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Non periodic dielectric mirror coatings

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Non periodic dielectric mirror coatings

- HR mirror coatings have 1/2 wavelength periodicity,
- normally 1/4H, 1/4L refraction index layers
- But also 1/8H, 3/8L (CSIRO suggested) work OK
- First and last layers are often different to match other requirements
- Fully periodic structures are not optimal
- Non periodic structures are difficult to calculate

How to design non periodic coatings

- Genetic Algorithm [J.H. Holland (1975) successfully applied to many constrained design problems]

- Example of one (conservative) optimization:
  - Minimizing transmittance ($\leq$ 20 ppm);
  - Minimizing Ta_2O_5 thickness ($\leq$ 2000 nm).

- Alternatives: *Regular* non-periodic coatings (e.g. pre-fractal) ?

Genetic synthesis in a nutshell

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- Multi-objective optimization: find

$$\vec{x} \quad S \quad R^N : \underbrace{\left| f_k(\vec{x}) \right| \qquad _k, k = 1,2,...,M}_{\text{multiple objectives/constraints}}$$

- Mimic natural selection, by way of analogy

$$\vec{x} = \underbrace{\left\{ x_1, x_2, ..., x_N \right\}}_{\text{genes}}$$

chromosome

One gene assigned to each layer thickness and its composition

Marriages, mutations, hanky-panky,…. Allowed

Best partner given first choice of preferred partner (requirement taste)

Darwinian selection based on requirements applied every generation

Genetic synthesis in a nutshell, II

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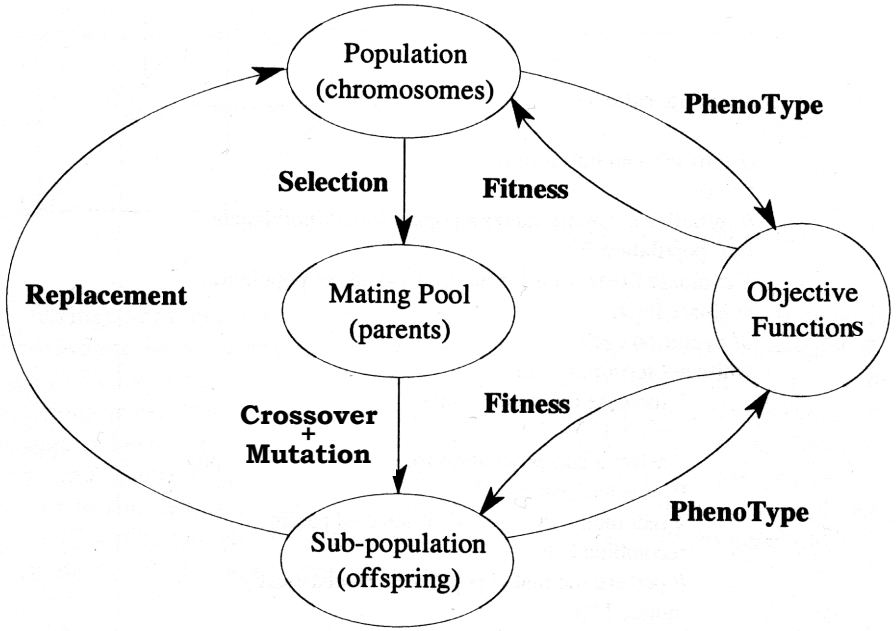
- Evolve initial (random/guess) chromosome *population* $A^{(0)} = \left\{ \vec{x}_1^{\,(0)}, \vec{x}_2^{\,(0)}, \ldots, \vec{x}_P^{\,(0)} \right\}$
- according to *evolutionary* schedule



Comparing mirrors (15ppm)

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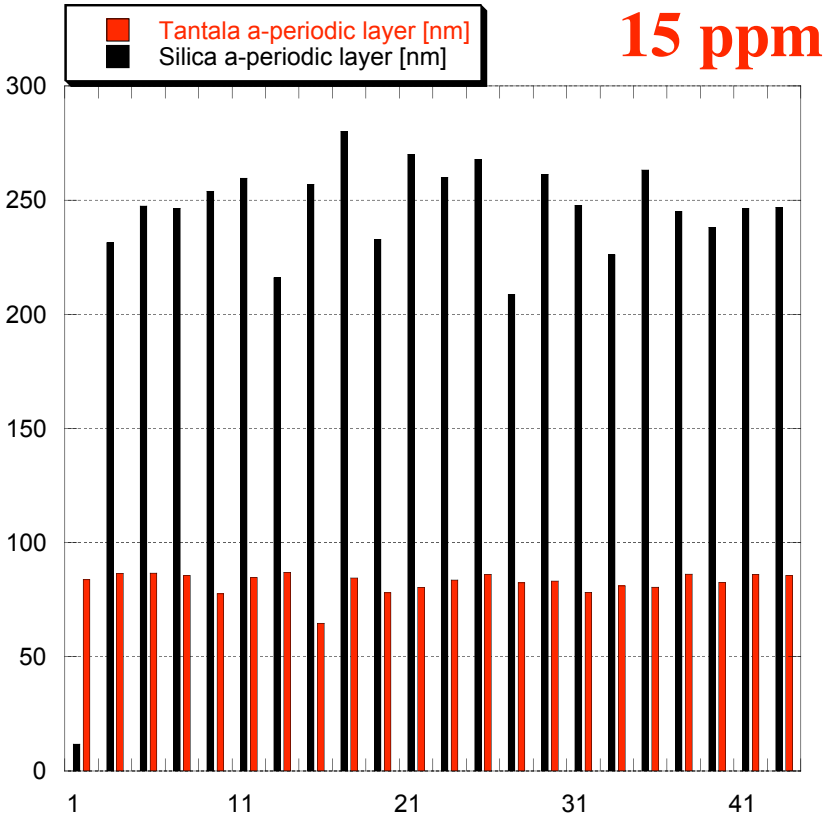
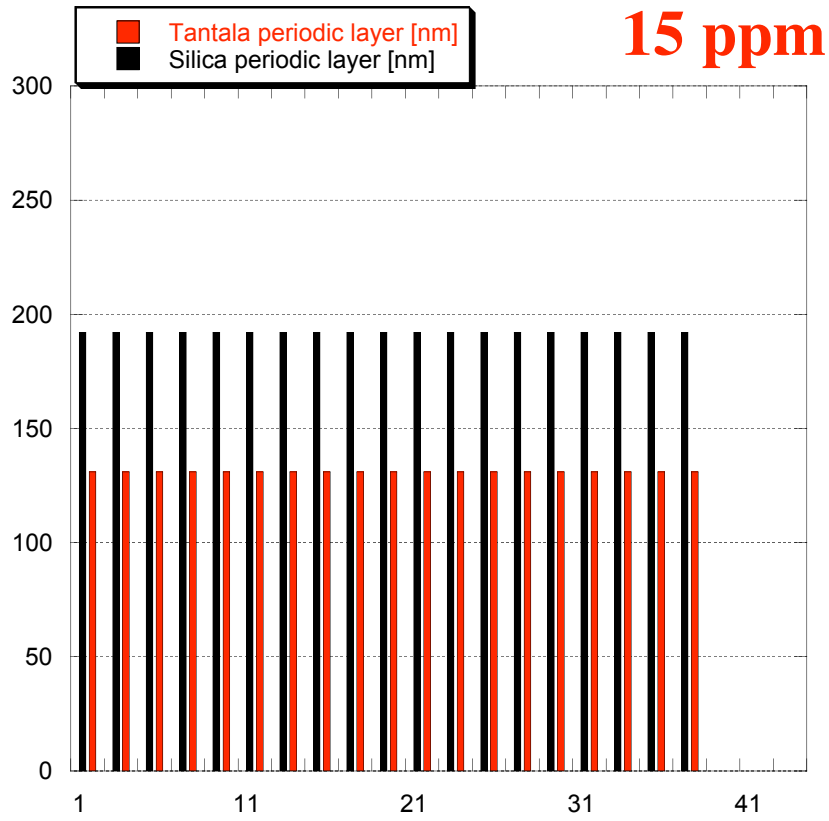
- non-periodic
- (44 layers, 7033 nm)
  1816 nm Ta_2O_5
  5217 nm SiO_2

periodic $\lambda/4+\lambda/4$
(38 layers, 6153nm)
2490 nm Ta_2O_5
3663 nm SiO_2



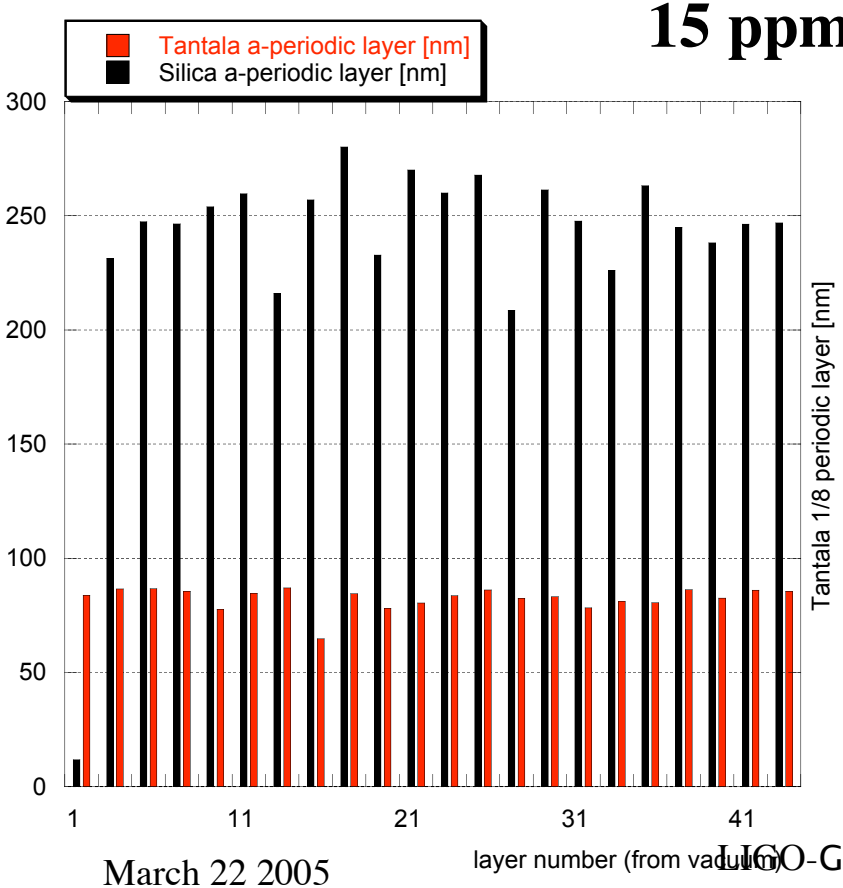


Comparing mirrors (44 layers)

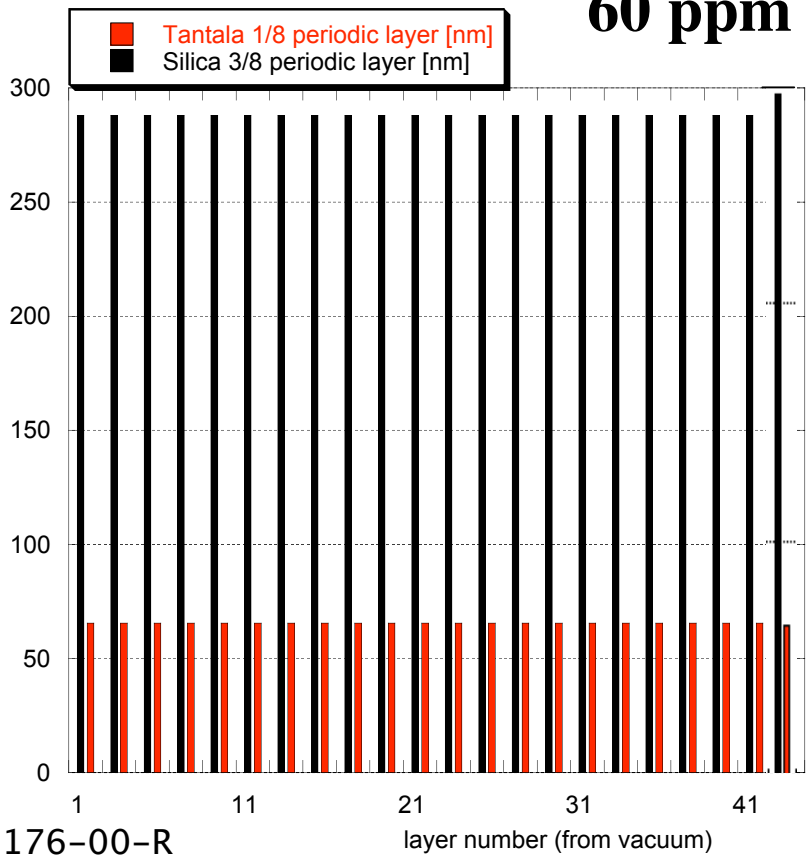
- non-periodic
- (44 layers, 7033 nm)
  1816 nm Ta_2O_5
  5217 nm SiO_2

periodic $3\lambda/8+\lambda/8$
(44 layers, 7766 nm)
1430 nm Ta_2O_5
6336 nm SiO_2

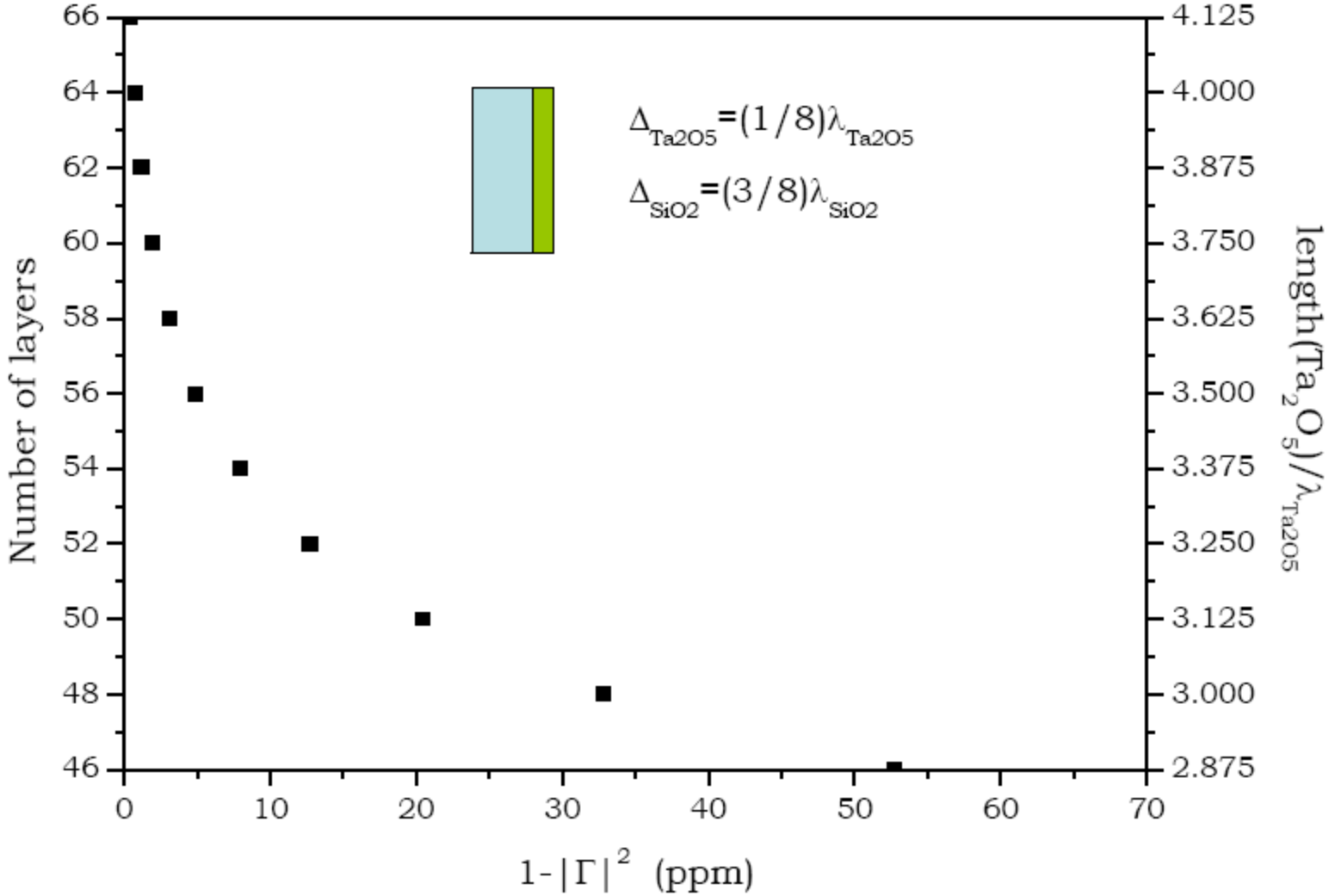
15 ppm



60 ppm



Periodic coatings $3\lambda/8$ SiO_2 $+\lambda/8$ Ta_2O_5



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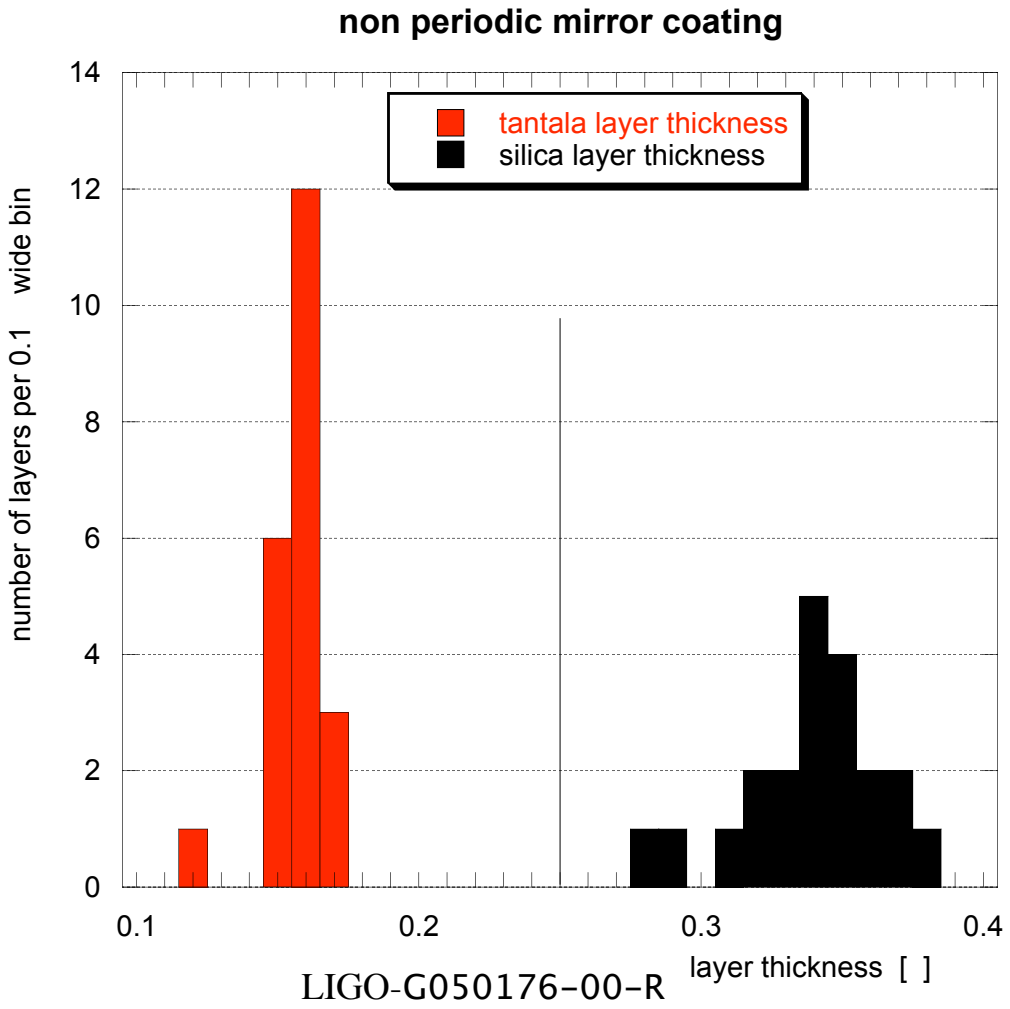
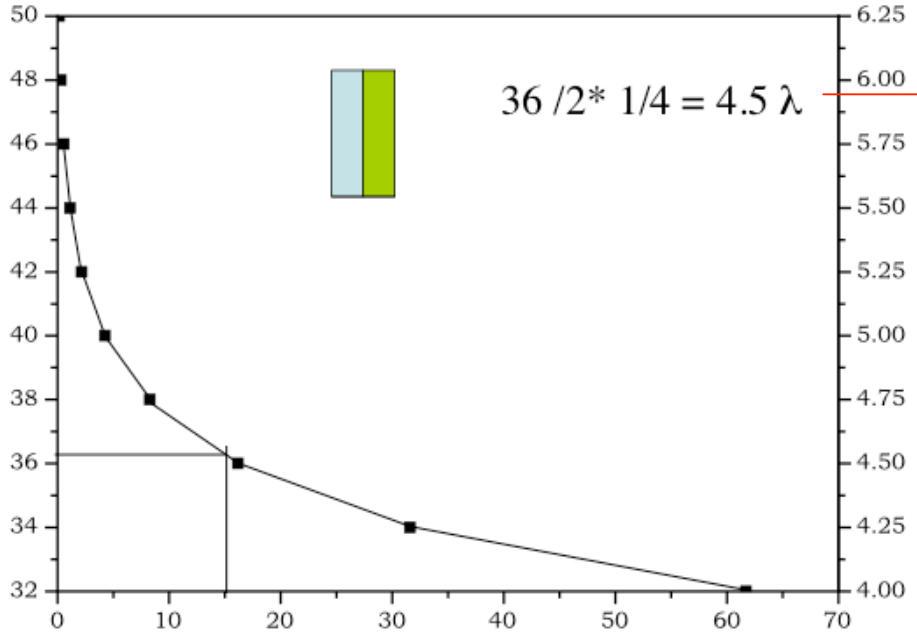
Comparing mirrors (≈15 ppm)

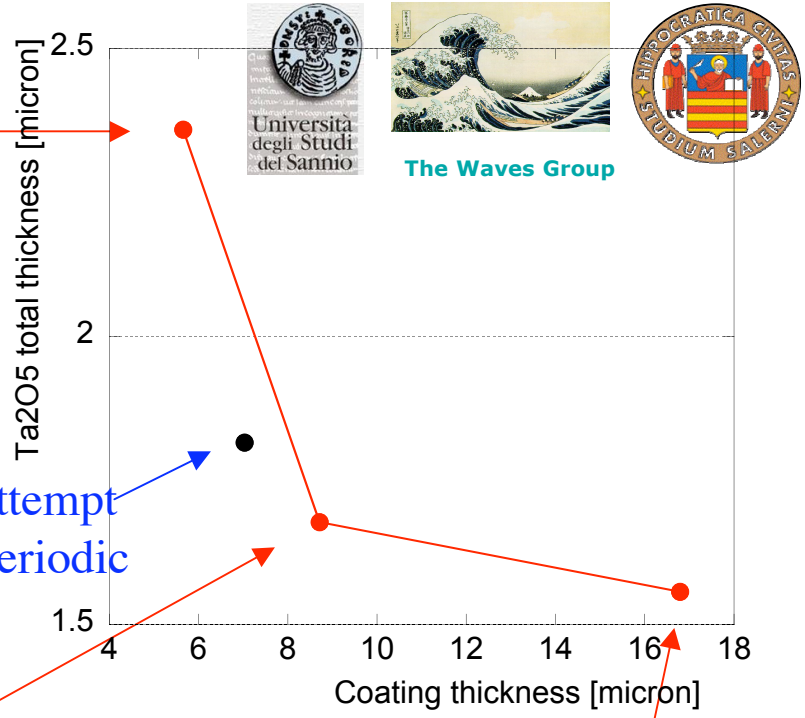
- non-periodic
- (44 layers, 7033 nm)
  1816 nm Ta_2O_5
  5217 nm SiO_2
  15 ppm

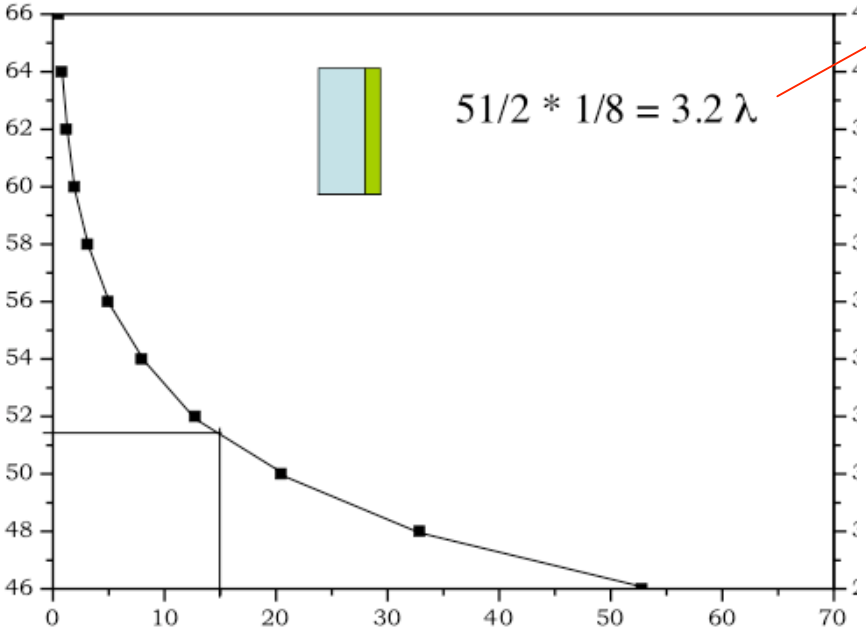
periodic $\lambda/8+3\lambda/8$
(52 layers, 9178 nm)
1690 nm Ta_2O_5
7488 nm SiO_2
13 ppm

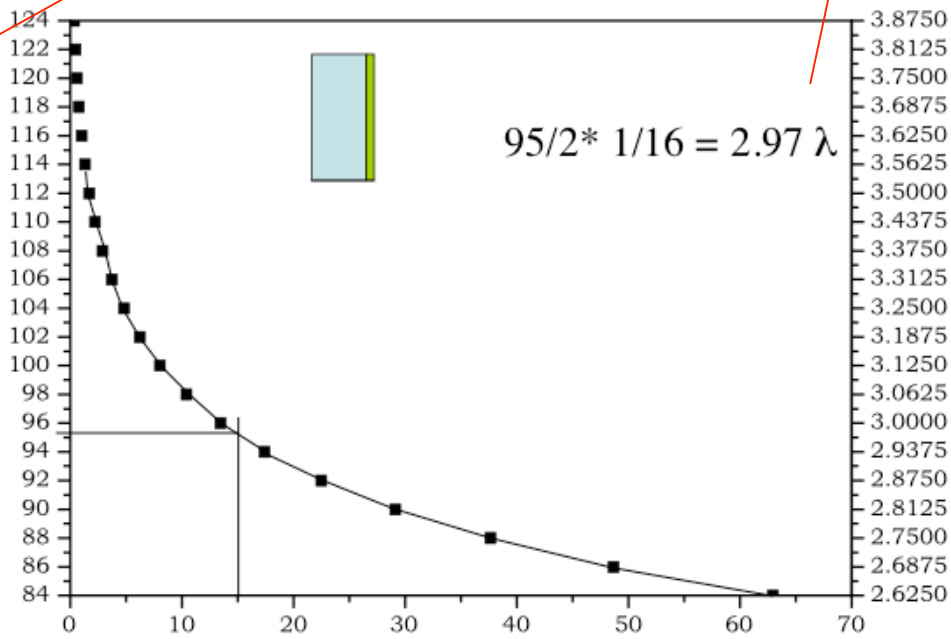
Non-periodic Coating structure properties




36 /2* 1/4 = 4.5 λ

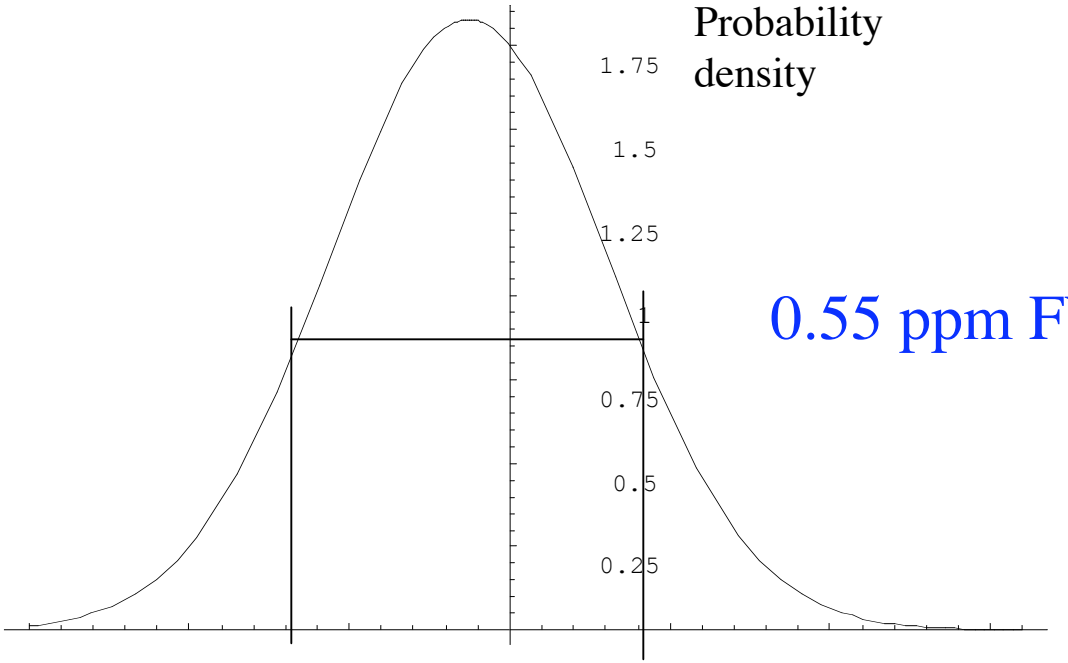

Ta2O5 total thickness [micron]
Coating thickness [micron]
First attempt
Non-periodic


51/2 * 1/8 = 3.2 λ


95/2* 1/16 = 2.97 λ

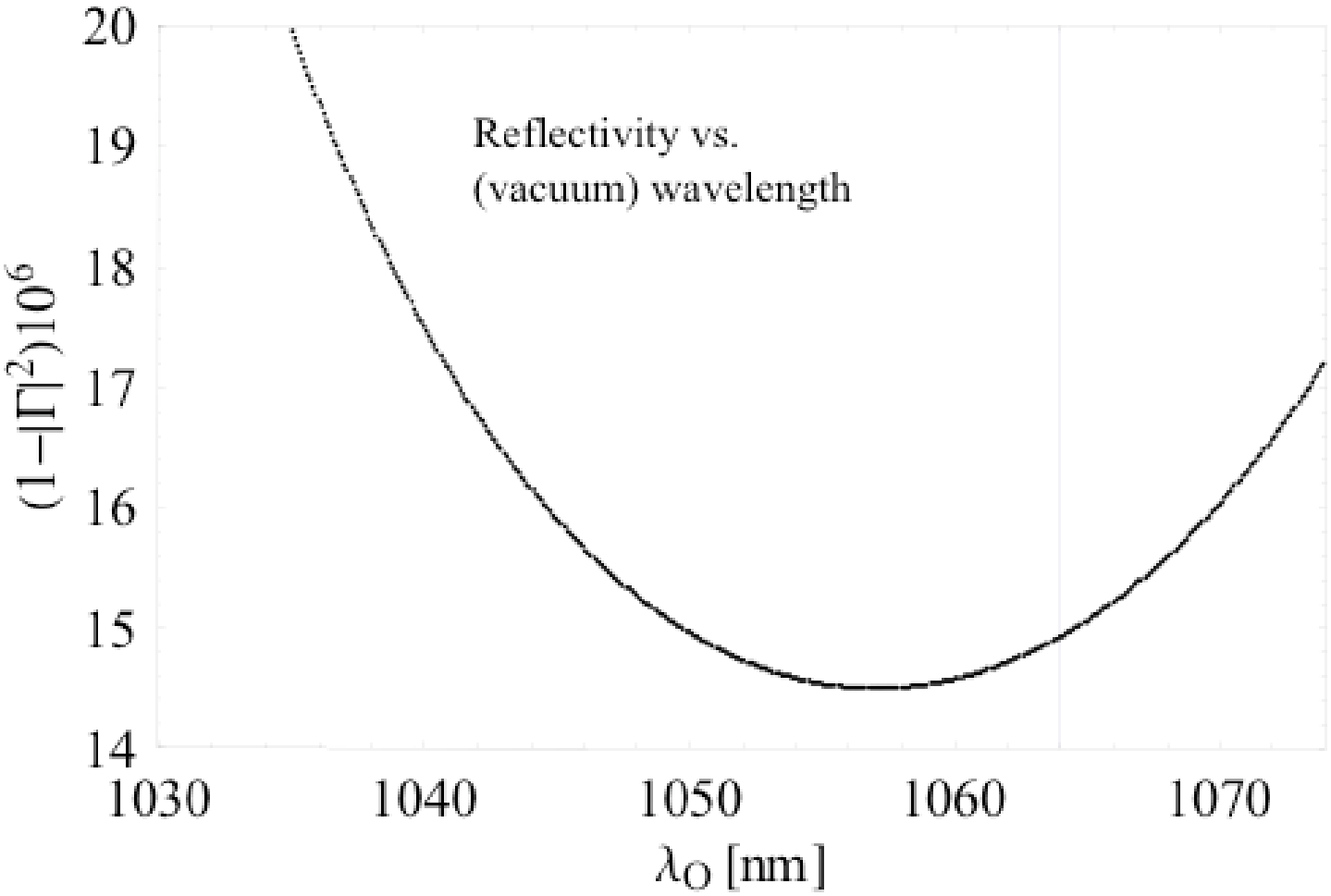
Genetically optimized (44 layer, 15ppm) non-periodic coating: Robustness

- Introducing 1 nm r.m.s. error on coating thickness
- 10,000 trials



0.55 ppm FWHM

Genetically optimized (44 layer, 15ppm) non-periodic coating: Bandwidth



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Conclusions

- Non-periodic coatings can be designed by genetic algorithms;
- Multiple heterogeneous (e.g., transmittance, thickness of constituents, etc.) constraints can be introduced;
- Preliminary results suggest better overall performance than non periodic coatings