

# DESIGN GRADE DE BRAGG

# SEMANA 1

## ESTUDO DE REFERENCIAS

# ESTUDO DE REFERENCIAS

Ref: T. Erdogan, "Fiber grating spectra," in Journal of Lightwave Technology, vol. 15, no. 8, pp. 1277-1294, Aug. 1997, doi: 10.1109/50.618322.

Para uma grade do tipo FBG, é interessante calcular analiticamente sua transmissão e refletância teorica

Para um caso mais simples as variáveis que podemos controlar são:

**Neff, Comprimento da grade, refletância maxima**

# ESTUDO DE REFERENCIAS

Podemos calcular  $r$  através da seguinte equação:

$$r = \frac{\sinh^2\left(\sqrt{\kappa^2 - \hat{\sigma}^2}L\right)}{\cosh^2\left(\sqrt{\kappa^2 - \hat{\sigma}^2}L\right) - \frac{\hat{\sigma}^2}{\kappa^2}}.$$

Logo, so precisamos definir  $\kappa$  e  $\hat{\sigma}$

# ESTUDO DE REFERENCIAS

K pode ser calculado a partir da reflexão máxima:

$$r_{\max} = \tanh^2(\kappa L)$$

$$k = \frac{\arctang(\sqrt{r_{\max}})}{L}$$

# ESTUDO DE REFERENCIAS

E sabendo que:

$$\hat{\sigma} \equiv \delta + \sigma - \frac{1}{2} \frac{d\phi}{dz}$$

Dado que a grade é uniforme:  $\frac{d\phi}{dz} = 0$

Desprezando o self-coupling:  $\sigma = 0$

$$\text{Logo: } \hat{\sigma} \equiv \delta = 2\pi n_{\text{eff}} \left( \frac{1}{\lambda} - \frac{1}{\lambda_D} \right)$$

# ESTUDO DE REFERENCIAS

E sabendo que:

$$\hat{\sigma} \equiv \delta + \sigma - \frac{1}{2} \frac{d\phi}{dz}$$

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$$\text{Logo: } \hat{\sigma} \equiv \delta = 2\pi n_{\text{eff}} \left( \frac{1}{\lambda} - \frac{1}{\lambda_D} \right)$$

# ESTUDO DE REFERENCIAS

## Exemplo 1

$$L = 1 \text{ mm} ,$$

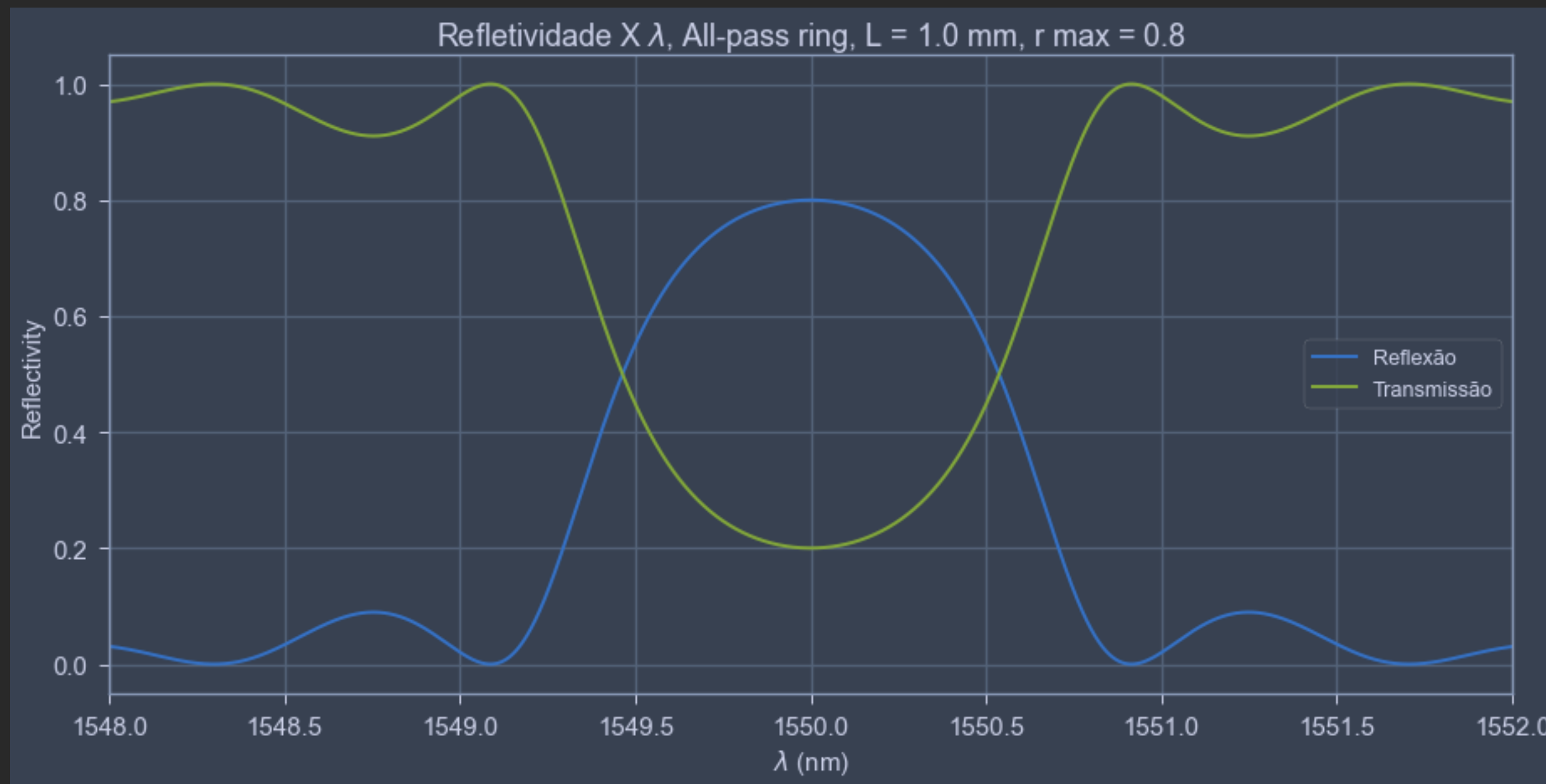
$$r_{\text{max}} = 0.8,$$

$$\text{Comprimento central} = 1550 \text{ nm}$$



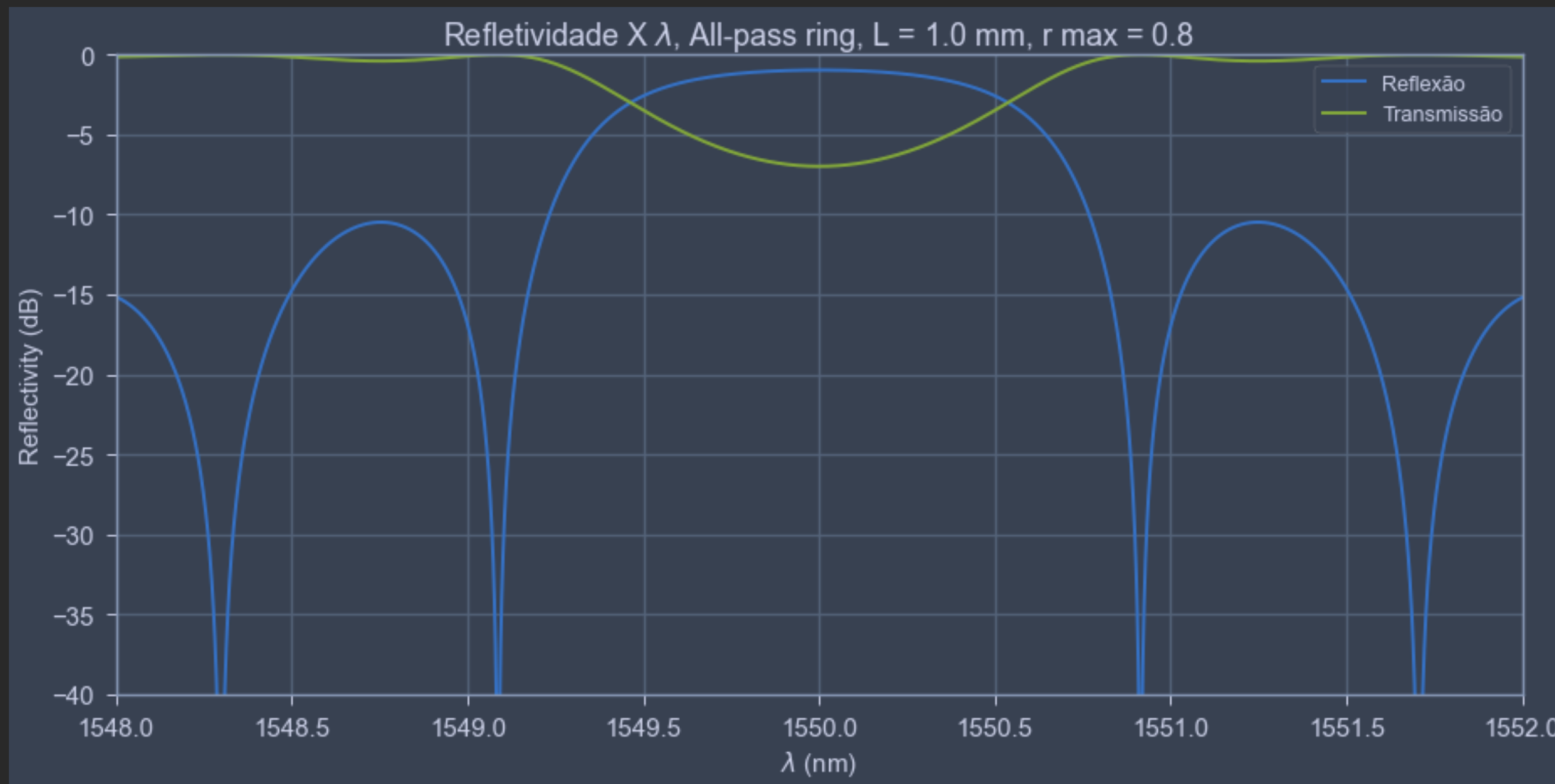
# ESTUDO DE REFERENCIAS

## Exemplo 1



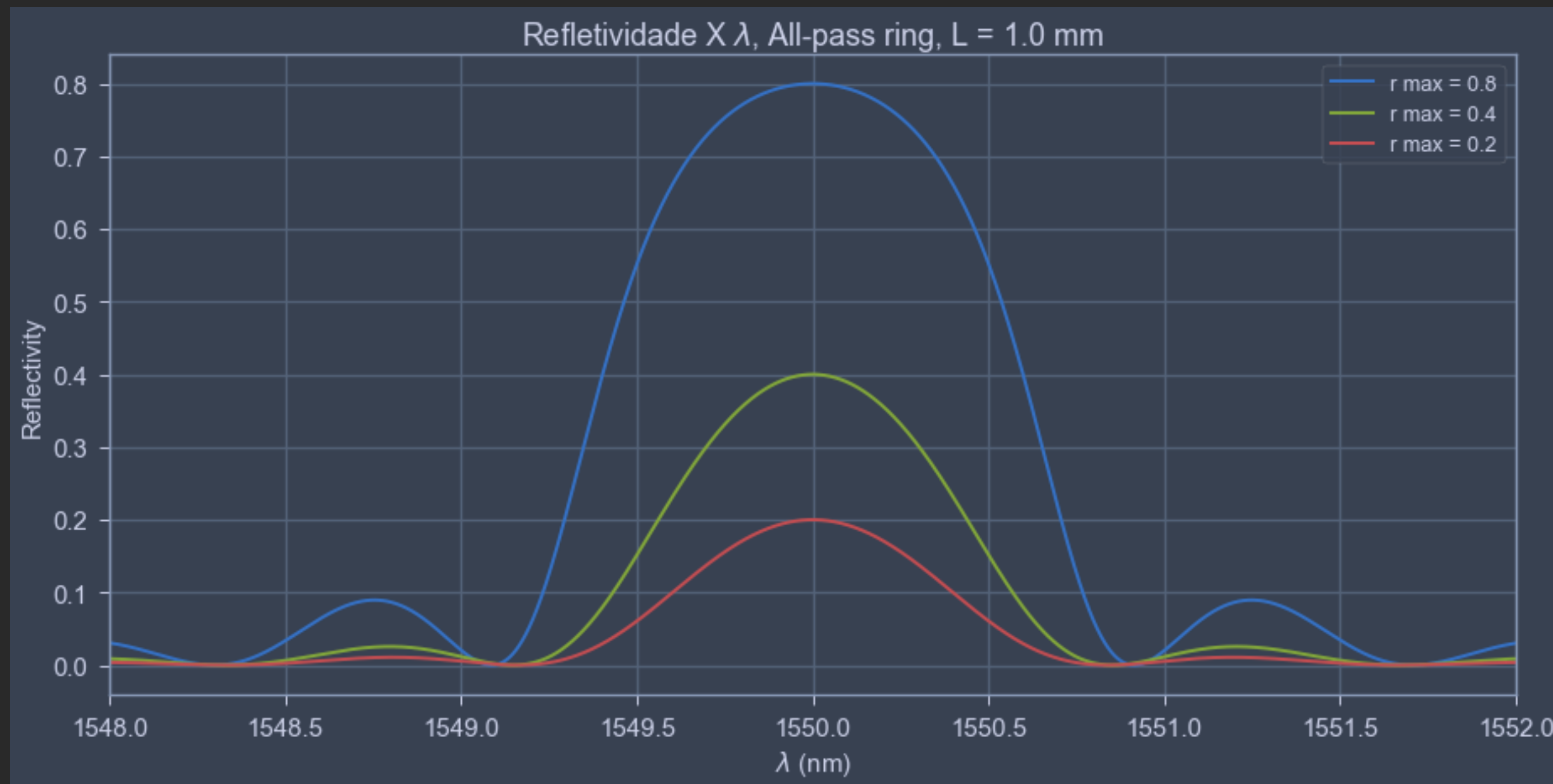
# ESTUDO DE REFERENCIAS

## Exemplo 1



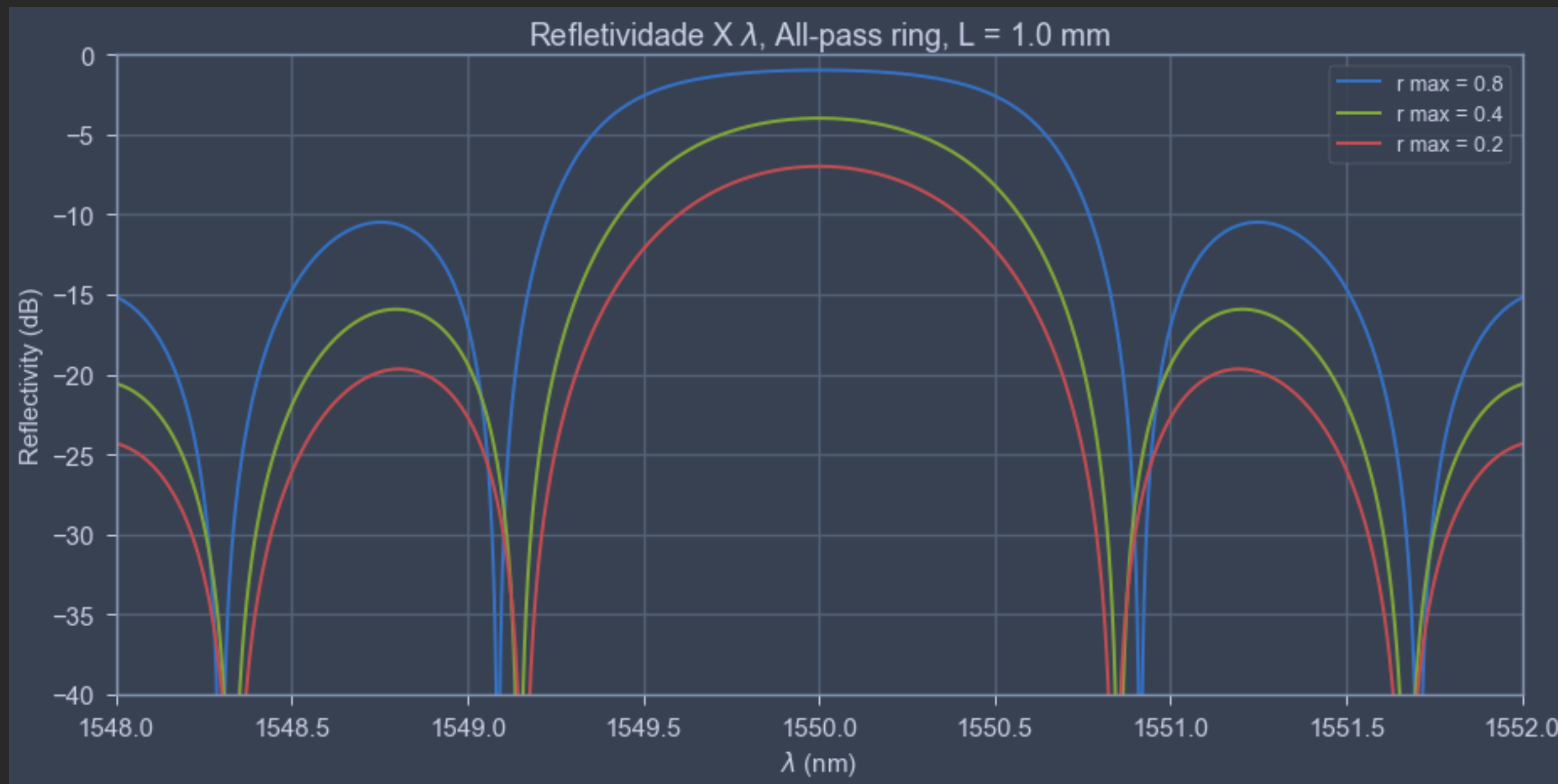
# ESTUDO DE REFERENCIAS

## Exemplo 1



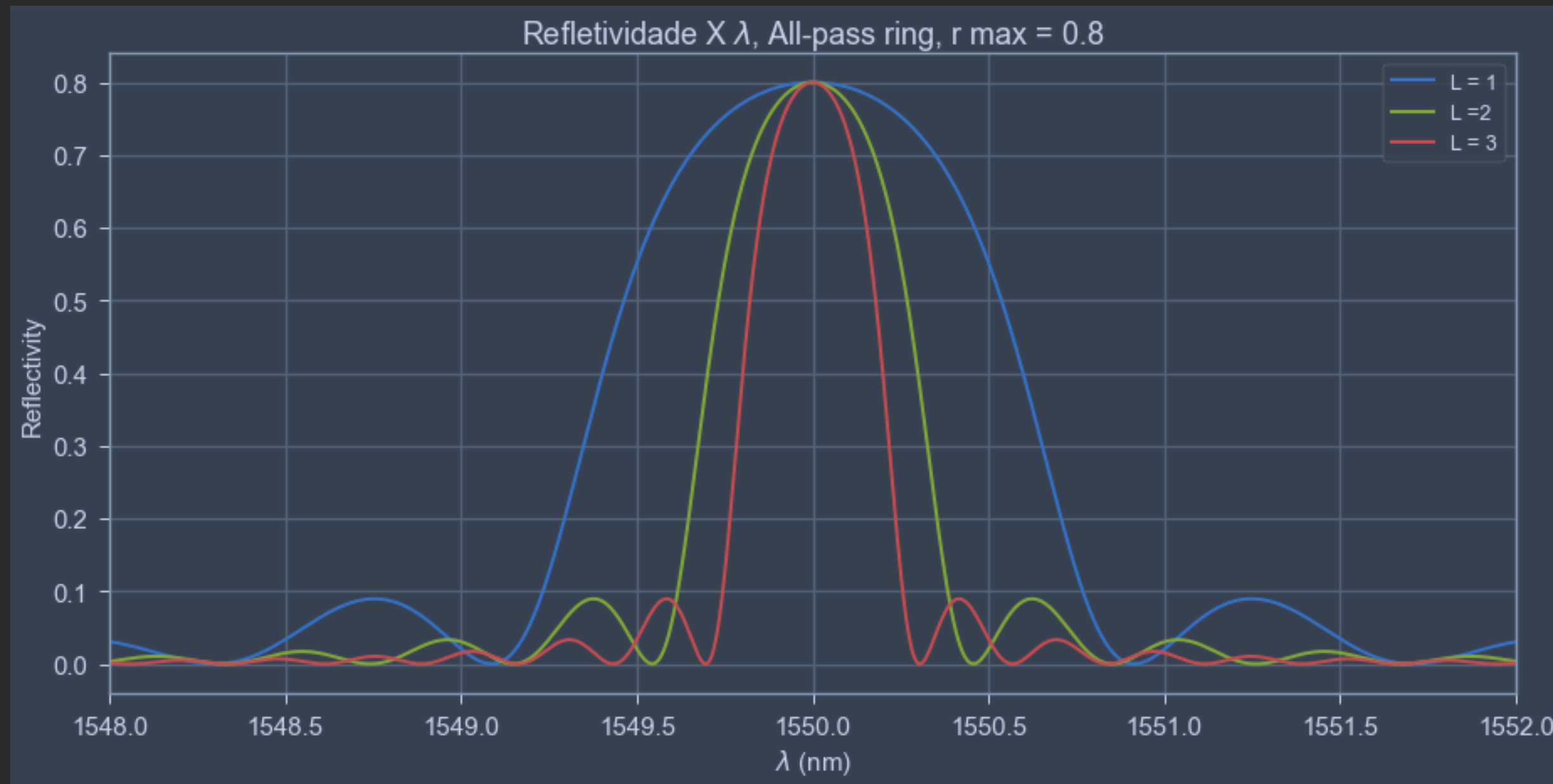
# ESTUDO DE REFERENCIAS

## Exemplo 1



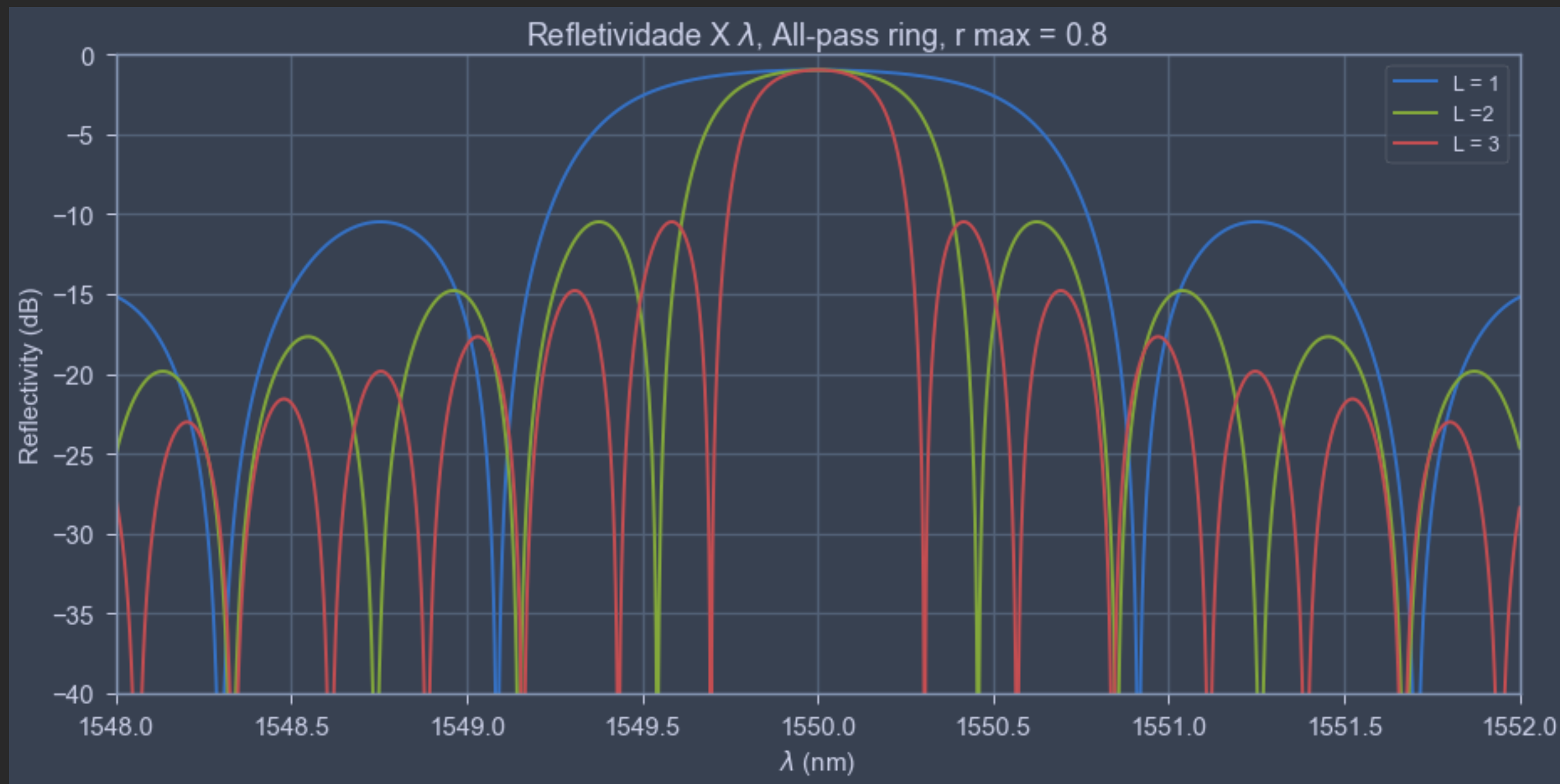
# ESTUDO DE REFERENCIAS

## Exemplo 1



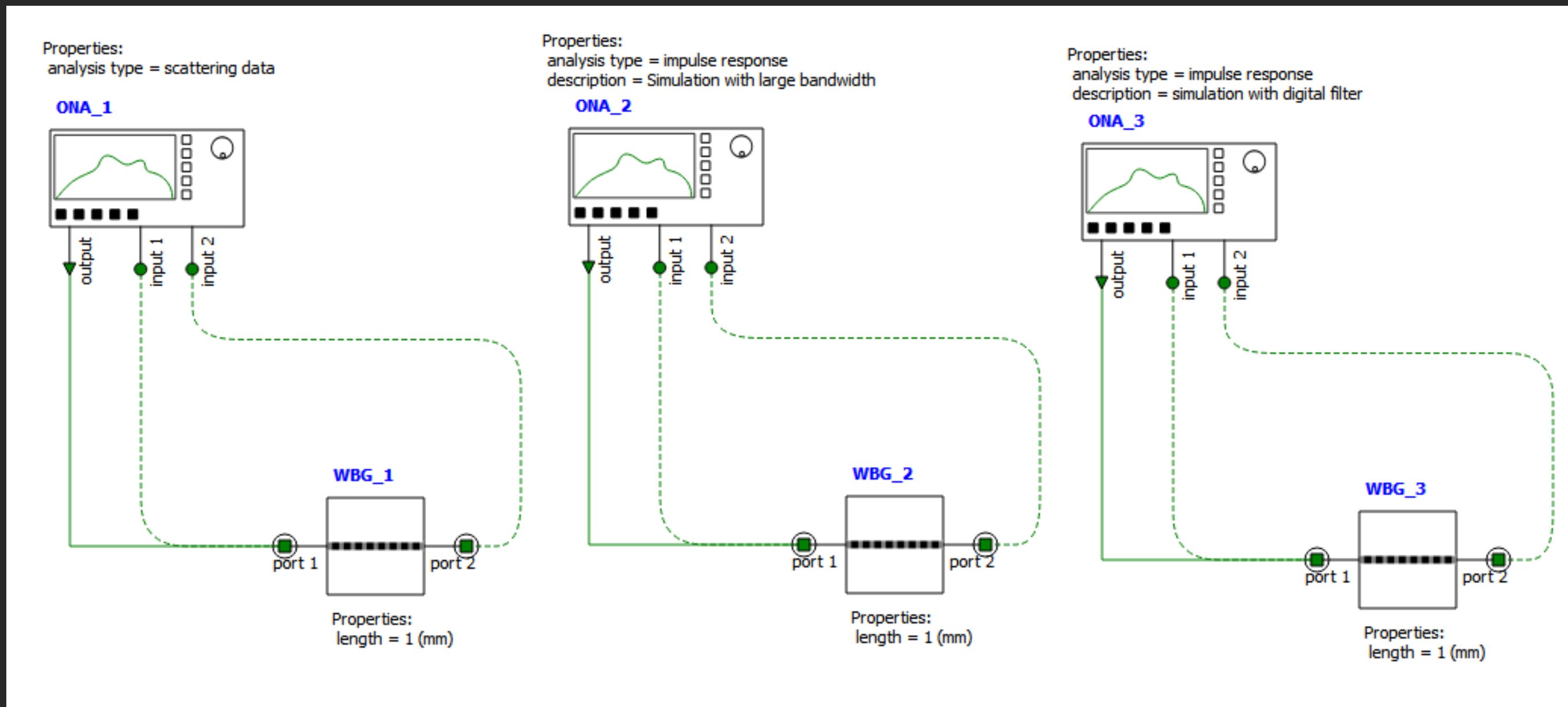
# ESTUDO DE REFERENCIAS

## Exemplo 1



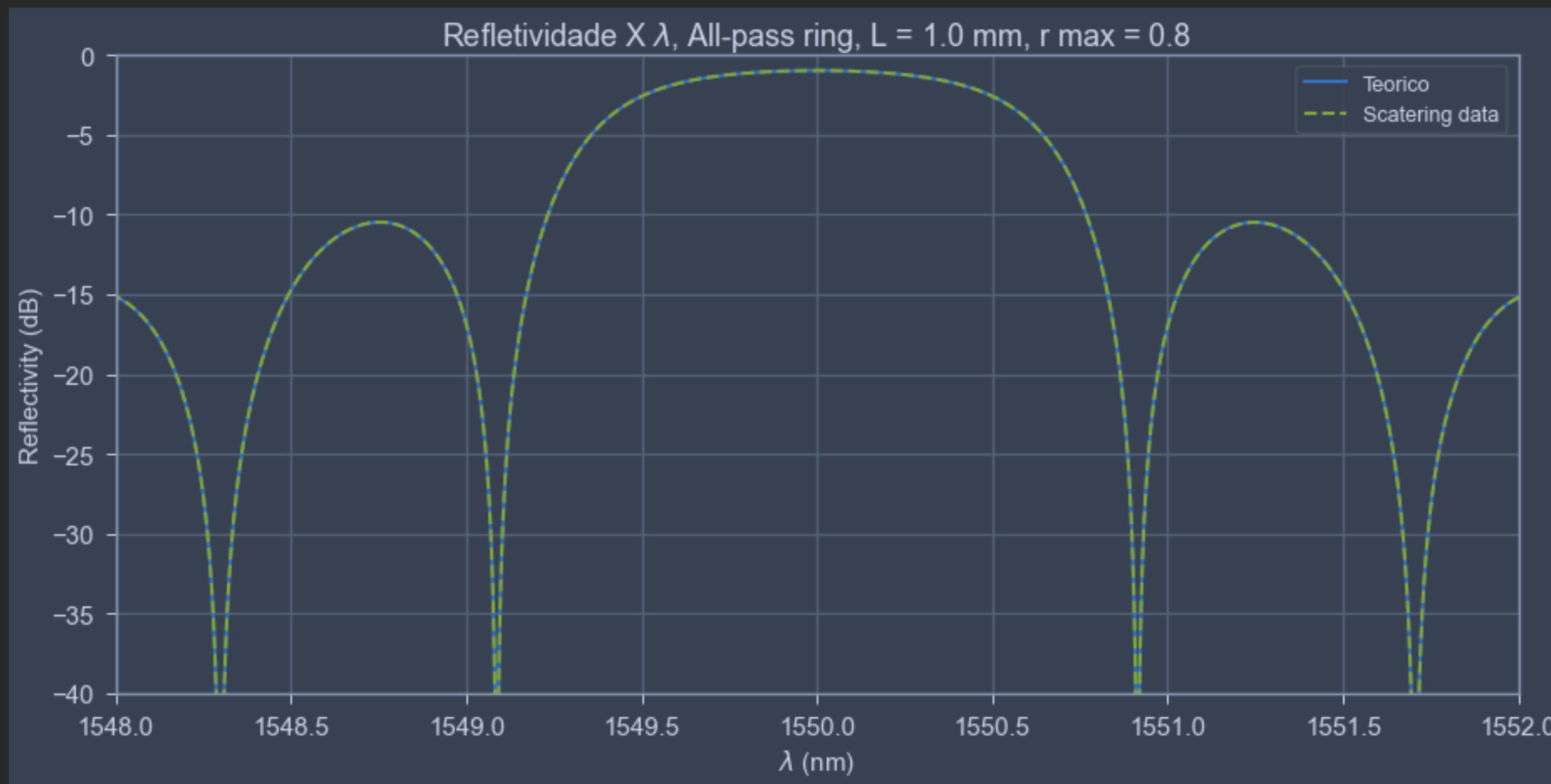
# ESTUDO DE REFERENCIAS

## Simulação interconnect Exemplo 1



# ESTUDO DE REFERENCIAS

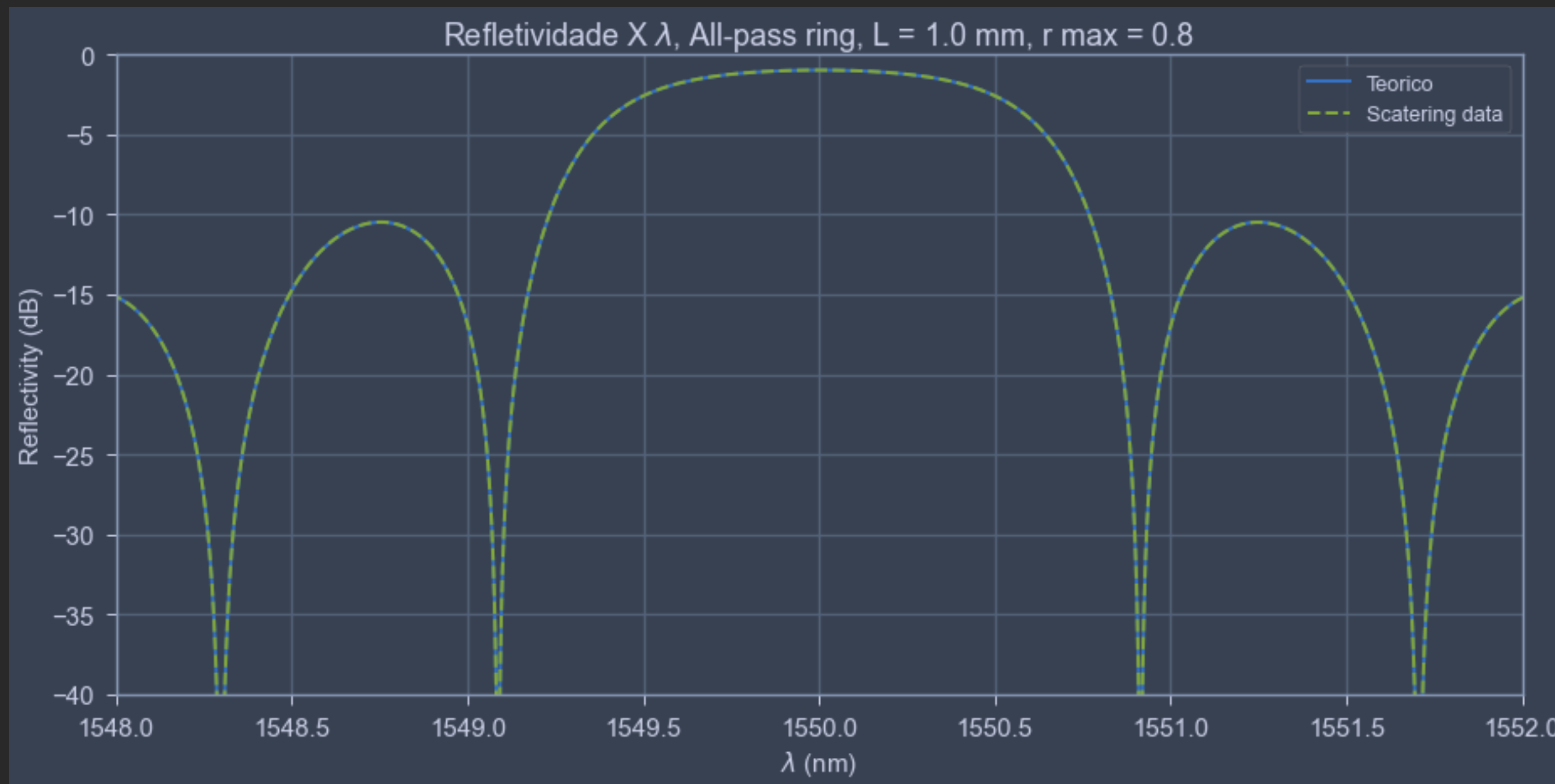
## Resultados





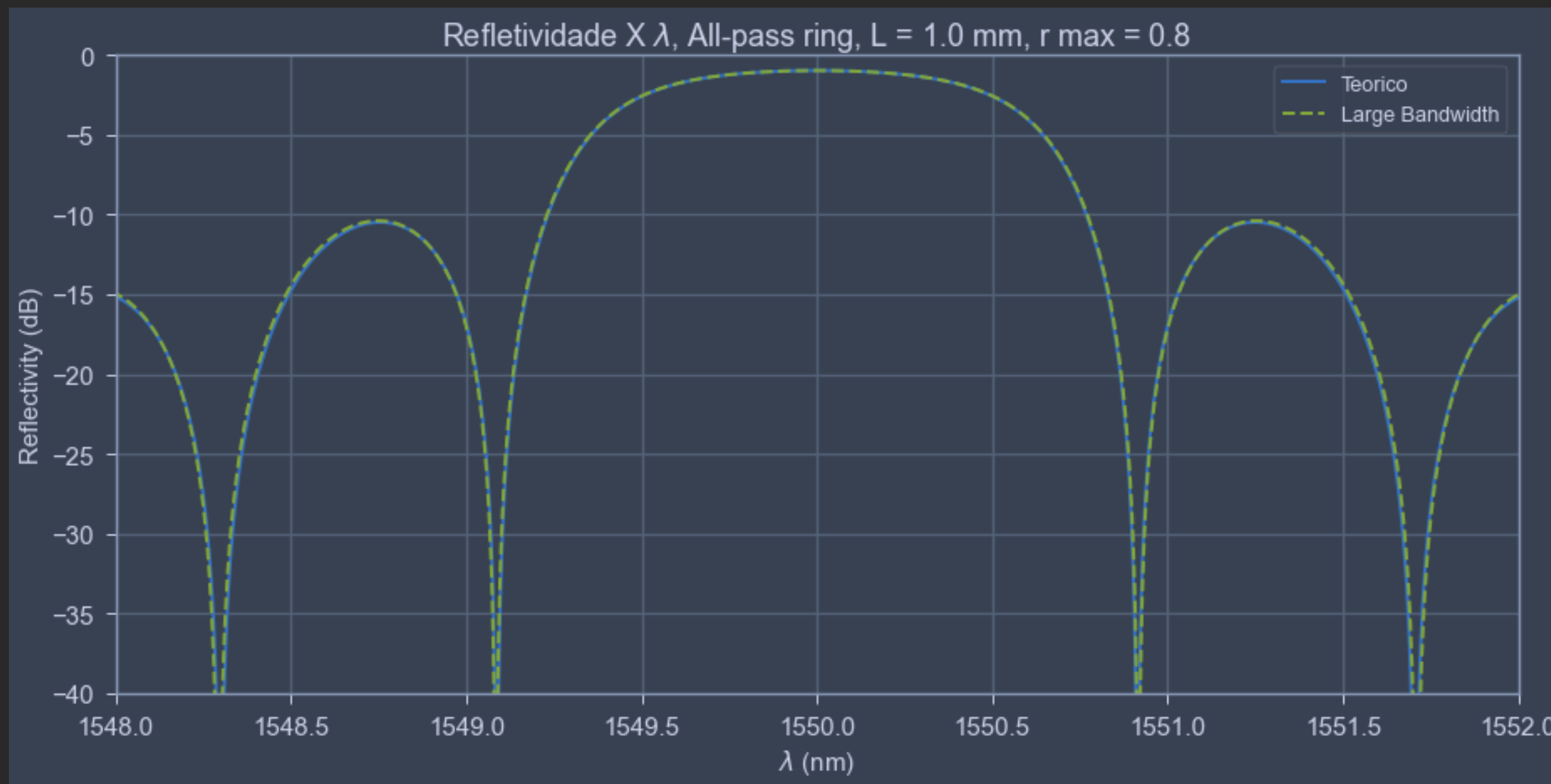
# ESTUDO DE REFERENCIAS

## Resultados



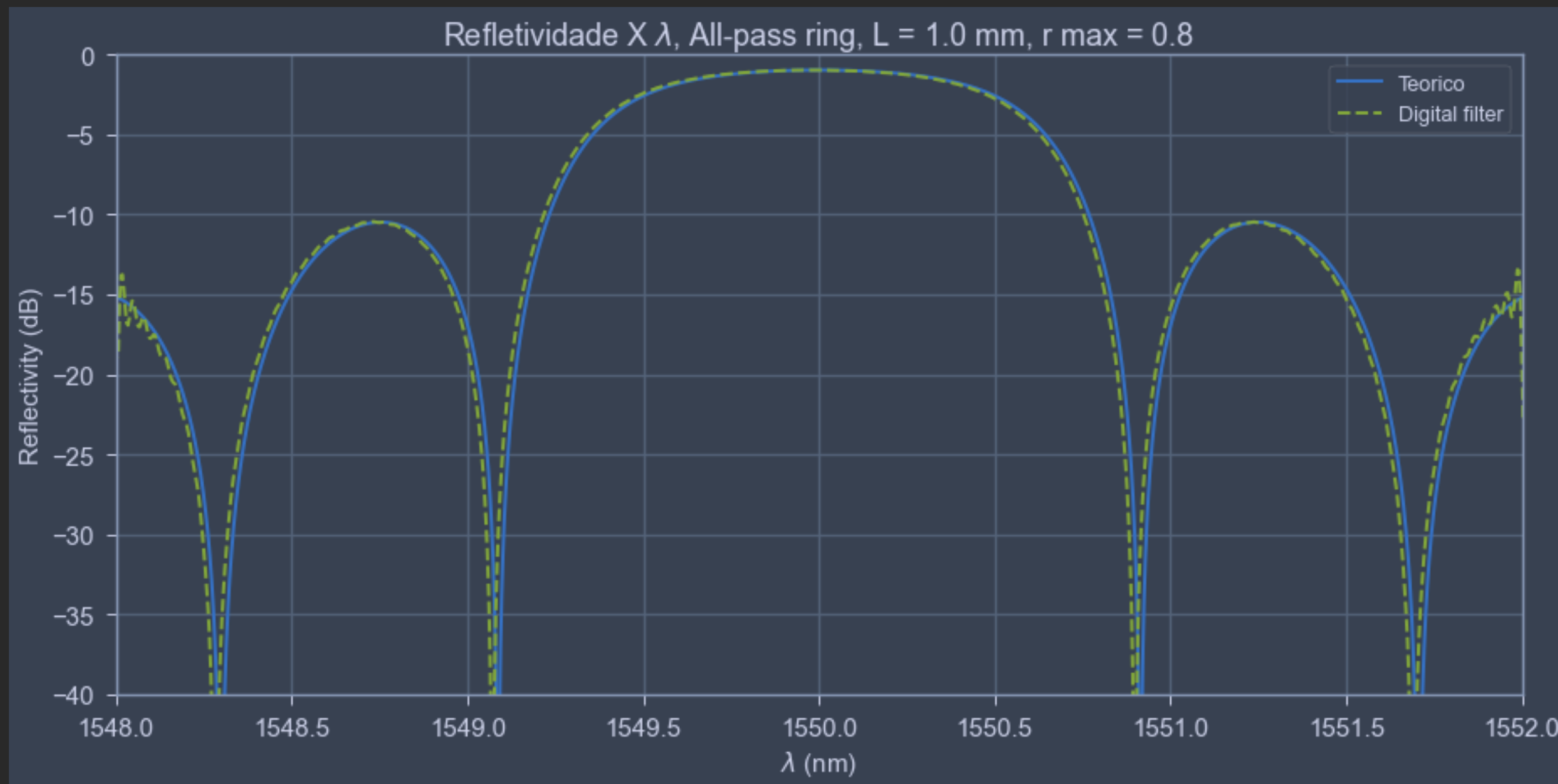
# ESTUDO DE REFERENCIAS

## Resultados



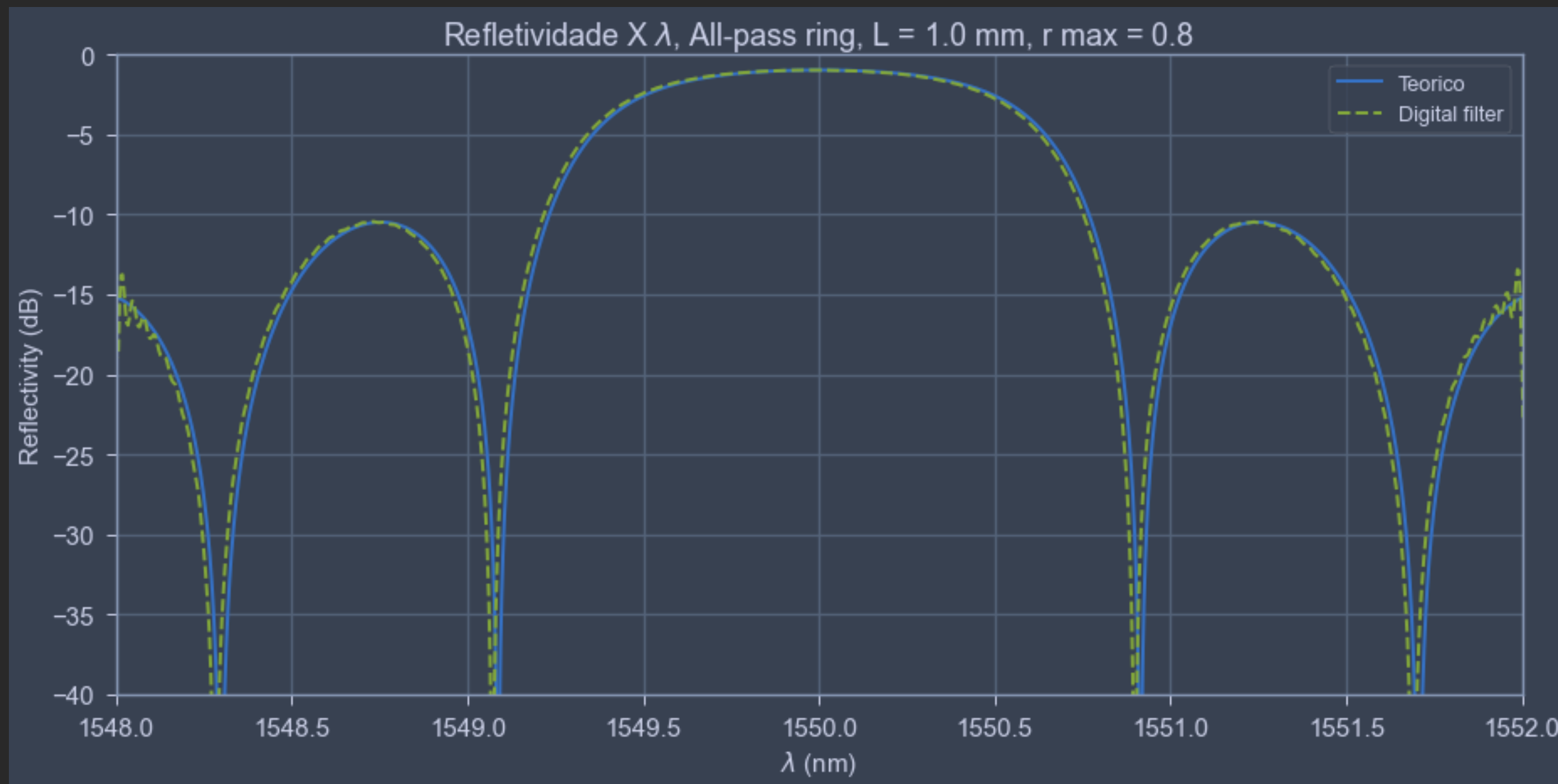
# ESTUDO DE REFERENCIAS

## Resultados



# ESTUDO DE REFERENCIAS

## Resultados



# SEMANA 2

## DESIGN DE FILTRO COM GRADE DE BRAGG

# SEMANA 2

## Design de filtro com Grade de Bragg

# DESIGN

## Parametros

**Comprimento central = 1540 nm**

**Fwhm = 20 nm**

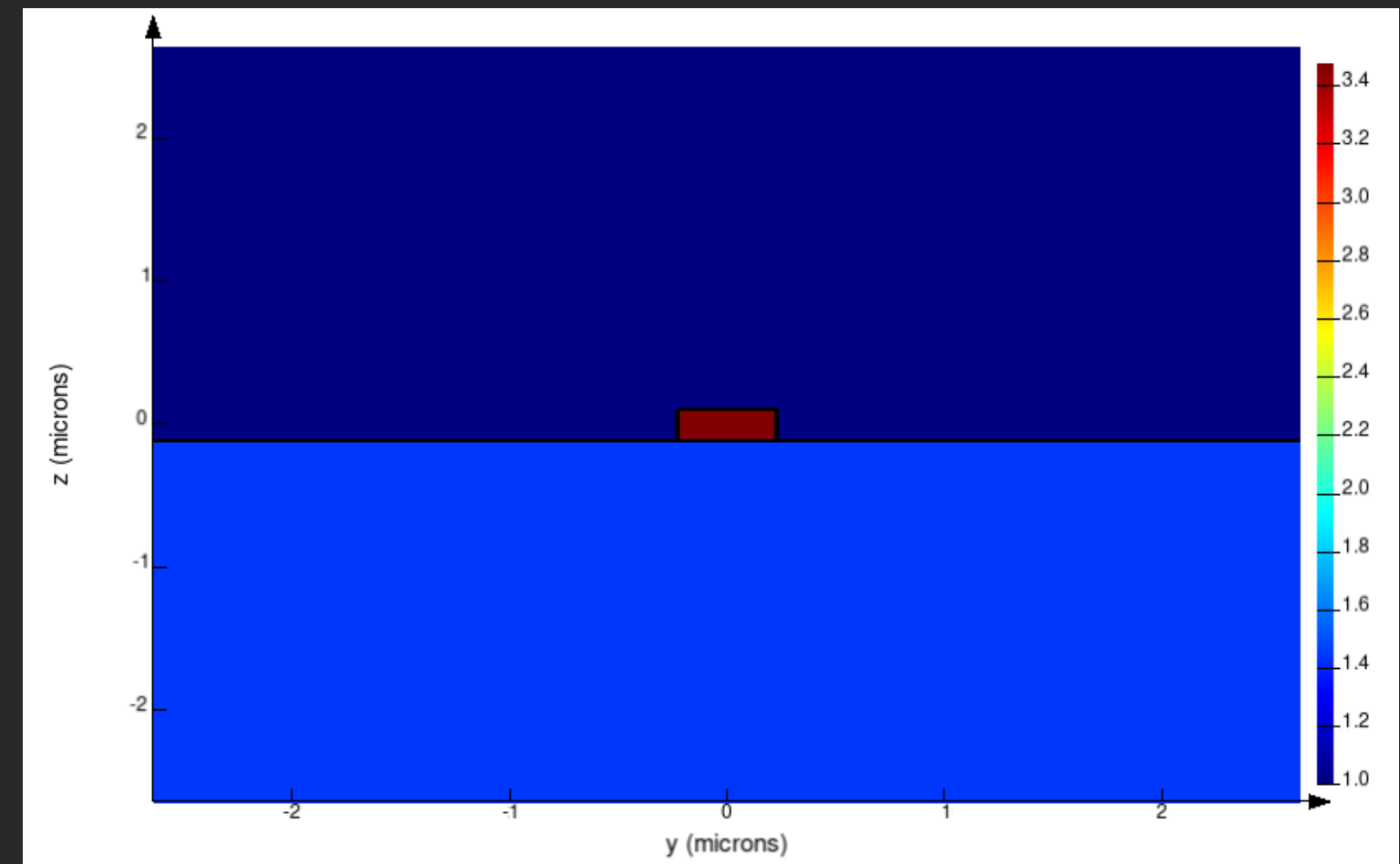
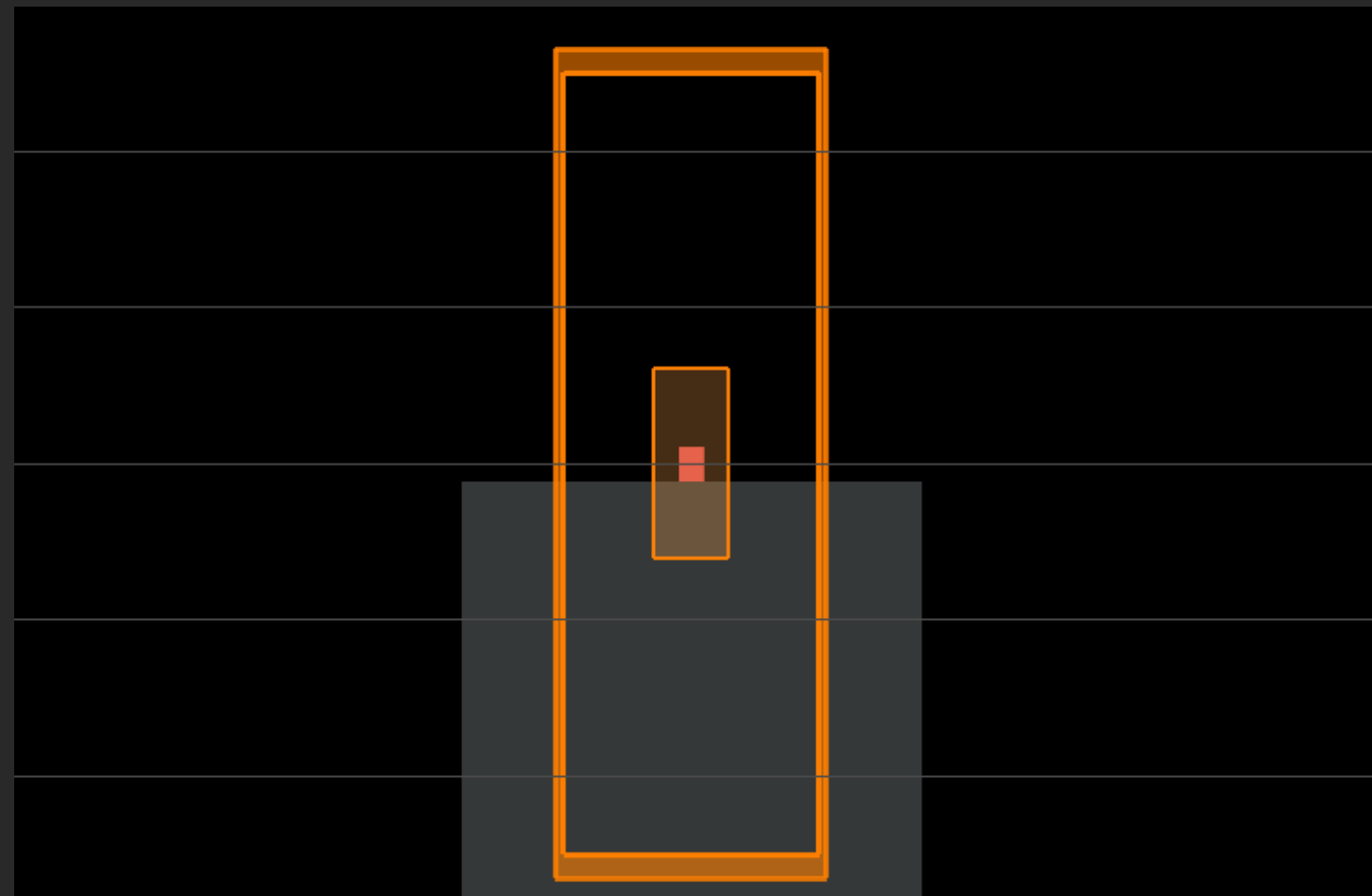
**Guia: 450 x 220 nm, SOI**

**Neff = 2.2875**

**Ng = 4.5878**

# DESIGN

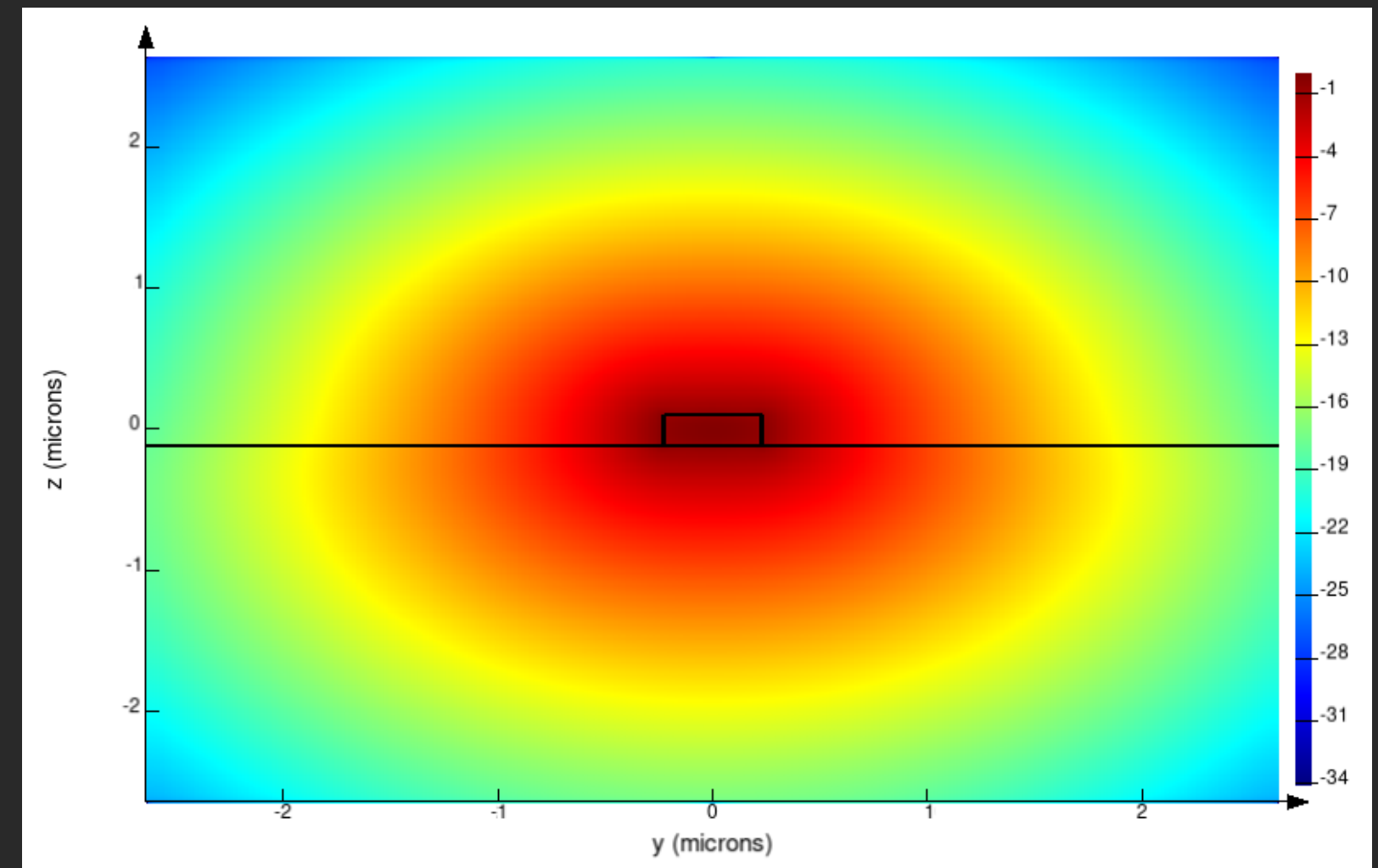
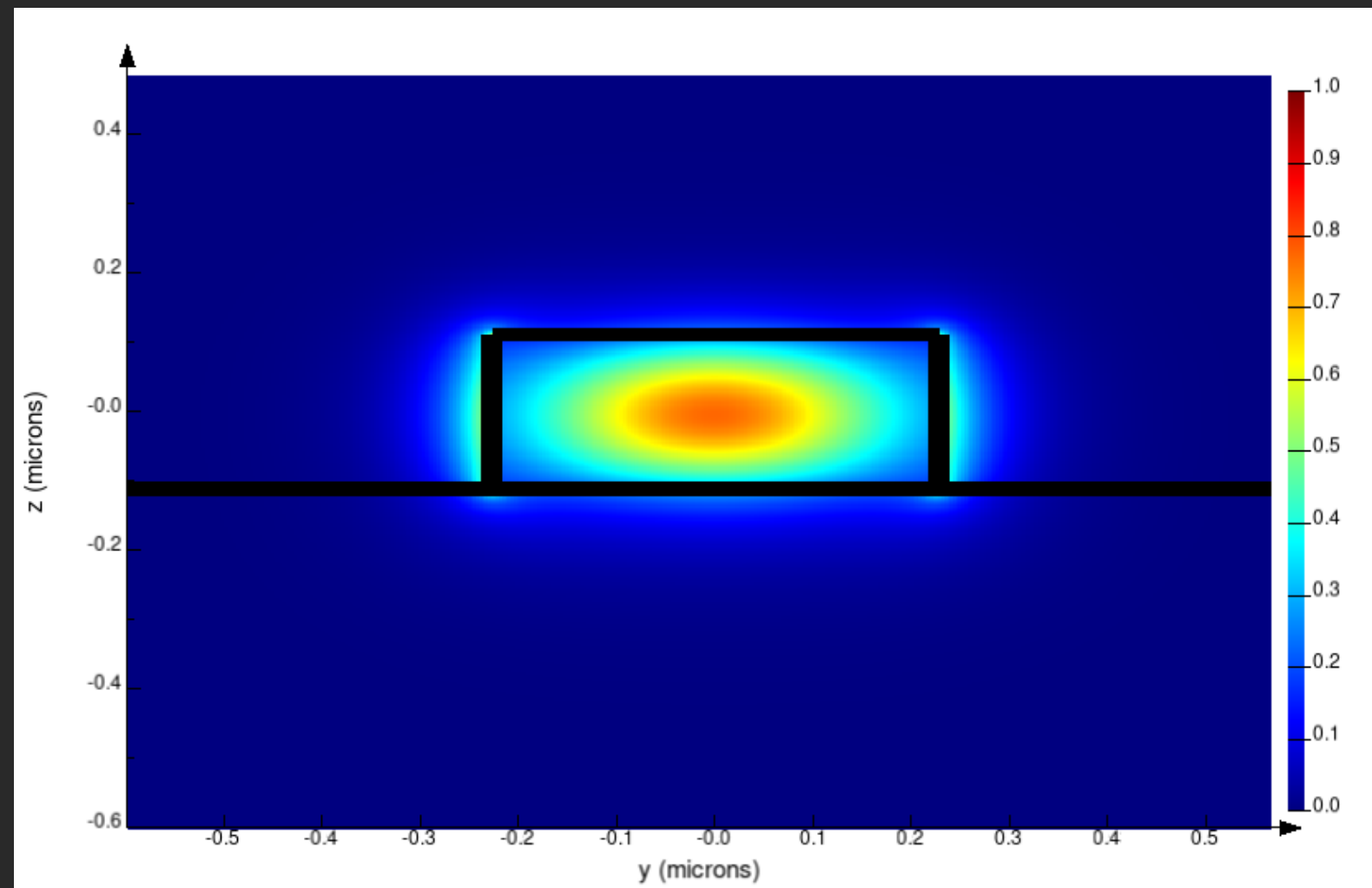
## Parametros





# DESIGN

## Simulação do guia



mode # ▾	effective index	wavelength (μm)	loss (dB/cm)	group index	TE polarization fraction (Ey)	waveguide TE/TM fraction (%)
1	2.287553-6.070278e-18i	1.54	-2.1512e-12	4.587824-8.341346e-16i	97	68.69 / 82.03
2	1.553599-2.755374e-07i	1.54	-0.097646	3.383983+2.583202e-05i	8	73.55 / 87.94

# DESIGN

Parametros:

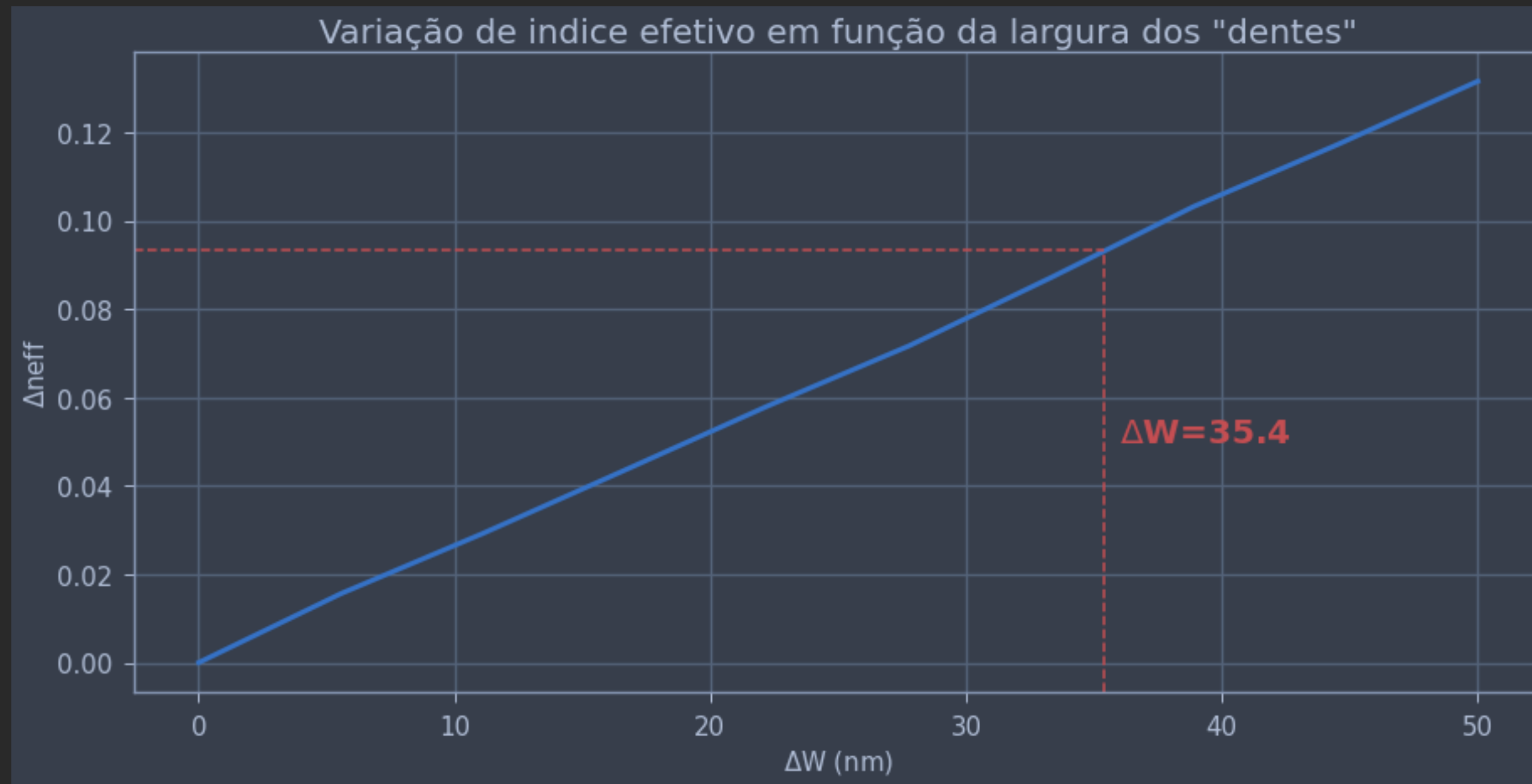
Para  $n_{eff} = 2.287$ : Período da grade = 336.612 nm

Para Número de períodos = 100:  $L = 33.6612 \mu m$

Para  $L = 336.612 \mu m$ ,  $\Delta n_{eff} = 0.09331$

# DESIGN

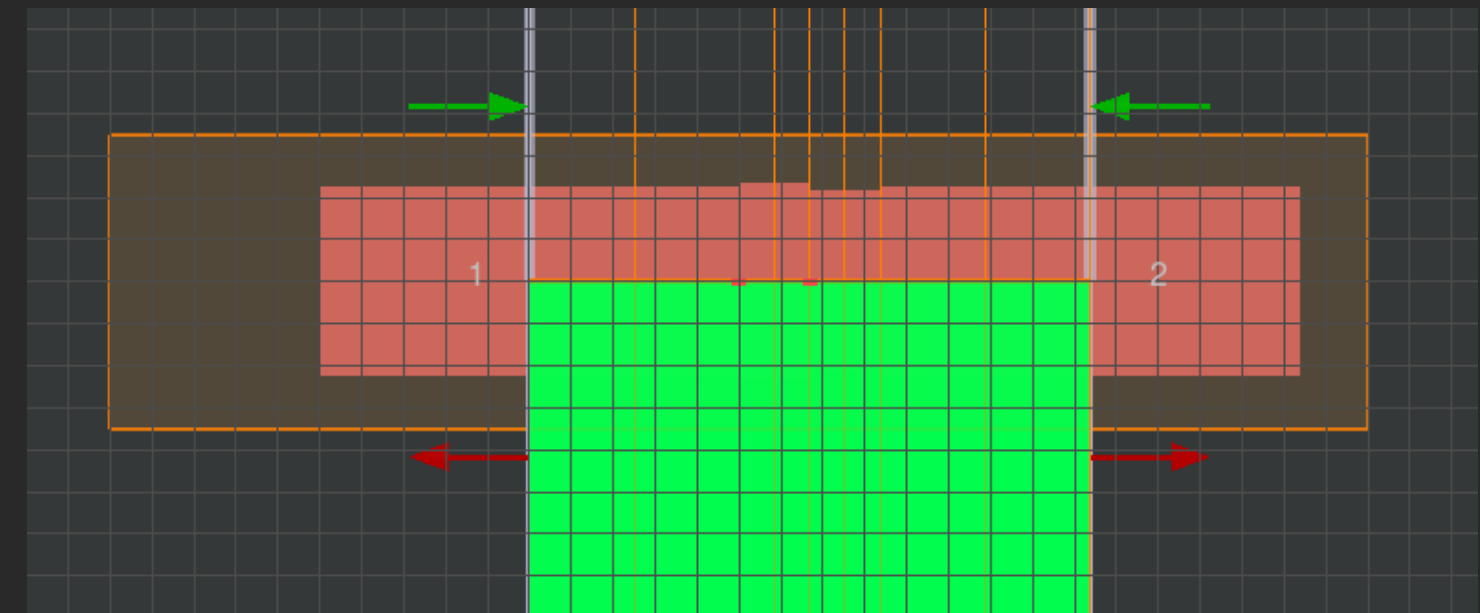
## Calculo do Delta W



# DESIGN

## Simulação no EME

#	Name	Type	Value	Unit
1	<a href="#">[l]</a> W	Length	0.45	um
2	<a href="#">[l]</a> altura	Length	0.22	um
3	<a href="#">[l]</a> deltaW	Length	0.0354	um
4	<a href="#">[l]</a> periodo	Length	0.336612	um
5	<a href="#">[l]</a> material	Material	Si (Silicon) - ...	
6	<a href="#">[l]</a> substrato	Material	SiO2 (Glass) -...	



# DESIGN

## Simulação no EME

EME Analysis Window

Define propagation distance

Cell group definition

energy conservation

make passive

	group spans (μm)	cells	subcell method	modes	custom	cell range	start (μm)	stop (μm)
1	0.5	2	none	10	default	[1,2]	-0.5	0
2	0.168306	2	none	10	default	[3,4]	0	0.168306
3	0.168306	2	none	10	default	[5,6]	0.168306	0.336612
4	0.5	2	none	10	default	[7,8]	0.336612	0.836612

Select source

amplitude

1

source port

port 1

source mode

mode 1

☒ override max modes

max modes

1

☐ override wavelength

wavelength (μm)

1.55

☒ Override periodicity

	start cell group	end cell group	periods
1	1	1	1
2	2	3	100
3	4	4	1

Cell group sequence

[(1)^1,(2,3)^100,(4)^1]

☒ include fast diagnostics

☒ update monitors

☐ include slow diagnostics

☐ calculate group delays

[Help me use diagnostics...](#)

eme propagate

advanced options ...

☐ Propagation sweep

parameter

group span 1

start (μm)

0

stop (μm)

0

interval

0

number of points

2

eme sweep

visualize eme sweep

☒ Wavelength sweep

start wavelength (μm)

1.52

stop wavelength (μm)

1.56

number of wavelength points

5000

calculate group delays

☐

wavelength sweep

visualize wavelength sweep

export to file

☐ Mode convergence sweep

start mode

1

mode interval

1

mode sweep

visualize mode sweep

S-matrix index mapping

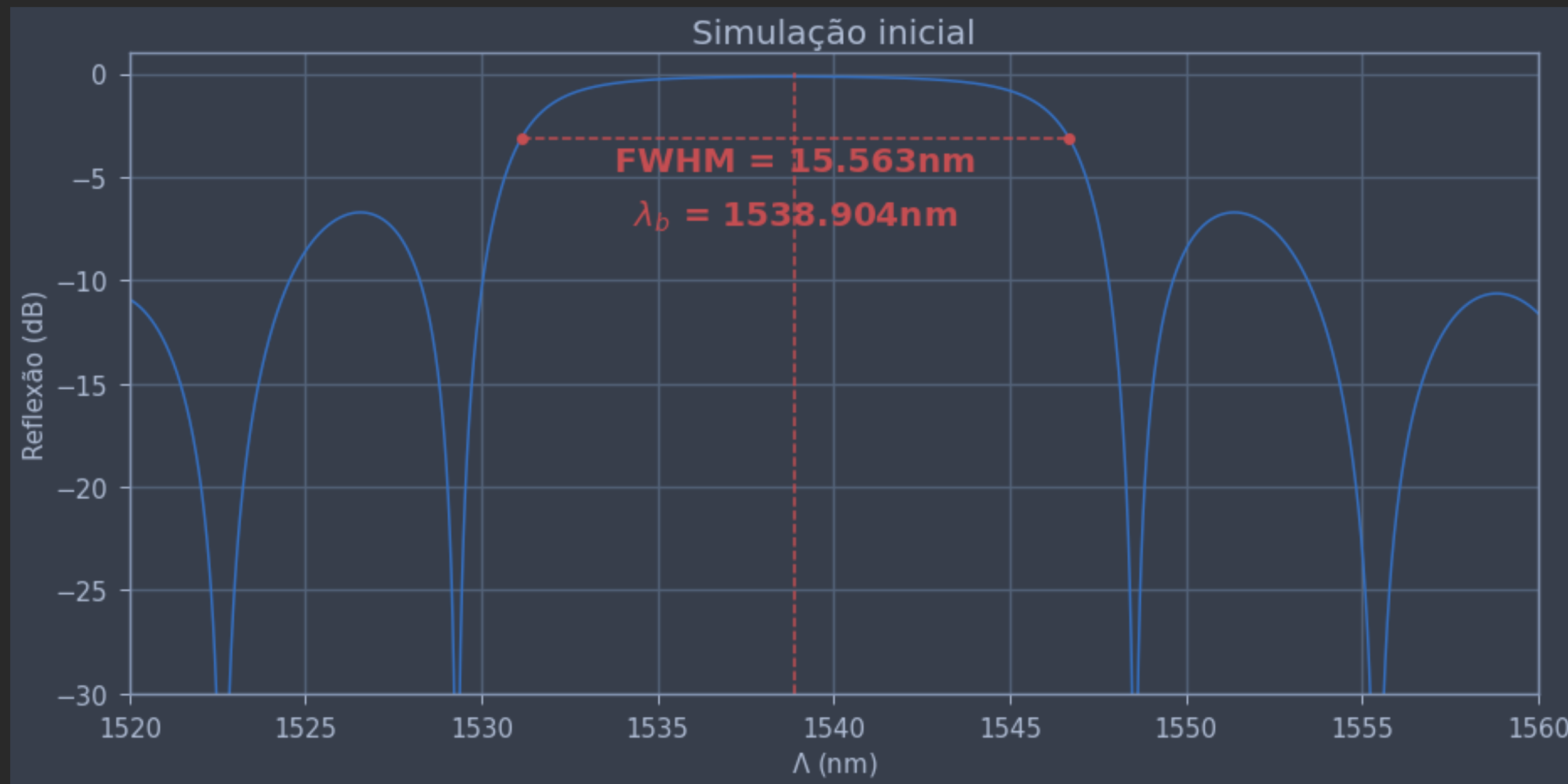
S-matrix index	Source mode
1	port 1 mode 1
2	port 2 mode 1

Redock

Hide

# DESIGN

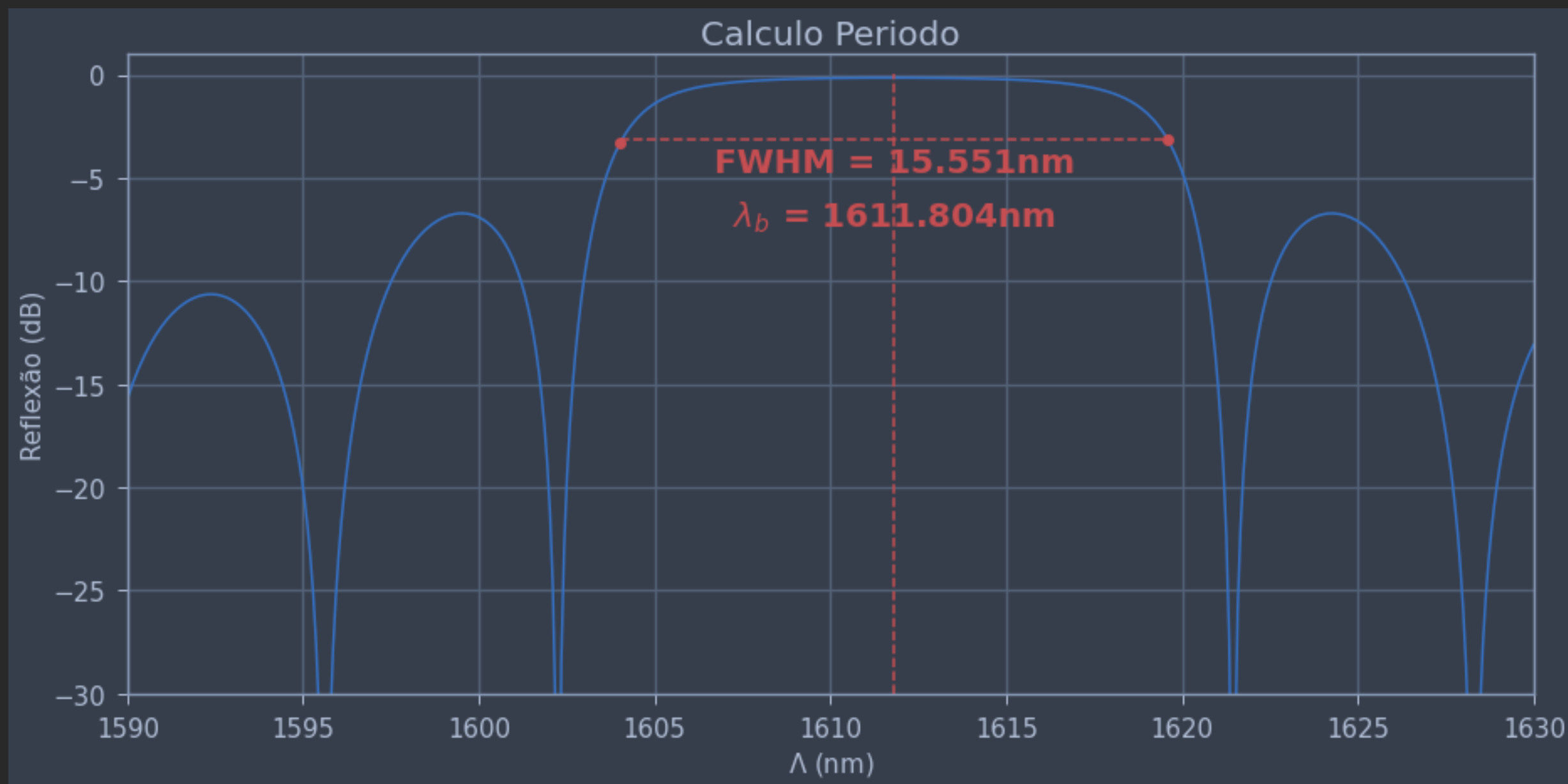
## Resultados Iniciais



# DESIGN

Calculando novo periodo ideal

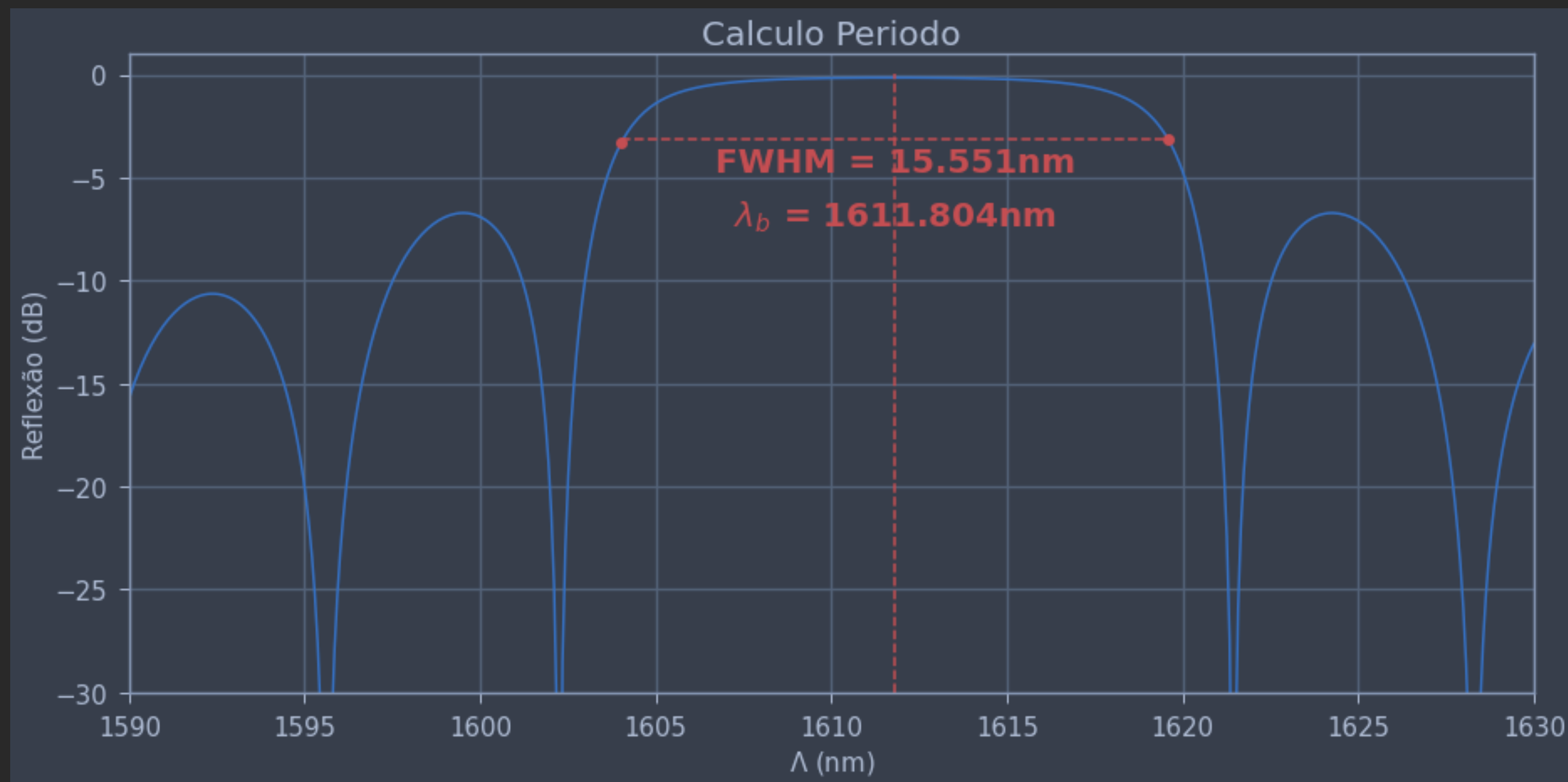
$$P = 0.3534426 \text{ nm (x1.05)}$$



# DESIGN

Calculando novo periodo ideal

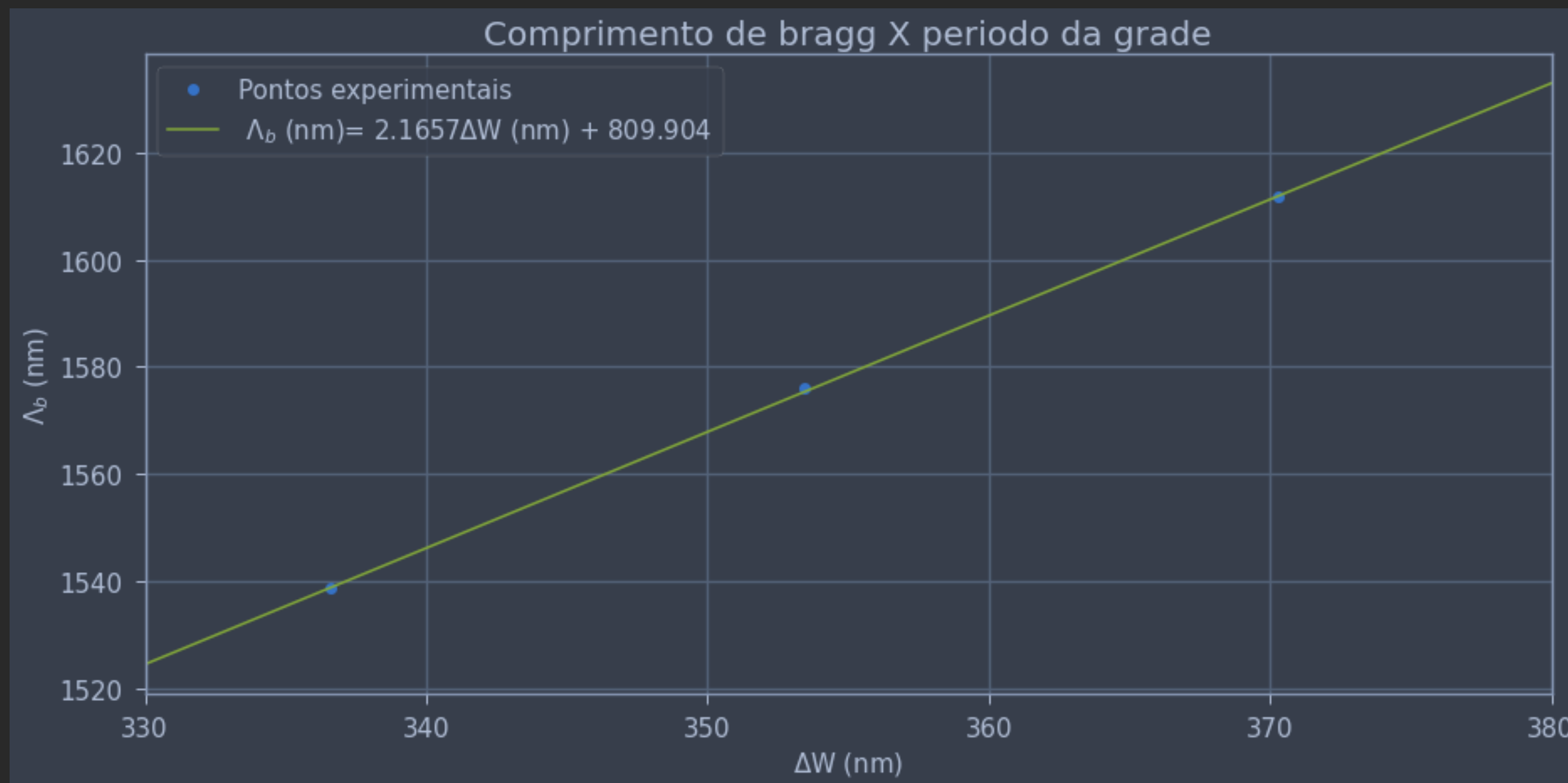
$$P = 0.3702732 \text{ nm (x1.1)}$$





# DESIGN

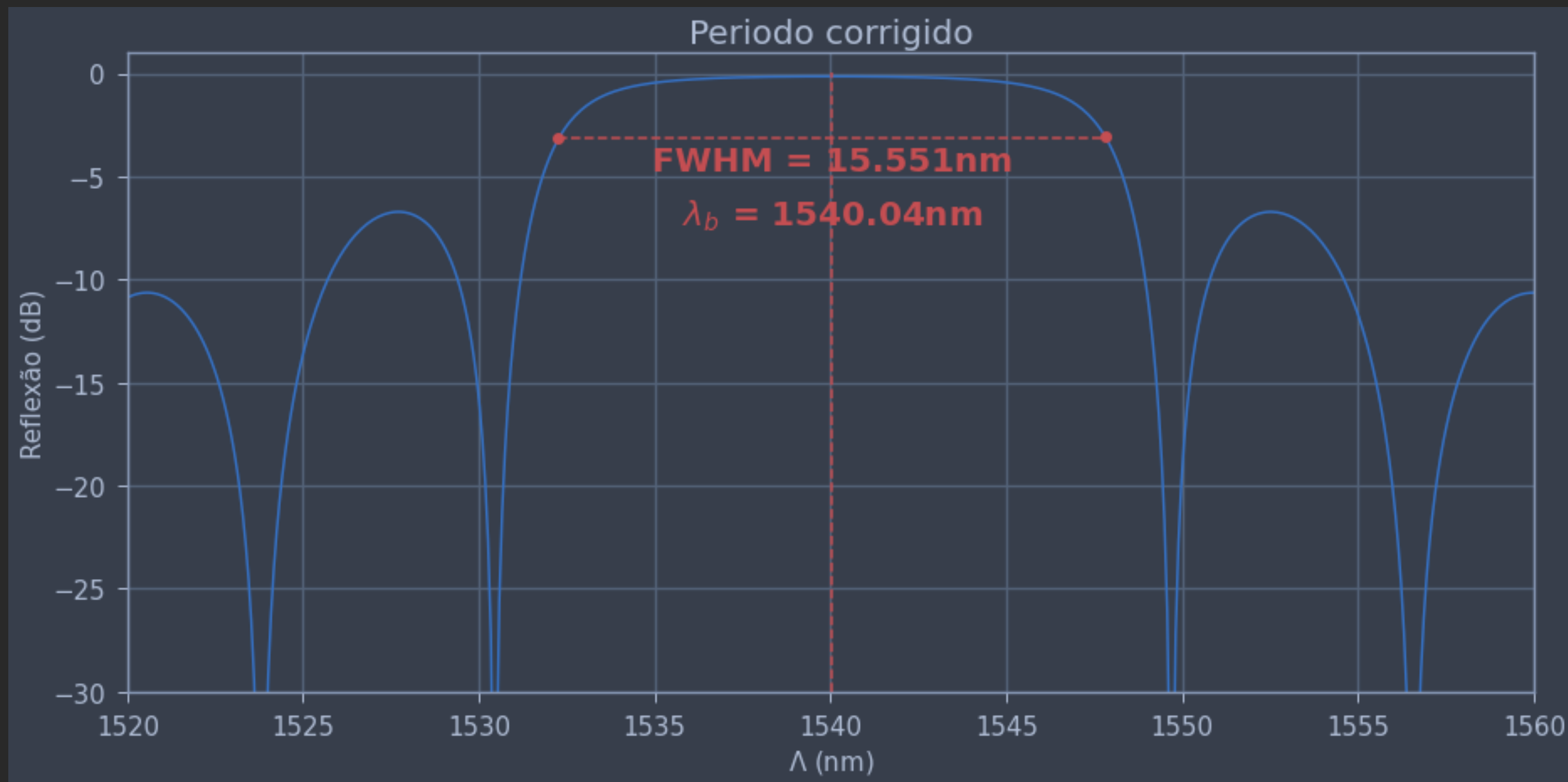
Calculando novo periodo ideal



# DESIGN

Novo periodo teorico

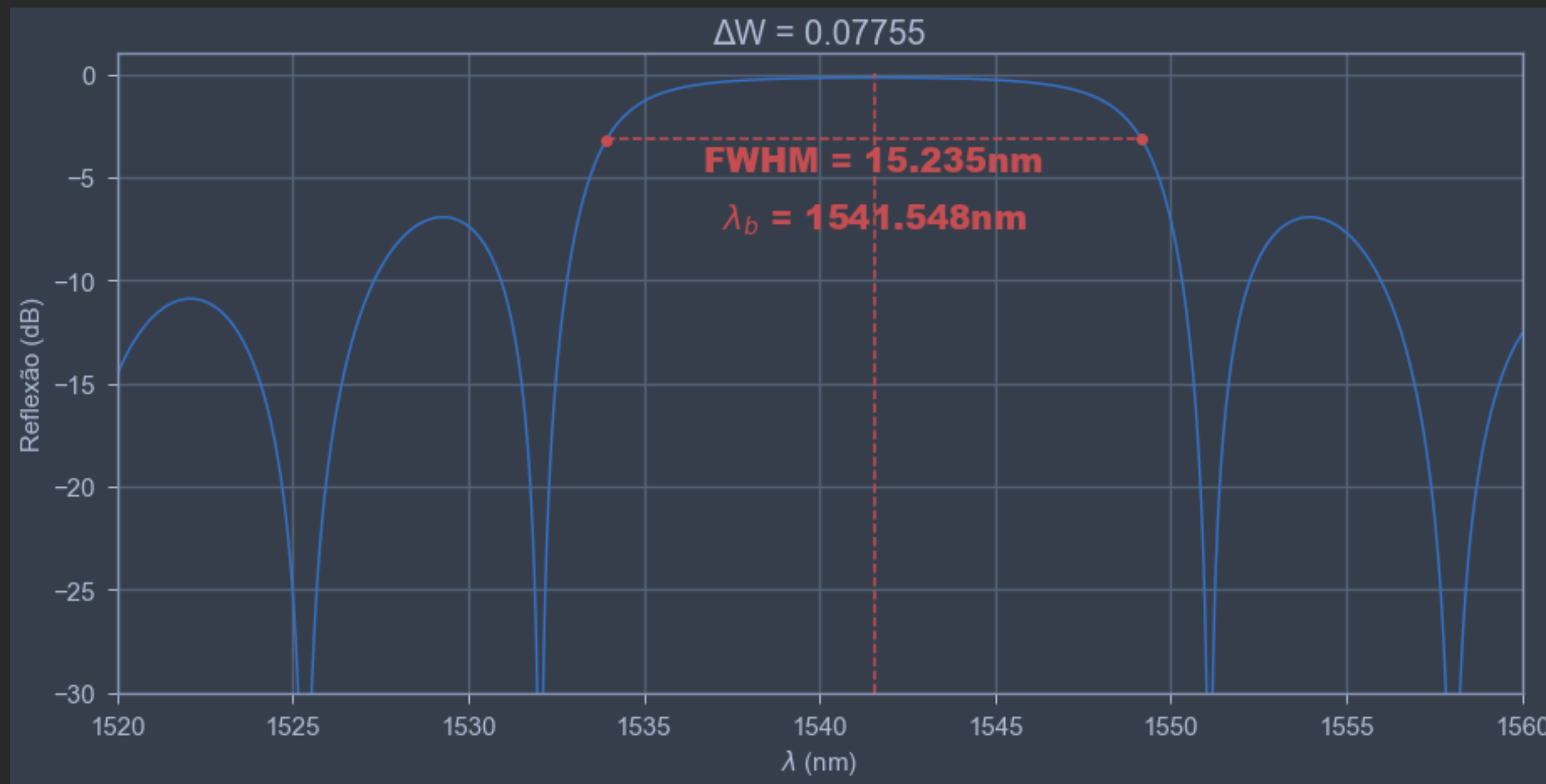
$$P = 0.337118 \text{ } \mu\text{m} \text{ (E = 0.15\%)}$$



# DESIGN

Corrigindo o FWHM, calculo de  $\Delta W$

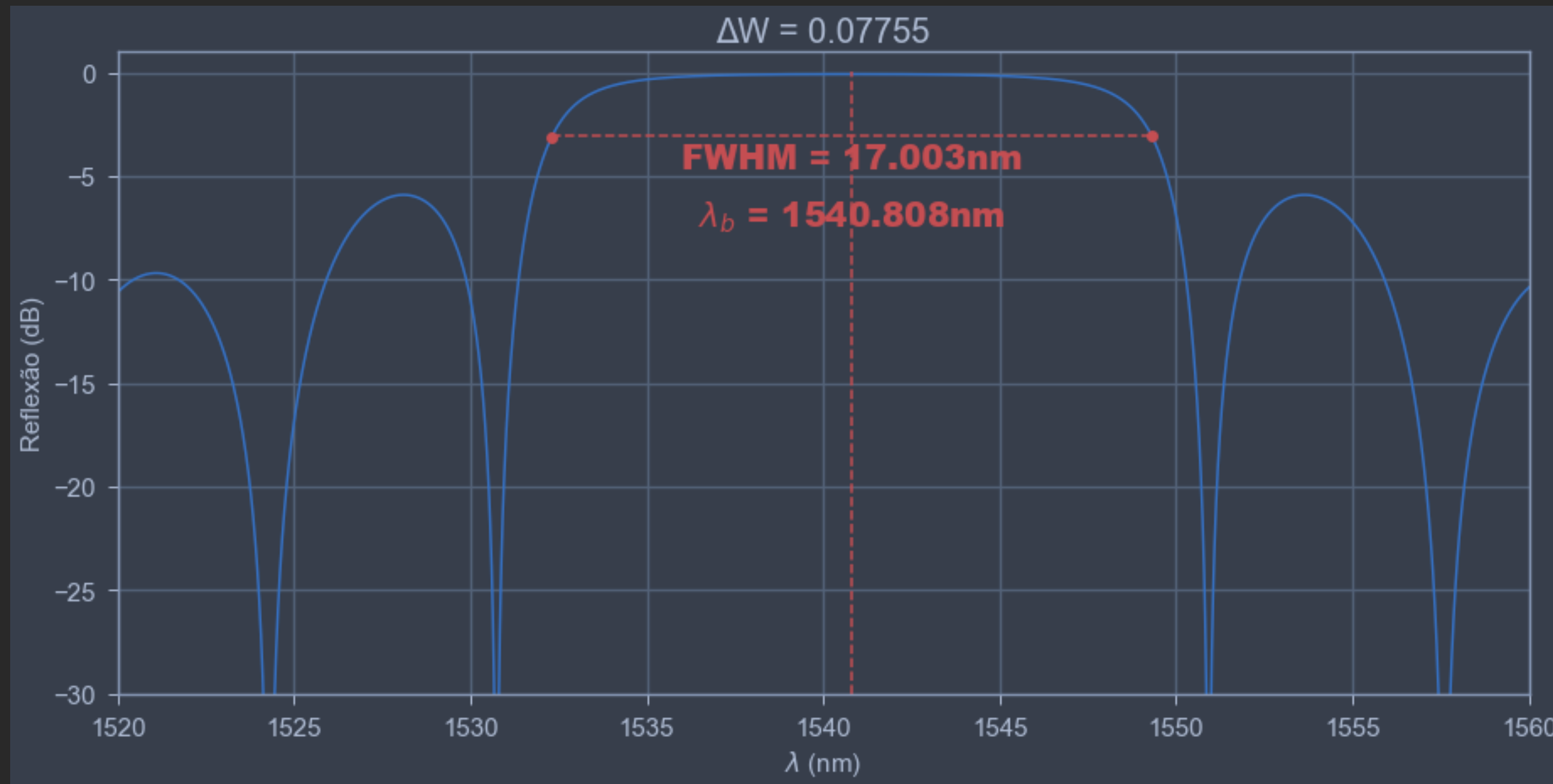
$$\Delta W = 0.03894 \text{ (x1.1)}$$



# DESIGN

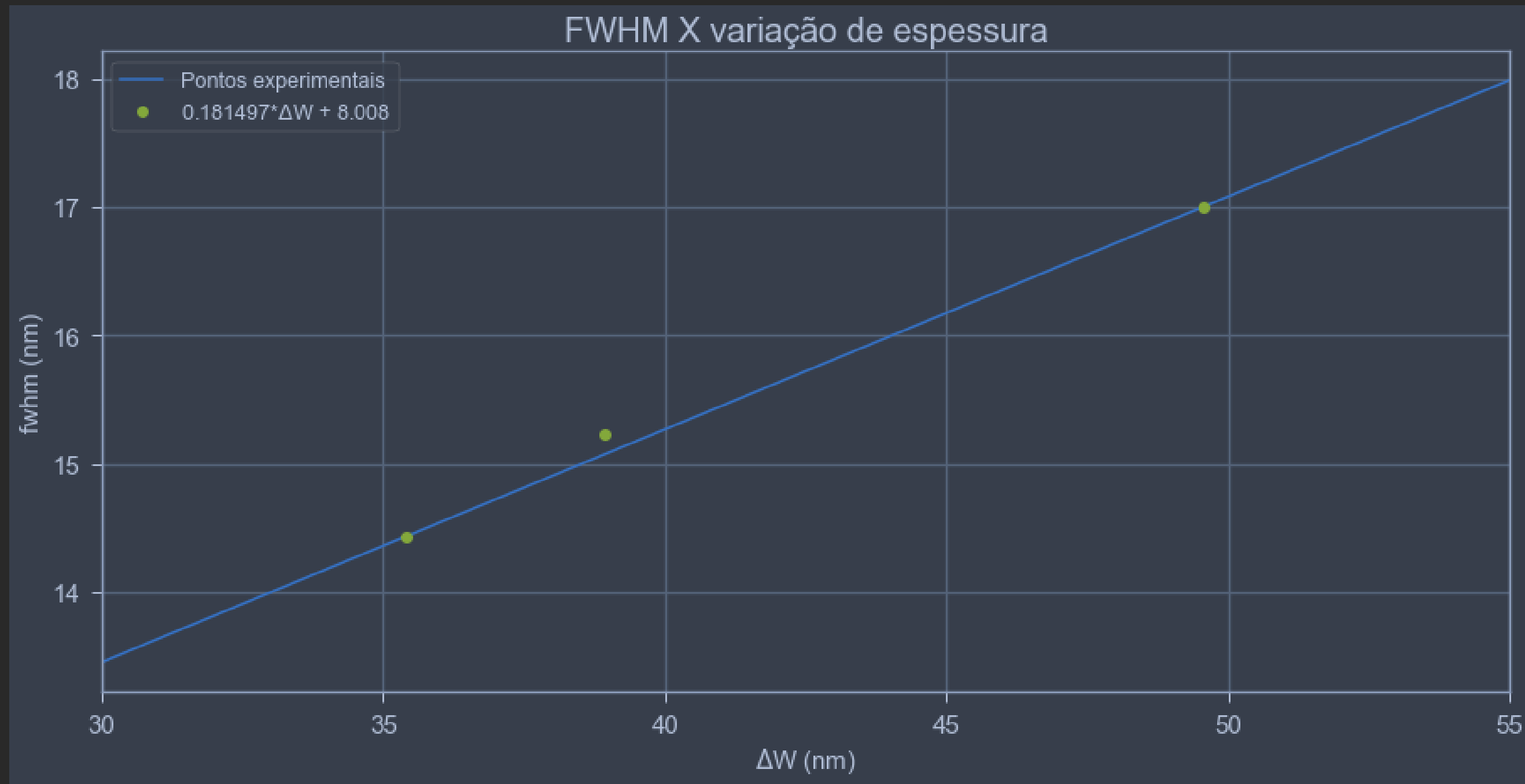
Corrigindo o FWHM, calculo de  $\Delta W$

$$\Delta W = 0.04956 \text{ (x1.5)}$$



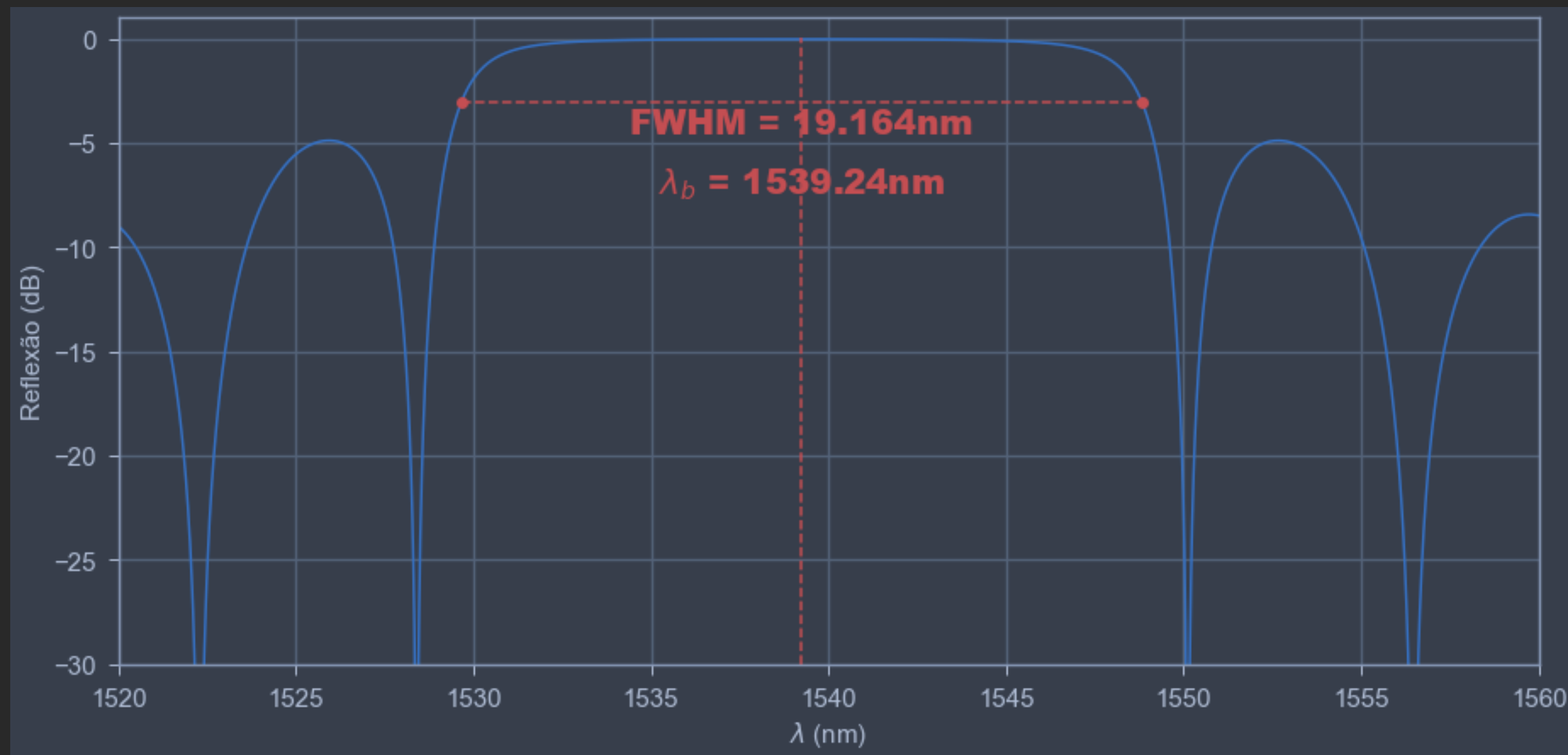
# DESIGN

Corrigindo o FWHM, calculo de  $\Delta W$   
 $\Delta W$  teorico = 0.0660727  $\mu\text{m}$  (E = 87.6%)



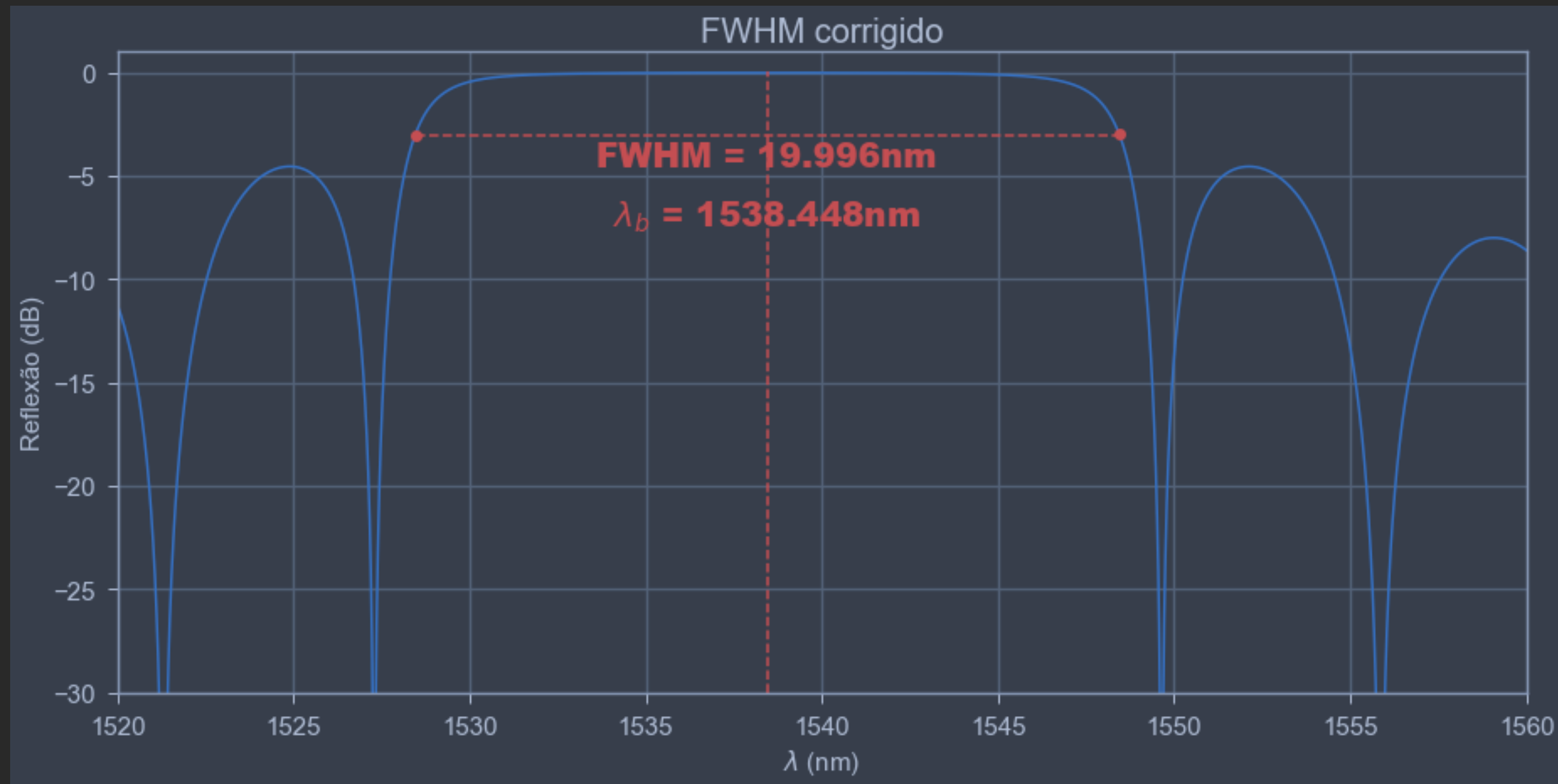
# DESIGN

## Correção do FWHMW



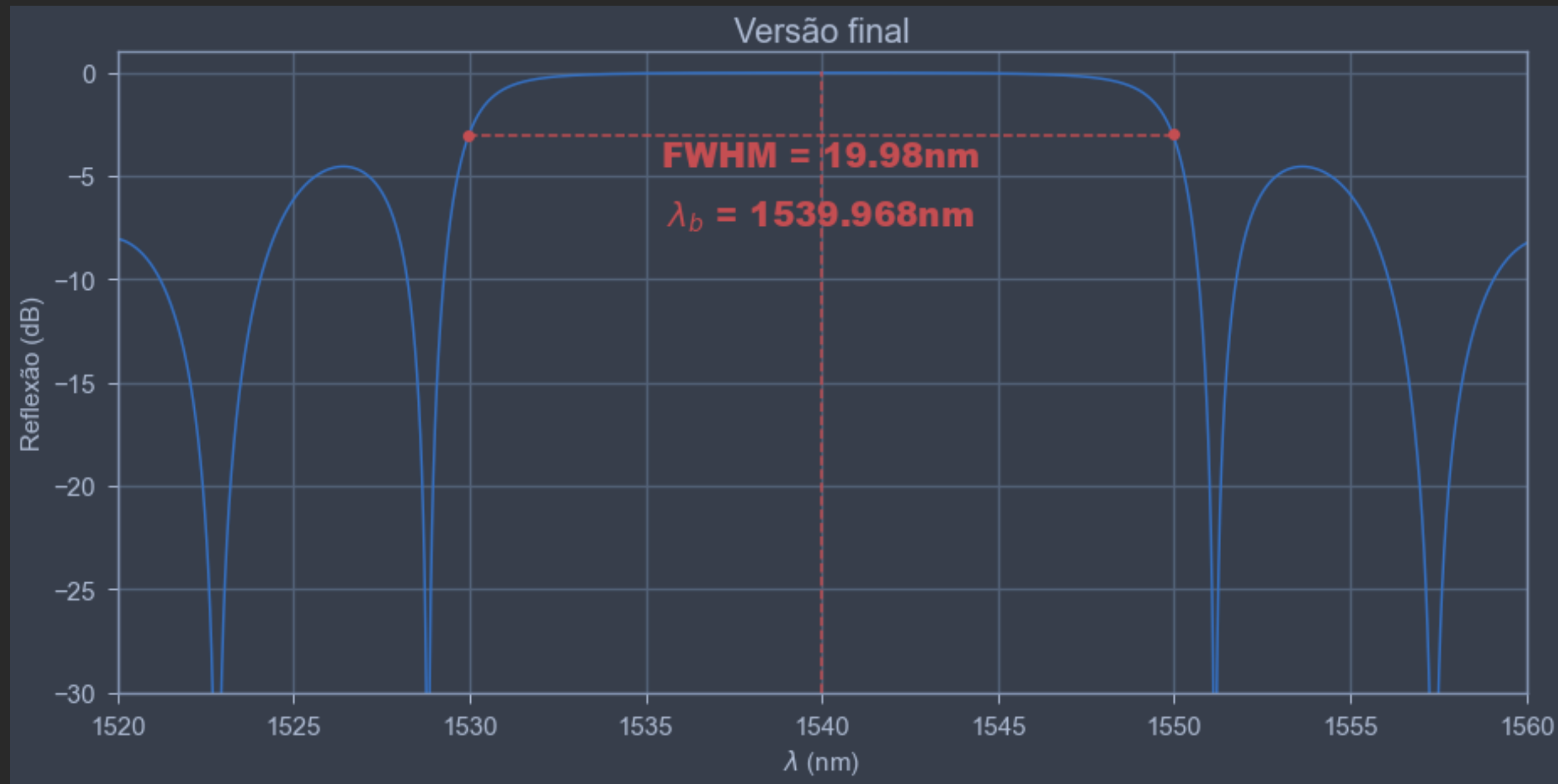
# DESIGN

## Correção do FWHMW



# DESIGN

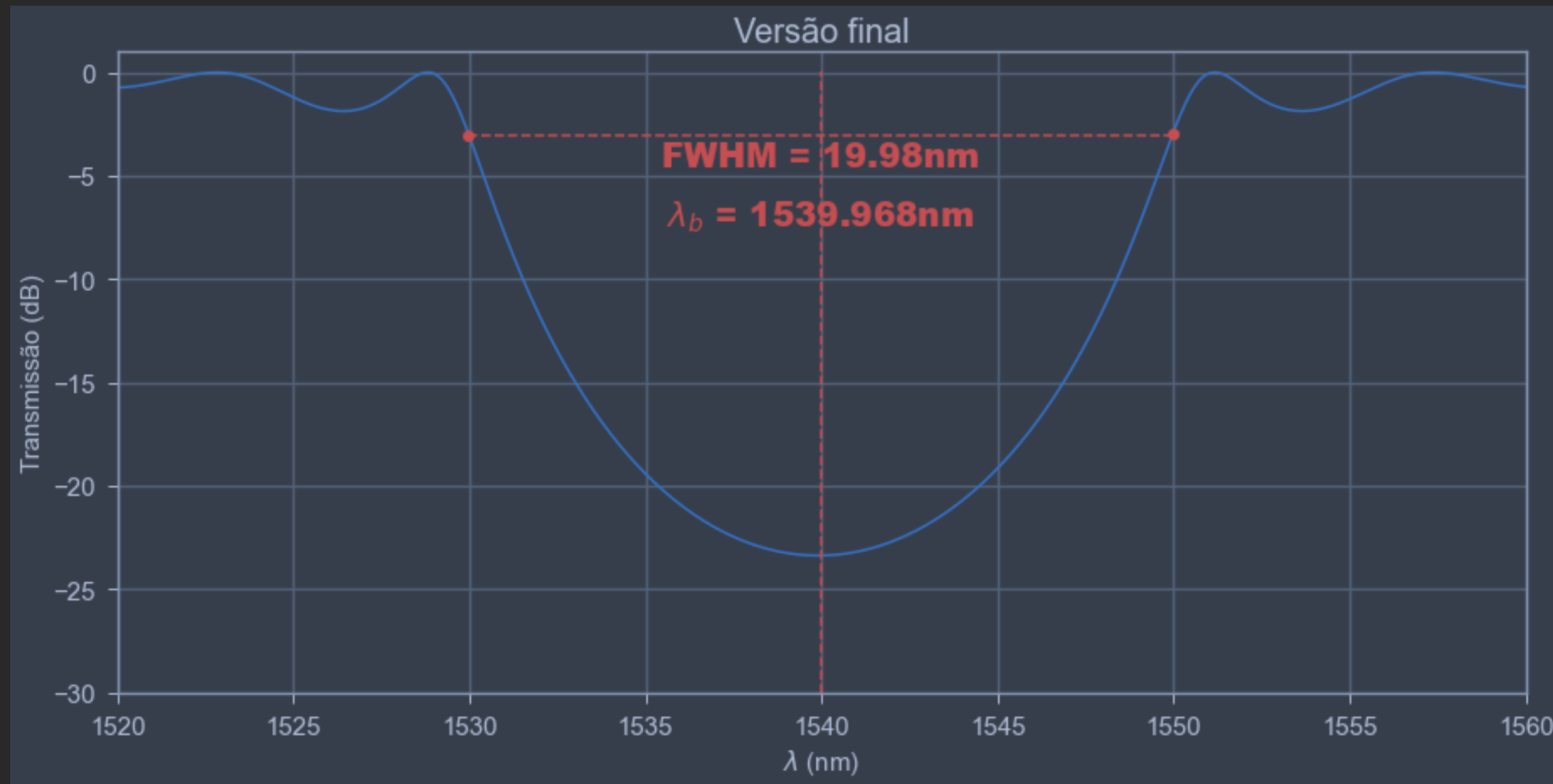
## 2º correção do periodo












# DESIGN

## 2º correção do periodo



# DESIGN

## Design Final

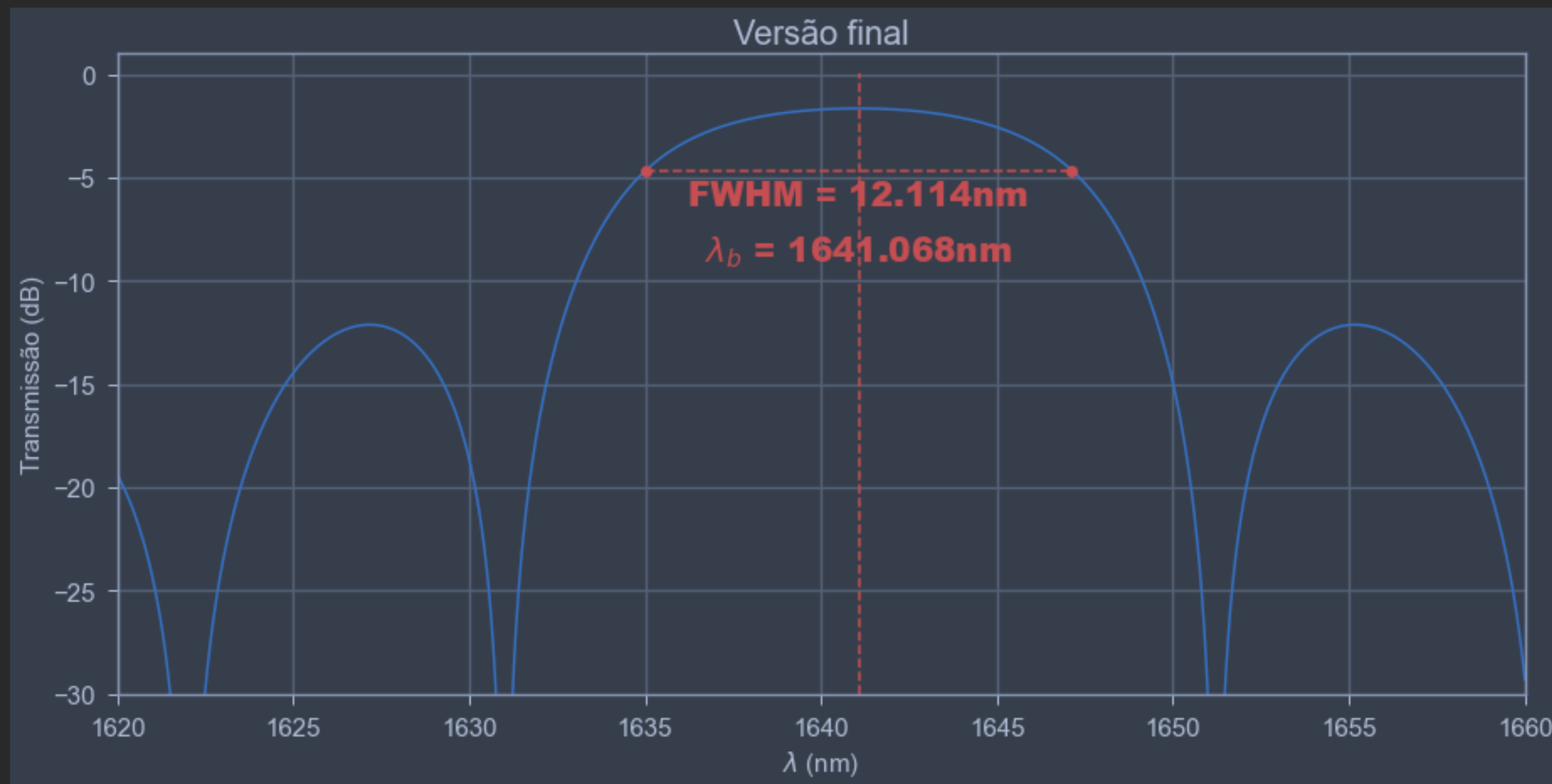
1	 W	Length	0,45	um
2	 altura	Length	0,22	um
3	 deltaW	Length	0,0734068	um
4	 periodo	Length	0,338535	um
5	 N	Number	100	
6	 material	Material	Si (Silicon) - Palik	
7	 substrato	Material	SiO2 (Glass) - P...	

# DESIGN

ALTERANDO O GUIA PARA 600 NM

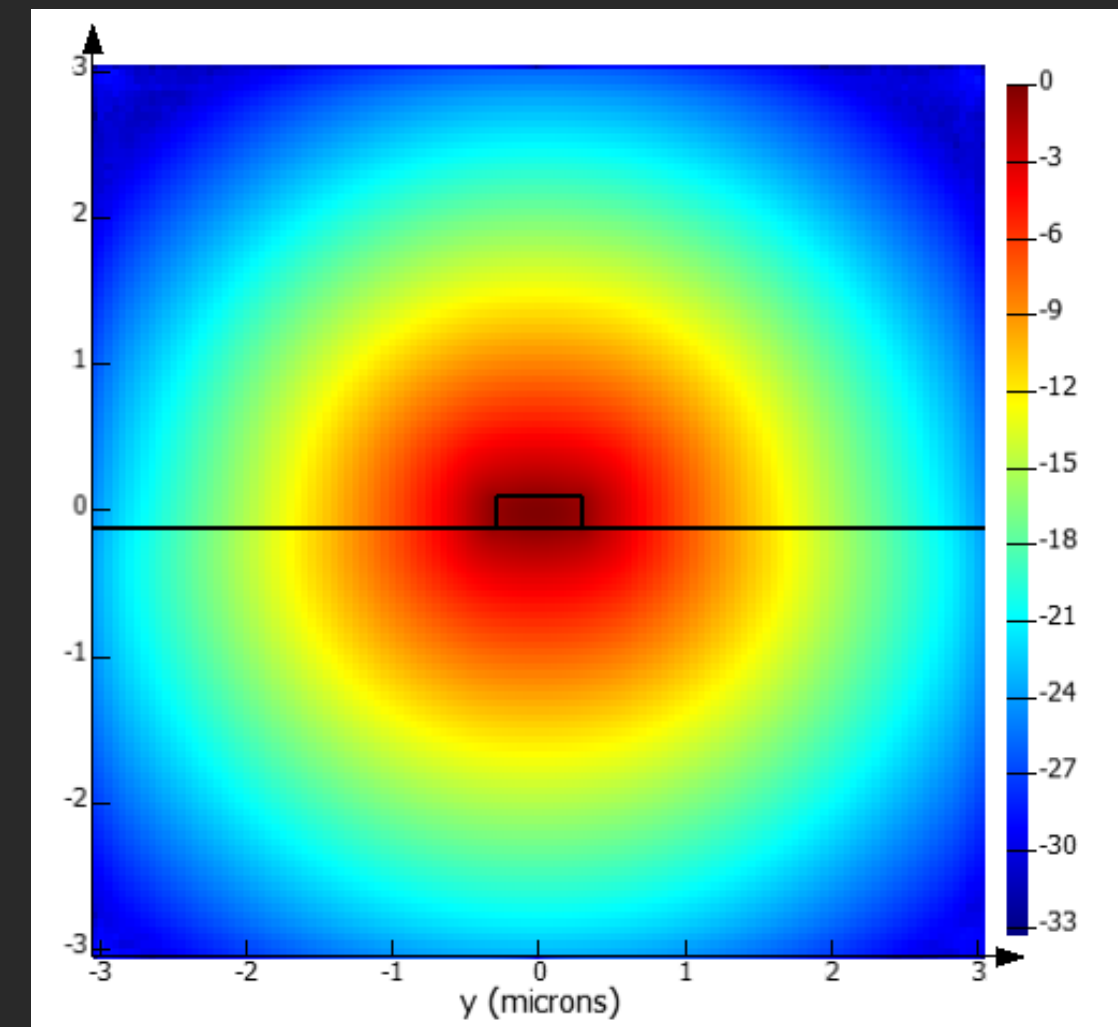
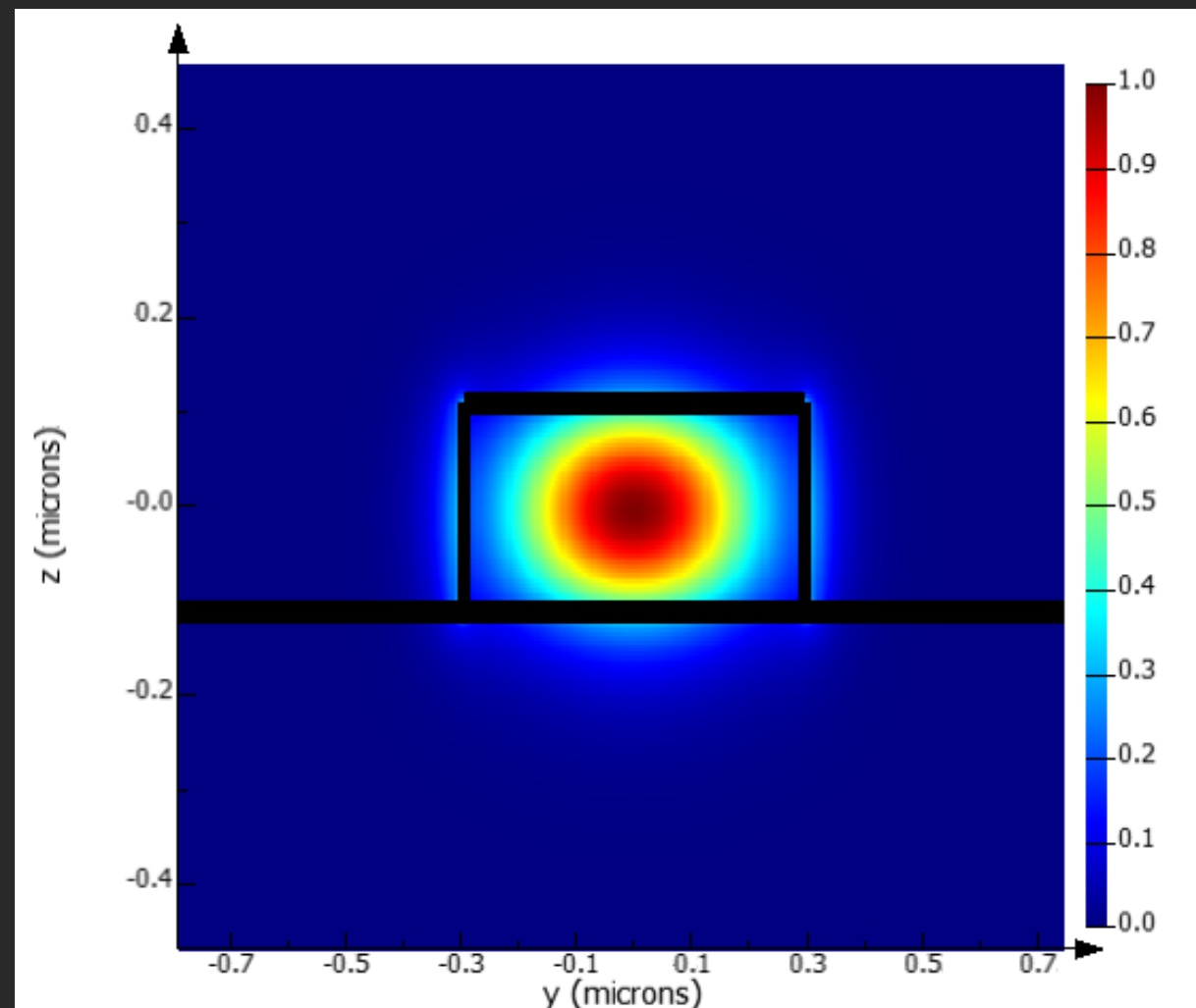
# DESIGN

Alterando o guia para 600 nm



# DESIGN

## Simulação do guia



mode #	effective index	wavelength (μm)	loss (dB/cm)	group index	TE polarization fraction (Ey)	waveguide TE/TM fraction (%)
1	2.537329+8.301567e-17i	1.54	2.9419e-11	4.198189+3.531844e-17i	99	80.25 / 81.12
2	1.667813+5.340745e-11i	1.54	1.8927e-05	3.920935-4.571173e-09i	12	67.94 / 90.11

# DESIGN

Parametros:

Para  $n_{eff} = 2.5373$

Periodo da grade = 303.468 nm

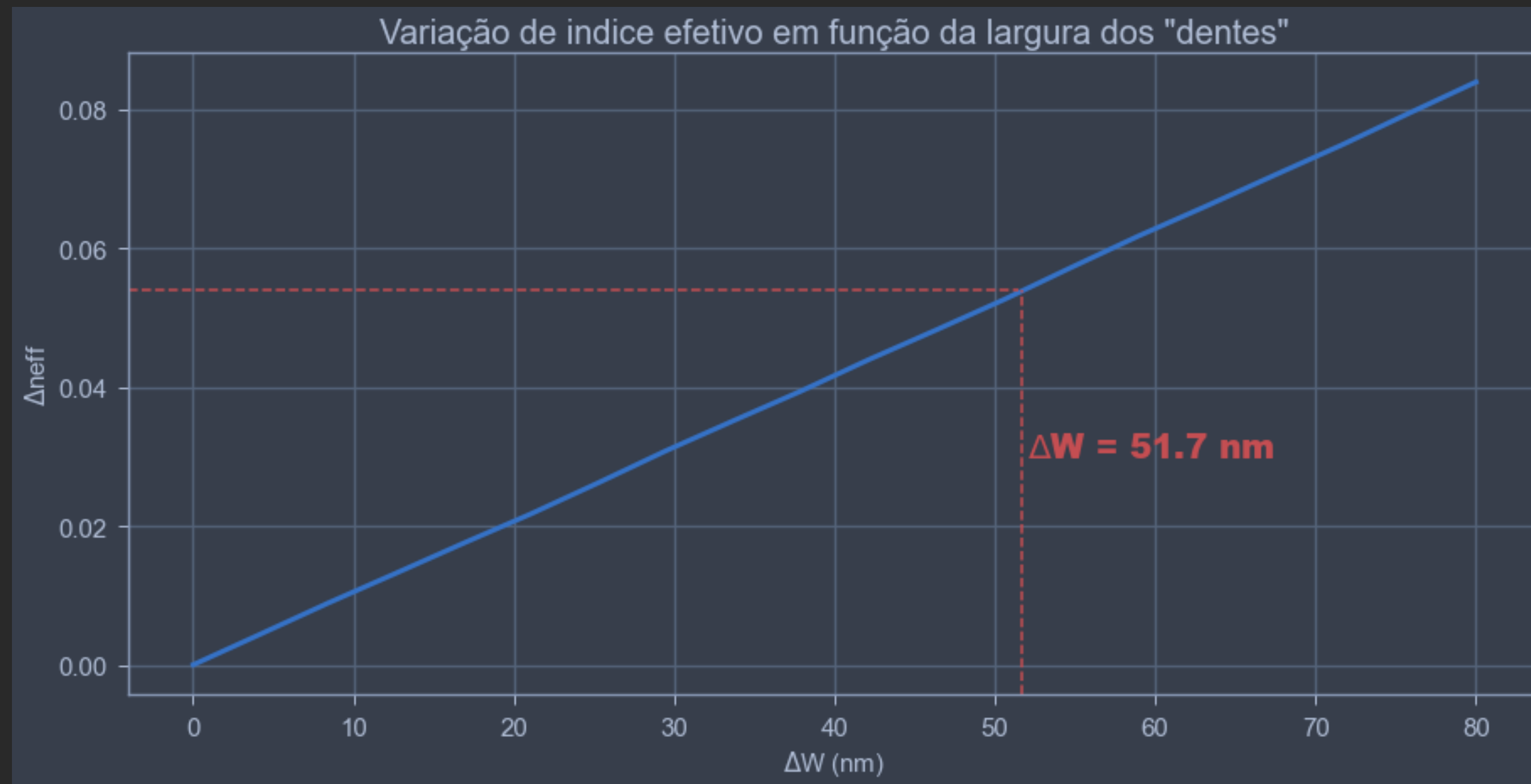
Para Numero de periodos = 250:  $L = 75.867 \text{ um}$

Para  $L = 36.416 \text{ um}$ ,  $\Delta n_{eff} = 0.05405$

$R_{max} = 0.988$








# DESIGN

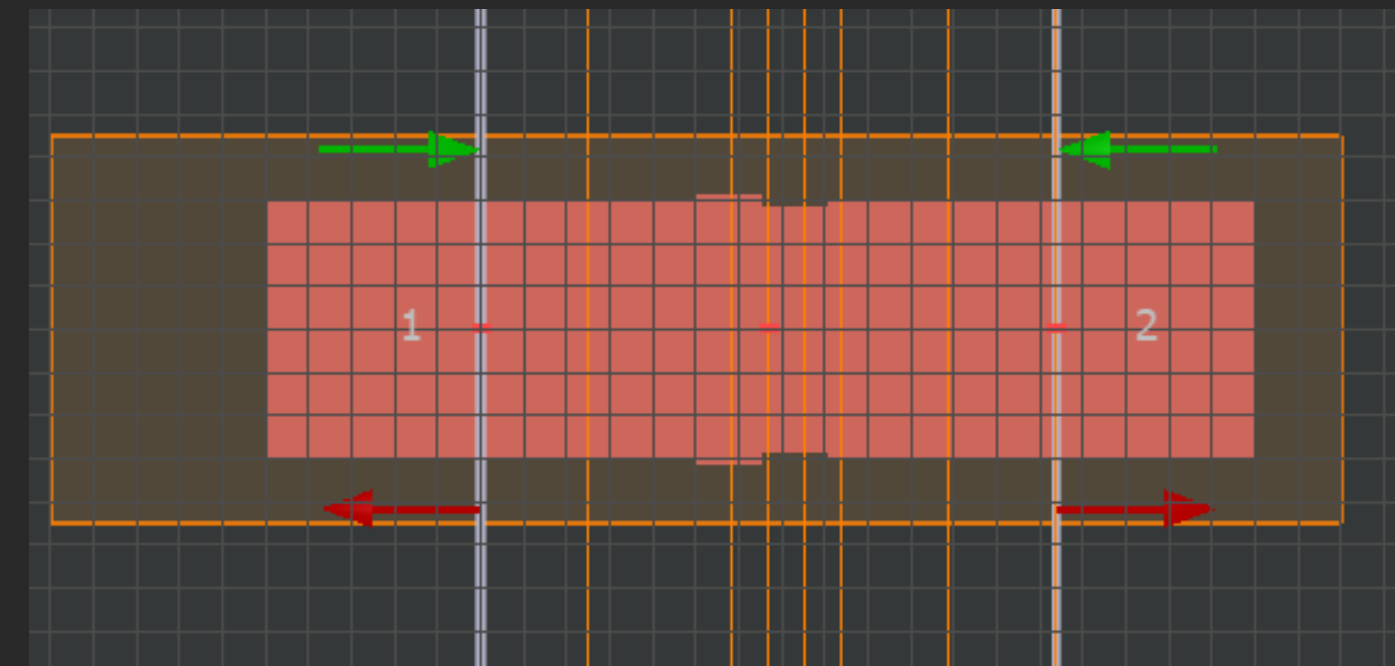
## Calculo do Delta W



# DESIGN

## Simulação no EME

1	 W	Length	0,6	um
2	 altura	Length	0,22	um
3	 deltaW	Length	0,0517	um
4	 periodo	Length	0,303469	um
5	 material	Material	Si (Silicon) - Palik	
6	 substrato	Material	SiO2 (Glass) - P...	
7	 N	Number	120	





# DESIGN

## Simulação no EME

General EME setup Transverse mesh settings Boundary conditions Material Advanced options

cell geometry

x min (μm)  number of cell groups

energy conservation  number of modes for all cell groups

☐ allow custom eigensolver settings

cell group definition

	group spans (μm)	cells	subcell method	modes	custom	cell range
1	0.5	2	CVCS	20	default	[1,2]
2	0.151734	2	CVCS	20	default	[3,4]
3	0.151734	2	CVCS	20	default	[5,6]
4	0.5	2	CVCS	20	default	[7,8]

< >

☒ display cells

y (μm)  y min (μm)

y span (μm)  y max (μm)

z (μm)  z min (μm)

z span (μm)  z max (μm)

periodicity

number of periodic groups

periodic group definition

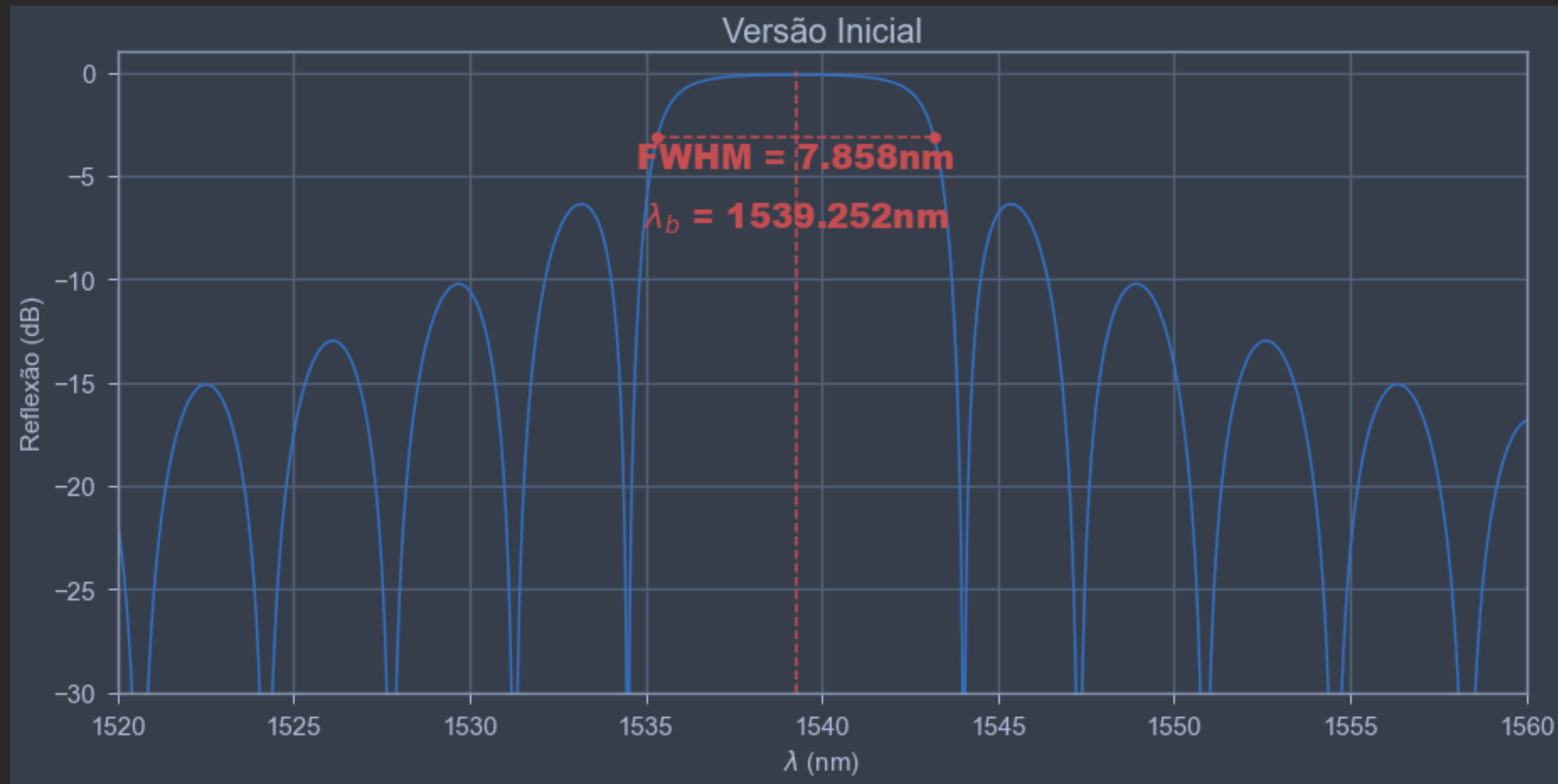
	start cell group	end cell group	periods
1	1	1	1
2	2	3	120
3	4	4	1

cell group sequence

$[(1)^1, (2,3)^{120}, (4)^1]$

# DESIGN

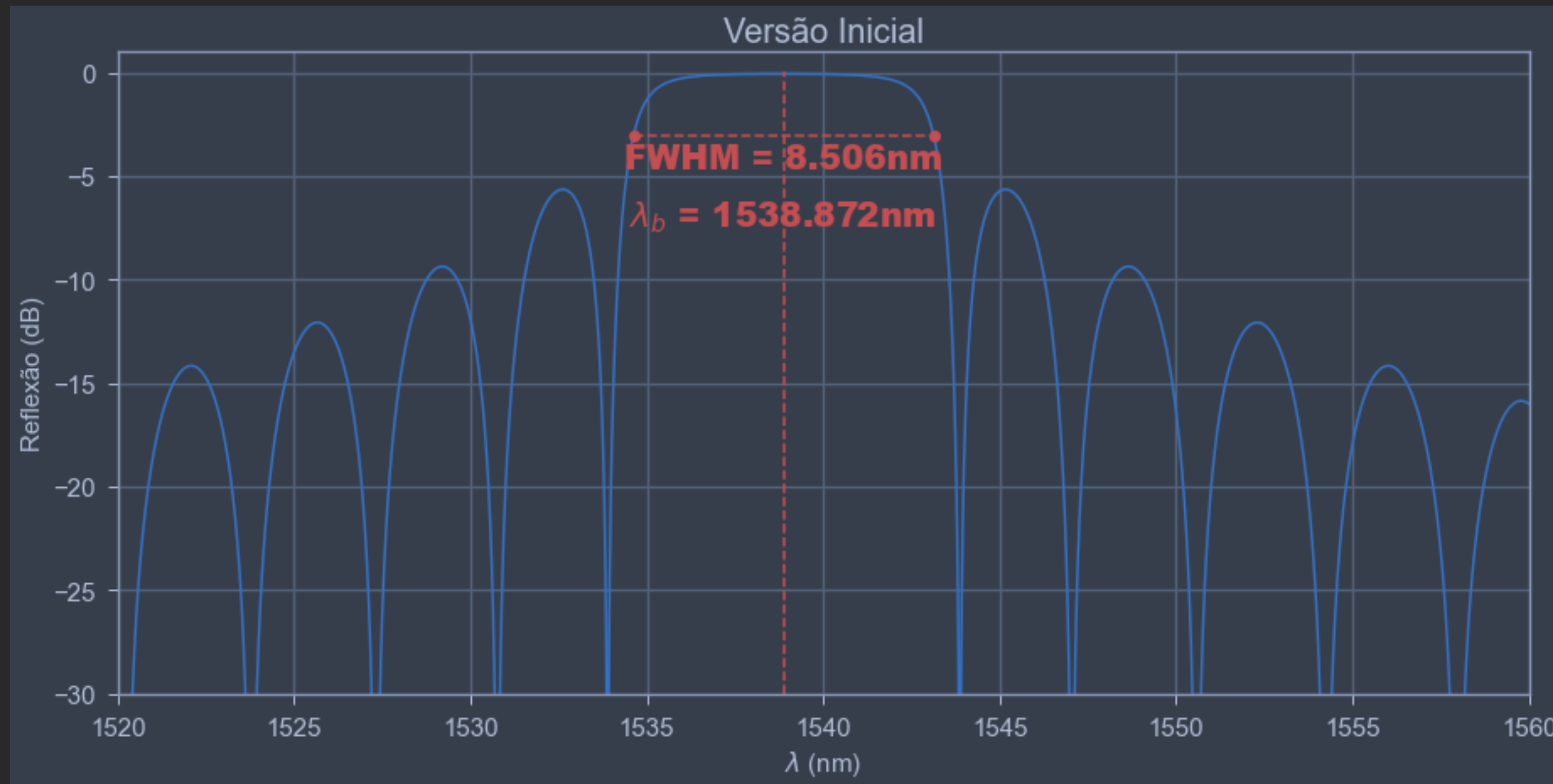
## Resultados Iniciais



# DESIGN

Correção do FWHM

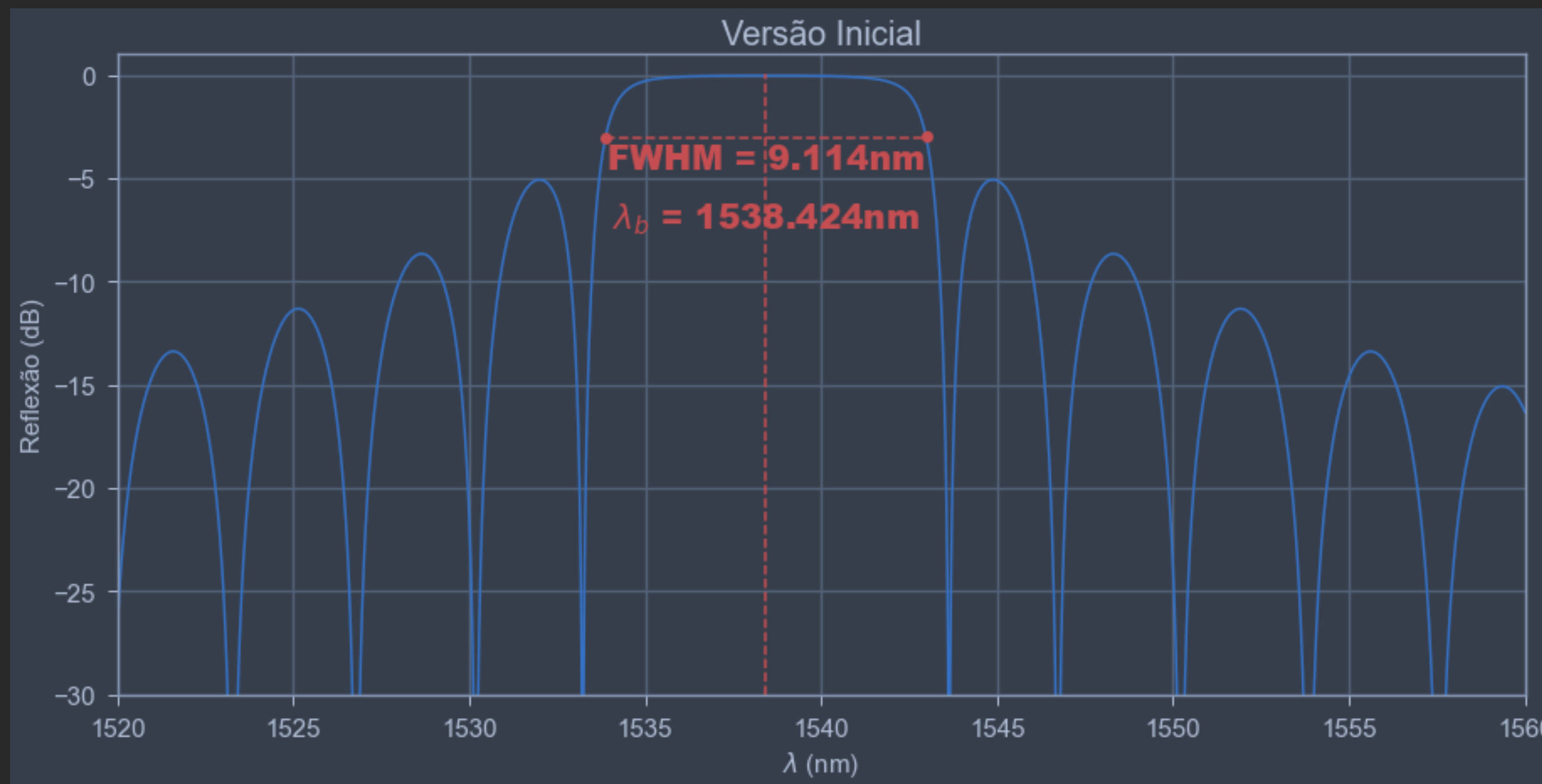
$$\Delta W = 0.064625 \text{ (x1.25)}$$



# DESIGN

Correção do FWHM

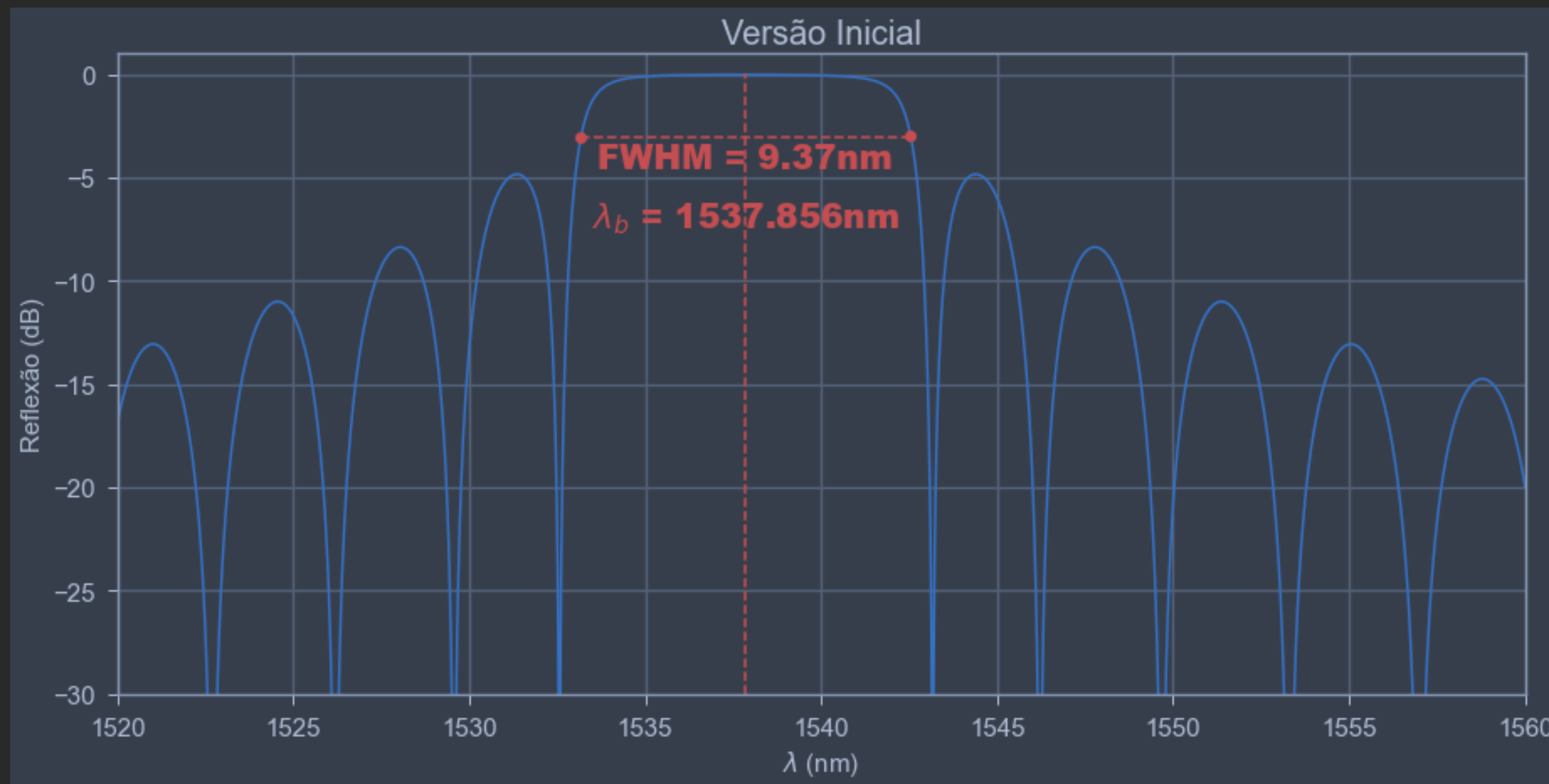
$$\Delta W = 0.07755 \text{ (x1.5)}$$



# DESIGN

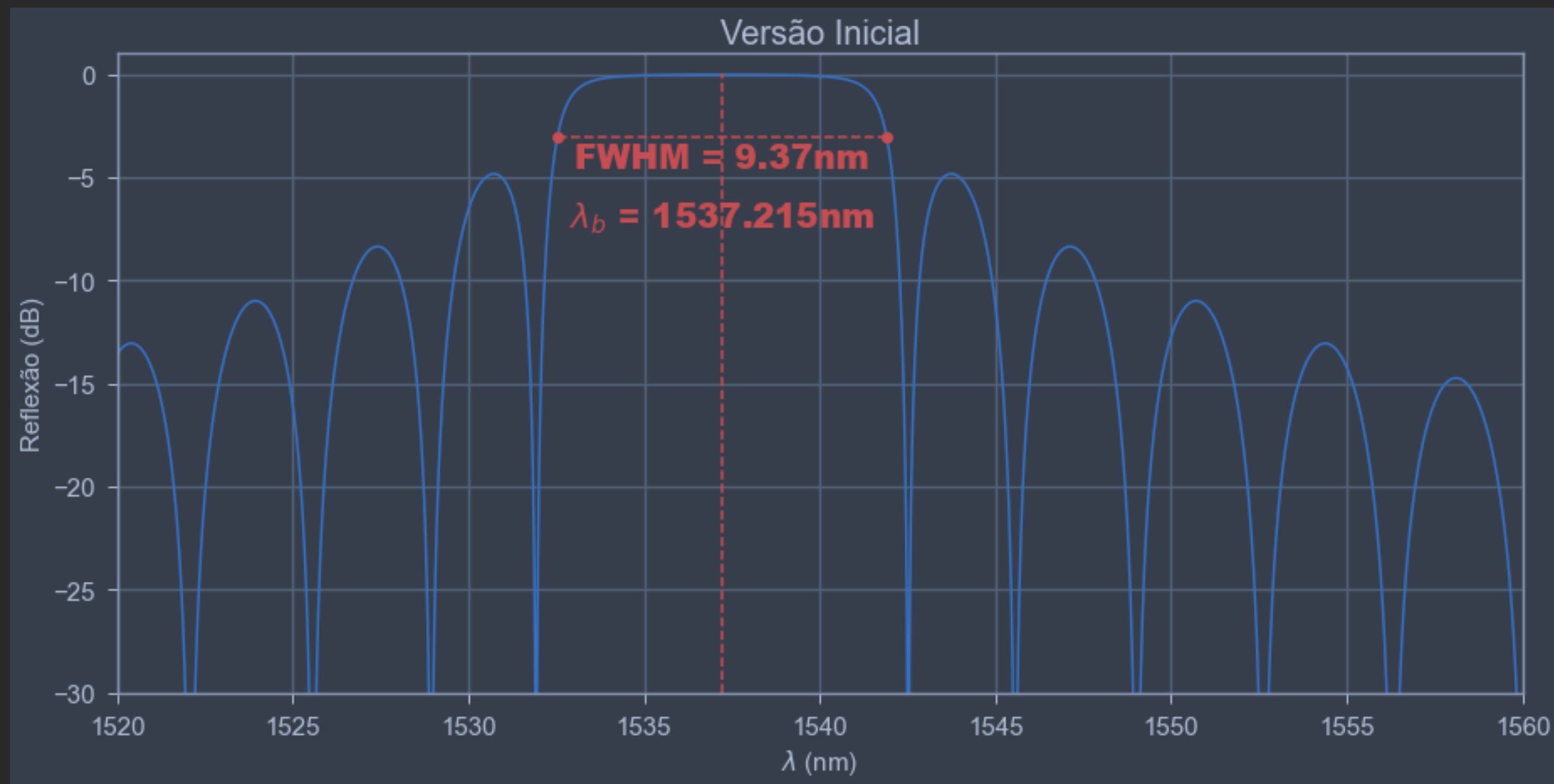
Correção do FWHM

$$\Delta W = 0.090475 \text{ (x1.75)}$$



# DESIGN

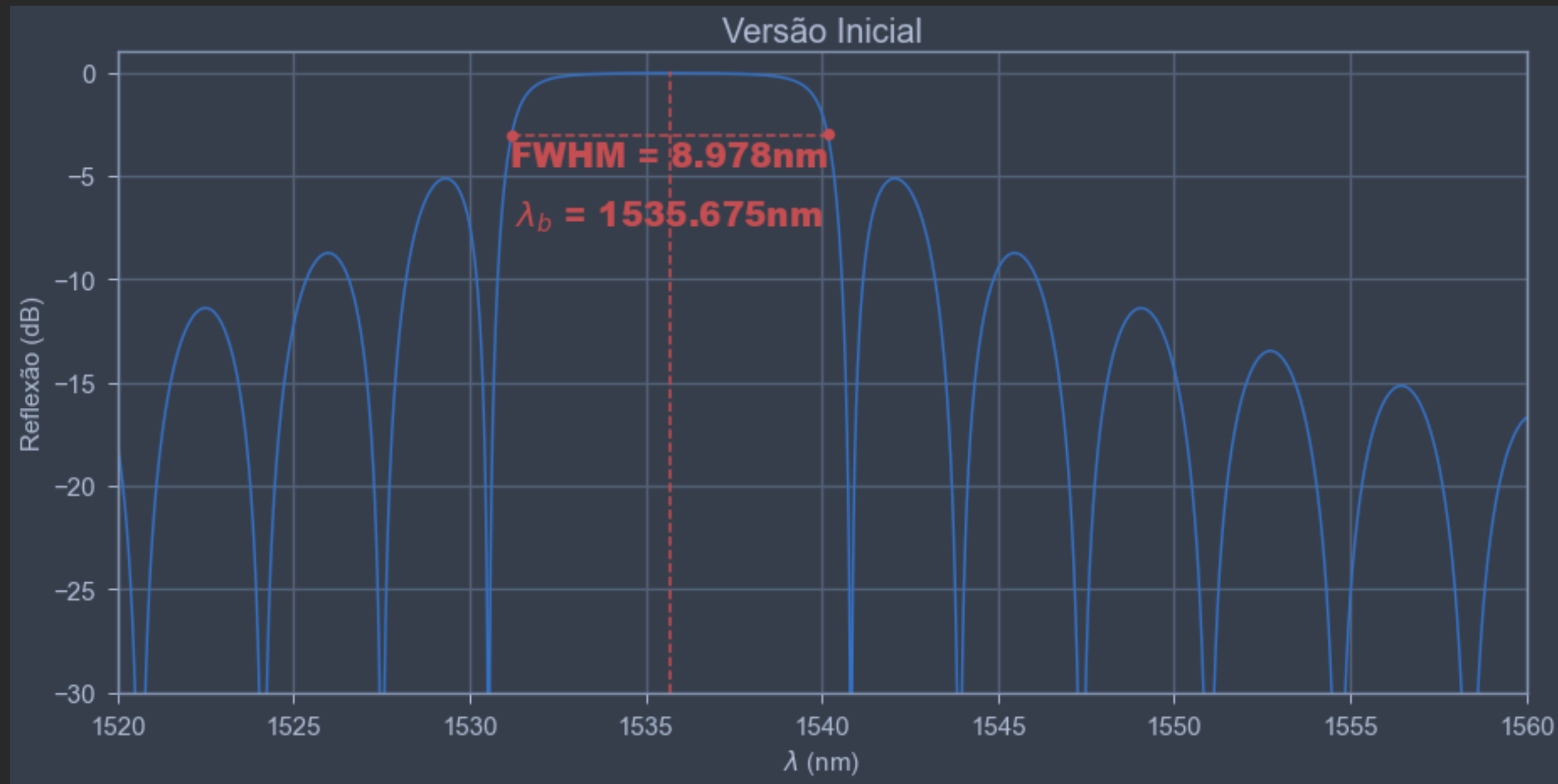
## Correção do FWHM

$$\Delta W = 0.1034 \text{ (x2)}$$


# DESIGN

Correção do FWHM

$$\Delta W = 0.12925 \text{ (x2.5)}$$



# DESIGN

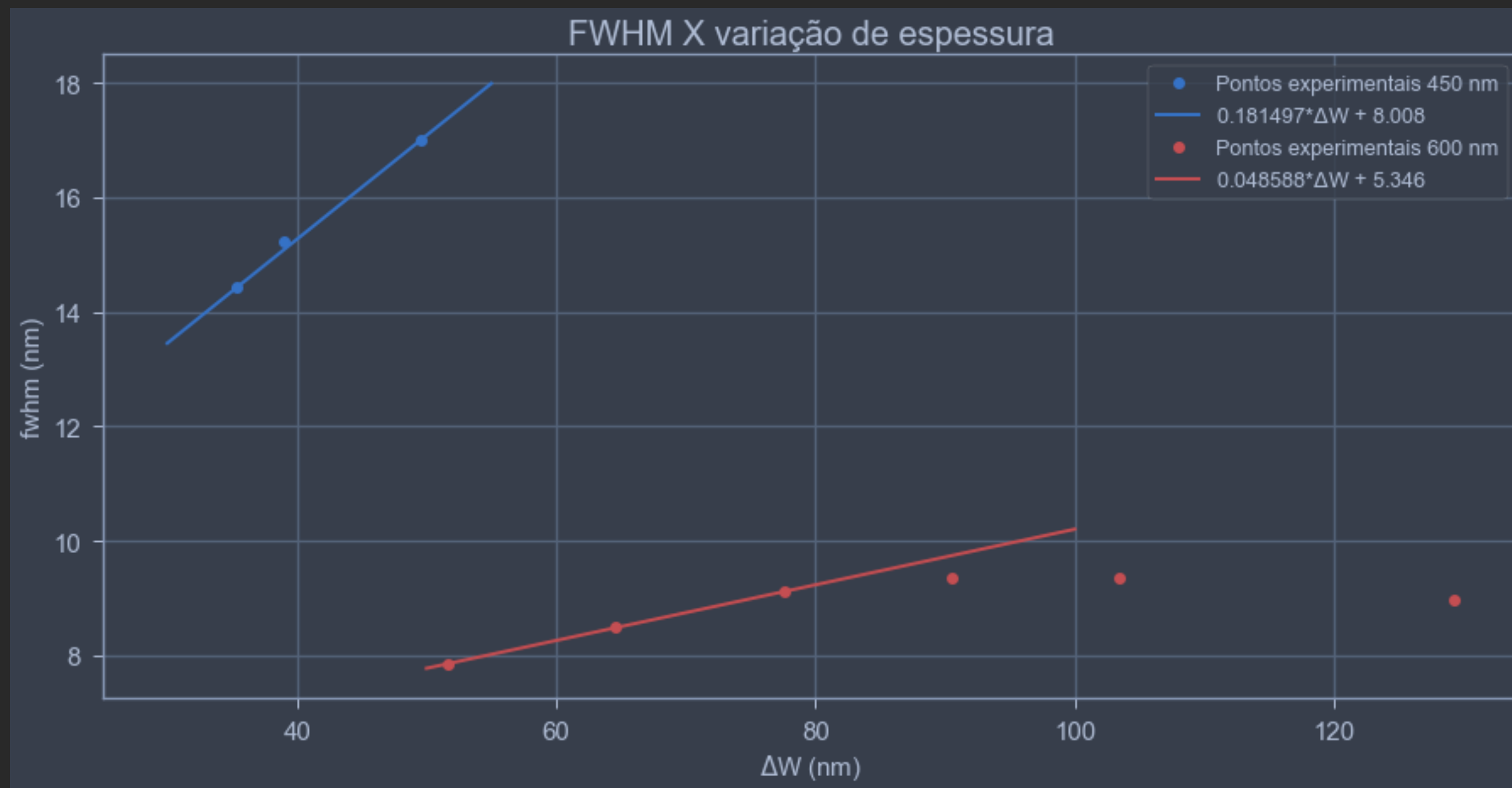
## Analise do FWHM





# DESIGN

Comparação com a grade anterior

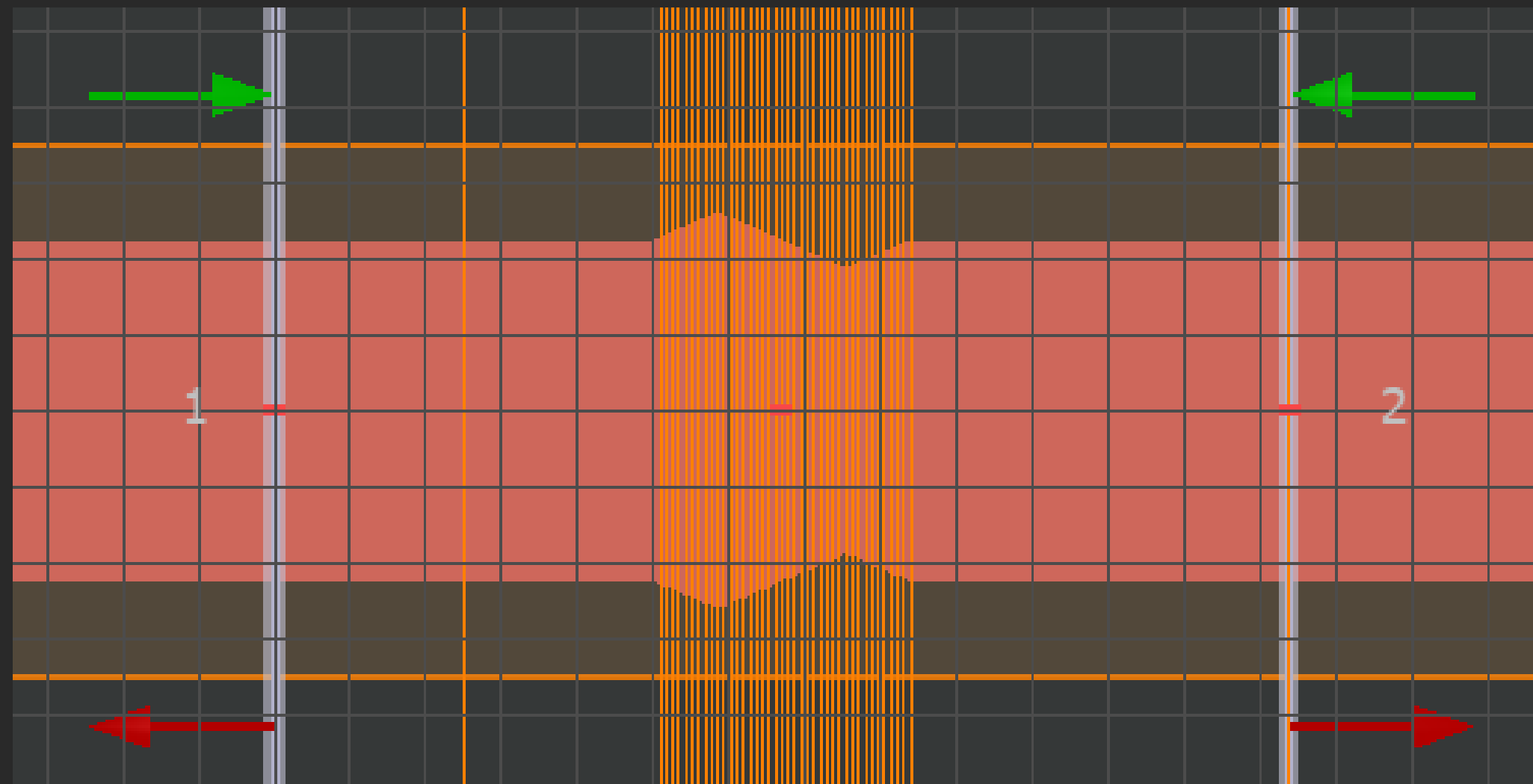


# DESIGN

ALTERANDO A GEOMETRIA DA 1 GRADE

# DESIGN

## Gemetria triangular



# DESIGN

## Gemetria triangular

Edit EME solver

name EME

General

EME setup

Transverse mesh settings

Boundary conditions

Material

Advanced options

cell geometry

x min (μm)

-0.5

number of cell groups

5

energy conservation

make passive

number of modes for all cell groups

2

allow custom eigensolver settings

cell group definition

	group spans (μm)	cells	subcell method	modes	custom	cell range
1	0.5	2	CVCS	2	default	[1,2]
2	0.0846337	10	CVCS	2	default	[3 ... 12]
3	0.169267	20	CVCS	2	default	[13 ... 32]
4	0.0846337	10	CVCS	2	default	[33 ... 42]
5	0.5	1	none	2	default	[43]

<

>

display cells

Clear settings for cell group 1

Custom settings for cell group 1

y (μm)

0

y min (μm)

-2.5

y span (μm)

5

y max (μm)

2.5

z (μm)

0

z min (μm)

-2

z span (μm)

4

z max (μm)

2

periodicity

number of periodic groups

3

periodic group definition

	start cell group	end cell group	periods
1	1	1	1
2	2	3	100
3	4	4	1

cell group sequence

[(1)^1,(2,3)^100,(4)^1,5]

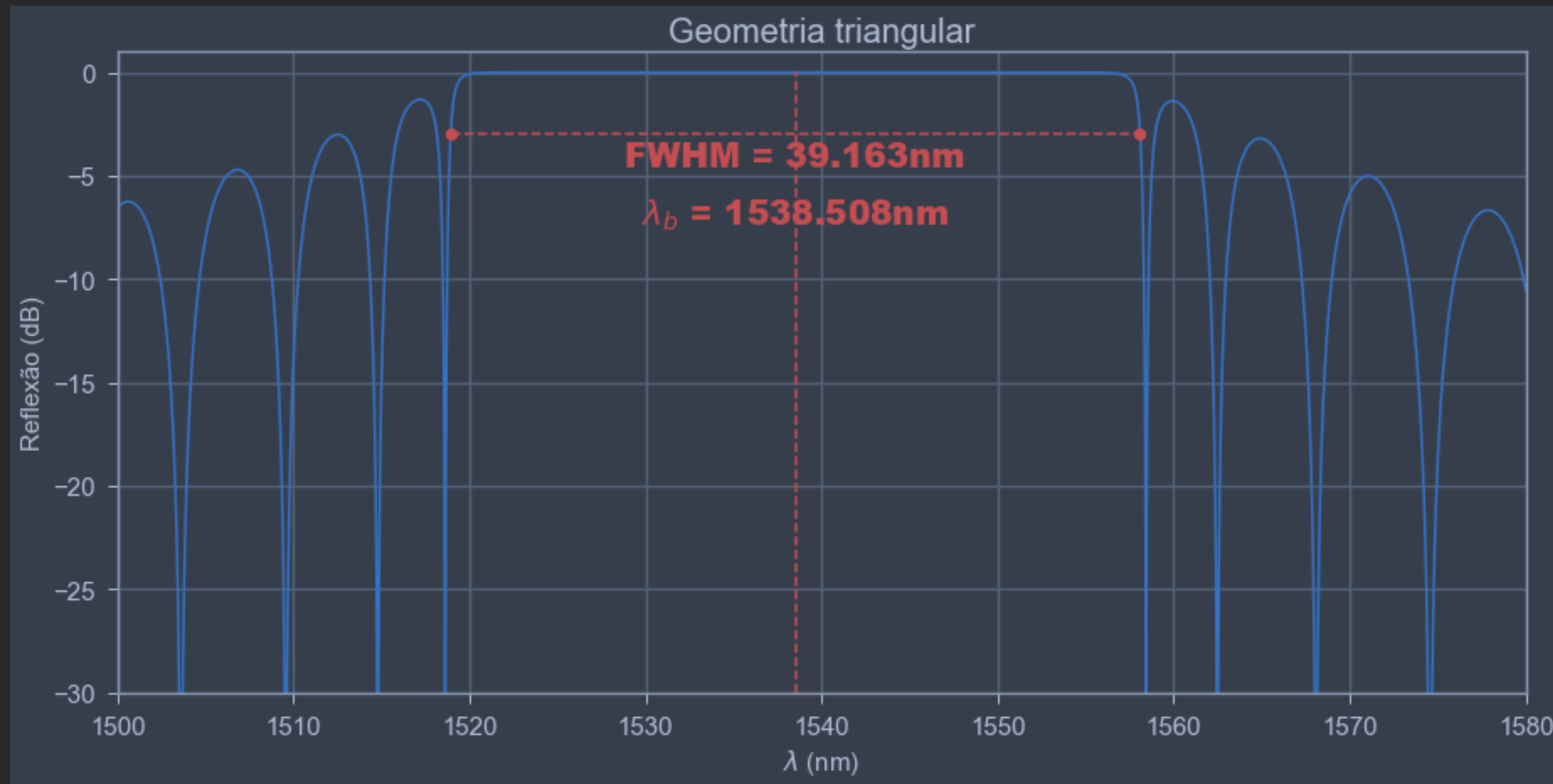
OK

Apply

Cancel

# DESIGN

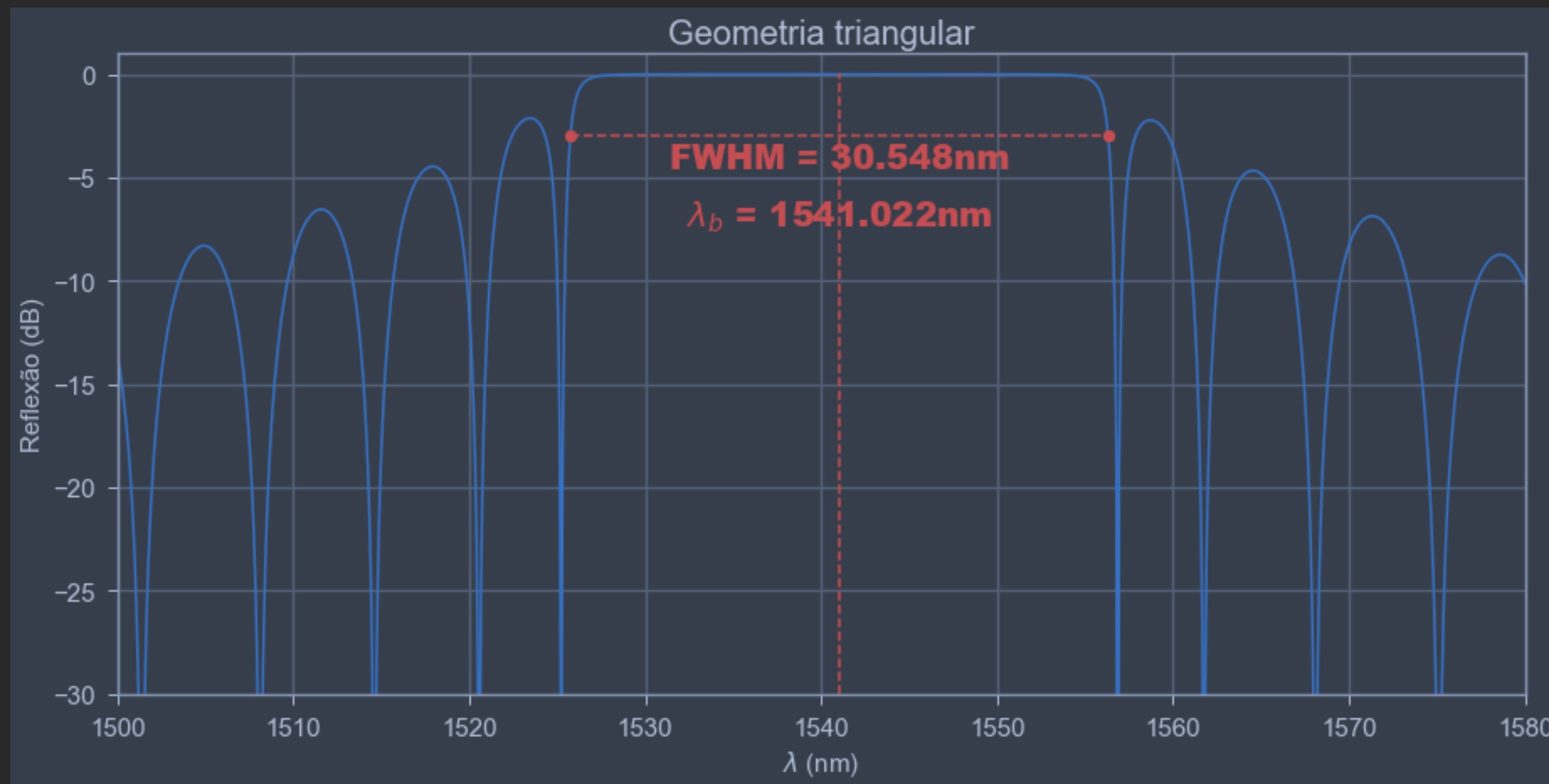
## Gemetria triangular



# DESIGN

Variando o  $\Delta W$

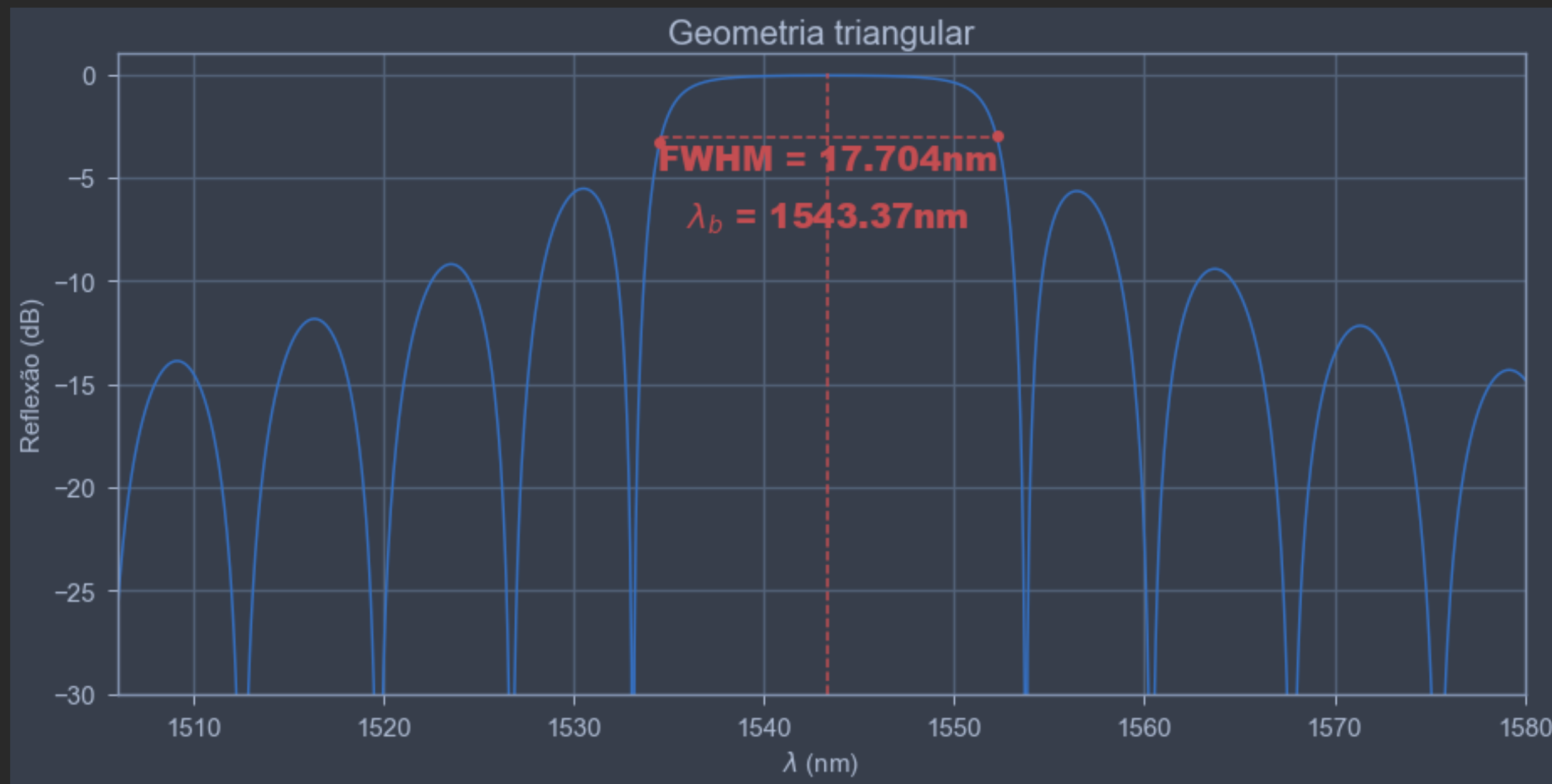
$$\Delta W = 0.0550551 (\times 0.75)$$



# DESIGN

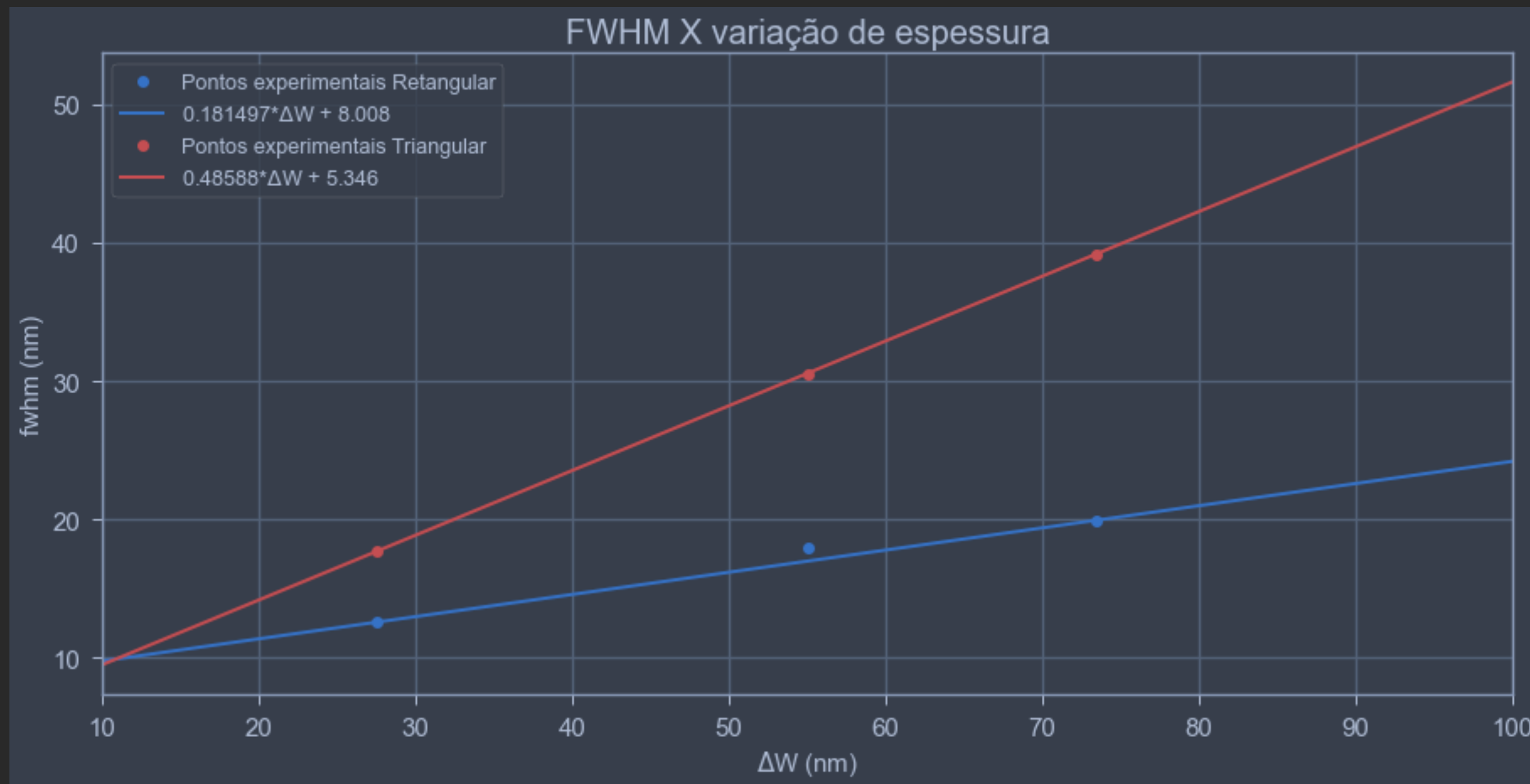
Variando o  $\Delta W$

$$\Delta W = 0.02752755 (\times 0.375)$$



# DESIGN

## Comparação entre grades



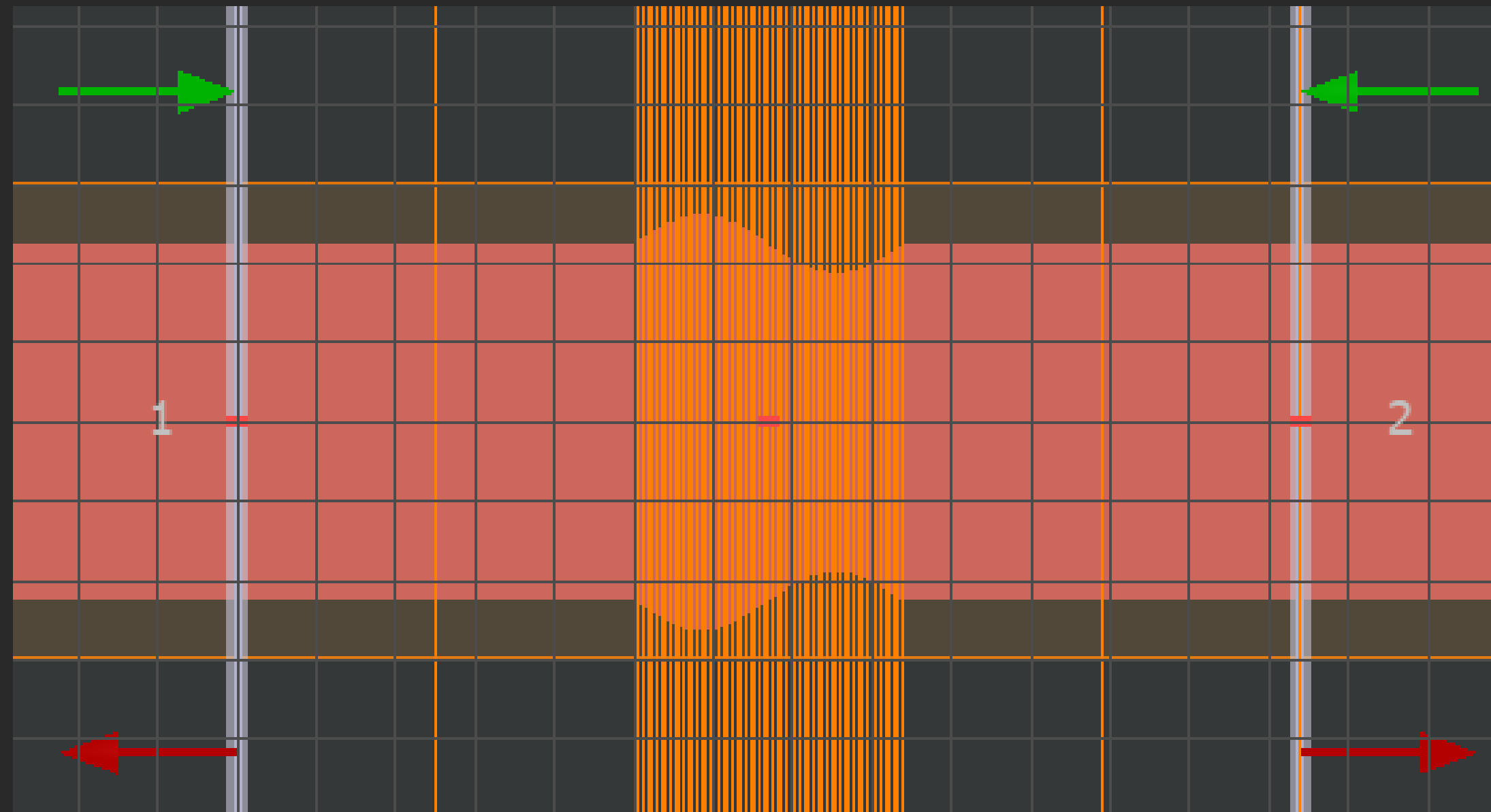


# DESIGN

ALTERANDO A GEOMETRIA DA 1 GRADE

# DESIGN

## Gemetria Senoidal



# DESIGN

## Gemetria triangular

cell geometry

x min (μm)

-0.5

energy conservation

make passive

number of cell groups

3

number of modes for all cell groups

2

☐ allow custom eigensolver settings

cell group definition

	group spans (μm)	cells	subcell method	modes	custom	cell range
1	0.5	2	CVCS	2	default	[1,2]
2	0.338535	60	CVCS	2	default	[3 ... 62]
3	0.5	2	none	2	default	[63,64]

<

>

☒ display cells
 

Clear settings for cell group 1

Custom settings for cell group 1

y (μm)

0

y min (μm)

-2.5

y span (μm)

5

y max (μm)

2.5

z (μm)

0

z min (μm)

-2

z span (μm)

4

z max (μm)

2

periodicity

number of periodic groups

3

periodic group definition

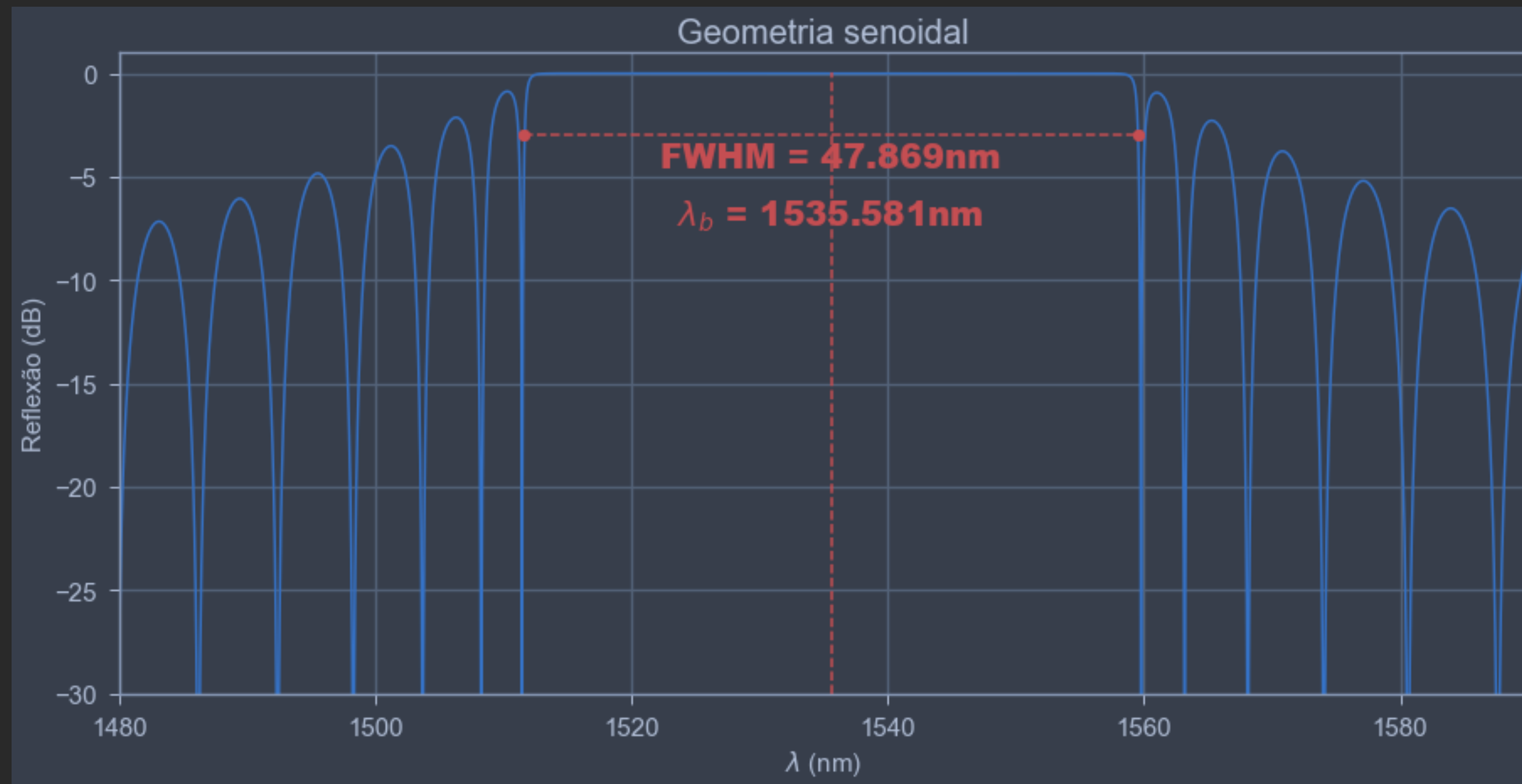
	start cell group	end cell group	periods
1	1	1	1
2	2	2	100
3	3	3	1

cell group sequence

[(1)^1,(2)^100,(3)^1]

# DESIGN

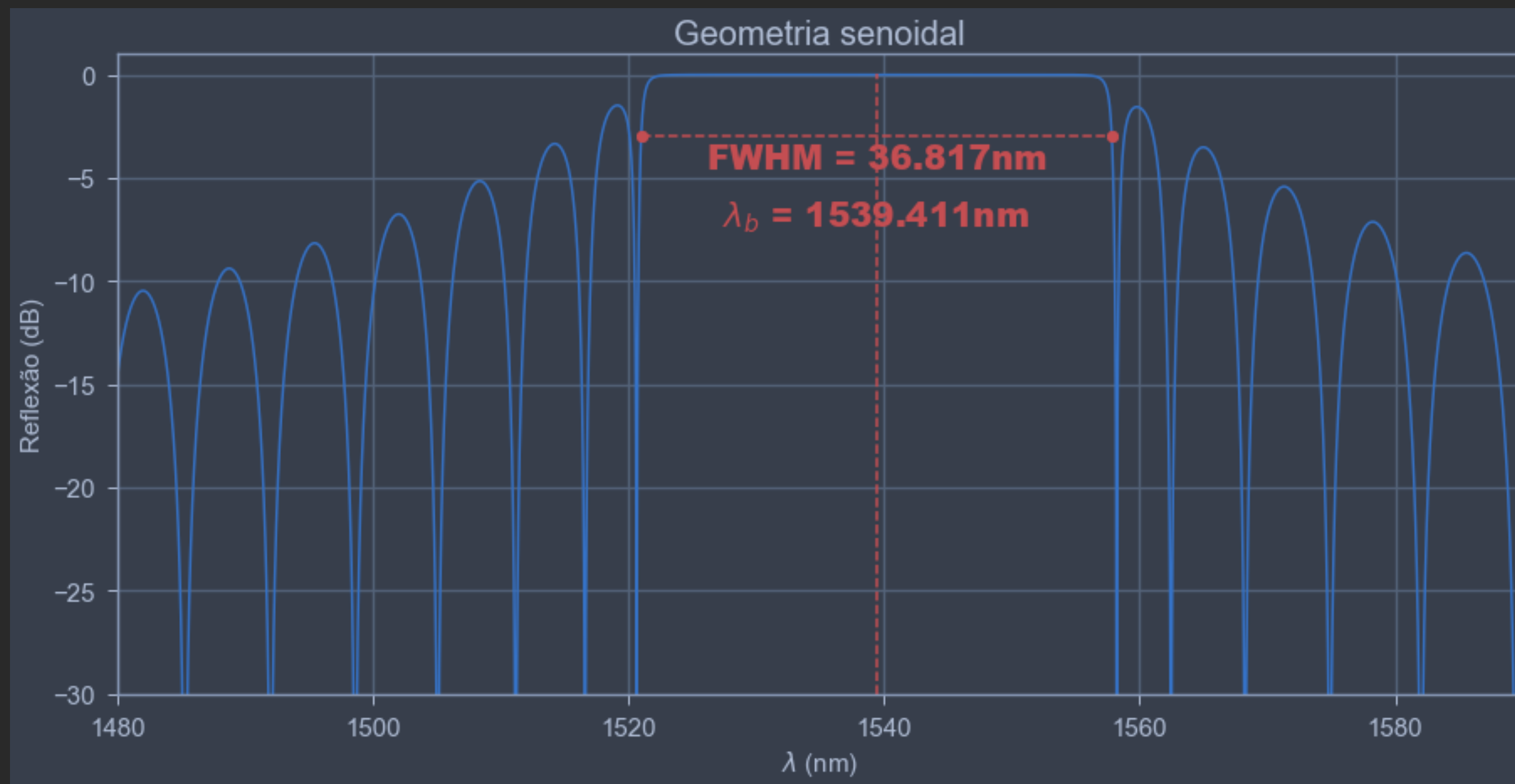
## Gemetria triangular



# DESIGN

Variando o  $\Delta W$

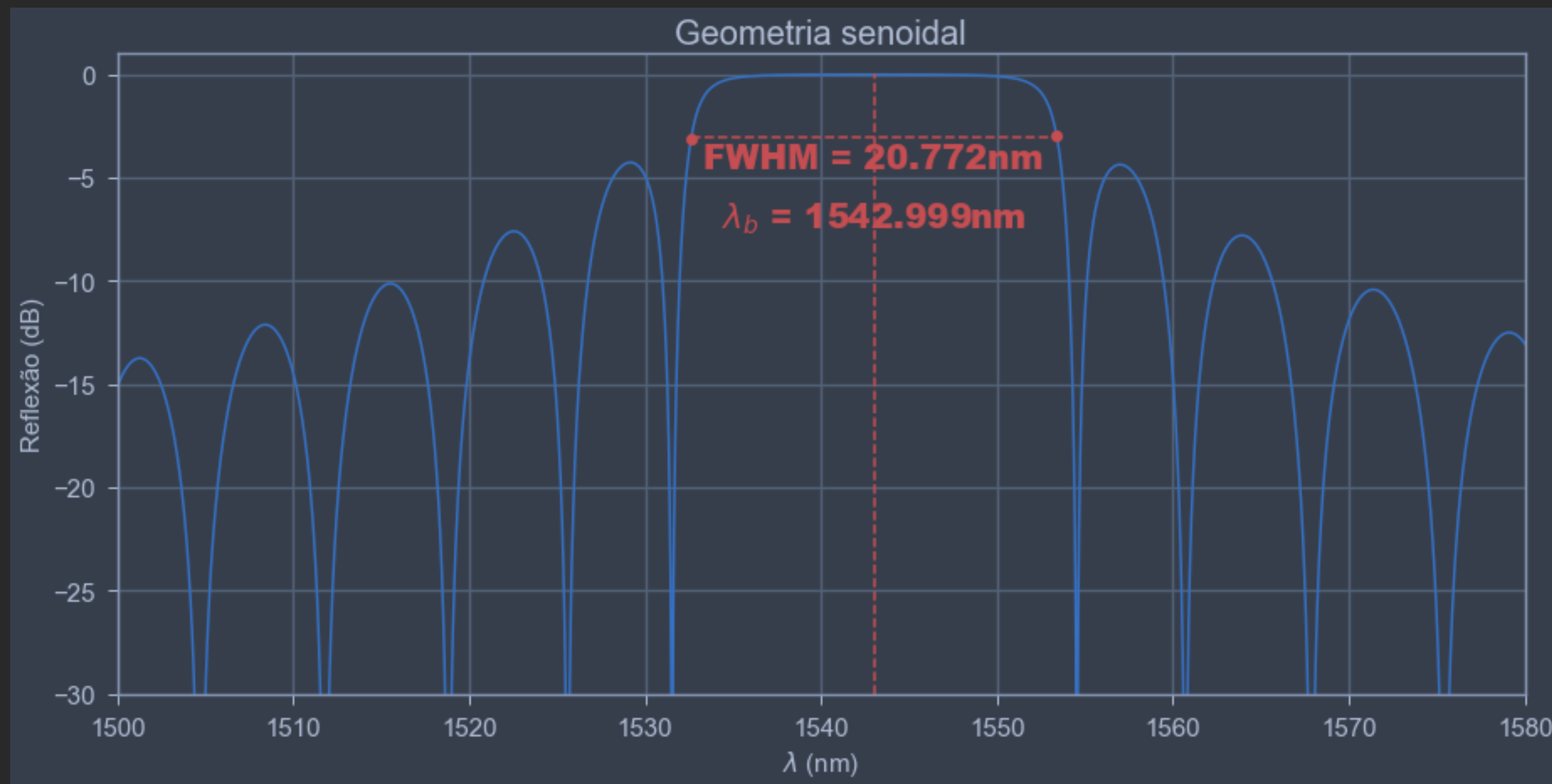
$$\Delta W = 0.0550551 (\times 0.75)$$



# DESIGN

Variando o  $\Delta W$

$$\Delta W = 0.02752755 (\times 0.375)$$



# DESIGN

## Comparação entre grades

