Principe - Physics 265 PS6

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1 Physics 265 Problem Set 6

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[1]:
```
import numpy as np
import matplotlib.pyplot as plt
from matplotlib import cm
```

2 Problem 6.1

2.1 Interference Signal Produced by Mercury Light Source

The visible light that is produced by an Hg lamp consists of the following spectral lines (nm) and their relative intensities (I): 312 (I = 70), 334 (I = 46), 365 (I = 96.7), 405 (I = 73), 436 (I = 93.3), 546 (I = 80), and 579 (I = 53).‘

‘Plot the total interference signal (Equation 15, Section 7.2, Born & Wolf) that is produced by an Hg lamp within the optical path difference range: −1.5 ΔS (micron) 1.5.

Consideration of the optical path difference yields the total intensity (I) for two monochromatic waves, expressed as:

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2 \cos\delta}. \tag{1}$$

Expressing in terms of the wavelength of light, we have

$$= I_1 + I_2 + 2\sqrt{I_1 I_2 \cos\left(\frac{2\pi}{\lambda_0}\Delta S\right)}. \tag{2}$$

For a single source, where $I_1 = I_2$, the total intensity (I) reduces to:

$$I = 2I_1 + 2I_1 \cos\left(\frac{2\pi}{\lambda_0}\Delta S\right) \tag{3}$$

This further simplifies to:

$$I = 2I_1 \left(1 + \cos\left(\frac{2\pi}{\lambda_0}\Delta S\right)\right) \tag{4}$$

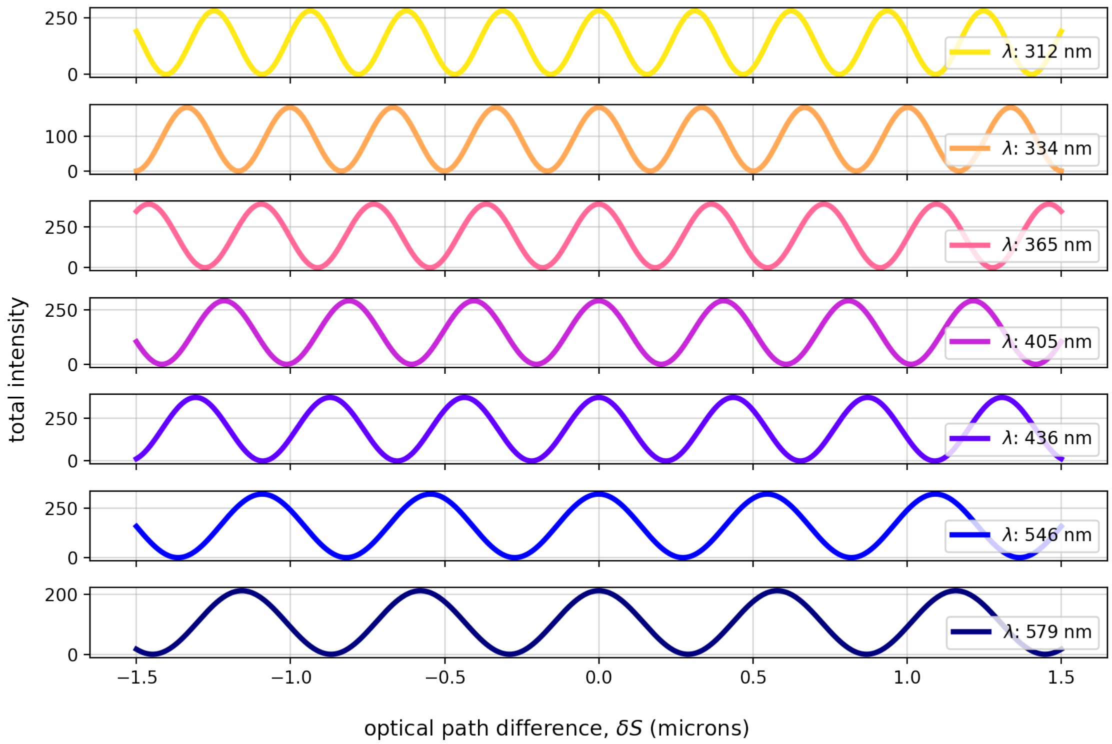
$$I = 2I_1 \left(2\cos^2\left(\frac{\pi}{\lambda_0}\Delta S\right)\right) \tag{5}$$

$$I = 4I_1 \cos^2\left(\frac{\pi}{\lambda_0}\Delta S\right) \tag{6}$$

[2]:
```
def total_intensity(I, delta_S , lambda_):
    return 4 * I * np.cos(np.pi*delta_S/lambda_)**2
```

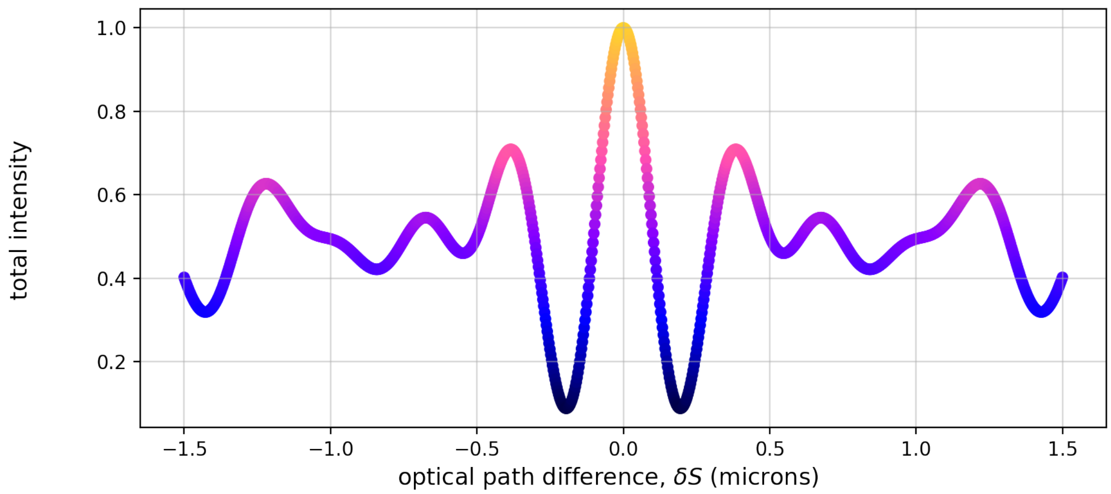
[3]:
```
peaks_mercury = np.array([312, 334, 365, 405, 436, 546, 579])
intesities_mercury = np.array([70, 46, 96.7, 73, 93.3, 80, 53])/100

opd = np.linspace(-1.5, 1.5, 1000)*1e3
```

[4]:
```
n_y = len(peaks_mercury)

fig, ax = plt.subplots(nrows=n_y,ncols=1, sharex='col',figsize=(9,6), dpi = 200)
fig.patch.set_facecolor('None')

total_I_mercury = np.zeros(len(opd))

for i, ax in enumerate(ax):
    I_i = intesities_mercury[i]
    lambda_ = peaks_mercury[i]
    I = total_intensity(I_i, opd , lambda_)

    total_I_mercury += I

    ax.grid(alpha = 0.5)
    ax.plot(opd*1e-3, I*100, lw = 3, color = plt.cm.gnuplot2_r((i+1)/(n_y+1)),
            label = '$\lambda$: %.0f nm' % (lambda_))
    ax.legend(loc = 'lower right', facecolor = 'white')

fig.supxlabel('optical path difference, $\delta S$ (microns)')
fig.supylabel('total intensity')
plt.tight_layout()
```



[5]:
```python
fig, ax = plt.subplots(nrows=1,ncols=1, sharex='col',figsize=(9,4), dpi = 200)
fig.patch.set_facecolor('None')

x = opd*1e-3
y = total_I_mercury*100

plt.grid(alpha = 0.5)
plt.scatter(x, y/max(y), c=cm.gnuplot2(y/max(y*1.2)), edgecolor='none')

fig.supxlabel('optical path difference, $\delta S$ (microns)')
fig.supylabel('total intensity')
```

[5]: Text(0.02, 0.5, 'total intensity')



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3 Problem 6.2

3.1 Interference Signal Produced by Sodium Light Source.

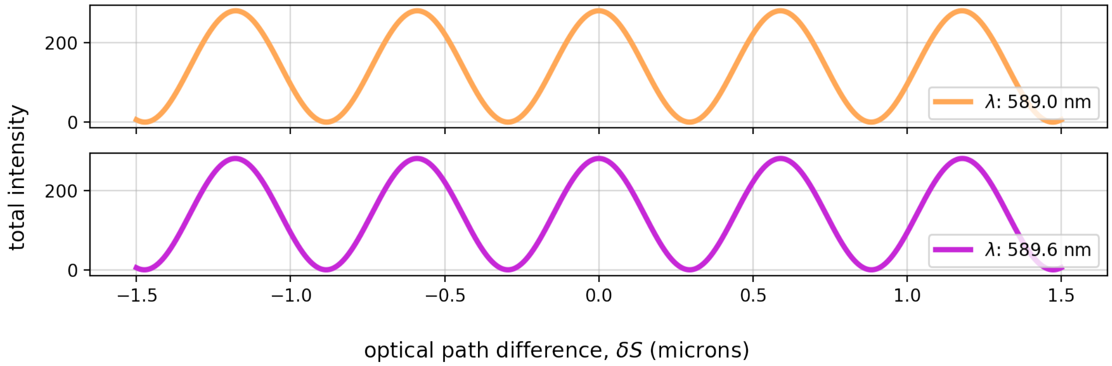
The visible light that is produced by a Sodium lamp consists of two (doublet) lines: 589.6 nm (I = 70), and 589 nm (I = 70).

Plot the total interference signal that is produced by Na lamp within the optical path difference range: -1.5 ΔS (micron) 1.5.

[6]:
```
peaks_sodium = np.array([589, 589.6])
intesities_sodium = np.array([70, 70])/100

opd = np.linspace(-1.5, 1.5, 1000)*1e3
```

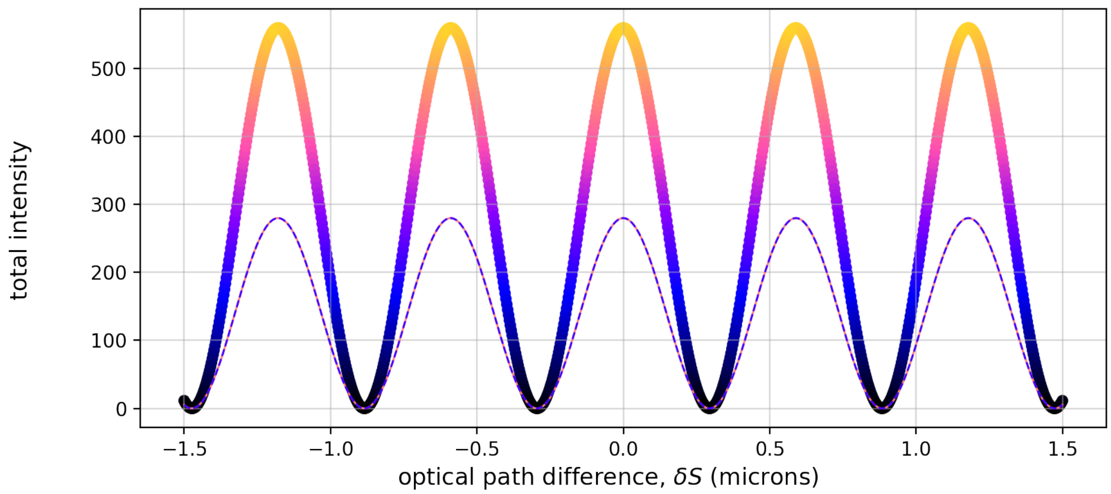
[7]:
```
n_z = len(peaks_sodium)

fig, ax = plt.subplots(nrows=n_z,ncols=1, sharex='col',figsize=(9,3), dpi = 200)
fig.patch.set_facecolor('None')

total_I_sodium = np.zeros(len(opd))

for i, ax in enumerate(ax):
    I_i = intesities_sodium[i]
    lambda_ = peaks_sodium[i]
    I = total_intensity(I_i, opd, lambda_)

    total_I_sodium += I
```

```
    ax.grid(alpha = 0.5)
    ax.plot(opd*1e-3, I*100, lw = 3, color = plt.cm.gnuplot2_r((i+1)/(n_z+2)),
            label = '$\lambda$: %.1f nm' % (lambda_))
    ax.legend(loc = 'lower right', facecolor = 'white')

fig.supxlabel('optical path difference, $\delta S$ (microns)')
fig.supylabel('total intensity')
plt.tight_layout()
```



[8]:
```
fig, ax = plt.subplots(nrows=1,ncols=1, sharex='col',figsize=(9,4), dpi = 200)
fig.patch.set_facecolor('None')

x = opd*1e-3
y = total_I_sodium*100

plt.grid(alpha = 0.5)

plt.plot(opd*1e-3, I*100, lw = 1, color = plt.cm.gnuplot2_r(1/3), ls = '-')
plt.plot(opd*1e-3, I*100, lw = 1, color = plt.cm.gnuplot2_r(2/3), ls = '--')


plt.scatter(x, y, c=cm.gnuplot2(y/max(y*1.2)), edgecolor='none')

fig.supxlabel('optical path difference, $\delta S$ (microns)')
fig.supylabel('total intensity')
```

[8]:
```
Text(0.02, 0.5, 'total intensity')
```



4 Problem 6.3

4.1 Visibility

Which light source (Hg or Na) produces an interference signal with higher visibility V where V = (Imax - Imin)/ (Imax + Imin)?

[9]:
```python
def visibility(I):
    Imax = np.max(I)
    Imin = np.min(I)
    V = (Imax-Imin)/(Imax+Imin)
    print('Maximum Intensity: % .2f' % Imax)
    print('Minimum Intensity: % .2f' % Imin)
    print('Visibility: % .6f' % V)
    return Imax, Imin, V
```

4.1.1 Mercury

[10]:
```python
visibility(total_I_mercury)
```

```
Maximum Intensity:  20.48
Minimum Intensity:  1.81
Visibility:  0.837981
```

[10]:
```
(20.477134574247376, 1.8050759135570595, 0.8379805347817697)
```

4.1.2 Sodium

[11]:
```
visibility(total_I_sodium)
```

```
Maximum Intensity:  5.60
Minimum Intensity:  0.00
Visibility:  0.999978
```

[11]:
```
(5.599941704572872, 6.23219742121721e-05, 0.999977742168071)
```

From the calculations, **sodium light source produces interference signal with higher visibility compared to mercury.**