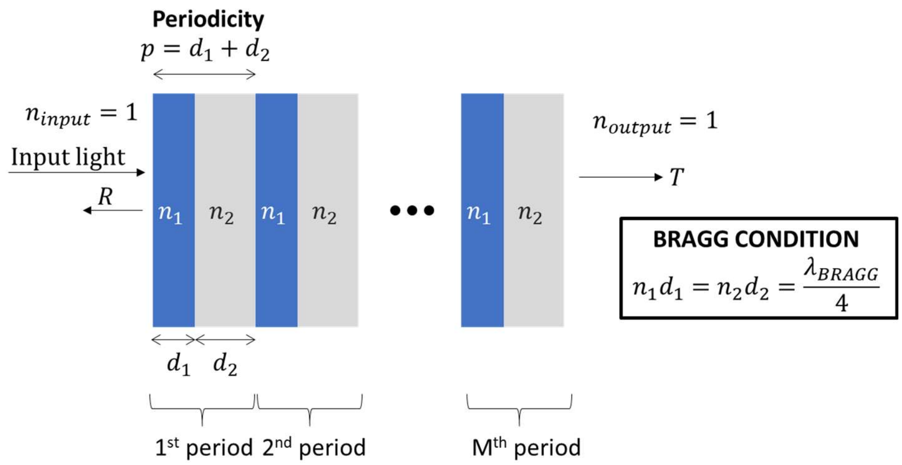
LAB EXERCISE: A dielectric mirror with high reflectivity

In the previous exercise we have analyzed an FP cavity with small finesse ($F = 4R/(1-R)^2$), due to the fact that the two "mirrors" provided small reflectance values.

A more effective way to build a highly-reflective, optical mirror is based on interference filters. These structures go under different names in the literature, such as photonic crystals, Bragg reflectors and dielectric mirrors. In this exercise we use the MATLAB function "tmm.m" to build a dielectric mirror. A dielectric mirror is a periodic structure made by alternating two films of different refractive indices (n_1 and n_2) and different thicknesses d_1 and d_2, as in the figure below. The design is quite simple. Let's suppose that we want a mirror action (high reflectance) centered at a specific wavelength, that we call Bragg wavelength, λ_{BRAGG}. The only requirement for the films in the periodic structure is that they respect the so-called BRAGG CONDITION, i.e., $n_1 d_1 = n_2 d_2 = \frac{\lambda_{BRAGG}}{4}$. The performance of the mirror, i.e., the value of reflectance obtained at the target wavelength λ_{BRAGG}, grows significantly with the number of periods in the structure (i.e., the number M in figure) and the index-difference between the two media that are alternated in the unit cell of the periodic structure ($n_1 - n_2$).



Step 1: Consider the following scenario:

- Input/output media are air, $n_{input} = n_{output} = 1$;
- The two films in the unit cell of the periodic structure are silicon ($n_1 = 3$) and silica ($n_2 = 1.5$)
- Angle of incidence $\theta_i = 0$, i.e., normal incidence
- The mirror should be highly-reflective at a wavelength of $3\mu m$, in other words $\lambda_{BRAGG} = 3\mu m$.

Plot the reflectance spectrum (R versus wavelength) in the frequency range f=linspace(6e13,6e14,1000), using different values of M (the number of periods in the structure).

Step 2. How many periods do we need in order to have reflectance R>99% at $3\mu m$?

Step 3. Consider the dielectric mirror with the number of periods determined in step 2 and modify the design by lowering the value of n_1 from 3 to 2 (hint: the thickness d_1 should be changed in order to satisfy the Bragg condition, $n_1 d_1 = \frac{\lambda_{BRAGG}}{4}$). Has the reflectance at $3\mu m$ changed with respect to step 2? How much has it changed?

Step 4. Modify the structure to realize a defect state at the center of the band gap.