Meep and MPB in Computational Photonics

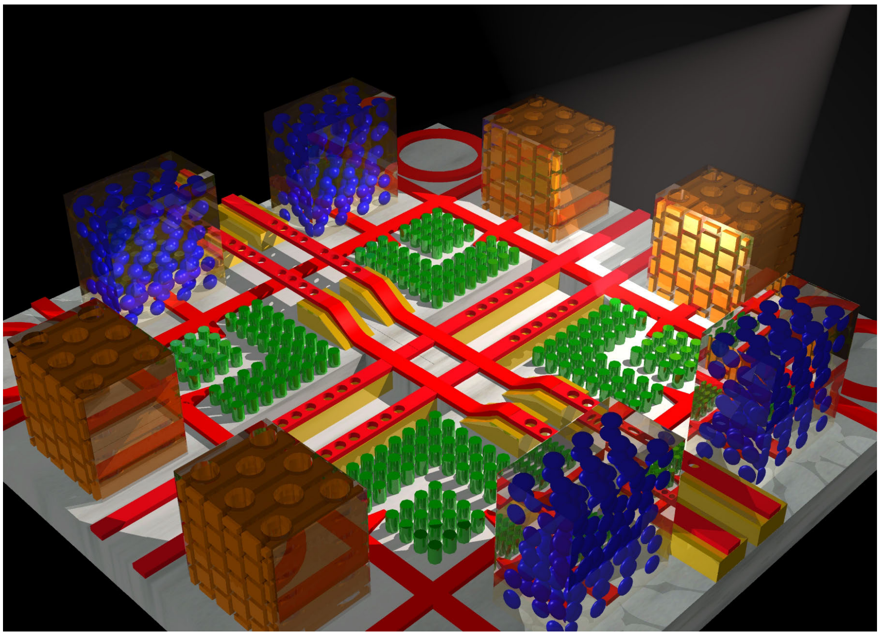

Figure downloaded from http://ab-initio.mit.edu/photons/micropolis-hires.jpg

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Contents

1 Introduction

Here we show how to .

In a word, we can use various fitting methods to fit the spectra and get the parameters of the nanophotonics structures.

Thus, the procedure of fitting can be divided into two key steps:

- Build the model of the spectra, which can be an expression, or an electromagnetic (EM) solver, or even a neural network.
- Use the fittingmethod to find the best parameters of the model.

Besides, we can also use the method of library searching (the library can be constructed by simulated data from the EM solver or the neural network, or by experimental data) to find the best-fit model.

2 Installation

In[1]:
```
from ipywidgets import interact, widgets
import matplotlib.pyplot as plt
import numpy as np
from scipy.interpolate import interp1d

plt.rcParams["font.family"] = "Helvetica"
%matplotlib inline
%config InlineBackend.figure_format = 'svg'
```

3 Tutorial

3.1 Spectra of thin films

First load the refractive index data of Si.

In[2]:
```
data_Si = np.loadtxt("./data/Si.txt", delimiter='\t', skiprows=1)
lda_Si = data_Si[:, 0]
n_Si = data_Si[:, 1]
k_Si = data_Si[:, 2]

n_Si_interp = interp1d(lda_Si, n_Si)
k_Si_interp = interp1d(lda_Si, k_Si)
```

Define the Cauchy model for Refractive index of SiO2.

In[3]:
```
def n_index_SiO2(A, B, lda):
    return A + B/lda**2
```

Load the simulated spectrum.

In[4]:
```
data_sim = np.loadtxt('./data/S4_Rp_SiO2onSi.csv', delimiter=',', skiprows=1)
lda_array = data_sim[:, 0]
Rp_sim = data_sim[:, 1]
```

Next we define a function of fit the two curves: - Simulated spectrum - Analytical spectrum

In[5]:
```
def fit_SiO2onSi(d_SiO2, A, B):
    """
    Fit simulated curve and analytical curve.

    Args:
        d_SiO2 (float): Thickness of SiO2 layer (nm).
```

```
        A (float): Parameter A in Cauchy model.
        B (float): Parameter B in Cauchy model. (nm^2)
    """
    r_numerator = np.e ** (
        4 * 1j * d_SiO2 * n_index_SiO2(A, B, lda_array) * np.pi / lda_array
    ) * (1 + n_index_SiO2(A, B, lda_array)) * (
        -1j * k_Si_interp(lda_array)
        - n_Si_interp(lda_array)
        + n_index_SiO2(A, B, lda_array)
    ) - (-1 + n_index_SiO2(A, B, lda_array)) * (
        1j * k_Si_interp(lda_array)
        + n_Si_interp(lda_array)
        + n_index_SiO2(A, B, lda_array)
    )
    r_denominator = -(
        np.e ** (4 * 1j * d_SiO2 * n_index_SiO2(A, B, lda_array) * np.pi /
 ↪lda_array)
    ) * (-1 + n_index_SiO2(A, B, lda_array)) * (
        -1j * k_Si_interp(lda_array)
        - n_Si_interp(lda_array)
        + n_index_SiO2(A, B, lda_array)
    ) + (1 + n_index_SiO2(A, B, lda_array)) * (
        1j * k_Si_interp(lda_array)
        + n_Si_interp(lda_array)
        + n_index_SiO2(A, B, lda_array)
    )

    Rp_ana = np.abs(r_numerator / r_denominator) ** 2

    fig, ax = plt.subplots(1, 1, figsize=(5, 3))
    ax.plot(lda_array, Rp_sim, color="gray", label="sim.")
    ax.plot(lda_array, Rp_ana, color="blue", lw=1, label="fit.")
    ax.set_xlabel("Wavelength (nm)")
    ax.set_ylabel("Reflectivity")
    ax.set_xlim([250, 850])
    ax.set_ylim([0, 1])
    ax.legend(loc=1)
    fig.tight_layout()
```

In [6]:
```
interact(
    fit_SiO2onSi,
    d_SiO2=widgets.FloatSlider(value=500, min=450, max=550, step=0.1),
    A=widgets.FloatSlider(value=1.447, min=1.3, max=1.6, step=0.001),
    B=widgets.FloatSlider(value=3540, min=3300, max=3600, step=10),
)
```

```
interactive(children=(FloatSlider(value=500.0, description='d_SiO2', max=550.0,
 ↪min=450.0), FloatSlider(value=…
```

Out[6]:
```
<function __main__.fit_SiO2onSi(d_SiO2, A, B)>
```

3.2 Spectra of photonic crystal slabs

$\omega a/2\pi c$

References

[1] Victor Liu and Shanhui Fan. *S4: A free electromagnetic solver for layered periodic structures.* Computer Physics Communications **183**: 2233, 2012.

[2] Lifeng Li. *New formulation of the Fourier modal method for crossed surface-relief gratings.* Journal of the Optical Society of America B **14**: 2758, 1997.

[3] E. Anderson, Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, D. Sorensen. *LAPACK Users' Guide*, 3rd ed. (Society for Industrial and Applied Mathematics, Philadelphia, PA, 1999).