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Microphotonics

CAD-LAB: Periodic Structure

Lukuan Zhang, Rui Zhu, Xiyuan Guo

GHENT UNIVERSITY
GLOBAL CAMPUS

Contents

1 Surface Grating

1.1

From Figure 1 of the k-vector diagram of the surface grating, we get

$$K = \frac{2\pi}{\Lambda} = \frac{k_0 n}{\sqrt{2}} \tag{1}$$

$$\Lambda = \frac{2\pi\sqrt{2}}{k_0 n} = 0.917\mu\mathrm{m} \tag{2}$$

So the period of surface grating is $0.917\mu\mathrm{m}$.

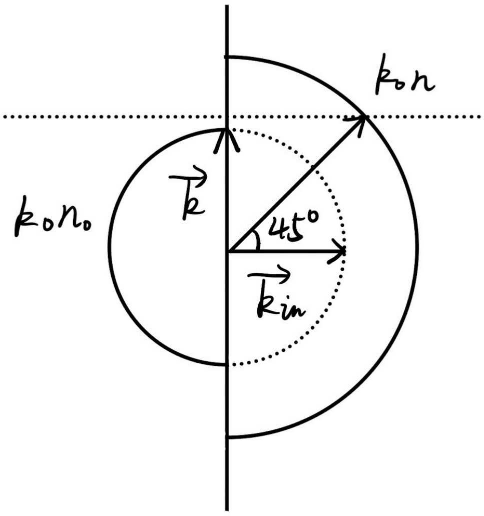

Figure 1: The k-vector diagram of the surface grating

1.2

Set D as $0.1\mu\mathrm{m}$ and period Λ as $0.917\mu\mathrm{m}$ and run the simulation, then we can get Figure 2, which shows the plane wave mainly propagates in the $0°$ direction, and partly propagates in the $45°$ and $-45°$ direction.

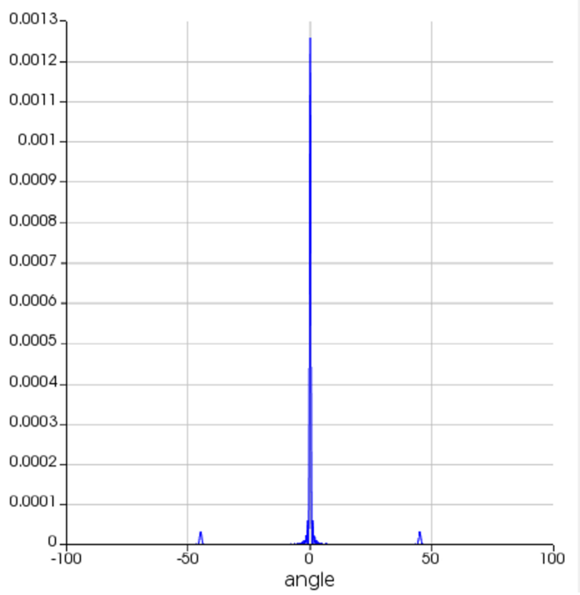

Figure 2: Distribution of E2 in farfield with period $0.917\mu\mathrm{m}$ and D $0.1\mu\mathrm{m}$

1.3

1. Increase the diffraction to the $45°$ orders

Getting the geometic relationship from Figure 3, an analytical expression can be figured out from

$$k_0\left(\sqrt{2}Dn - n_0D\right) = 2\pi m \tag{3}$$

When $\lambda = 1.55\mu\mathrm{m}$, $n = 2.39$, $n_0 = 1$ and $m = 1$, we get $D = 0.6513\mu\mathrm{m}$. Adjusting the parameters and running the simulation again, we can see an apparent improvement in Figure 4

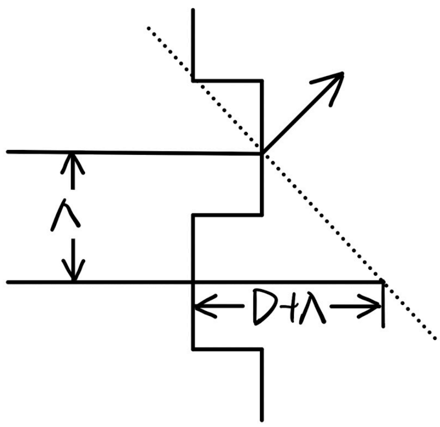

Figure 3: The surface gating diagram

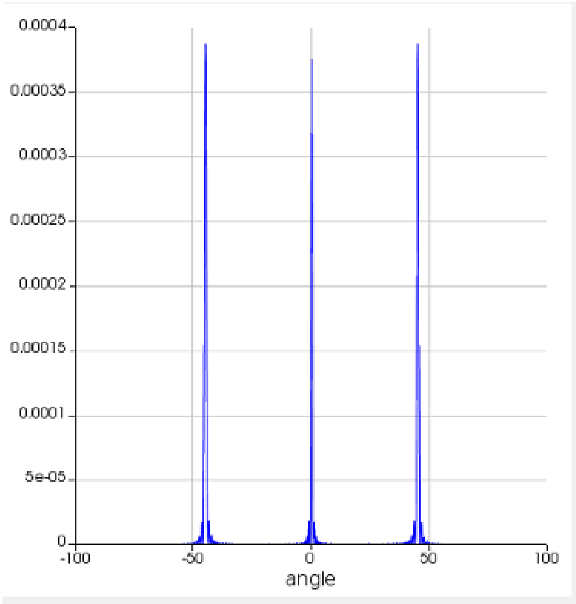

Figure 4: Distribution of E2 in farfield with period $0.917\mu\mathrm{m}$ and D $0.6513\mu\mathrm{m}$

2. Decrease the 0° diffraction

An analytical expression can be figured out from

$$k_0\left((D+\Lambda)n - n_0 D\right) = 2\pi m \tag{4}$$

When $\lambda = 1.55\mu\mathrm{m}$, $\Lambda = 0.917\mu\mathrm{m}$, $n = 2.39$, $n_0 = 1$ and $m = 1$, we get $D = 0.6536\mu\mathrm{m}.$ Adjusting the parameters and running the simulation again, we can also see an apparent improvement in Figure 5.

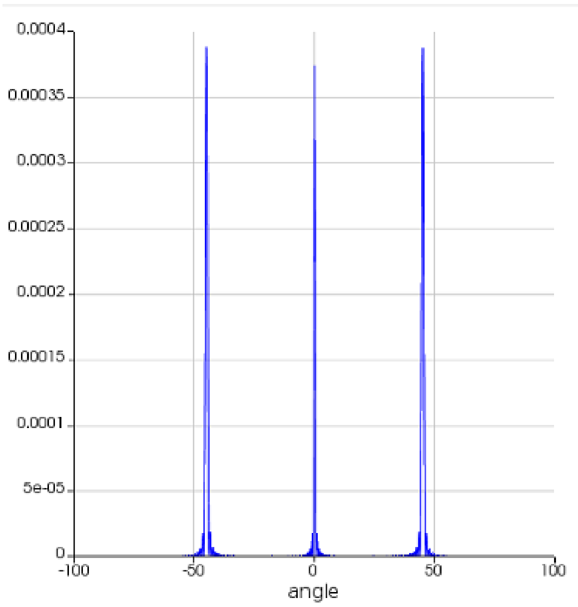

Figure 5: Distribution of E2 in farfield with period $0.917\mu\mathrm{m}$ and D $0.6536\mu\mathrm{m}$

2 Distributed Bragg Refector

According to the k-diagram in Figure 6, we can calculate the period required,

$$\Lambda = \frac{\lambda}{2n_{neff}} = 0.322917\mu m \tag{5}$$

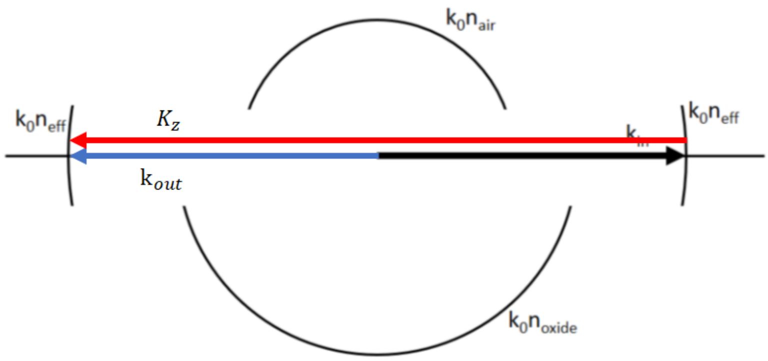

Figure 6: κ vector diagram

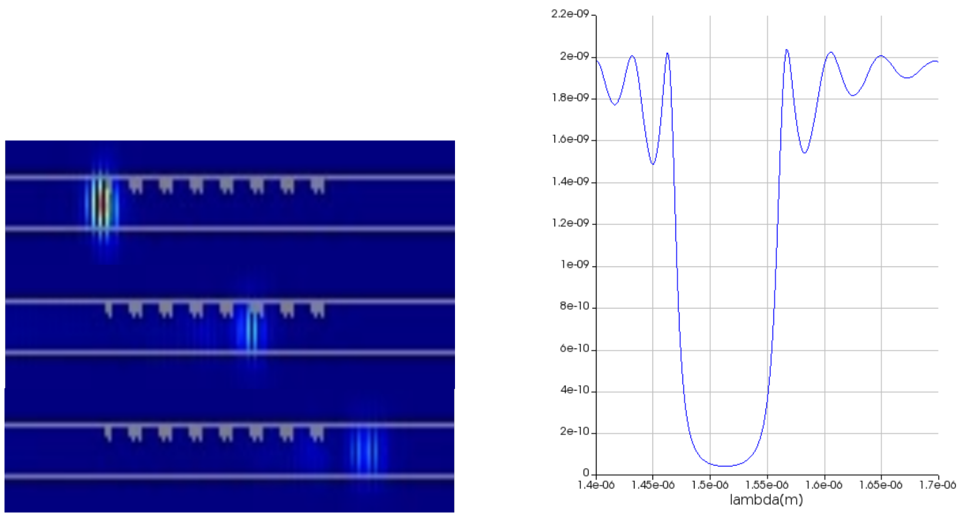

Figure 7: Propagation process(Left). The transmission spectrum of the grating(Right)

Adjusting it in the *WaveguideGrating.fsp* simulation file, the result is shown in Figure 8. Obviously, it is not what we expect. The smallest transmission is not at $\lambda = 1.55\mu m$. We think it's because the air surounding and boundary condition or other reasons that have influences on the effective refractive index. If the simulation is real, the real n_{eff} should meet

$$\frac{\lambda'}{2n'_{eff}} = \frac{\lambda}{2n_{eff}} \tag{6}$$

Then we get $n_{eff} = 2.346$ and $\Lambda = 0.3304$. In the simulation, we get the reflectivity 0.972. According to formula (6.87), we calculate κ

$$\kappa = \frac{1}{2N\Lambda} \ln \frac{1+\sqrt{R}}{1-\sqrt{R}} = 0.250\mu\mathrm{m}^{-1} \tag{7}$$

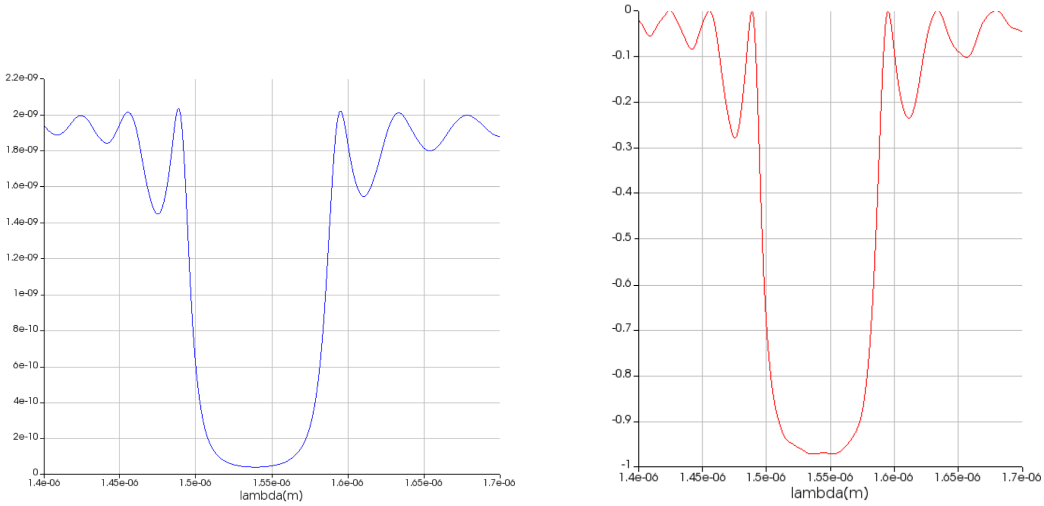

Figure 8: The transmission spectrum of the grating when $n_{eff} = 2.346$(Left). The reflectivity(Right)

After changing N, we could get the relation between κL and R, as shown in Figure 9. Obviously, L is proportional to $\tanh^{-1}\sqrt{R}$. Simulating it with Matlab, we get $\kappa = 0.2292\mu m^{-1}$.

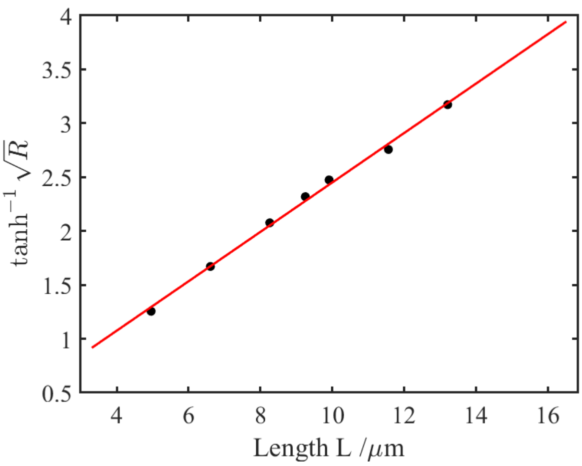

Figure 9: Relation between $\tanh^{-1}\sqrt{R}$ and L.

3 Grating Coupler

3.1

From Figure 10 of the k-vector diagram of the waveguide grating, the period of waveguide grating is calculated as $0.645\mu\mathrm{m}$.

$$K = \frac{2\pi}{\Lambda} = k_{in} = \frac{2\pi}{\lambda} n_{eff} \tag{8}$$

$$\Lambda = \frac{\lambda}{n_{\text{eff}}} = \frac{1550\ \mathrm{nm}}{2.4} = 645.8\ \mathrm{nm} \tag{9}$$

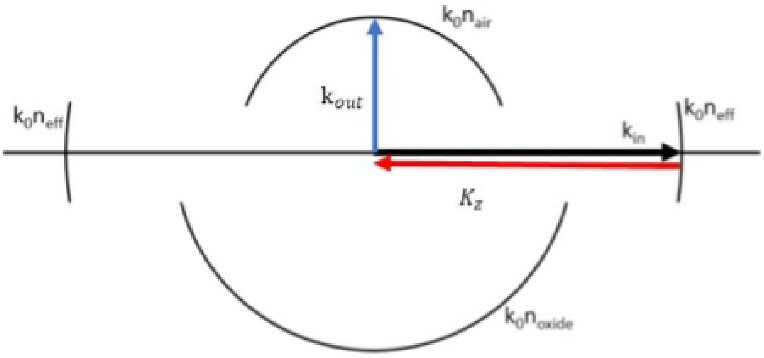

Figure 10: The k-vector diagram of the waveguide grating

3.2

Figure 11 shows transmission spectrum when the light propagates upwards. There is a dip around $1550\mathrm{nm}$, not as expected. In theory, there may be a peak instead of a dip at about $1550\mathrm{nm}$. The reason is that n_{eff} is smaller than the theoretical value 2.4 for the periodic structure. The effective refractive index of unetched part waveguide is 2.4, but the etched part is smaller, so the effective refractive index of the whole waveguide is smaller than 2.4.

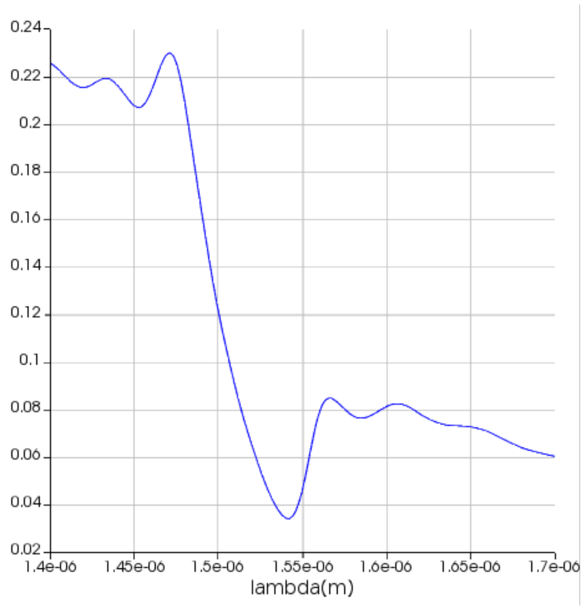

Figure 11: Transmission spectrum of monitor_up at $\Lambda = 645.8\mathrm{nm}$

3.3

Figure 12 shows the far-field radiation pattern of upward. The maximum of E is only 1.5×10^{-7}. By varying the wavelength, we found that E reaches the maximum 7.3×10^{-7} at $\lambda = 1468.7\mathrm{nm}$, as Figure 13 shown. This wavelength also corresponds to the peak of transmission spectrum when the light propagates upwards, shown as Figure 14.

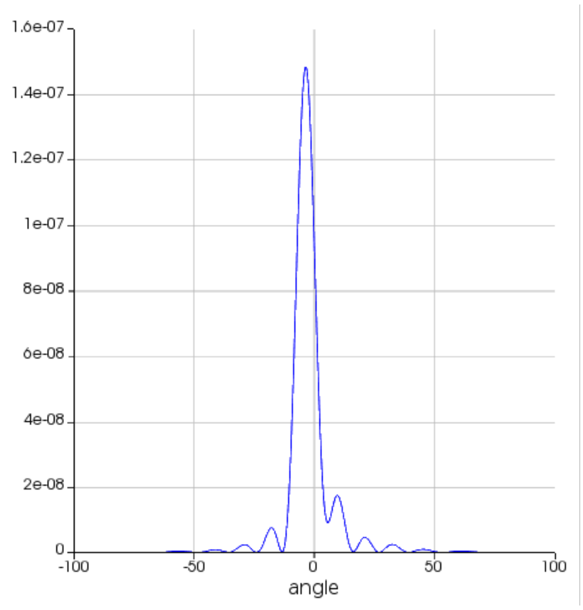

Figure 12: Far-field radiation pattern of upward at $\Lambda = 645.8\mathrm{nm}$, $\lambda = 645.8\mathrm{nm}$ and $n_{eff} = 2.4$

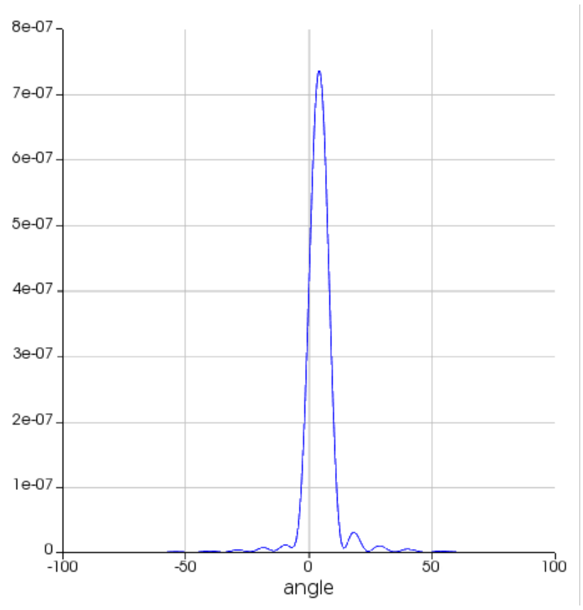

Figure 13: Far-field radiation pattern of upward at $\Lambda = 645.8\text{nm}$, $\lambda = 1468.7\text{nm}$ and $n_{eff} = 2.4$

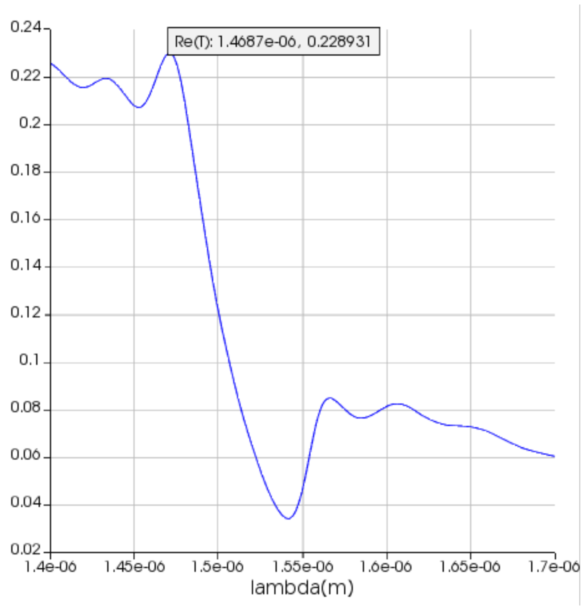

Figure 14: The peak of upward transmission spectrum at $\Lambda = 645.8\text{nm}$, $\lambda = 1468.7\text{nm}$

3.4

The method to correct the dip in the trasmission spectrum is to enlarge Λ, because the real n_{eff} is smaller than the theoretical value 2.4. Figure 15 shows that the upward transmission spectrum for $\Lambda = 691.2\text{nm}$, and the peak of transmission spectrum is $\lambda = 1550.55\text{nm}$. Figure 16 illustrates the far-field radiation pattern of upward at $\Lambda = 691.2\text{nm}$ and $\lambda = 1550.55\text{nm}$, and the diffracttion angle is $3.5°$, $T = 6.22 \times 10^{-7}$.

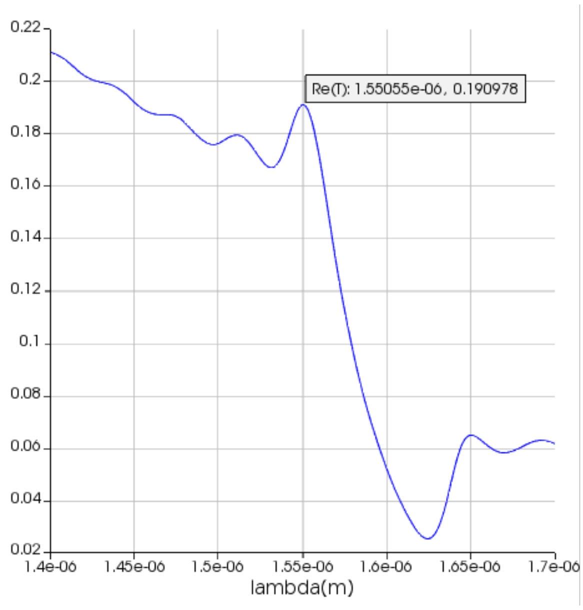

Figure 15: Upward transmission spectrum at $\Lambda = 691.2\mathrm{nm}$

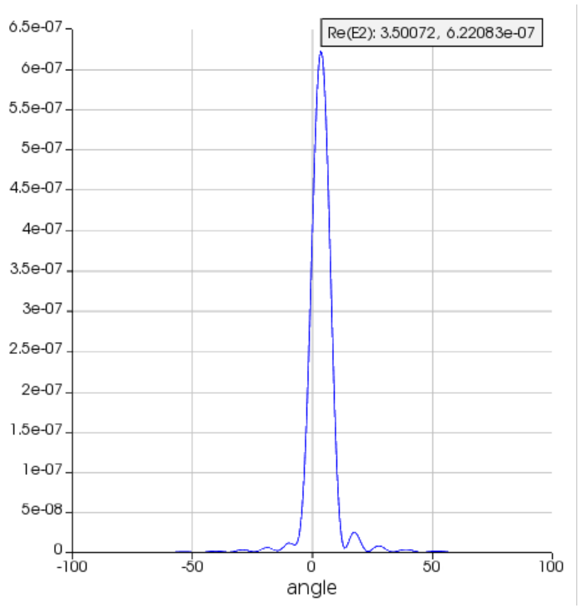

Figure 16: Far-field radiation pattern of upward at $\Lambda = 691.2\mathrm{nm}$, $\lambda = 1550.55\mathrm{nm}$