Calcback

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Contents

1 What is this?

This is a script to get the complex refractive index $n = n * ik$ from the ellipsometric parameters Δ and Ψ I got from a simulation. The result for 300nm SiO_2 should look like this:

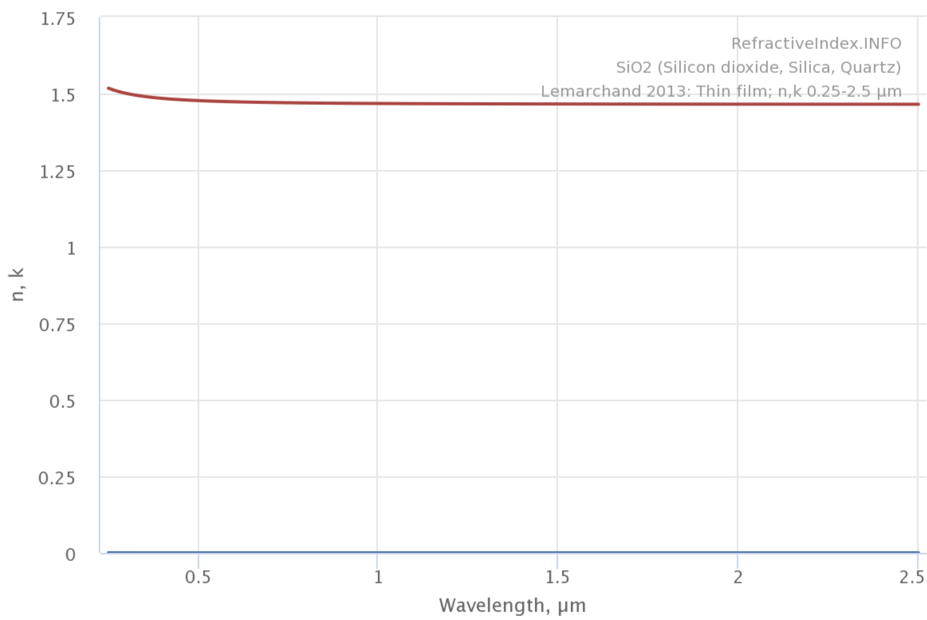


Figure 1: Refractive index should look like this

2 List of Todos:

2.1 TODO Write a loop for all wavelengths after it works for one.

2.2 TODO Then take even more wavelengths (rows)

3 Imports:

4 Defining some variables:

Defining some variables for later use:

5 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)

:DEBUG: The array looks like this:

```
[[ 4.00000000e+02  4.63752956e+01 -8.41522003e+01  5.62650000e+00
   3.30100000e-01]
 [ 4.01000000e+02  4.66645899e+01 -8.40149297e+01  5.59460000e+00
   3.18200000e-01]
 [ 4.02000000e+02  4.69702190e+01 -8.38513987e+01  5.56370000e+00
   3.07000000e-01]
 ...
 [ 7.98000000e+02  3.32352187e+01  1.00231229e+02  3.69890000e+00
   4.10000000e-03]
 [ 7.99000000e+02  3.31871064e+01  1.00206655e+02  3.69810000e+00
   4.00000000e-03]
 [ 8.00000000e+02  3.31422918e+01  1.00188647e+02  3.69740000e+00
   4.00000000e-03]]
```

6 Calculate ρ

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

Change the last number in the "linspaces" to adjust the resolution.

This gives the following matrix:

```
[1.    1.004 1.008 ... 4.992 4.996 5.   ]
```

6.2 Calculate ρ:

6.2.1 First we define some functions:

1. Snell's Law to calculate the refractive angles: Phi is the incident angle for the layer, n1 and n2 are refractive indices of first and second medium. Returns the angle of refraction.

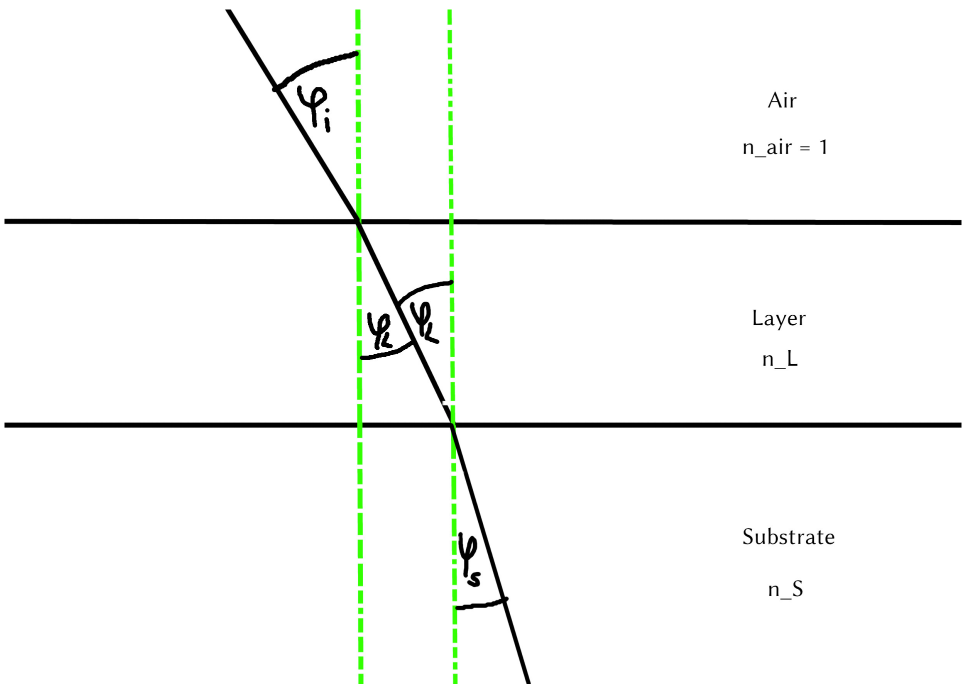


Figure 2: Snell's Law

2. Calculate r_p and r_s with Fresnel equations:

3. Calculate ρ for the layer with eq. 5.2 in Spectroscopic Ellipsometry fujiwara2009spectroscopic:

6.2.2 Then we call these functions one after another to calculate ρ:

Get refractive index of the substrate (n_S) and lambda from the csv:

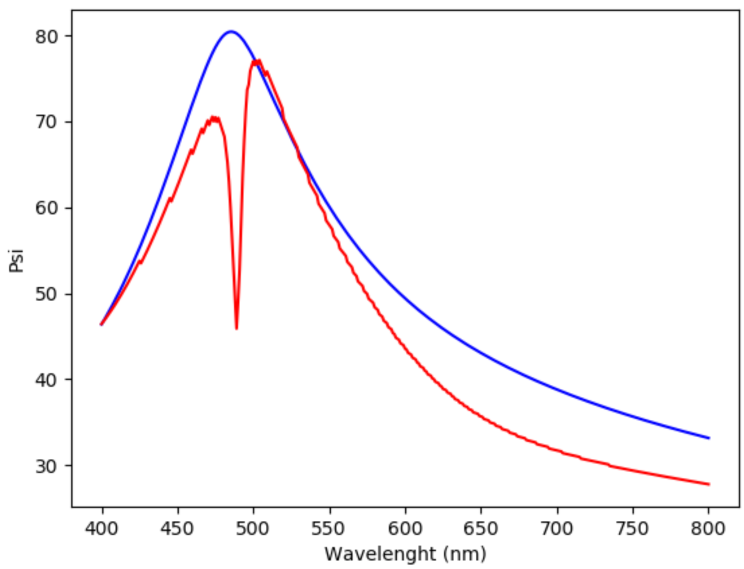
6.2.3 Identify the best fitting rho with $\rho = \tan(\psi) * e^{i\Delta}$:

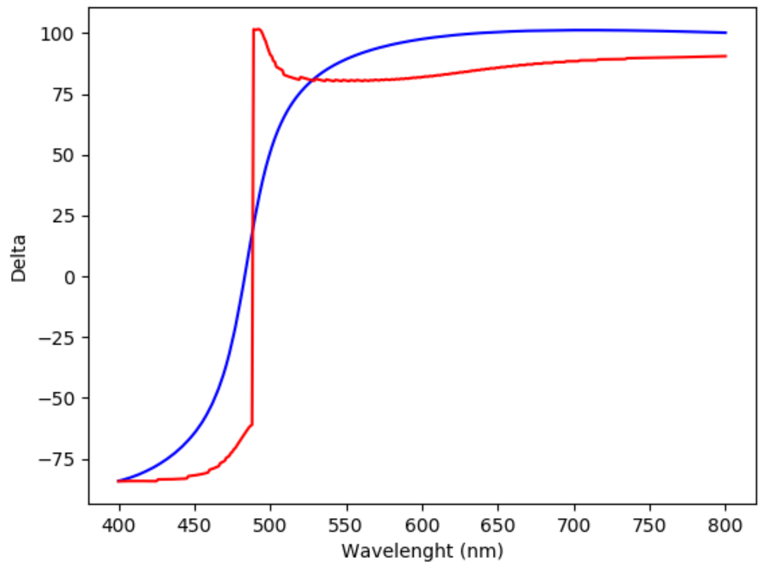
7 Plot some things for checking results:

If we use a high resolution, those plots are not showing much, thats why they are only showing the first 10000 values.

7.1 Plot Δ & Ψ:

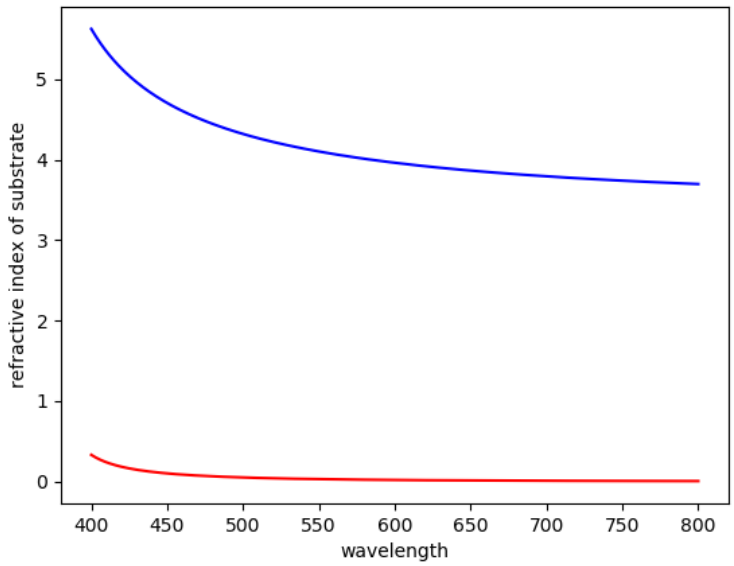
Ψ from input in blue, Ψ_L in red.





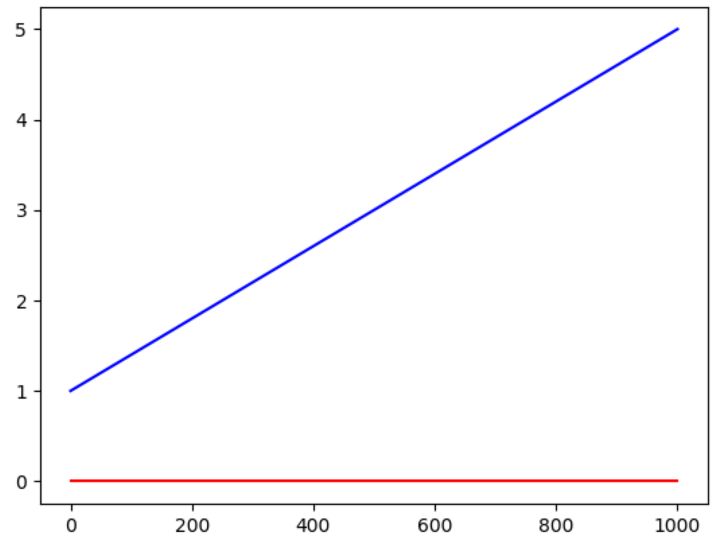
7.2 Plot refractive index of substrate n_S:

Real part n in blue, imaginary part k in red



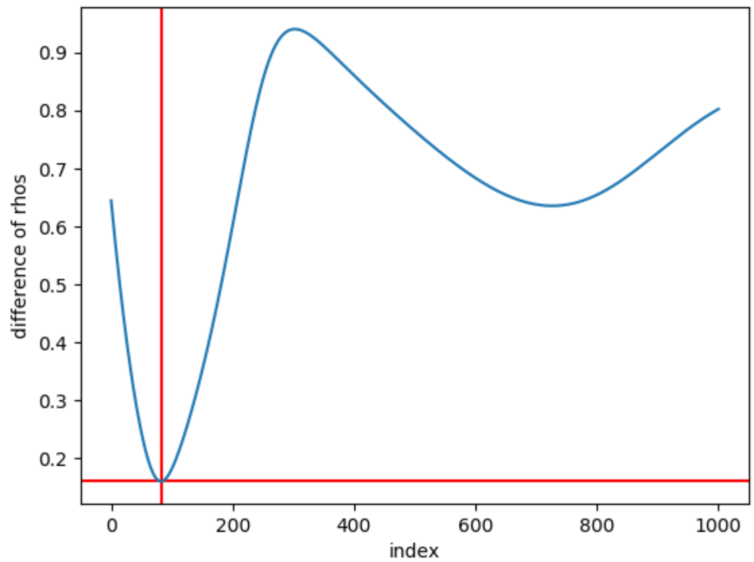
7.3 Plot real and imaginary part of the created $\mathbf{n_L}$ matrix:

Real part is blue, imaginary is red.



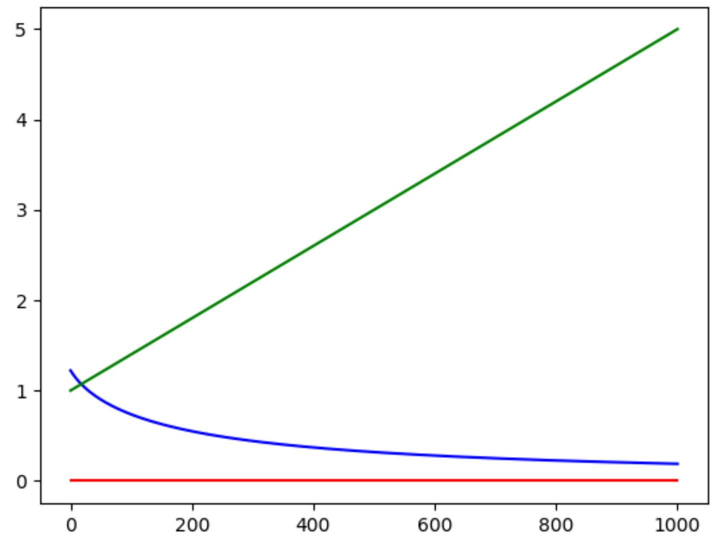
7.4 Plot of the difference between ρ_{L} and the given ρ and determined minimum:

The difference is shown in blue, the red lines show the minimum.



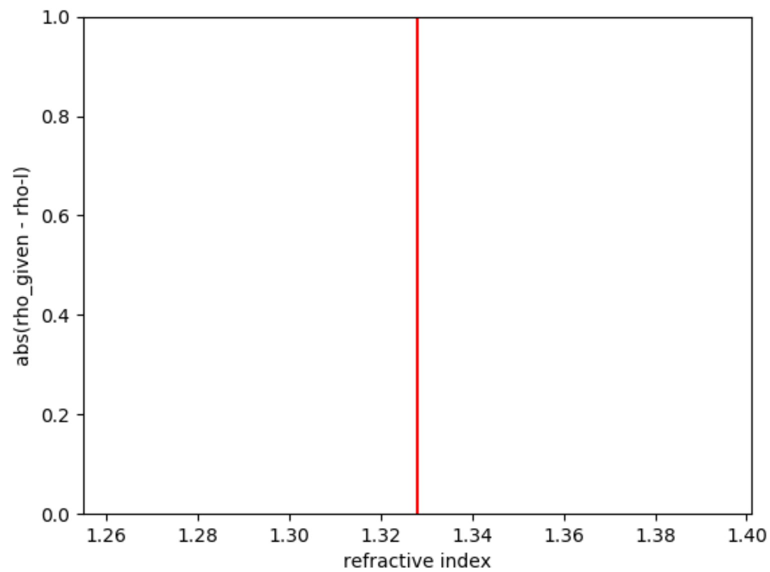
7.5 Plot refractive angle phi_L and n_L:

n_L is shown in green, real part of phi_L in blue, imaginary in red. A relation between these should be visible.



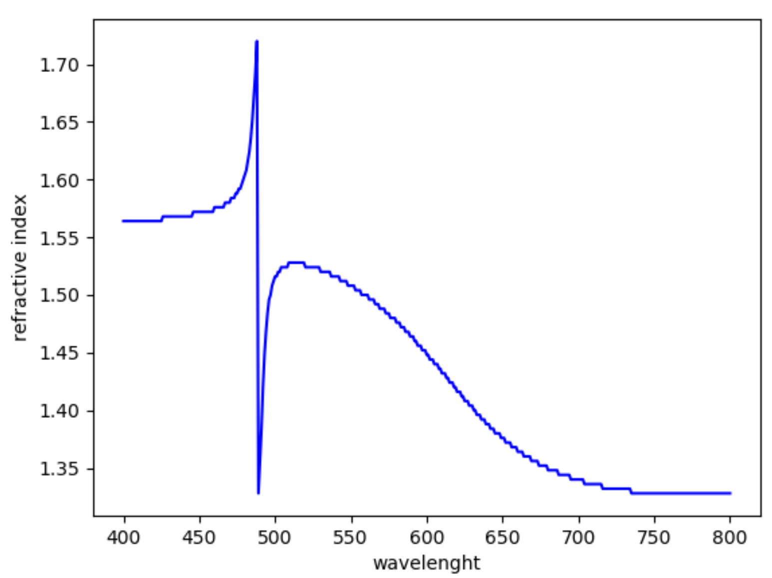
7.6 Plot $\rho_{\mathbf{given}}$ - $\rho_{\mathbf{L}}$

Red line shows the found refractive index at the minimum



abs(rho_given - rho-l)
refractive index

7.7 Plot n



refractive index
wavelenght

8 Testing:

Testing with constant n_L, phi_i at i=0

8.1 snell():

should be: (1.220429-0.02737074 i)

0.25693777375213495-0.0029123892267902147j

should be: (0.151671-0.175494i)

8.2 fresnel():

rs_{al}, rp_{al} = fresnel(n_{air}, phi_i, n_L, phi_L)
rs_{ls}, rp_{ls} = fresnel(n_L, phi_L, n_S, phi_S)

```
0.0
```

should be: (-0.003398-0.04239i)

```
0.0
```

should be:

-0.8254138705368641-0.00029432103501708976j

0.13326188486753962+0.00015550190551111361j

8.3 $calc_{rho}$():

rho_L = $calc_{rho}$(rs_{al}, rp_{al}, rs_{ls}, rp_{ls}, d_L, n_L, $lambda_{vac}$) Just copied this from above with beta returned

```
0.805865977238737
```

should be: 2.1558487+0.18312240i

-0.16144861157373563-0.00013082428937188695j