LCGT coating design for green laser locking

Reference: LIGO-G0900205

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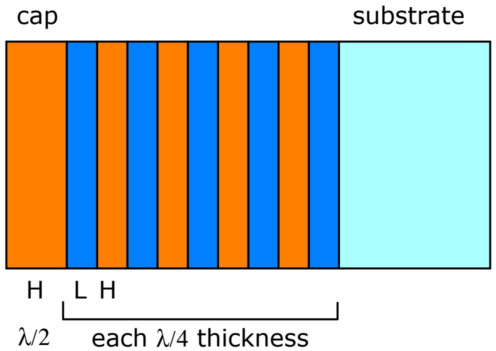
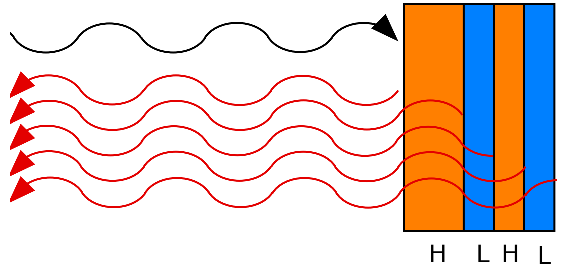
Design A) Mono-chromatic mirror

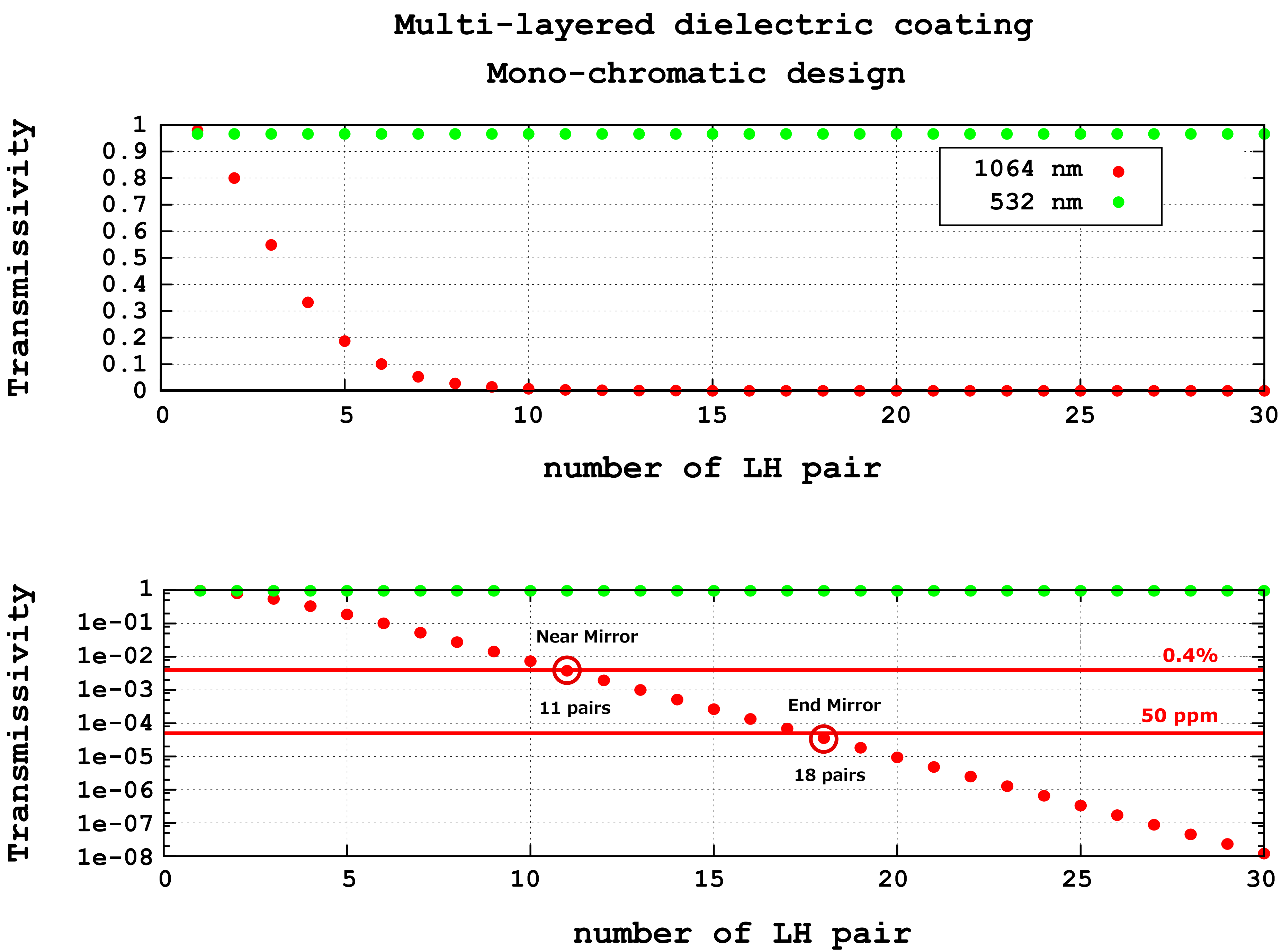


H 1/4 λ
L 1/4 λ

TAMA mirror
n_L=1.5510 SiO_2
n_H=2.0251 Ta_2O_5

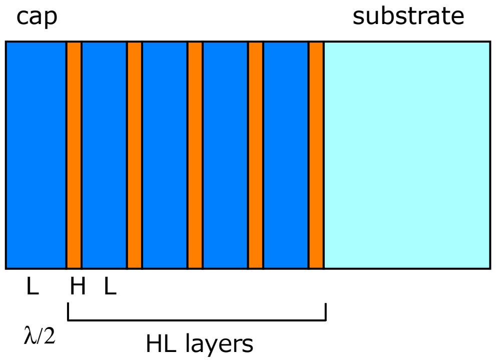


	Number of LH pairs	Reflectance Transmittance	Designed Value
Near Mirror	**11**	0.996220E+00 0.377978E-02	0.996 0.4E-02
End Mirror	**18**	0.999964E+00 0.355937E-04	0.999950 50E-6



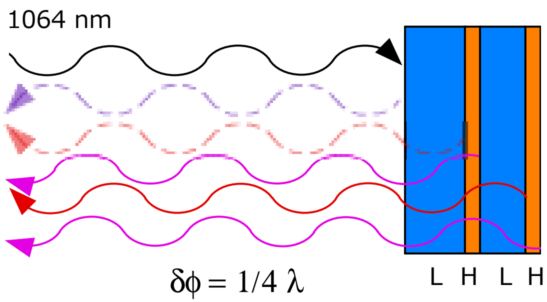
Multi-layered dielectric coating
Mono-chromatic design
Transmissivity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
1064 nm
532 nm
number of LH pair
Transmissivity
1
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
1e-07
1e-08
Near Mirror
11 pairs
End Mirror
18 pairs
0.4%
50 ppm
0
5
10
15
20
25
30
number of LH pair

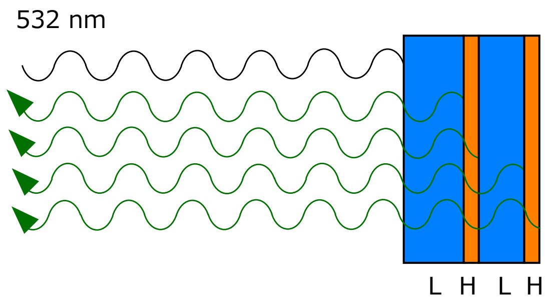
Design B) Dichroic mirror (base design)



H $1/8\,\lambda = 1/4\ (\lambda/2)$

L $3/8\,\lambda = 1/4\ (\lambda/2) + 1/2\ (\lambda/2)$

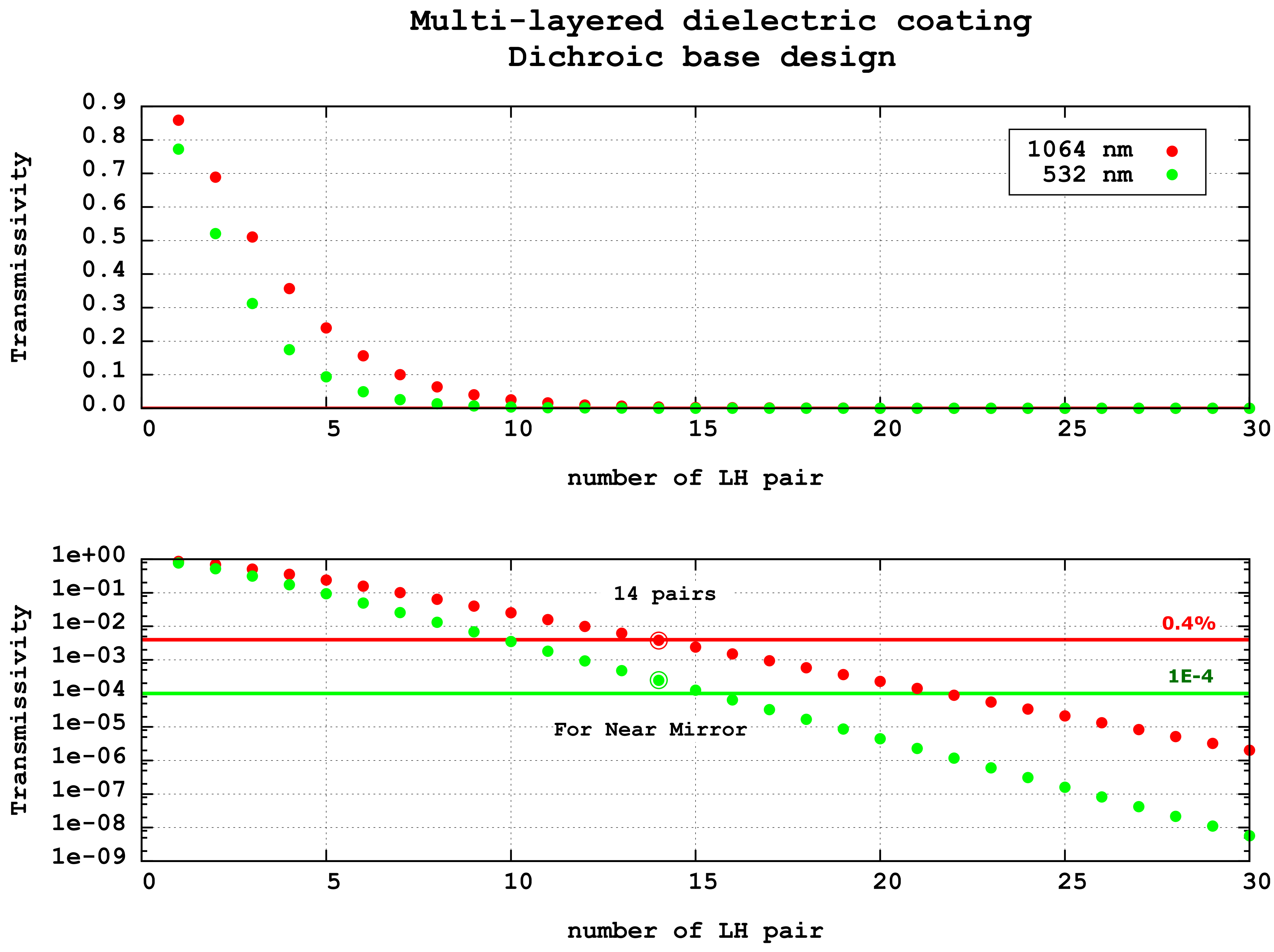




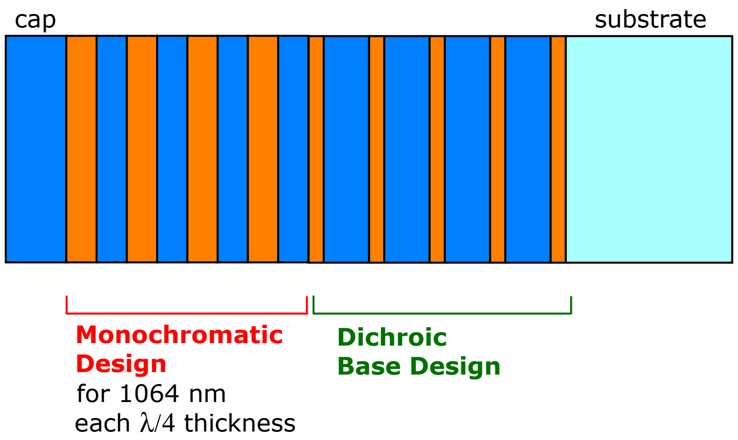
$\mathbf{R_{1064\ nm} < R_{532\ nm}}$

This is not good for End Test Mass.

		1064 nm		532 nm	
	Number of LH pairs	**Reflectance Transmittance**	**Designed Value**	**Reflectance Transmittance**	**Designed Value**
Near Mirror	**14**	0.996145E+00 0.385461E-02	0.996 0.4E-02	0.999756E+00 0.243683E-03	> 0.999 < 0.001
End Mirror	**---**	**---**	0.999950 50E-6	**---**	0.95 0.05

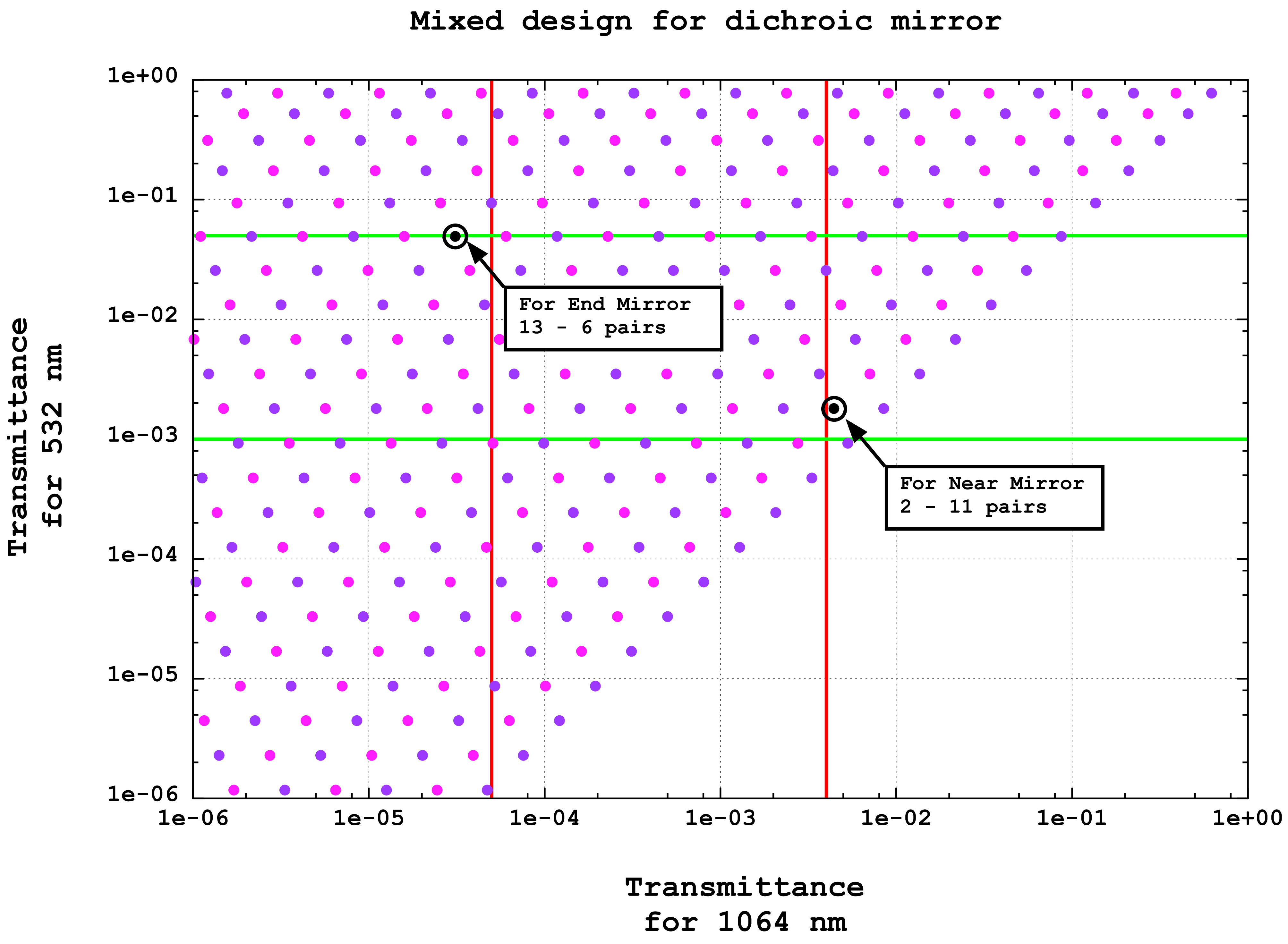

Multi-layered dielectric coating
Dichroic base design
Transmissivity
number of LH pair
1064 nm
532 nm
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
5
10
15
20
25
30
1e+00
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
1e-07
1e-08
1e-09
14 pairs
0.4%
1E-4
For Near Mirror

Design C) Mixed Dichroic mirror



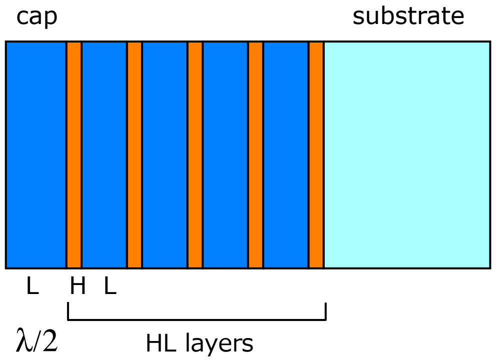
		1064 nm		532 nm	
	Number of LH pairs	Reflectance Transmittance	Designed Value	Reflectance Transmittance	Designed Value
Near Mirror	2- 11	0.995584E+00 0.441642E-02	0.996 0.4E-02	0.998201E+00 0.179954E-02	> 0.999 < 0.001
End Mirror	13- 6	0.999969E+00 30.96768E-06	0.999950 50E-6	0.950746E+00 0.492544E-01	0.95 0.05

... maybe need fine tuning



Mixed design for dichroic mirror
Transmittance for 532 nm
Transmittance for 1064 nm
1e+00
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
1e-06
1e-05
1e-04
1e-03
1e-02
1e-01
1e+00
For End Mirror
13 - 6 pairs
For Near Mirror
2 - 11 pairs

Design D) Stacked Doublets Design (Dichroic)



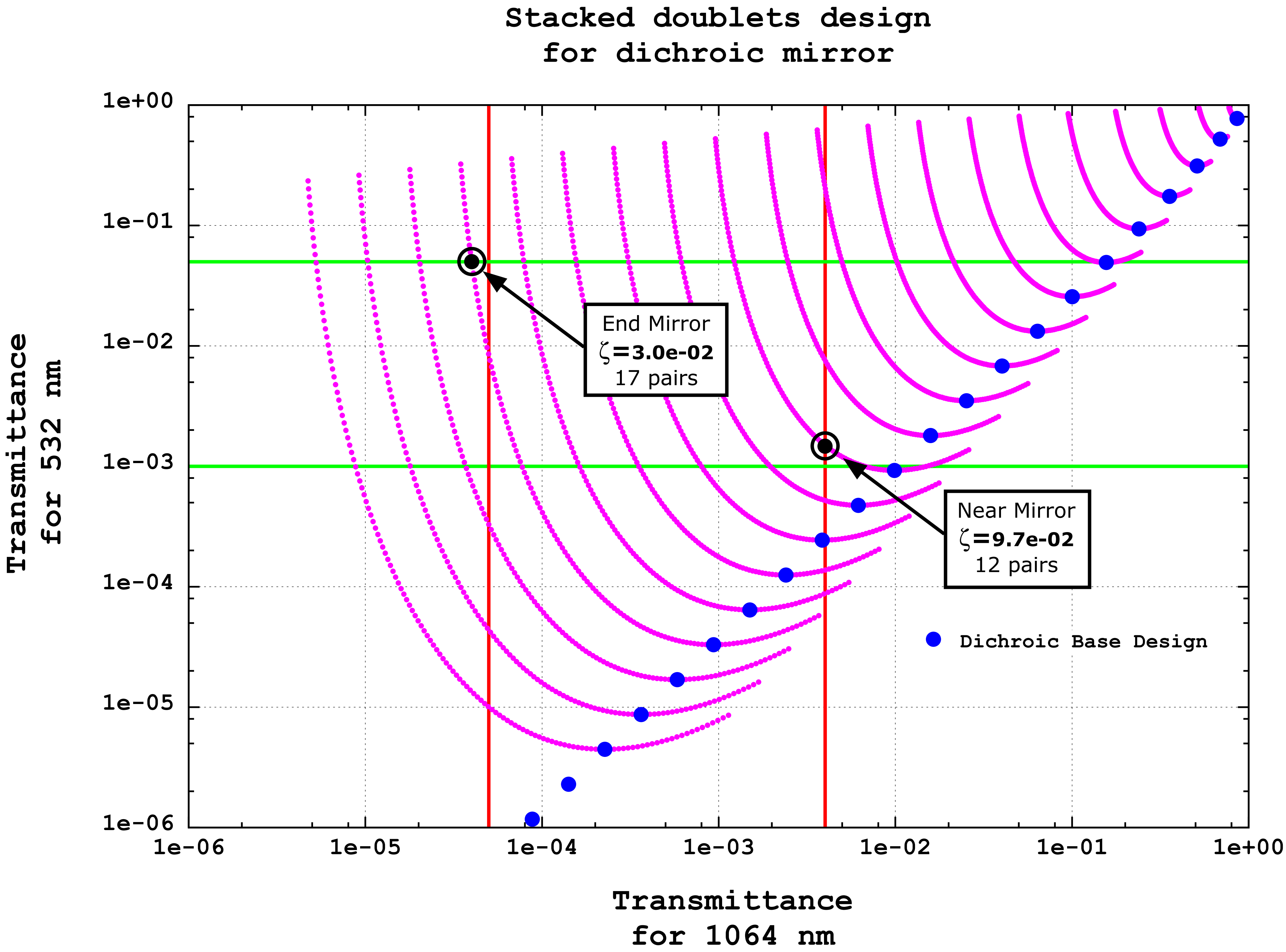
H $(1/4 - \zeta)\,\lambda$

L $(1/4 + \zeta)\,\lambda$

$\zeta=0$ monochromatic design

$\zeta=1/8$ dichroic base design

		1064 nm		532 nm	
	Number of LH pairs	**Reflectance Transmittance**	**Designed Value**	**Reflectance Transmittance**	**Designed Value**
Near Mirror	ζ=**9.7e-02** **12**	0.996041E-00 0.395860E-02	0.996 0.4E-02	0.998485E-00 0.151457E-02	> 0.999 < 0.001
End Mirror	ζ=**3.0e-02** **17**	0.999960E-00 40.32729E-06	0.999950 50E-6	0.954114E-00 0.458864E-01	0.95 0.05



Stacked doublets design
for dichroic mirror
End Mirror
ζ=3.0e-02
17 pairs
Near Mirror
ζ=9.7e-02
12 pairs
Dichroic Base Design
Transmittance
for 532 nm
Transmittance
for 1064 nm
1e+00
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
1e-06
1e-05
1e-04
1e-03
1e-02
1e-01
1e+00

Total thickness of H layers

	Near Mirror	End Mirror
Monochromatic Design	11 x (λ/4) = 2.750 λ	18 x (λ/4) = 4.500 λ
Mixed Dichroic Design	2 x (λ/4) + 11 x (λ/8) = 1.875 λ	13 x (λ/4) + 6 x (λ/8) = 4.000 λ
Stacked Doublet Design	12 x (1/4-9.7E-2)λ = (3 - 1.164)λ = 1.836 λ	17 x (1/4-3.0E-2)λ = (4.25 - 0.51)λ = 3.740 λ

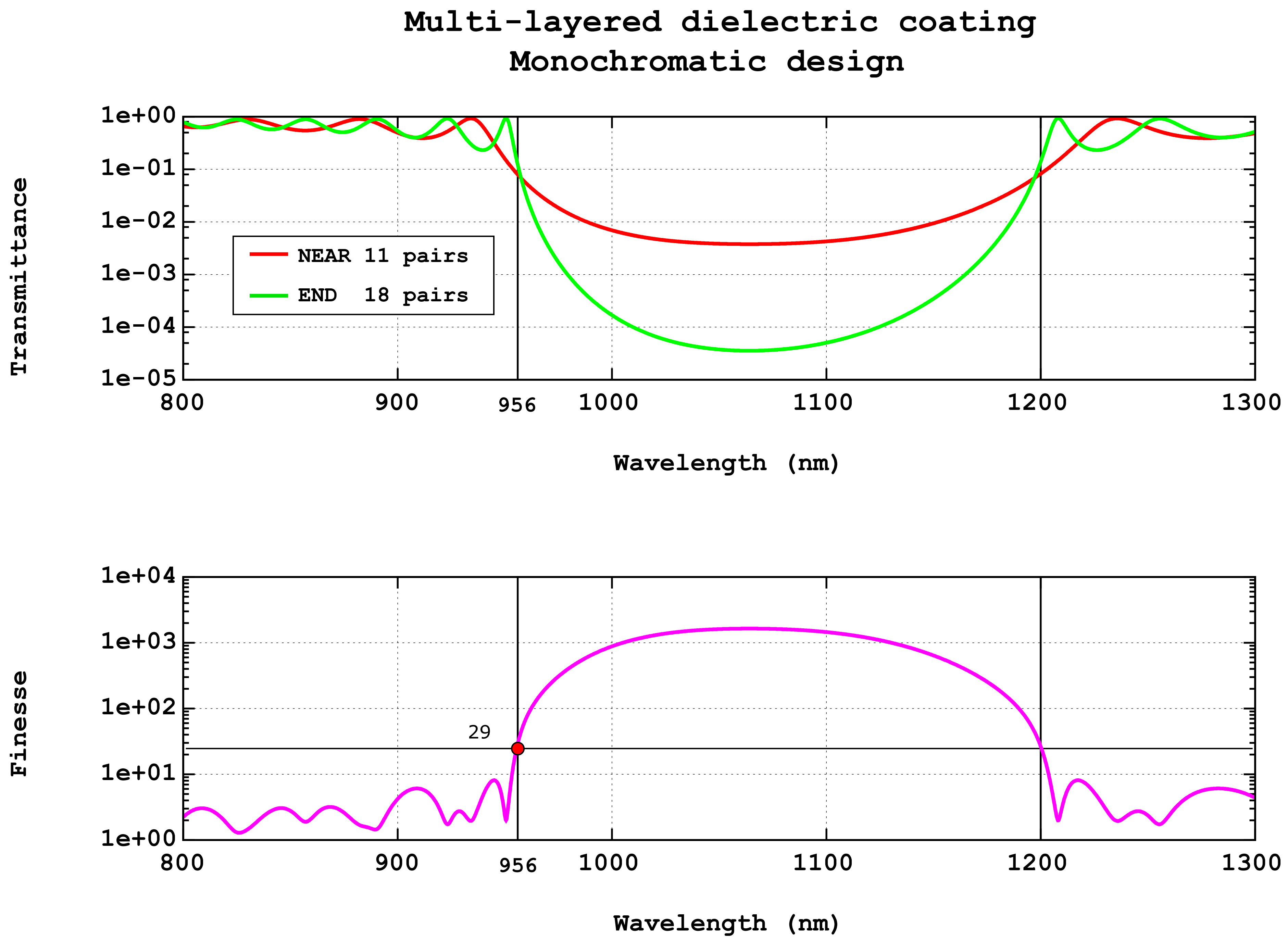
It is supposed that mechanical loss of the coating is dominated by high refractive index films.
If mechanical loss of L layers are negligible, the thinner H layers are, the lower mechanical loss of the coatings is.
It means that coating thermal noise could be reduced by coating design.

Conclusion

We can obtain the desired LCGT coating for green laser locking with both mixed and stacked doublet design.

At the point of coating thickness, stacked doublet design is thinner than that of mixed and monochromatic design.

It seems that stacked doublet design is the best.
Only the problem of the stacked doublet design is feasibility of fine tuning of coating thickness.



Multi-layered dielectric coating
Monochromatic design
Transmittance
1e+00
1e-01
1e-02
1e-03
1e-04
1e-05
NEAR 11 pairs
END 18 pairs
800
900
956
1000
1100
1200
1300
Wavelength (nm)
Finesse
1e+04
1e+03
1e+02
1e+01
1e+00
29
800
900
956
1000
1100
1200
1300
Wavelength (nm)