

# Phono3py

## Introduction

This GPL software calculates phonon-phonon interactions via the third order force constants. It allows to obtain lattice thermal conductivity, phonon lifetime/linewidth, imaginary part of self energy at the lowest order, joint density of states (JDOS) and weighted-JDOS. For details see Phys. Rev. B 91, 094306 (2015) and <http://atztego.github.io/phono3py/index.html>

Load the phono3py/0.9.14-ictce-7.3.5-Python-2.7.9 module

```
$ module load phono3py/0.9.14-ictce-7.3.5-Python-2.7.9
```

## Example of calculating thermal conductivity of Si using VASP code.

### Calculating force constants

One needs to calculate second order and third order force constants using the diamond structure of silicon stored in POSCAR (the same form as in VASP) using single displacement calculations within supercell.

```
$ cat POSCAR Si 1.0 5.4335600309153529 0.0000000000000000 0.0000000000000000
0.0000000000000000 5.4335600309153529 0.0000000000000000
0.0000000000000000 0.0000000000000000 5.4335600309153529 Si
8 Direct 0.8750000000000000 0.8750000000000000 0.8750000000000000
0.8750000000000000 0.3750000000000000 0.3750000000000000
0.3750000000000000 0.8750000000000000 0.3750000000000000
0.3750000000000000 0.3750000000000000 0.8750000000000000
0.1250000000000000 0.1250000000000000 0.1250000000000000
0.1250000000000000 0.6250000000000000 0.6250000000000000
0.6250000000000000 0.1250000000000000 0.6250000000000000
0.6250000000000000 0.6250000000000000 0.1250000000000000
```

### Generating displacement using 2x2x2 supercell for both second and third order force constants

```
$ phono3py -d --dim="2 2 2" -c POSCAR
```

111 displacements is created stored in disp\_fc3.yaml, and the structure input files with this displacements are POSCAR-00XXX, where the XXX=111.

```
disp_fc3.yaml POSCAR-00008 POSCAR-00017 POSCAR-00026 POSCAR-00035 POSCAR-00044 POSCAR-00053
POSCAR POSCAR-00009 POSCAR-00018 POSCAR-00027 POSCAR-00036 POSCAR-00045 POSCAR-00054
POSCAR-00001 POSCAR-00010 POSCAR-00019 POSCAR-00028 POSCAR-00037 POSCAR-00046 POSCAR-00055
```

```

POSCAR-00002 POSCAR-00011 POSCAR-00020 POSCAR-00029 POSCAR-00038 POSCAR-00047 POSCAR-00056
POSCAR-00003 POSCAR-00012 POSCAR-00021 POSCAR-00030 POSCAR-00039 POSCAR-00048 POSCAR-00057
POSCAR-00004 POSCAR-00013 POSCAR-00022 POSCAR-00031 POSCAR-00040 POSCAR-00049 POSCAR-00058
POSCAR-00005 POSCAR-00014 POSCAR-00023 POSCAR-00032 POSCAR-00041 POSCAR-00050 POSCAR-00059
POSCAR-00006 POSCAR-00015 POSCAR-00024 POSCAR-00033 POSCAR-00042 POSCAR-00051 POSCAR-00060
POSCAR-00007 POSCAR-00016 POSCAR-00025 POSCAR-00034 POSCAR-00043 POSCAR-00052 POSCAR-00061

```

For each displacement the forces needs to be calculated, i.e. in form of the output file of VASP (vasprun.xml). For a single VASP calculations one needs KPOINTS, POTCAR, INCAR in your case directory (where you have POSCARS) and those 111 displacements calculations can be generated by prepare.sh script. Then each of the single 111 calculations is submitted run.sh by submit.sh.

```

$ ./prepare.sh $ls disp-00001 disp-00009 disp-00017 disp-00025 disp-00033 disp-00041 disp-00049
disp-00002 disp-00010 disp-00018 disp-00026 disp-00034 disp-00042 disp-00050 disp-00058 d
disp-00003 disp-00011 disp-00019 disp-00027 disp-00035 disp-00043 disp-00051 disp-00059 d
disp-00004 disp-00012 disp-00020 disp-00028 disp-00036 disp-00044 disp-00052 disp-00060 d
disp-00005 disp-00013 disp-00021 disp-00029 disp-00037 disp-00045 disp-00053 disp-00061 d
disp-00006 disp-00014 disp-00022 disp-00030 disp-00038 disp-00046 disp-00054 disp-00062 d
disp-00007 disp-00015 disp-00023 disp-00031 disp-00039 disp-00047 disp-00055 disp-00063 d
disp-00008 disp-00016 disp-00024 disp-00032 disp-00040 disp-00048 disp-00056 disp-00064 d

```

Taylor your run.sh script to fit into your project and other needs and submit all 111 calculations using submit.sh script

```
$ ./submit.sh
```

## Collecting results and post-processing with phono3py

Once all jobs are finished and vasprun.xml is created in each disp-XXXXX directory the collection is done by

```
$ phono3py --cf3 disp-{00001..00111}/vasprun.xml
```

and disp\_fc2.yaml, FORCES\_FC2, FORCES\_FC3 and disp\_fc3.yaml should appear and put into the hdf format by

```
$ phono3py --dim="2 2 2" -c POSCAR
```

resulting in fc2.hdf5 and fc3.hdf5

## Thermal conductivity

The phonon lifetime calculations takes some time, however is independent on grid points, so could be splitted:

```
$ phono3py --fc3 --fc2 --dim="2 2 2" --mesh="9 9 9" --sigma 0.1
--wgp
```

### Inspecting ir\_grid\_points.yaml

```
$ grep grid_point ir_grid_points.yaml num_reduced_ir_grid_points:
35 ir_grid_points: # [address, weight] - grid_point: 0 -
grid_point: 1 - grid_point: 2 - grid_point: 3 - grid_point: 4 -
grid_point: 10 - grid_point: 11 - grid_point: 12 - grid_point: 13 -
grid_point: 20 - grid_point: 21 - grid_point: 22 - grid_point: 30 -
grid_point: 31 - grid_point: 40 - grid_point: 91 - grid_point: 92 -
grid_point: 93 - grid_point: 94 - grid_point: 101 - grid_point: 102
- grid_point: 103 - grid_point: 111 - grid_point: 112 - grid_point:
121 - grid_point: 182 - grid_point: 183 - grid_point: 184 -
grid_point: 192 - grid_point: 193 - grid_point: 202 - grid_point:
273 - grid_point: 274 - grid_point: 283 - grid_point: 364
```

one finds which grid points needed to be calculated, for instance using following

```
$ phono3py --fc3 --fc2 --dim="2 2 2" --mesh="9 9 9" -c POSCAR --sigma
0.1 --br --write-gamma --gp="0 1 2"
```

one calculates grid points 0, 1, 2. To automate one can use for instance scripts to submit 5 points in series, see gofree-cond1.sh

```
$ qsub gofree-cond1.sh
```

Finally the thermal conductivity result is produced by grouping single conductivity per grid calculations using

```
$ phono3py --fc3 --fc2 --dim="2 2 2" --mesh="9 9 9" --br --read_gamma
```