

Hands-on introduction of OpenMX – Lecture –

Ozaki group
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Schedule:
14:30~15:30 Lecture
15:50~17:20 Practice

Outline

- Introduction : Basic OpenMX
 - What is OpenMX ?
 - What can OpenMX do ?
- Install OpenMX
- Input file
 - Keywords
 - OpenMX viewer
- Run, Parallelization
- Output
 - Standard output and *.out file
 - Visualization
 - Post process
- Remarks and Tips for OpenMX
- Post query into OpenMX forum

What is OpenMX

First-principles program package based on density functional theory with

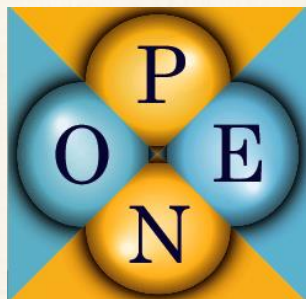
pseudopotentials

and

numerical local orbitals basis set

Reduce numerical cost by using carefully constructed potential for the valence electrons

Describe efficiently Kohn-Sham orbitals in atomic, molecular, solid systems.



Open source package for Material eXplorer

Main developer : T. Ozaki

More than 20 contributors

<http://www.openmx-square.org/>

What can OpenMX do ?

- Total energy, charge/spin density, force, stress
- Band, DOS, PDOS, Fermi surface, Wannier function
- Variable-cell MD, structural optimization, reaction path (NEB)
- LDA, GGA, vdW functional, DFT+U
- Non-collinear magnetism, spin-orbit coupling
- Order-N
- Electronic transport with NEGF method
- Spin-Spin coupling constant
- Unfolding of band structure of surface, interface, etc.
- OpenMP + MPI hybrid parallelism
- Visualization and GUI input generation
- Etc.

Install OpenMX : Download

Welcome to OpenMX
Open source package for Materials

Contents

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[International Summer Workshop for July 2nd-12th, 2018](#)
[Patch \(Ver. 3.8.5\) to OpenMX Ver. 3.8 \(June 12, 2018\)](#)

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Up

Download of OpenMX

Available packages in terms of [GNU-GPL](#)

- [openmx3.8](#) (release date: 03/April/2016, 136 MB) + [patch](#) (12/June/2018) [README.txt](#)
- [openmx3.7](#) (release date: 23/May/2013, 112 MB) + [patch](#) (21/Feb./2015) [README.txt](#)
- [openmx3.6](#) (release date: 10/Nov./2011, 079 MB) + [patch](#) (14/Nov./2011) [README.txt](#)

```
$ tar xzvf openmx3.8.tar.gz
$ cd openmx3.8/source
$ tar xzvf ../../patch3.8.5.tar.gz
```

- `source/` : source code for OpenMX (C & fortran)
- `work/` : sample inputs
- `DFT_DATA13/` : pseudo potential & basis set

Build OpenMX

Edit makefile in source/directory to apply your system

Macro for make command

- CC : C compiler and compile option.
E.g./ mpicc -fopenmp -O3 -I /usr/local/include/ -Dscalapack
- FC : fortran compiler and compile option
E.g./ mpif90 -fopenmp -O3 -I /usr/local
- LIB : linker option
E.g./ -mkl=parallel -lmpi_f90 -lmpi_f77

```
$ make all
```

- openmx : Main program
- bandgnu13 : Utility for plotting band structure
- DosMain : Utility for DOS and PDOS
- jx : Utility for exchange (spin-spin) coupling
- bin2txt, cube2xsf, md2axsf : File-format converter

Input file : General rule of Keywords

```
#
# File Name
#
System.CurrentDirectory ./ # default=./
System.Name GaAs
level.of.stdout 1 # default=1 (1-3)
level.of.fileout 1 # default=1 (0-2)
```

Key.Word Value

```
#
#
# Definition of Atomic Species
#
```

comment

```
Species.Number 3
<Definition.of.Atomic.Species
Ga Ga7.0-s2p2d1 Ga_CA13
As As7.0-s2p2d1 As_CA13
proj As7.0-s1p1d1 As_CA13
Definition.of.Atomic.Species>
```

<Key.Word.List
Value1a Value1b Value1c
Value2a Value2b Value2c
Value3a Value3b Value3c
Key.word.List>

Uppercase and Lowercase are not distinguished.

Keyword for path, title, IO

Full path or relative path to DFT_DATA13 (pseudopotentials)

The label of output files:

GaAs.out, GaAs.md, GaAs.Band, ...

```
DATA.PATH  /home/public/program/openmx3.8/DFT_DATA13/
System.CurrentDirectory  ./  # default=./
System.Name              mgb2
level.of.stdout          1   # default=1 (1-3)
level.of.fileout         1   # default=1 (0-2)
```

Amount of output data:

It should be ≥ 1 if we want to produce some volumetric files (charge-density, potential, etc.).

Keyword for atomic species and structure

Basis file DFT_DATA13/PAO/B7.0.pao
(omitting .pao)

“7.0” is the radius of basis

Pseudopotential file
DFT_DATA13/VPS/B_PBE13.vps
(omitting “.vps”)

Functional (GGA-PBE)

```
Species.Number 4
<Definition.of.Atomic.Species
  B B7.0-s2p2d1 B_PBE13
  Mg Mg7.0-s3p3d2 Mg_PBE13
Definition.of.Atomic.Species>
Atoms.Number 3
Atoms.SpeciesAndCoordinates.Unit Ang
<Atoms.SpeciesAndCoordinates
1 Mg 0.000000 0.000000 0.000000 4.000000 4.000000
2 B 1.542500 0.890563 1.761500 1.500000 1.500000
3 B 0.000000 1.781126 1.761500 1.500000 1.500000
Atoms.SpeciesAndCoordinates>
Atoms.UnitVectors.Unit Ang
<Atoms.UnitVectors
 3.085000 0.000000 0.000000  $\vec{a}_1$ 
-1.542500 2.671688 0.000000  $\vec{a}_2$ 
 0.000000 0.000000 3.523000  $\vec{a}_3$ 
Atoms.UnitVectors>
```

Basis
configuration

Atomic position

Occupation for
initial guess

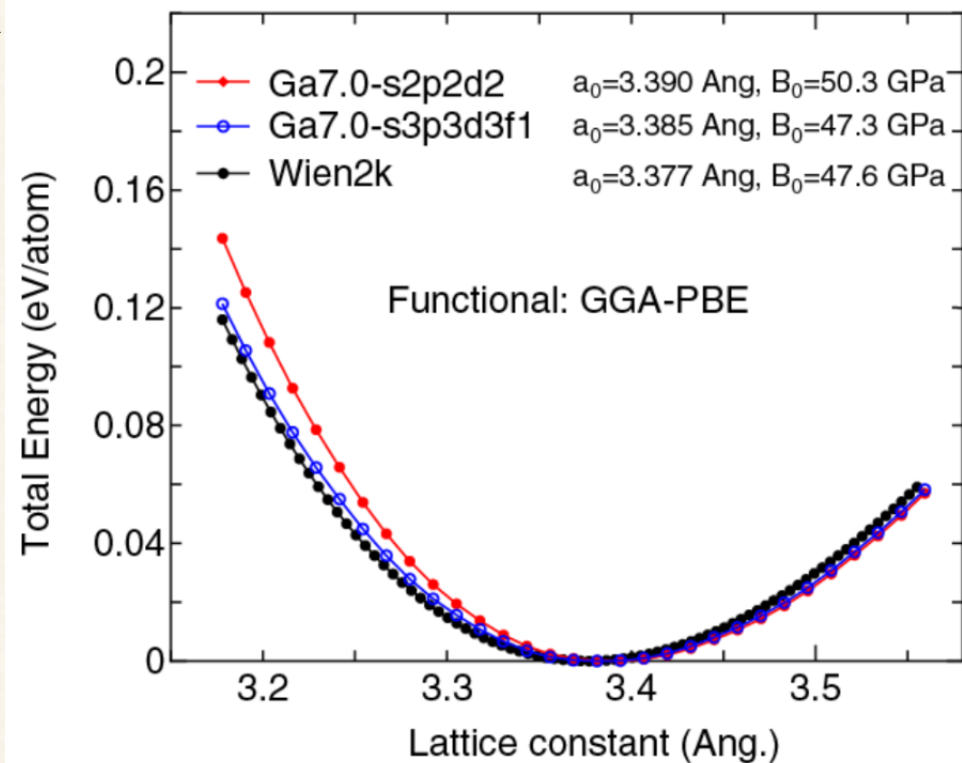
How we choose basis configuration ?

(1) Follow the configuration in literature if we reproduce it.

(2) Suggestion in the OpenMX Web page

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 - ADPACK



(3) Input file generator in OpenMX Viewer, etc.

→ It will be shown in this lecture and practice.

Condition of DFT calculation

Cutoff energy for FFT grid.
Small “scf.energycutoff” causes bad SCF convergence (See manual).

```

scf.XcType          GGA-PBE      # LDA|LSDA-CA|LSDA-PW|GGA-PBE
scf.SpinPolarization off        # On|Off|NC
scf.SpinOrbit.Coupling off       # On|Off, default=off
scf.energycutoff    300.0        # default=150 (Ry)
scf.EigenvalueSolver band       # DC|GDC|Cluster|Band
scf.ElectronicTemperature 5000.0 # default=300 (K)
scf.Kgrid           14 14 10    # means n1 x n2 x n3
  
```

Denser k -grid is required for metallic system.

For the Brillouin-zone integration.
It is not the same as the real temperature.

12/31 Input Keyword for convergence

SCF convergence

```
scf.maxIter          50          # default=40
scf.criterion        1.0e-7      # default=1.0e-6 (Hartree)
scf.Init.Mixing.Weight 0.20      # default=0.30
scf.Min.Mixing.Weight 0.001     # default=0.001
scf.Max.Mixing.Weight 0.500     # default=0.40
scf.Mixing.History    7          # default=5
scf.Mixing.StartPulay 7          # default=6
scf.Mixing.EveryPulay 1          # default=6
```

For good convergence:

- Small mixing
- Large mixing history
- Large startpulay
- Large electronic temperature
- Large enegycutoff

**See section
“SCF convergence”
In OpenMX manual**

Structural optimization

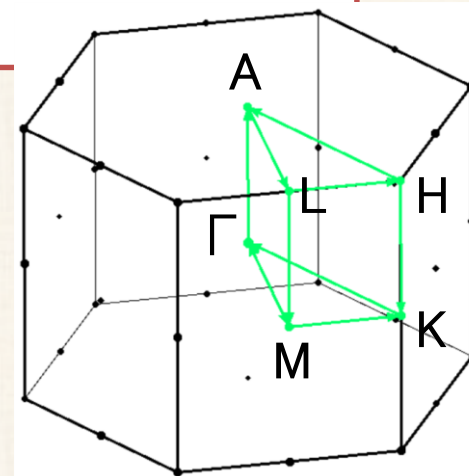
```
MD.Type      OPT
MD.Opt.DIIS.History    3
MD.Opt.StartDIIS      30
MD.Opt.EveryDIIS      200
MD.maxIter           100
MD.Opt.criterion      0.0005
MD.Opt.Init.Hessian    Schlegel # Schlegel|iden
```

Keyword for post process (1)

```
scf.restart      on
orbitalOpt.Force.Skip  on
```

The post-process should be separated from the SCF calculation

```
Band.dispersion      off
Band.Nkpath  9
<Band.kpath
11  0.000000  0.000000  0.000000  0.500000  0.000000  0.000000  GAMMA M
6   0.500000  0.000000  0.000000  0.333333  0.333333  0.000000  M K
13  0.333333  0.333333  0.000000  0.000000  0.000000  0.000000  K GAMMA
8   0.000000  0.000000  0.000000  0.000000  0.000000  0.500000  GAMMA A
11  0.000000  0.000000  0.500000  0.500000  0.000000  0.500000  A L
6   0.500000  0.000000  0.500000  0.333333  0.333333  0.500000  L H
13  0.333333  0.333333  0.500000  0.000000  0.000000  0.500000  H A
8   0.500000  0.000000  0.500000  0.500000  0.000000  0.000000  L M
8   0.333333  0.333333  0.500000  0.333333  0.333333  0.000000  H K
Band.kpath>
```



Keyword for post process (2)

DOS, PDOS

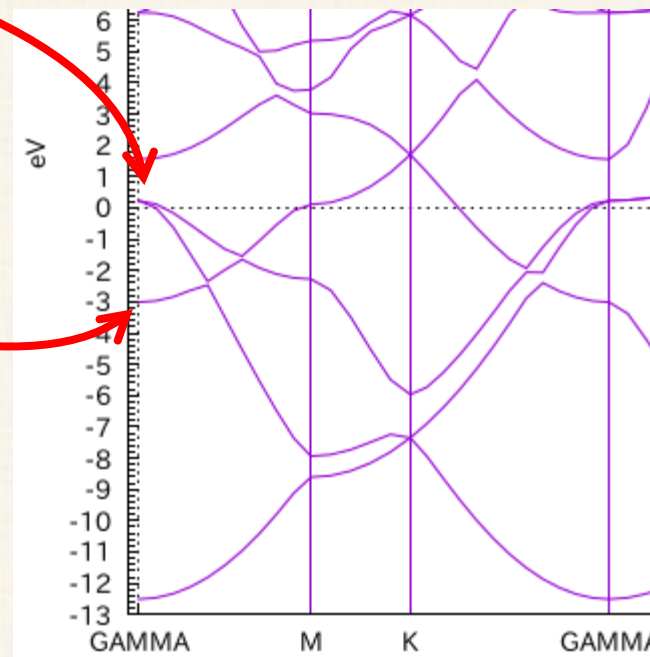
```
Dos.fileout      on
Dos.Erange      -3.0  3.0
Dos.Kgrid       28 28 20
```

Energy range is measured from E_F

k -grid for DOS should be denser than that for SCF (e.g. twice as large as)

Display Kohn-Sham orbitals

```
MO.fileout on
num.LUMOs  2
num.HOMOs  1
MO.Nkpoint 1
<MO.kpoint
0.0  0.0  0.0
MO.kpoint>
```



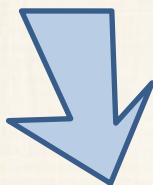
How can we generate input file ?

(1) Write input-file by our own hand.

(2) Generate input file from CIF (Crystallographic information format) file

(a) Get CIF file from any database.

- ICSD (Commercial)
- Crystallography Open Database (<http://www.crystallography.net/cod/>)
- AtomWork (<http://crystdb.nims.go.jp/>) : requires sign-up
- Etc.



- OpenMX Viewer (<http://www.openmx-square.org/>)
- C-Tools (<https://sourceforge.net/projects/c-tools/>)
- Python script by kawamura



Input generator in OpenMX Viewer

The image shows a screenshot of the OpenMX Viewer web application. The main window displays a 3D molecular model with several atoms represented as spheres (yellow and green) on a black background. A pink arrow points from a file explorer window on the right to the model, indicating a drag-and-drop action. A blue arrow points from a 'select' dropdown menu at the bottom to the model. The file explorer window shows a directory with files like `nscf.out`, `scf.out`, `band.gp`, `taas.cif`, `taas.xyz`, `test.xsf`, `bands.out.gnu`, `anime.gif`, `bands.out.rap`, `taas.save`, and `taas_rst`. The OpenMX Viewer interface includes a toolbar at the bottom with various options like `Reset`, `Supercell`, `Atoms rendering`, `Bonds rendering`, `Bond Color`, `Atom Size`, `Bond Thickness`, `Bond Factor`, `Cells`, `Axes`, `Perspective`, `Spin`, `Force`, `Velocity`, `Rot on x`, `Rot on y`, `Rot on z`, `Save`, `OpenMX website`, `Rotate: click+drag`, `Zoom: scroll`, `Translate: ctrl+click+drag`, `Note: click`, `select`, `xyz`, `cif`, `OMX (xyz)`, `OMX (frac)`, `Number`, `Symbol`, `BGC black`, `Dynamics`, `Net Charge off`, `Examples select`, and `button for Safari`.

Drag & Drop

Run

```
$ mpirun -np 7 openmx input-file -nt 4
```

Parallelization:

- MPI parallelization for atoms
- MPI for k-parallelization
- Eigenvalue solver (ELPA)
- Real-space grid (FFT etc.)
- Frequency in NEGF
- More parallelization in $O(N)$
- Etc.

Outputs

- Standard output, *.out file
- Structural data
 - *.md, *.md2
- Volumetric data
 - Charge/Spin density, potential, Orbital
- Post-processing
 - Band
 - Dos, Partial DOS

Standard output

Check the progress of the SCF calculation from the standard output.

```

***** MD= 1  SCF= 4 *****
<Poisson> Poisson's equation using FFT...
<Set_Hamiltonian> Hamiltonian matrix for VNA+dVH+Vxc...
<Band> Solving the eigenvalue problem...
KGrids1:  -0.46428  -0.39286  -0.32143  -0.25000  -0.17857  -0.10714  ...
KGrids2:  -0.46429  -0.39286  -0.32143  -0.25000  -0.17857  -0.10714  ...
KGrids3:  -0.45000  -0.35000  -0.25000  -0.15000  -0.05000   0.05000  ...
<Band_DFT> Eigen, time=2.525886
<Band_DFT> DM, time=7.088623
   1   Mg  MulP   4.0500  4.0500 sum   8.1000
   2    B  MulP   1.4750  1.4750 sum   2.9500
   3    B  MulP   1.4750  1.4750 sum   2.9500
Sum of MulP: up    =    7.00000 down    =    7.00000
              total=   14.00000 ideal(neutral)=   14.00000
<DFT> Total Spin Moment (muB) =  0.000000000000
<DFT> Mixing_weight= 0.400000000000
<DFT> Uele   = -14.134678018779  dUele    =  0.012438791157
<DFT> NormRD =  0.127025852654  Criterion = 0.000001000000

```

XXX.out file

Output

This file is generated at the end of the calculation.

- SCF history
- Structure optimization/MD history
- Each contribution of the total energy
- All eigenvalues, eigenvectors (optional)
- Mulliken populations
- Computational time at each procedure

When we browse with “less” command,
We can jump each section as :

`/¥*` ↩

```

*****
*****
                SCF history at MD= 1
*****
*****

SCF=  1  NormRD=  1.000000000000  Uele= -14.025400095131
SCF=  2  NormRD=  0.589538767138  Uele= -14.093890088826
SCF=  3  NormRD=  0.249943520955  Uele= -14.122239457714
SCF=  4  NormRD=  0.127025831723  Uele= -14.134678255608
SCF=  5  NormRD=  0.073388775646  Uele= -14.140692161282
SCF=  6  NormRD=  0.044342510992  Uele= -14.144151844345
SCF=  7  NormRD=  0.027111841578  Uele= -14.146375438069
SCF=  8  NormRD=  0.016634903597  Uele= -14.147860482646
SCF=  9  NormRD=  0.010224951888  Uele= -14.148853983324

```

The amount of information depends on “level.of.fileout”.

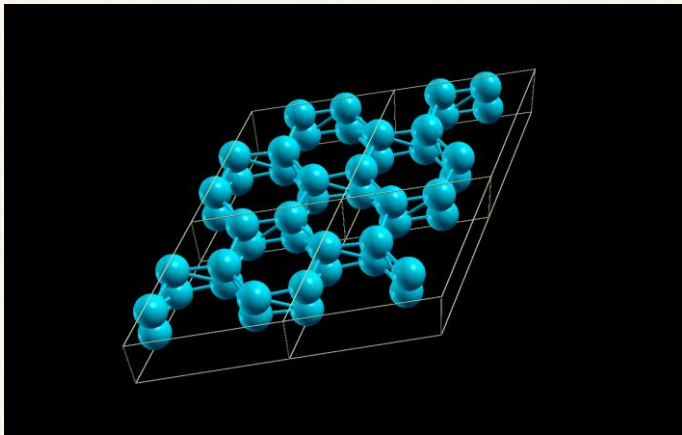
Output Structural data for MD and optimization

XXX.md : Structure at each MD step

XXX.md2 : Final structure

XCrySDen can read “.axsf” file.

```
$ md2axsf XXX.md XXX.axsf
$ xcrysdem --axsf XXX.axsf
```



The screenshot displays two windows from the XCRYSDEN software. The left window, titled 'Animation Control Center', contains the following settings:

- Delay between slides (in msec): 50
- Animation step: 1
- Current slide: 1/100
- Animated-GIF options:
 - use global color-map
 - minimize GIF file size
 - make transparent background
- Movie format:
 - AVI/MPEG
 - Animated-GIF
- Store temporary image frame files in:
 - current working directory
 - scratch directory
- Format of temporary frame files:
 - non-compressed PPM
 - compressed PNG
 - compressed JPEG
- Movie options:
 - Repeat first frame No. times: 1
 - Repeat last frame No. times: 1
 - Time delay between slides (1/100 sec): 10
 - Loop animation number of times (0=forever): 0
- Encoding:
 - Edit flags or parameter-file before encoding

The right window, titled 'XCrySDen: Ba12_P6_3smcm_280680.axsf.raw.1', shows a 3D ball-and-stick model of a crystal structure. The interface includes a menu bar (File, Display, Modify, AdvGeom, Properties, Tools, Help) and a toolbar with navigation and display controls. The right sidebar contains panels for Translation Step (0.05), Rotation (Rot +X, Rot -X, Rot +Y, Rot -Y, Rot +Z, Rot -Z), Rotation+zoom buttons mode (Discrete), Rotation Step (10), Lighting (On/Off), and Mode (Preset, Logic). The bottom status bar shows 'Atoms Info', 'Distance', 'Angle', 'Dihedral', and 'F', 'Maxi', 'Exit' buttons.

OpenMX Viewer also can display animation of MD.

It can read *.md file.

22/31

Charge density, potential

Output

level.of.fileout 1

or level.of.fileout 2

```
$ cube2xsf *.cube  
$ VESTA mgb2_tden.xsf
```

Gaussian Cube format is not suitable for the periodic system.

The screenshot shows the VESTA software interface with the file 'mgb2_tden.xsf' open. The main window displays a 3D model of the crystal structure with yellow and red spheres representing atoms and a blue-to-red color map representing charge density. Several dialog boxes are open:

- Lattice Planes - mgb2.tden.xsf**: Phase: 1, XCRYSDEN XSF file. Material: Specular: 255, 255, 255; Shininess (%): 100. Edges: Show edges, Line width: 1.0.
- Properties - mgb2.tden.xsf**: General tab. Material: Specular: 0, 0, 0; Shininess (%): 100. Isosurfaces: F(min) = 0.0154900; F(max) = 3.98100; Render from front to back. Positive and negative. Opacity 1 (0~255): 127; Opacity 2 (0~255): 255; Color: 255, 255, 0. Surface coloring: F(min) = 0.00000; F(max) = 0.00000; Inverse color; Saturation level: Max.: 0.1 (100 %); Min.: 0.1 (0 %). Preview. Buttons: Cancel, OK, Save as Default.
- Bonds - mgb2.tden.xsf**: Phase: 11, XCRYSDEN XSF file. Search bonds and atoms: Search mode: Search A2 bonded to A1; Search atoms bonded to A1; Search molecules. Boundary mode: Do not search atoms beyond the boundary; Search additional atoms if A1 is included in the boundary; Search additional atoms recursively if either A1 or A2 is visible. Search by label; Show polyhedra. A1: Mg; A2: Mg; Min. length: 0; Max. length: 1.6. Table:

No.	Atom 1	Atom 2	Min. (Å)	Max. (Å)	Bound.	Poly.	New
1	B	B	0	1.85846	2	<input checked="" type="checkbox"/>	Delete, Clear

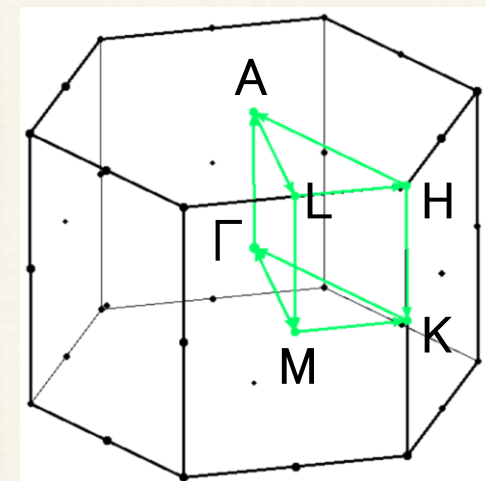
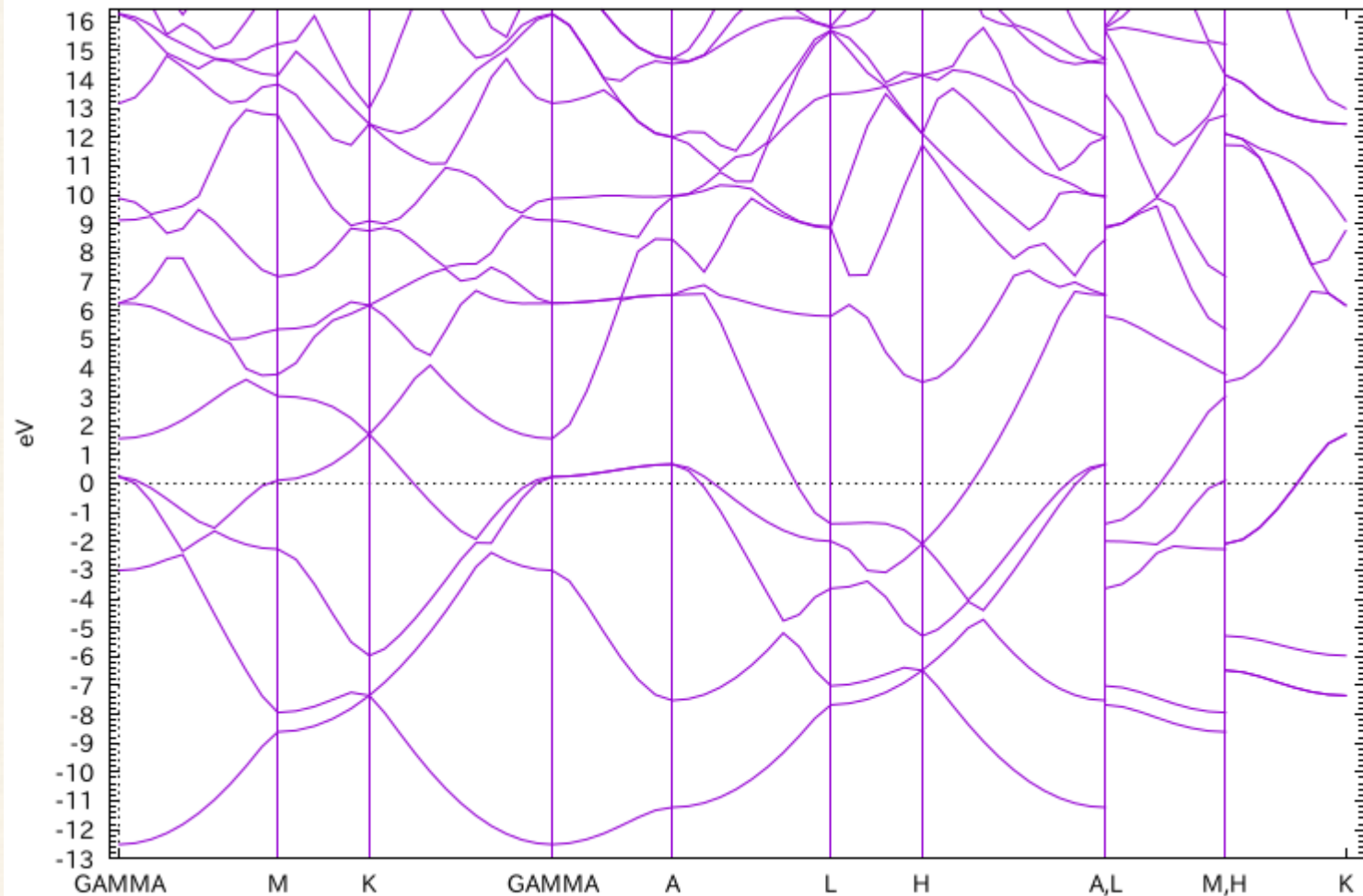
Buttons: Apply, Cancel, OK.

Band structure

Output

Band.dispersion on

```
$ bandgnu13 mgb2.Band
$ gnuplot mgb2.GNUBAND
```



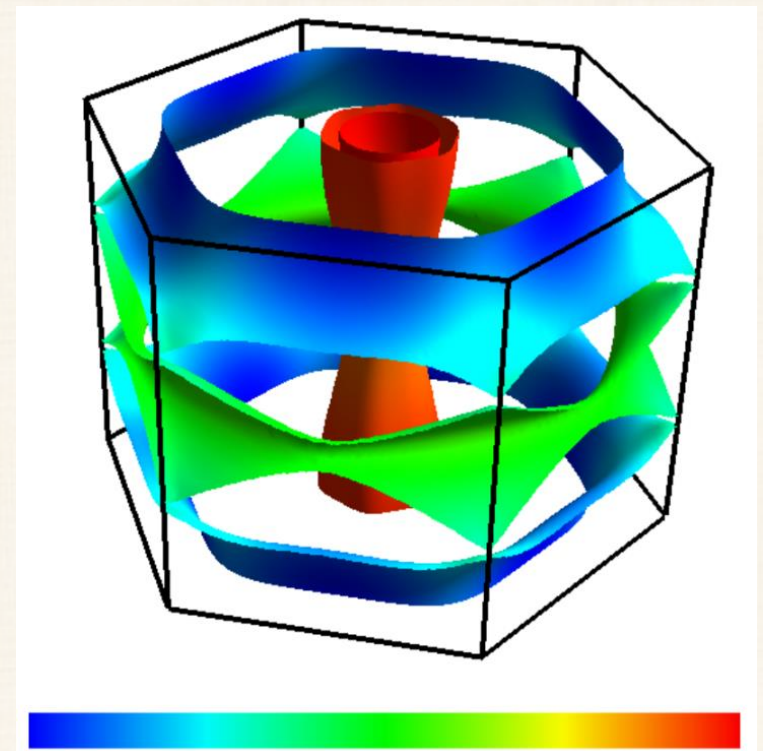
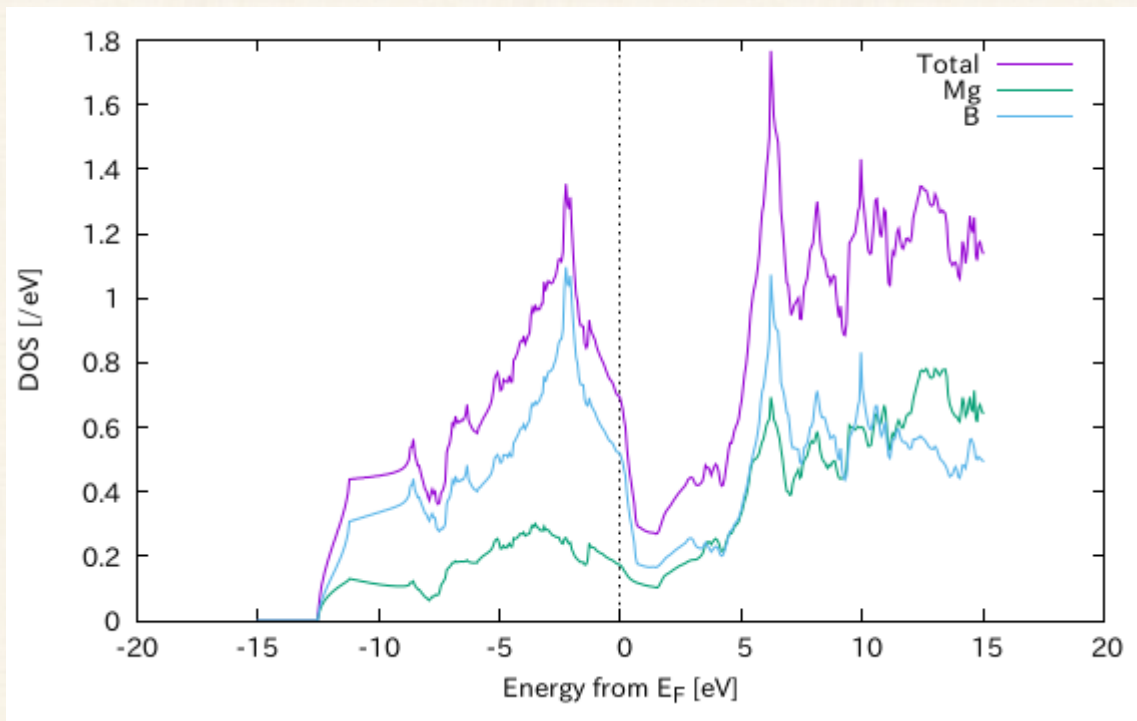
DOS and Fermi surface

```
Dos.fileout      on
```

```
$ DosMain mgb2.Dos.val mgb2.Dos.vec
```

The **tetrahedron method** is highly recommended.

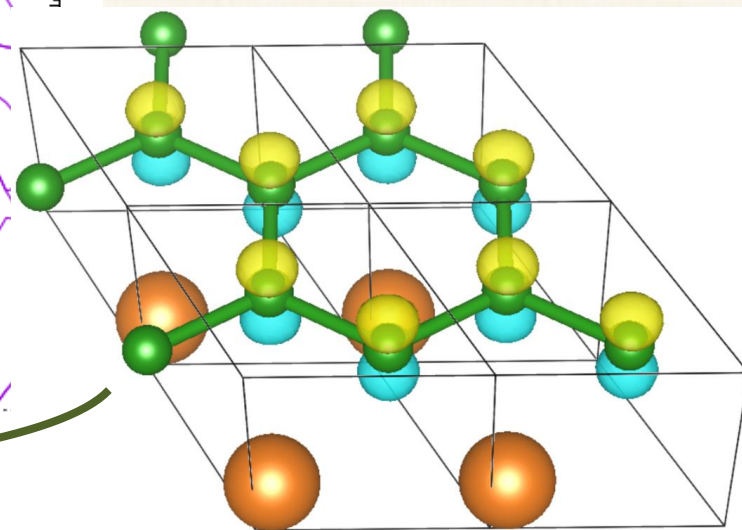
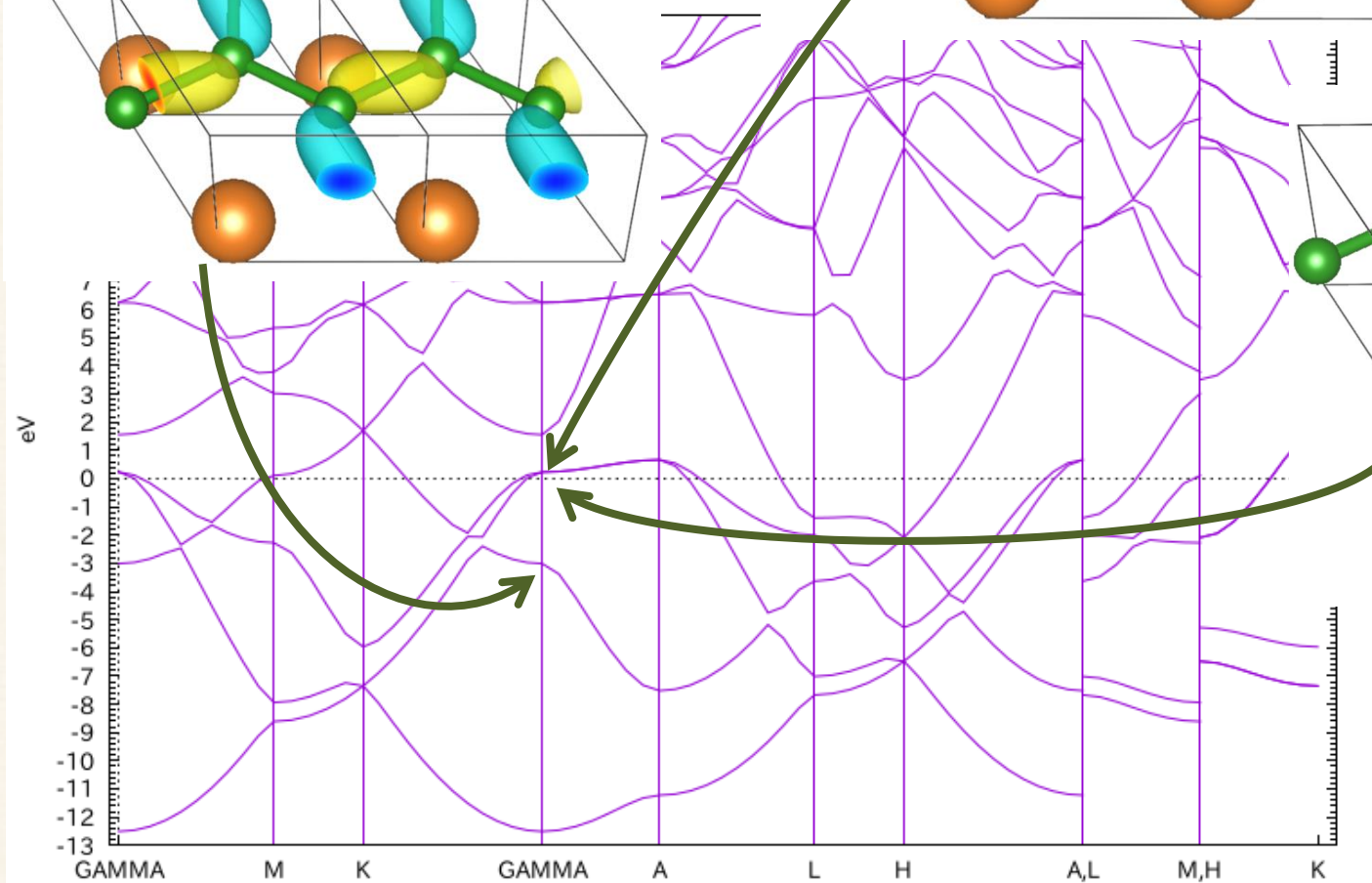
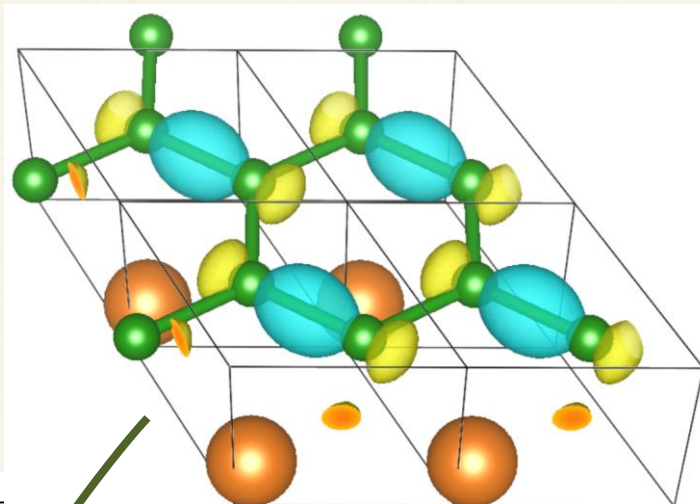
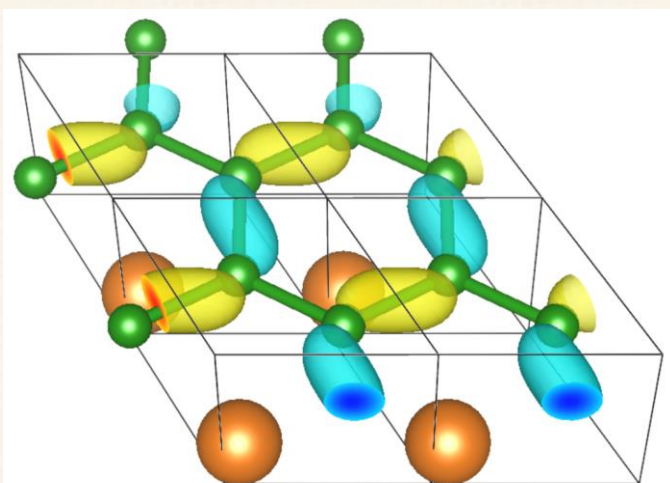
```
gnuplot> plot "mgb2.DOS.Tetrahedron" u 1:2 w l tit "Total", ¥
"mgb2.PDOS.Tetrahedron.atom1" w l tit "Mg", ¥
"mgb2.PDOS.Tetrahedron.atom2" u 1:($2*2) w l tit "B"
```



```
$ fermisurfer mgb2.FermiSurf_s0_a2.frmsf
```


Kohn-Sham Bloch orbitals

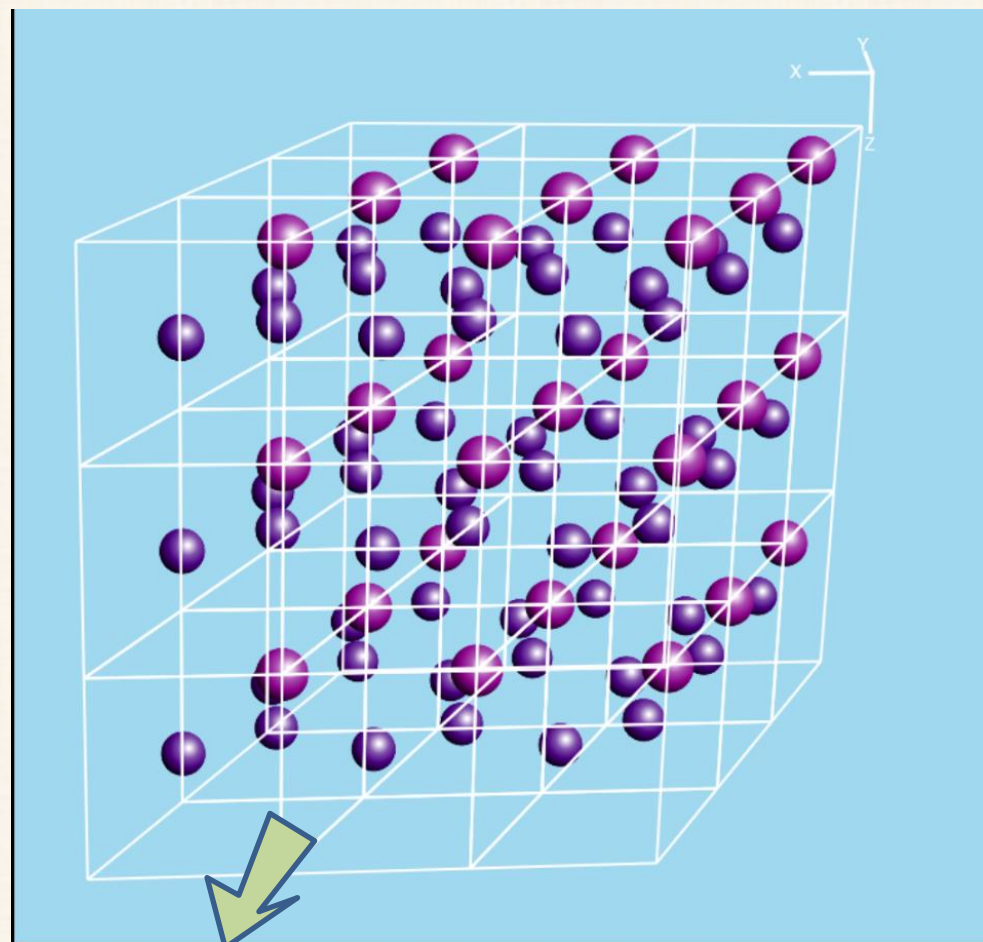
```
$ cube2xsf *_r.cube
$ VESTA *_r.xsf
```



How can we construct supercell ?

For the supercell written as $N_1 \times N_2 \times N_3$:

OpenMX Viewer



Reset Supercell 3 x 3 x 3 Atoms rendering Bonds off Bond Color palepurple Number
 Symbol BGC skyblue Atom Size 1.0 Bond Thickness 1.0 Bond Factor 1.0 Cells Axes
 Perspective Structure Dynamics Net Charge off Spin off Force Velocity Rot on x
 0 Rot on y 0 Rot on z 0 Save select Examples select
 OpenMX website Rotate: click+drag Zoom: scroll Translate: ctrl+click+drag Note: click the middle button for Safari

$$(\vec{a}'_1, \vec{a}'_2, \vec{a}'_3) = (\vec{a}_1, \vec{a}_2, \vec{a}_3) \begin{pmatrix} P_{11} & P_{12} & P_{13} \\ P_{21} & P_{22} & P_{23} \\ P_{31} & P_{32} & P_{33} \end{pmatrix}$$

VESTA → "Edit" → "Edit Data"

Unit Cell Transformation

Rotation matrix P

4	2	0
0	4	0
0	0	2

Origin shift p

0.000000
0.000000
0.000000

The new basis vectors \mathbf{a}' , \mathbf{b}' , \mathbf{c}' are related to the basis vectors \mathbf{a} , \mathbf{b} , \mathbf{c} by

$$(\mathbf{a}' \ \mathbf{b}' \ \mathbf{c}') = (\mathbf{a} \ \mathbf{b} \ \mathbf{c}) \mathbf{P}$$

$$= (\mathbf{a} \ \mathbf{b} \ \mathbf{c}) \begin{pmatrix} P_{11} & P_{12} & P_{13} \\ P_{21} & P_{22} & P_{23} \\ P_{31} & P_{32} & P_{33} \end{pmatrix}$$

$$= (P_{11}\mathbf{a} + P_{21}\mathbf{b} + P_{31}\mathbf{c}, P_{12}\mathbf{a} + P_{22}\mathbf{b} + P_{32}\mathbf{c}, P_{13}\mathbf{a} + P_{23}\mathbf{b} + P_{33}\mathbf{c})$$

A shift of origin is defined by the shift vector

$$\mathbf{p} = p_1\mathbf{a} + p_2\mathbf{b} + p_3\mathbf{c}$$

Normalize the range of fractional coordinates

Lattice parameters

a (Å)	b (Å)	c (Å)	α (°)	β (°)	γ (°)
12.32920	10.67740	7.02922	90.00000	90.00000	90.00000
s.u.: 0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

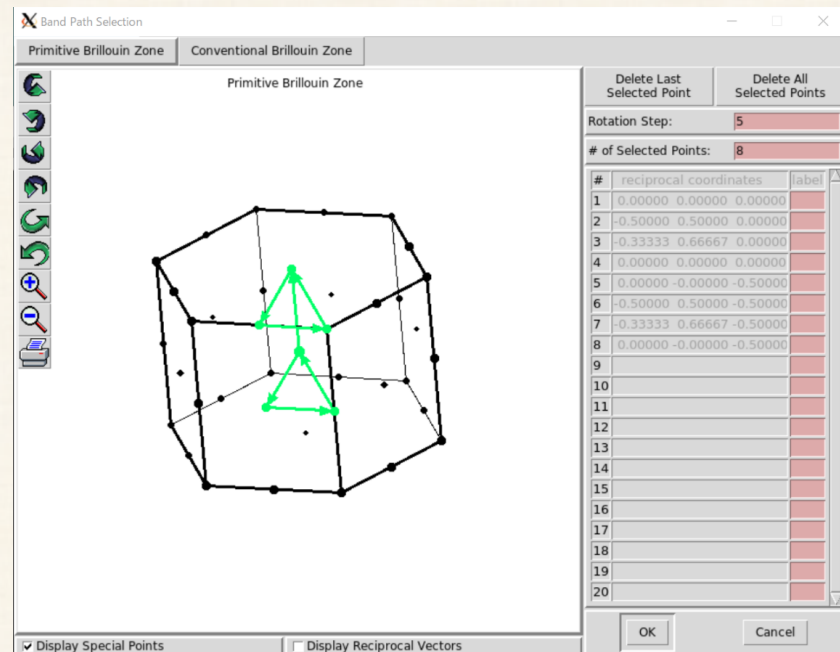
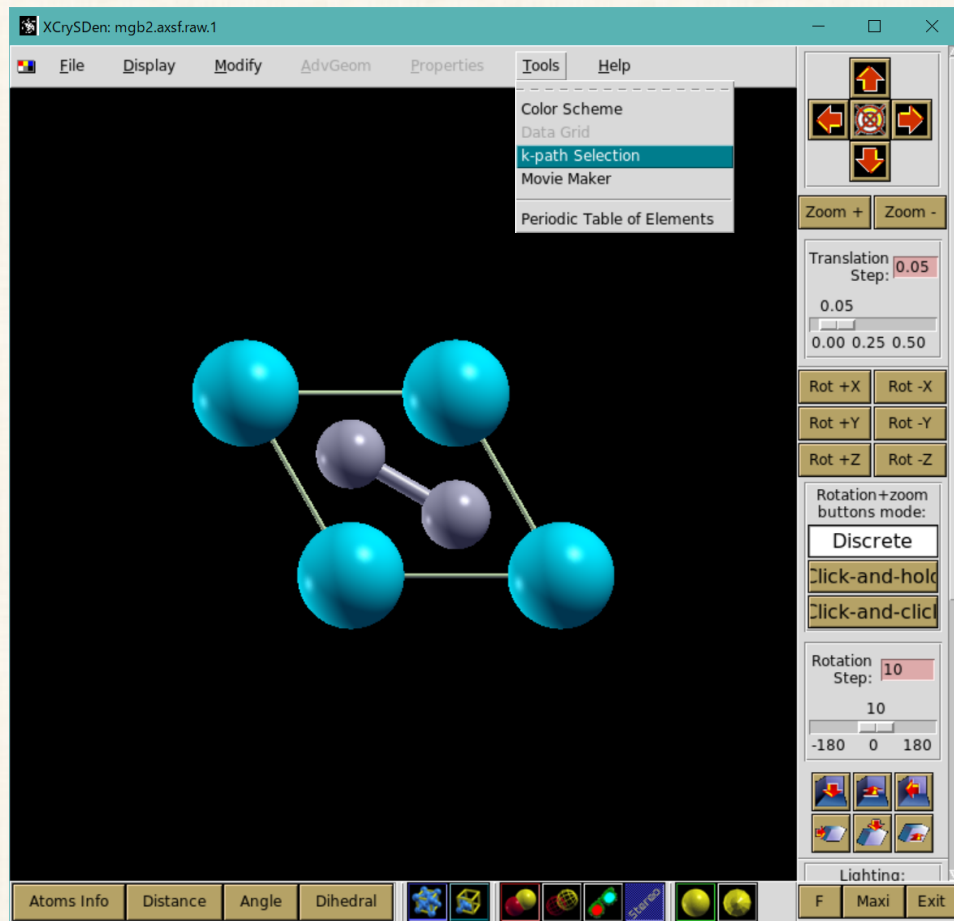
Remove symmetry

OK Cancel Apply

Then, export CIF and read from OpenMX Viewer

Specifying your own k -path

```
$ md2axsf XXX.md XXX.axsf
$ xcrysden --axsf XXX.axsf
```



Save k -points in arbitrary format.

The label of each special k -point is shown in “Wikipedia brillouin-zone” (English).

More information

Welcome to OpenMX
open source package for Material explorer

Google Custom Search

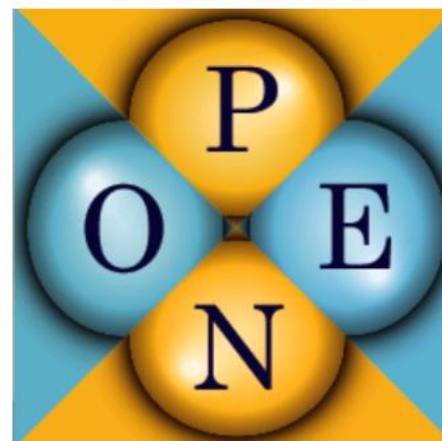
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Contact, ask, discussion, bug report, ...

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Known issue can be searched.

OpenMX Forum

Google Custom Search

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Topics	Author	Replies	Views	Last Modified
⚠ From Administrator	Taisuke Ozaki	0	5222	2005/01/09 05:33 by Taisuke Ozaki
📁 convergence for ESM calculation with on2+EF	jiang	0	9	2018/06/21 10:20 by jiang
📁 error in make all	sara.shafaei	1	15	2018/06/20 01:26 by Naoya Yamaguchi
📁 calculations of Z2 and Chern number	Wenliang Liu	1	46	2018/06/16 12:03 by T. Ozaki
📁 Geometry optimization of metal slab yields nan forces	Dechamps Samuel	9	69	2018/06/12 23:39 by Dechamps Samuel
📁 How to solve this problem:APPLICATION TERMINATED WITH THE EXIT STRING: Killed (signal 9)	xmzhang	1	42	2018/06/12 10:12 by T. Ozaki
📁 Patch 3.8.5 to OpenMX Ver. 3.8	T. Ozaki	0	51	2018/06/12 10:05 by T. Ozaki
📁 transport direction for thin film	Prashant	2	69	2018/06/11 22:50 by T. Ozaki
📁 a bad relaxed structure from the RFC5 geometry optimizaiton	Jack	2	36	2018/06/05 09:18 by Jack
📁 Work Function of graphene	Renato	2	56	2018/05/26 00:02 by Renato
📁 How to plot Vhart in a given direction.	Carlos	2	44	2018/05/23 03:16 by Carlos
📁 Step3 of Transport Calculation is not successful	Mobin	5	87	2018/05/22 02:04

Summary

- We overview the typical usage of OpenMX. The following external utilities is useful to generate input file, visualize results.
 - OpenMX Viewer
 - XCrysDen
 - VESTA
 - FermiSurfer
- In the next practice, we will gain the experience of OpenMX with these programs.

Prepare for practice : ssh client

Case 1: Use ssh command (Linux, UNIX, macOS, WSL)

```
$ ssh -Y user-name@server-name
```

Your PC may ask you to add this workstation to “known-hosts”.

Enter your password.

Case 2: GUI ssh-client in Windows

Google “xming putty”

The screenshot shows a Google search for "xming putty". The search bar contains "xming putty" and a magnifying glass icon. Below the search bar are navigation tabs: "すべて", "動画", "画像", "ショッピング", "ニュース", "もっと見る", "設定", "ツール". The search results show approximately 84,800 items in 0.28 seconds. Several results are highlighted with blue arrows:

- xming+puttyでのXの使い方マニュアル** (zodiac30.cse.kyutech.ac.jp/~fujiwara/setup/xming-putty/) - Arrow pointing to the title.
- PuTTY + Xming でX を使おう** (www.ep.sci.hokudai.ac.jp/~epnetfan/tebiki/server-login/xming.html) - Arrow pointing to the title.
- WindowsでPuTTYとXmingを利用して、大学外からSun, Moodleに...** (www.rc.mce.ucc.ac.jp/sun_moodle/windows/putty_xming2.htm) - Arrow pointing to the title.
- 【今更感】XmingとPuttyでWindowsに最高の開発環境を作る - 波打際の...** (alfa.hatenablog.jp/entry/2016/05/19/101456) - Arrow pointing to the title.
- Installing/Configuring PuTTY and Xming** (www.geo.mtu.edu/geoschem/docs/putty_install.html) - Arrow pointing to the title.

WinSCP is also required in this case.