasemap should now display good pixels in red and the center of pixels by the a black circle.
19. Go to MackeCTE.m.
    1. In MakeCTE line 44, change t0 to the thickness of sample in microns, and n0 to the base index of sample.
    2. In MakeCTE, change the values of line 97 and 98 and run the function.

**Q&A**

Q: Fringes vibrate a lot, what can be the problem?

A: vibration isolation is not working. Optics might in contact with espec chamber. Pump the feet.

Q: What should be replaced if we want IR measurements?

A: we should the replace the 6 visible anti reflection windows by 3 IR anti reflection windows. The windows are located in the first drawer.