Photonics, Spring 2025

Exercises to be returned via Google Classroom by 10:00 on Monday **12.05.2025.**

Please, notice that running simulations in HPC platform may take some time (tasks 5 and 6)!
Start preparing your answers early!

Simulation Exercises (tot. 8 Points)

The last exercises are FDTD-simulations in HPC platform. Prerequisites for these are the following:

- Windows-laptop
- Access rights to clusters (*provided by the course staff in advance, no actions required*)
- Installed PuTTy, WinSCP
- Installed MEEP in HPC-platform

Before starting to use HPC platform, please, read both Lustre and HPC User Guides.

1. HPC platform (1 Point)

Explain the following terms and concepts briefly (in context of high-performance computing):

a) Federated cluster

b) Lustre

c) Node

d) Batch job

e) LUMI (inc. relevant specs)

2. Job Controls (1 Point)

Hint 1: Basic commands

Write the right terminal commands to carry out the following tasks (*these will be the core commands when working in HPC platform*):

a) Send the job file *meep_exercise_1.sh* for execution

b) List all jobs from the username *joomusto*

c) Cancel a job from node *Kale* with the job-id *73576922*

3. Job file (1 Point)

Fulfill the following blank job file and save it with .sh suffix. You may assume that you are going to carry out Python script *meep-exercise-1.py* that takes a couple minutes to execute. Select the proper node (ukko / kale / carrington) and node queue arguments (short / medium / long) and motivate your decisions.

```
#!/bin/bash
#SBATCH -J meep_test  # NameÂ Â Â Â
#SBATCH -e out_%j       # stderrÂ
#SBATCH -o out_%j       # stdout
#SBATCH --mem-per-cpu=8192
#SBATCH -n 24
#SBATCH -M [add node name]
#SBATCH -p [add node's queue]
#SBATCH --mail-type=END
[set up email notification]

#-----------------------------------------------------
# Run the program
#-----------------------------------------------------

. ~/.bashrc
conda activate pmp

mpirun python [add here your python file name]

conda deactivate
```

4. MEEP (1 Point)

Read article Oskooi et al. (2010), Meep: A flexible free-software package for electromagnetic simulations by the FDTD method, Computer Physics Communications, 181(3) *and answer the questions:*

a) What is a FDTD simulation?

b) What kind of pros and cons does MEEP have compared to FEM, BEM or traditional FDTD simulations?

5. Optical waveguide (2 Points)

Hint. Check MEEP-tutorials.

By using MEEP, build a 2D linear dielectric plate waveguide (x = ∞, y = 1μm, z = ∞) with permittivity ε = 12. Specify a computational cell (x length = 16 μm, y length= 8μm, z length = 0). Define a single current point source J_z as a continuous (monochromatic) source with a frequency *f* (*be careful with the units)*, located at (x = -7 μm, y = 0, z = 0). Add perfectly matched layer (PML) of thickness 1μm around all sides of the cell. Choose a proper resolution (> 8 pixels / wavelength) and run simulation until time of 200 [MEEP units]. Visualize your result by creating an image of scalar electric field E_z overlaying the dielectric function ε.

a) Show how result images differ between each other with the following frequencies: f = [44.95, 89.95, 135] THz.

b) Explain your results.

6. Photonic Nanojet (2 Points)

The given simulation model *pnj.py* generates a photonic nanojet by using perfect microsphere as a lens. In real life, this may not be the case always. *NB! To work, this simulation requires having PTP file in the same folder as the Python script.*

a) (1 Point) Run the simulation model in HPC platform with the perfect microsphere. Return the resulted image that shows the formation of the photonic nanojet.

b) (1 Point) Make your own lens, as close to egg shape as you can, and run the simulation again. Return the resulted image and your code.