Ultra narrowband Metasurface

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In this simulation of Paper Link, I did 1200-1600nm parameter sweep, and linear polarization. Finding the transmittance of this structure.

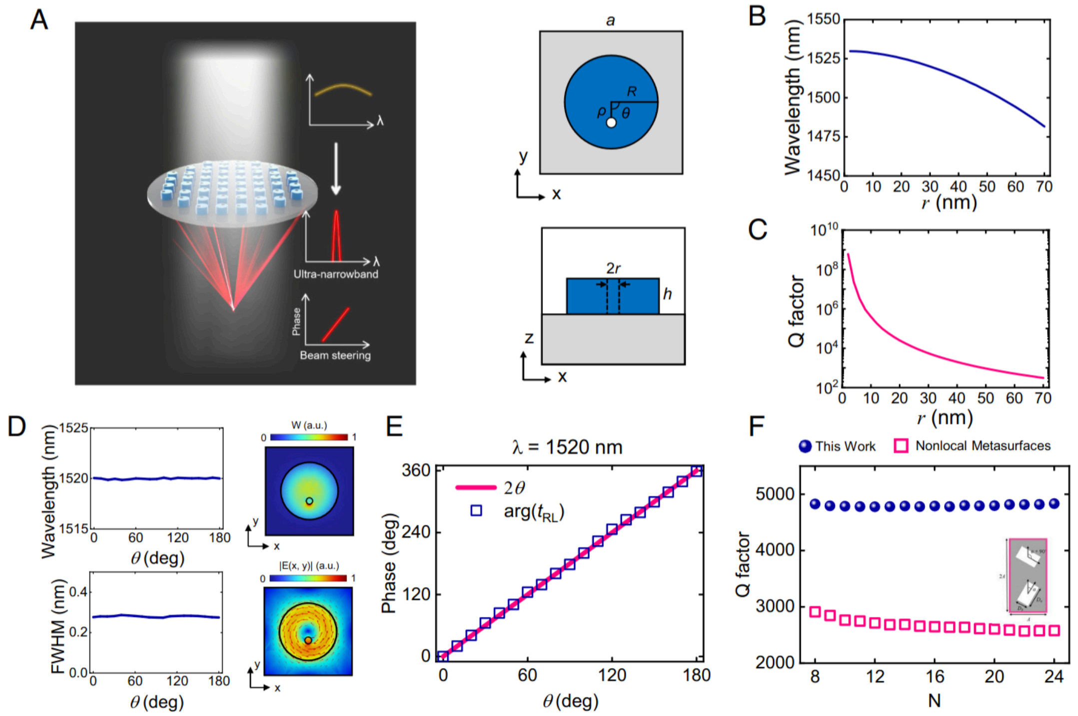
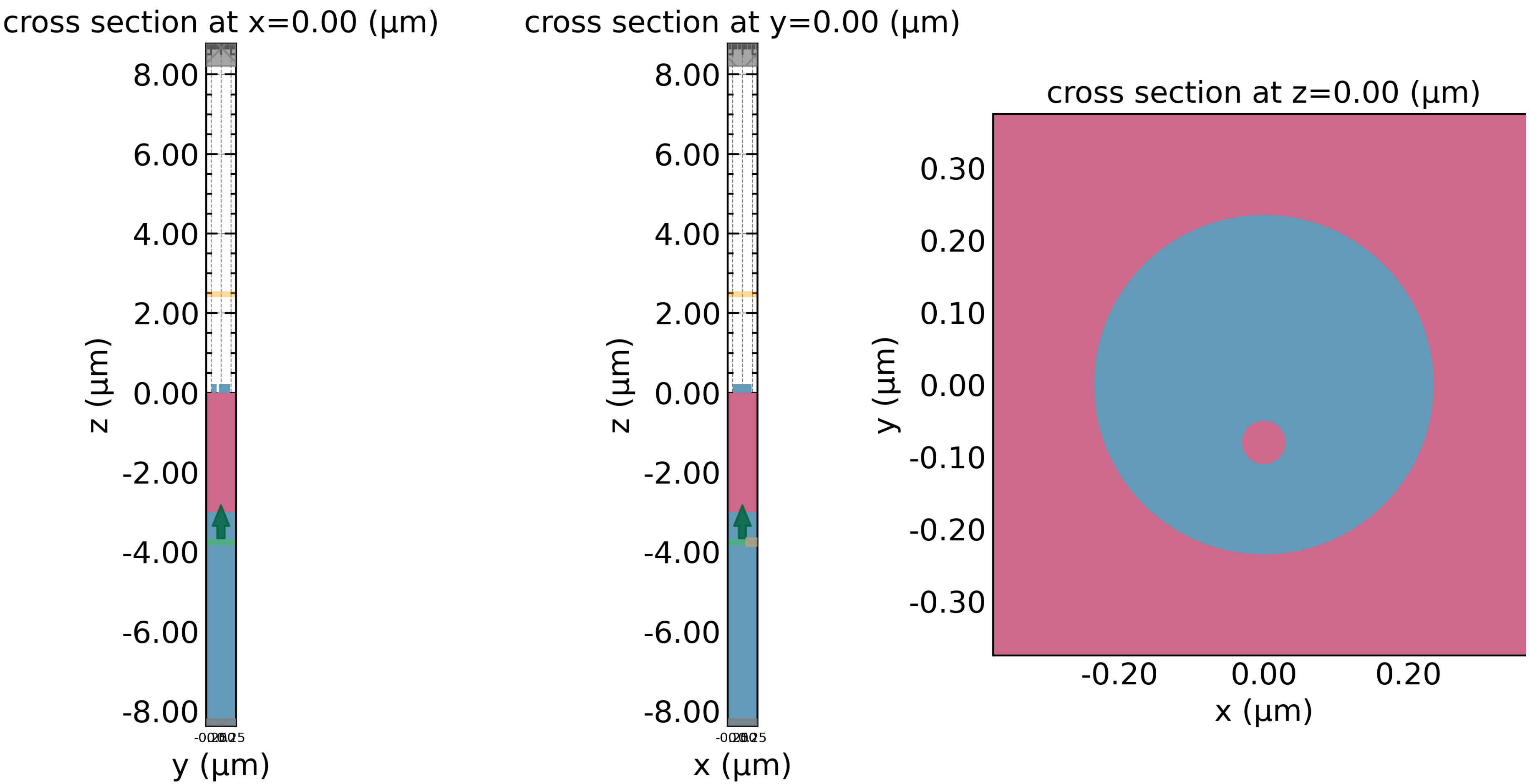
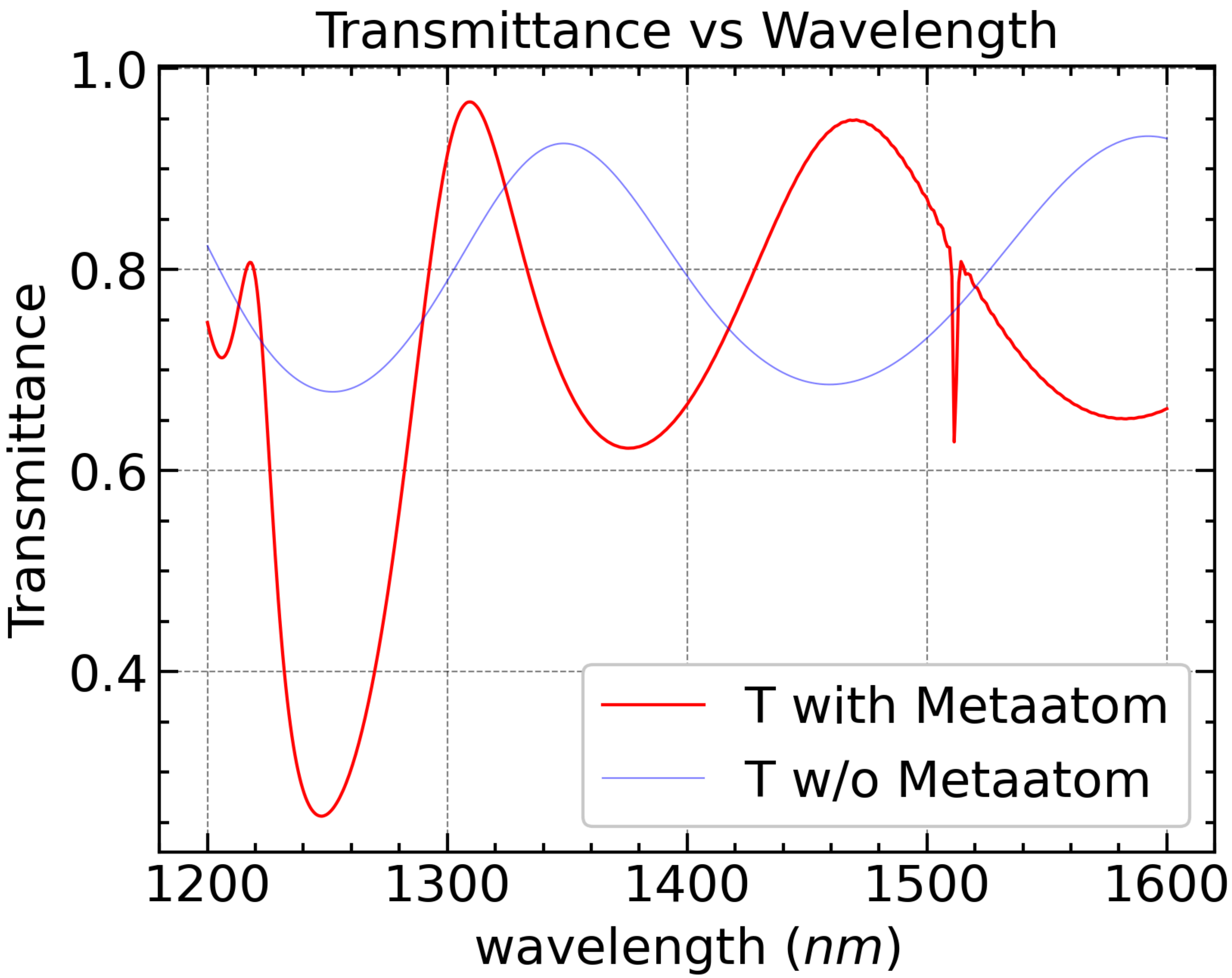


Fig. 1. Concept of high-Q phase-gradient metasurfaces. (*A*) Schematic picture of the Si metasurface. *Insets* show a single cell with detailed structural parameters. (*B*) and (*C*) show the dependence of resonant wavelength and Q factor of BIC mode on the radius of an air hole. (*D*) Resonant wavelength (*Top*) and FWHM (*Bottom*) of quasi-BIC mode as a function of rotational angle θ. Here, the size of the air hole is fixed at r = 30 nm. *Insets* show the numerically calculated distributions of power (*Top*) and electric field (*Bottom*). (*E*) Acquired geometric phase ϕ_{PB} (dots) as a function of rotational angle θ. The solid line represents the curve of $\phi_{PB} = 2\theta$. (*F*) Dependence of Q factors of supercells containing N phase steps of our metasurface (dots) and conventional nonlocal metasurface (open squares). Here, the position parameter ρ is fixed at ρ = 80 nm. The *Inset* shows the schematic of a conventional nonlocal metasurface structure.

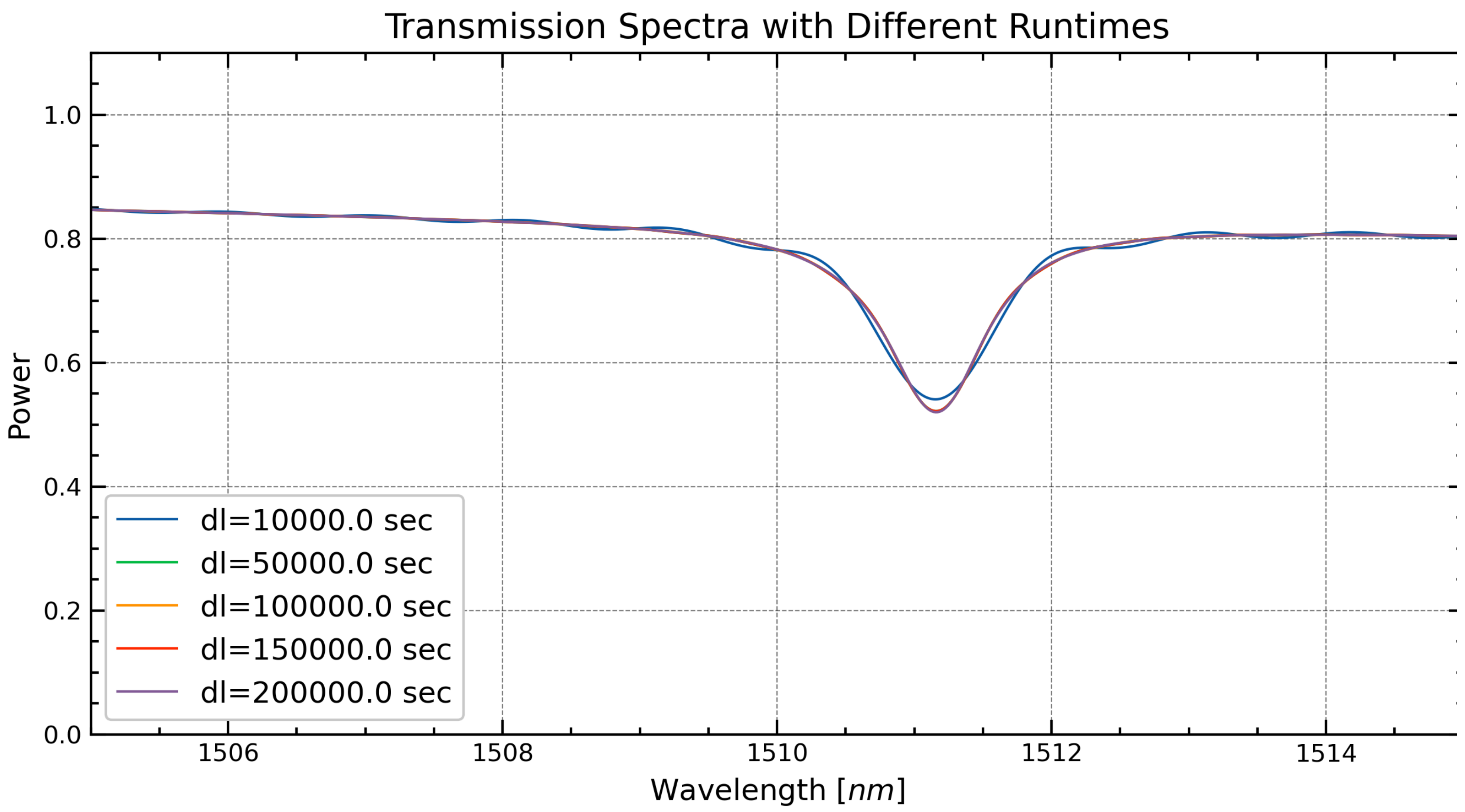
Figure from paper



cross section at x=0.00 (μm)
cross section at y=0.00 (μm)
cross section at z=0.00 (μm)
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
z (μm)
y (μm)
x (μm)
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.20
0.00
0.20



Transmittance vs Wavelength
1.0
0.8
0.6
0.4
Transmittance
1200
1300
1400
1500
1600
wavelength (nm)
T with Metaatom
T w/o Metaatom


Transmission Spectra with Different Runtimes
Power
Wavelength [nm]
0.0
0.2
0.4
0.6
0.8
1.0
1506
1508
1510
1512
1514
dl=10000.0 sec
dl=50000.0 sec
dl=100000.0 sec
dl=150000.0 sec
dl=200000.0 sec

Preconditions

```python
# Import the necessary packages
import matplotlib.pyplot as plt
import numpy as np
import tidy3d as td
import tidy3d.web as web
from tidy3d import material_library
import scienceplots

td.config.logging_level = "ERROR"
```

```python
# 0 Define a FreqRange object with desired wavelengths
fr = td.FreqRange.from_wvl_interval(wvl_min=1.2, wvl_max=1.6)
N = 501 # num_points
fwidth = fr.fmax - fr.fmin
freq0 = fr.freq0
lda0 = td.C_0 / fr.freq0
```

```python
# 1 Computational Domain Size
h = 0.210  # Height of cylinder
spc = 8
sh = 3  # height of the SiO2
Lz = spc + h + spc + h

Px = Py = P = 0.750 # periodicity
sim_size = [Px, Py, Lz]
```

```python
# 2 Grid Resolution
dl = P / 32
horizontal_grid = td.UniformGrid(dl=dl)
vertical_grid = td.AutoGrid(min_steps_per_wvl=32)
grid_spec=td.GridSpec(
    grid_x=horizontal_grid,
    grid_y=horizontal_grid,
    grid_z=vertical_grid,
)
```

```python
# 3 Structures and Materials
R = 0.235  # radius of the cylinder
r = 0.030  # radius of the inner hole
p = 0.080  # distance between hole to center of circle
theta = np.deg2rad(90) # angle between x-axis and p vector

Si = material_library['cSi']['Green2008']
SiO2 = material_library['SiO2']['Horiba']

outer_cylinder = td.Cylinder(
    center=[0, 0, h / 2],
    radius=R,
    length=h,
    axis=2
)

inner_cylinder = td.Cylinder(
    center=[p*np.cos(theta), -p*np.sin(theta), h / 2],
    radius=r,
    length=h,
```

```python
source = td.PlaneWave(
    source_time=td.GaussianPulse(freq0=fr.freq0, fwidth=fwidth),
    size=(td.inf, td.inf, 0),
    center=(0, 0, -Lz/2 + spc - (sh - h) - 0.5 * lda0),
    direction="+",
    pol_angle=0,
)
```

```python
monitor = td.FluxMonitor(
    center=(0, 0, Lz/2 - spc + 1.5 * lda0),
    size=(td.inf, td.inf, 0),
    freqs=fr.freqs(N),
    name="flux_monitor"
)
```

```python
bandwidth = fr.fmax - fr.fmin
run_time = 500 / bandwidth # run_time for the transmittance simulation
```

```python
bc = td.BoundarySpec(
    x=td.Boundary.periodic(),
    y=td.Boundary.periodic(),
    z=td.Boundary.pml()
)
```

Simulation

```
sim_empty = td.Simulation(
    size=sim_size,
    grid_spec=grid_spec,
    structures=[substrate, dioxide],
    sources=[source],
    monitors=[monitor],
    run_time=run_time,
    boundary_spec=bc
)

sim_actual = td.Simulation(
    size=sim_size,
    grid_spec=grid_spec,
    structures=[substrate, dioxide, atom],
    sources=[source],
    monitors=[monitor],
    run_time=run_time,
    boundary_spec=bc
)
```

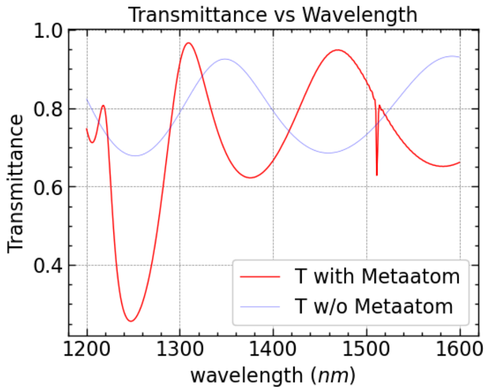
```
sims = {
    "actual": sim_actual,
    "norm": sim_empty
}
```

```
sims["actual"].plot_3d()
```

Postprocess

```python
T_actual = batch_data["actual"]["flux_monitor"].flux
T_norm = batch_data["norm"]["flux_monitor"].flux
```

```python
# this uses scienceplots to make plots look better
plt.style.use(['science', 'notebook', 'grid'])
# plot transmission, compare to paper results, look similar
fig, ax = plt.subplots(1, 1, figsize=(6, 4.5))
plt.plot(td.C_0 / fr.freqs(N) * 1000, T_actual, "r", lw=1, label="T with Metaatom")
plt.plot(td.C_0 / fr.freqs(N) * 1000, T_norm, "b", lw=0.5, alpha=0.5, label="T w/o Metaa
plt.xlabel(r"wavelength ($nm$)")
plt.ylabel("Transmittance")
plt.legend()
plt.title("Transmittance vs Wavelength")
plt.savefig("power_geom", dpi=300)
plt.show()
```



Zooming in and doing Runtime Analysis

```python
# 0 Define a FreqRange object with desired wavelengths
fr = td.FreqRange.from_wvl_interval(wvl_min=1.505, wvl_max=1.515)
N = 701 # increased num_points
fwidth = fr.fmax - fr.fmin
freq0 = fr.freq0
lda0 = td.C_0 / fr.freq0
```

```python
source = td.PlaneWave(
    source_time=td.GaussianPulse(freq0=fr.freq0, fwidth=fwidth),
    size=(td.inf, td.inf, 0),
    center=(0, 0, -Lz/2 + spc - (sh - h) - 0.5 * lda0),
    direction="+",
    pol_angle=0,
)

monitor = td.FluxMonitor(
    center=(0, 0, Lz/2 - spc + 1.5 * lda0),
    size=(td.inf, td.inf, 0),
    freqs=fr.freqs(N),
    name="flux_monitor"
)

bandwidth = fr.fmax - fr.fmin
# run_time = 50 / bandwidth # run_time for the transmittance simulation
```

```python
bc = td.BoundarySpec(
    x=td.Boundary.periodic(),
    y=td.Boundary.periodic(),
    z=td.Boundary.pml()
)
```

```python
# Runtime Loop Assignment
alphas = [10, 50, 100, 150, 200]
run_times = [x / bandwidth for x in alphas]
sims = {}

for i, run_time in enumerate(run_times):
    sim_actual = td.Simulation(
        size=sim_size,
        grid_spec=grid_spec,
        structures=[substrate, dioxide, atom],
        sources=[source],
        monitors=[monitor],
        run_time=run_time,
        boundary_spec=bc
    )

    sims[f"actual{i}"] = sim_actual
```

```python
batch = web.Batch(simulations=sims, verbose=True)
batch_data = batch.run(path_dir="data/geom_lin")
```

```
21:01:35 EDT Started working on Batch containing 5 tasks.
21:01:40 EDT Maximum FlexCredit cost: 7.571 for the whole batch.
             Use 'Batch.real_cost()' to get the billed FlexCredit cost after the
             Batch has completed.
21:01:43 EDT Batch complete.
```

```python
# Runtime Analysis Postprocess
plt.style.use(['science', 'notebook', 'grid'])

x = td.C_0 / fr.freqs(N) * 1000
Ts = []
for i in range(len(alphas)):
    Ts.append(batch_data[f"actual{i}"]["flux_monitor"].flux)
```

```python
plt.figure(figsize=(10, 5))
for i, T in enumerate(Ts):
    plt.plot(x, T, "-",lw=1, label=f"dl={alphas[i] * 1000:.1f} sec")
plt.xlabel(r"Wavelength [$nm$]", fontsize=12)
plt.ylabel("Power", fontsize=12)
plt.xlim(1505, 1515)
plt.ylim(0, 1.1)
plt.legend(fontsize=12)
plt.tick_params(axis='both', labelsize=10) # change tick label size to 10
plt.title("Transmission Spectra with Different Runtimes", fontsize=14)
plt.savefig("runtimes.png", dpi=300)
plt.show()
```