Calcback

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Contents

1 What is this?

I'm coding a program to get the complex refractive index $n = n * ik$ from the ellipsometric parameters Δ and Ψ I got from a simulation.

2 Imports:

```
import numpy as np
import matplotlib
from matplotlib import pyplot
```

3 Defining some variables:

Defining some variables for later use:

```
CSVFILE = "head300nmSiO2.csv"
phi_i = 70 * np.pi / 180
d_L = 300
n_air = 1
rerange = 5
imrange = 5
i = 0
```

4 Read .csv-file:

Read the values into a two dimensional numpy array as [[lambda,Psi,Delta,n_{S,k_S}],...]
(Skip columns 3 and 4)

```
csv = np.loadtxt(CSVFILE, usecols=(0,1,2,5,6),  delimiter=",", skiprows=1)
```

:DEBUG: The array looks like this:

```
print(csv)
```

300	55.2217535	84.37228319	2.6726	3.0375
303	50.11187439	93.3085011	2.7346	3.0381
306	46.35824553	98.43681392	2.7967	3.0368
309	43.50539341	101.18051798	2.8588	3.0334
312	41.29392865	102.19236832	2.9206	3.0279
315	39.48751217	101.93002	2.9822	3.0205
318	37.90308303	100.64846104	3.0435	3.0109
321	36.47640803	98.54577151	3.1042	2.9994
324	35.12615859	95.72242205	3.1644	2.9858

5 Calculate ρ

5.1 Create a matrix containing every possible refractive index (n+ik):

```
lsp_re = np.linspace(0.1, rerange, 101)
lsp_im = np.linspace(0.1, imrange, 101)
re, im = np.meshgrid (lsp_re, lsp_im, copy=False)
matrix = 1j * im + re
```

This gives the following matrix:

```
print(matrix)
```

```
[[0.1  +0.1j   0.149+0.1j   0.198+0.1j   ... 4.902+0.1j   4.951+0.1j
  5.   +0.1j  ]
 [0.1  +0.149j 0.149+0.149j 0.198+0.149j ... 4.902+0.149j 4.951+0.149j
  5.   +0.149j]
 [0.1  +0.198j 0.149+0.198j 0.198+0.198j ... 4.902+0.198j 4.951+0.198j
  5.   +0.198j]
 ...
 [0.1  +4.902j 0.149+4.902j 0.198+4.902j ... 4.902+4.902j 4.951+4.902j
  5.   +4.902j]
 [0.1  +4.951j 0.149+4.951j 0.198+4.951j ... 4.902+4.951j 4.951+4.951j
  5.   +4.951j]
 [0.1  +5.j    0.149+5.j    0.198+5.j    ... 4.902+5.j    4.951+5.j
  5.   +5.j   ]]
```

5.2 Calculate:

5.2.1 By using Snell's Law to calculate the refractive angles inside the media.

Phi is the incident angle for the layer, n1 and n2 are refractive indices of first and second medium. Returns the angle of refraction.

```
def snell(phi, n1, n2):
    phi_ref = np.arcsin((np.sin(phi) * n1) / n2)
    return phi_ref
```

5.2.2 TODO Calculate r_p and r_s with Fresnel equations:

```
def fresnel(n1, phi1, n2, phi2):
    return rs, rp
```

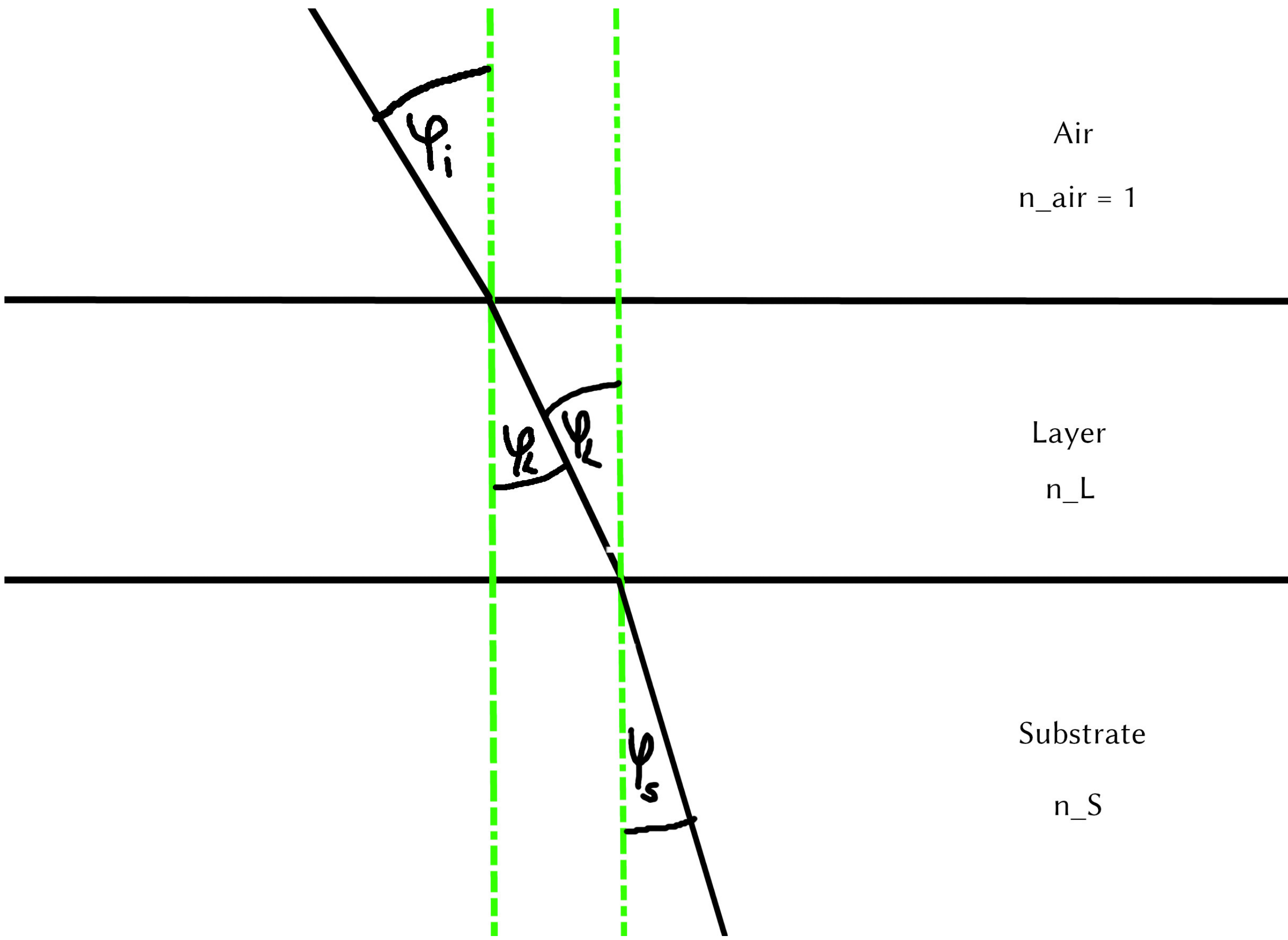

Figure 1: Snell's Law

5.2.3 TODO Calculate ρ after Fujiwara [?]:

5.2.4 TODO Wrap a for-loop around these functions to calculate ρ for every $\mathbf{n_L}$ in the matrix

```
n_S = (csv[i,3] + 1j* csv[i,4])
lambda_vac = csv[i,0]
for n_L in matrix.flat:
      phi_L = snell(phi_i,n_air,n_L)
      phi_S = snell(phi_L,n_L,n_S)
      # Fresnel equations:
      #
      # air/layer:
      rs_al = (n_air * np.cos(phi_i) - n_L * np.cos(phi_L)) / (n_air * np.cos(phi_i) +
      rp_al = (n_L * np.cos(phi_i) - n_air * np.cos(phi_L)) / (n_L * np.cos(phi_i) + n_
      # layer/substrate:
      rs_ls = (n_L * np.cos(phi_L) - n_S * np.cos(phi_S)) / (n_L * np.cos(phi_L) + n_S
      rp_ls = (n_S * np.cos(phi_L) - n_L * np.cos(phi_S)) / (n_S * np.cos(phi_L) + n_L
      # Fujiwara:
      beta = 2 * np.pi * d_L * n_L * np.cos(phi_L) / lambda_vac
      rp_L = (rp_al + rp_ls * np.exp(-2*1j*beta)) / (1 + rp_al * rp_ls * np.exp(-2 * 1j
      rs_L = (rs_al + rs_ls * np.exp(-2*1j*beta)) / ( 1 + rs_al * rs_ls * np.exp(-2 * 1
      rho = rp_L / rs_L
      output = []
      output.append([n_L, rho])
```

```
for n_L =  (5+5j)
at lambda =  300.0
phi_L (0.09369049752311029-0.0942436309601521j)
phi_S (0.1516718935900151-0.1754940397472108j)
rs_al (-0.9322788656900732-0.06447800755339925j)
rp_al (0.47076999129408226+0.32915273622391117j)
rs_ls (0.2706645644366405-0.037805743704596925j)
rp_ls (-0.27413124901624036+0.021323198111731292j)
beta (31.139752412112067+31.69455000949363j)
rp_L (1.426723122645158-0.9975355870956931j)
rs_L (-1.067534044700266+0.07383248803644696j)
rho (-1.3944229215529675+0.8379890813445299j)
output [[(5+5j), (-1.3944229215529675+0.8379890813445299j)]]
```

5.3 Compare calculated rho with given Δ and ψ: