19. Conception optimisée des filtres RAPAS

Design of multilayer band-pass filters for processing RAPAS alerts

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Abstract

- The alerts provided by the Gaia satellite are processed and classified by the RAPAS network [1,2]. The network uses **three optical filters reproducing the satellite spectral bands** to compare optical measurements.
- Three multilayer filters are proposed composed of **SiO_2 and TiO_2 on a BK7** substrate that meet the specifications.
- The use of **other substrates and thin metal layers are also investigated**, which allow to reduce the number of layers required to respect the specifications.

1. INTRODUCTION

- **Gaia** : launched in 2013 to map a part of the galaxy [1].
- **RAPAS** : network of amateur astronomers processing GAIA alerts. They use 3 optical filters reproducing the satellite spectral bands [2].

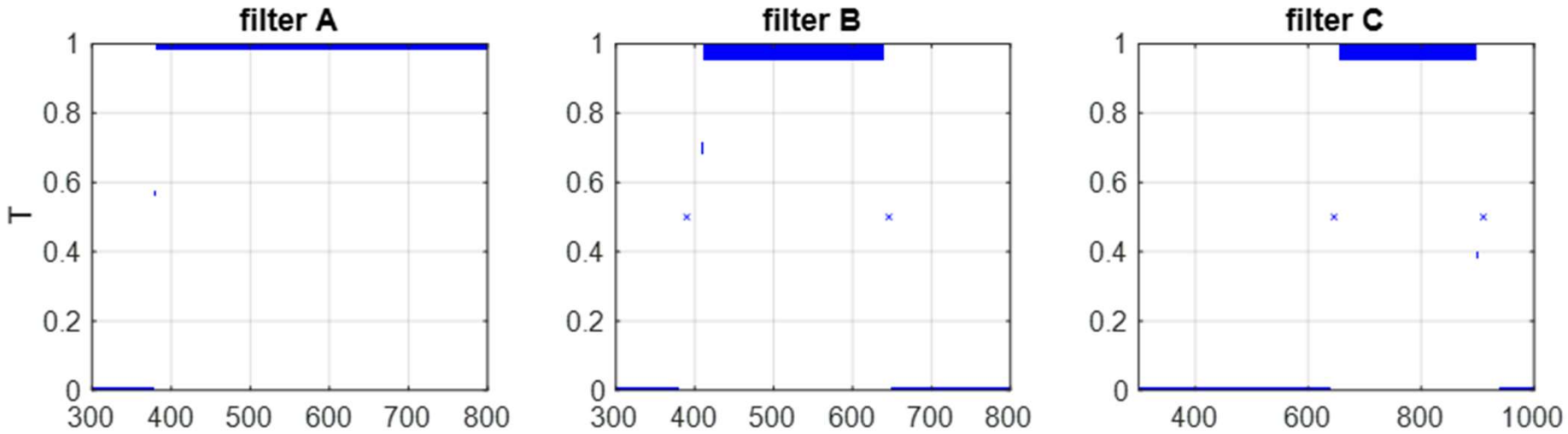

Figure 1: The specifications for the 3 filters. The transmittance curve must pass through the blue zones. The x-axis is the wavelength in nm and the y-axis is the transmittance.

2. METHODOLOGY

Optimization of multilayer filters composed of SiO_2 and TiO_2 on a BK7 substrate.

Merit function :

$$MF(\vec{d}) = \left[\sum_{\lambda} \left(T(\vec{d},\lambda) - \widetilde{T}_{\lambda}\right)^2\right]^{\frac{1}{2}}$$

$\vec{d}$: layers thickness, λ : wavelength, T : computed transmittance, $\widetilde{T}_{\lambda}$: desired transmittance

- Levenberg-Marquardt
- Needle algorithm
- Genetic algorithm

Figure 3 : sketch of the multilayer filter.

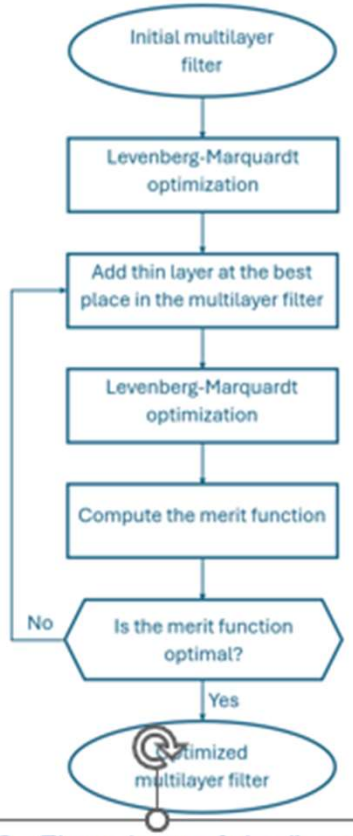

Figure 2 : Flowchart of the "needle" algorithm.

3. RESULTS

- **Filter A**

$$T(\lambda < 380\ nm\ ) < 0.01$$
$$T(\lambda > 380\ nm) > 0.98$$

10 layers on each sides of the substrate

- **Filter B**

$$T(410\ nm < \lambda < 640\ nm) > 0.95$$
$$T(\lambda < 410\ nm, \lambda > 640\ nm) < 0.01$$

20 layers on each sides of the substrate

- **Filter C**

$$T(655\ nm\ < \lambda < 900\ nm\ ) > 0.95$$
$$T(\lambda < 655\ nm, \lambda > 900\ nm) < 0.01$$

20 layers on each sides of the substrate

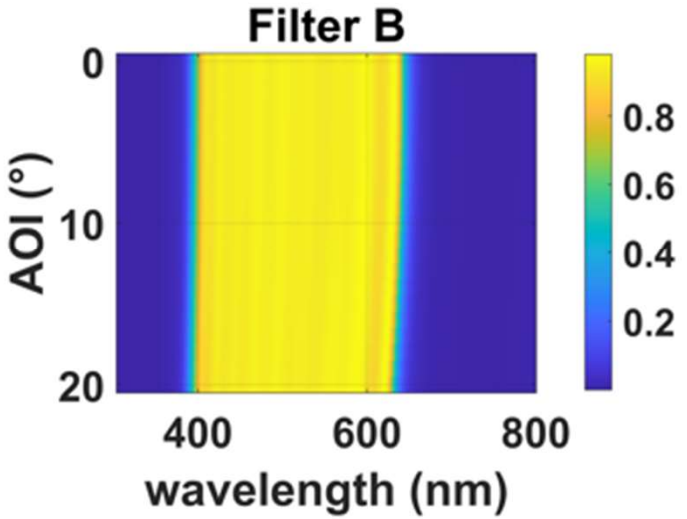

Figure 7 : Transmittance of filter B versus incidence angle in degrees and the wavelength (nm)

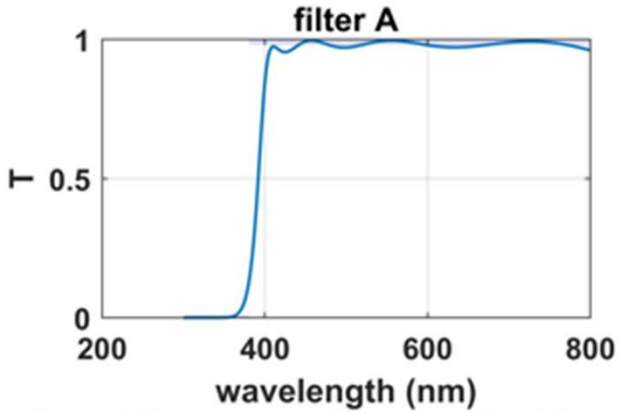

Figure 4 : Transmittance of an optimized multilayer filter for the case A.

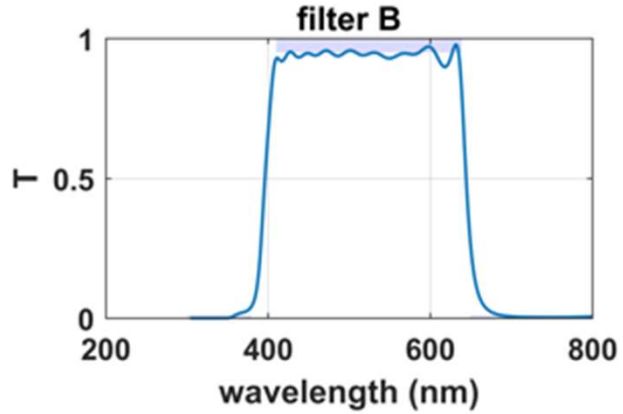

Figure 5 : Transmittance of an optimized multilayer filter for the case B.

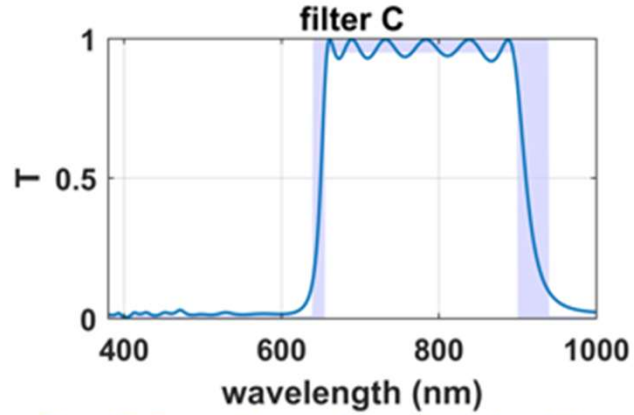

Figure 6 : Transmittance of an optimized multilayer filter for the case C.

4. REDUCING THE NUMBER OF LAYERS ?

Case of filter B:

- **Choice of substrate**

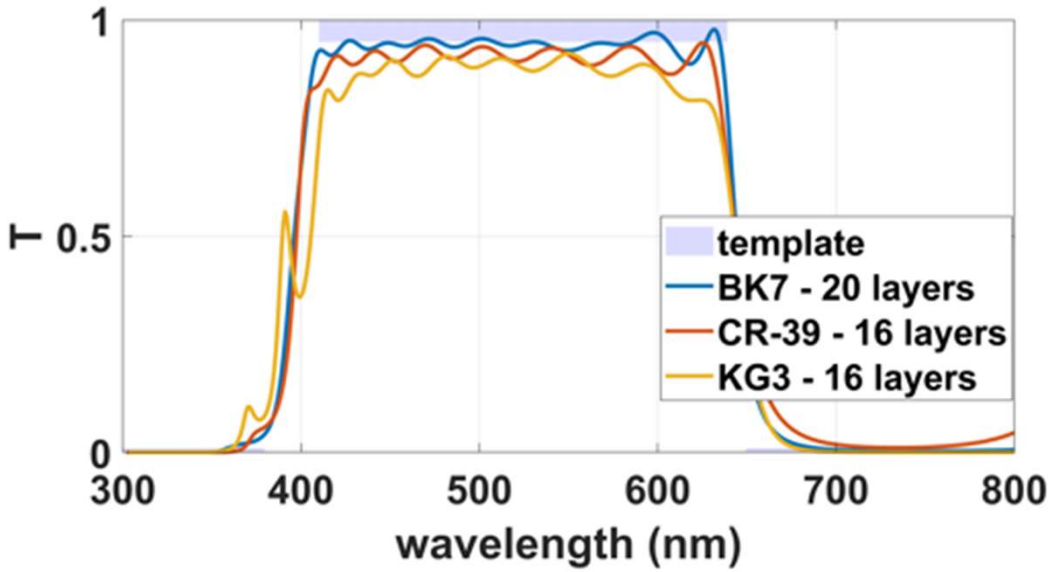

Figure 8 : Comparison between 3 multilayer filters with BK7, CR-39 and KG3 substrates.

- **Using thin metallic layers**

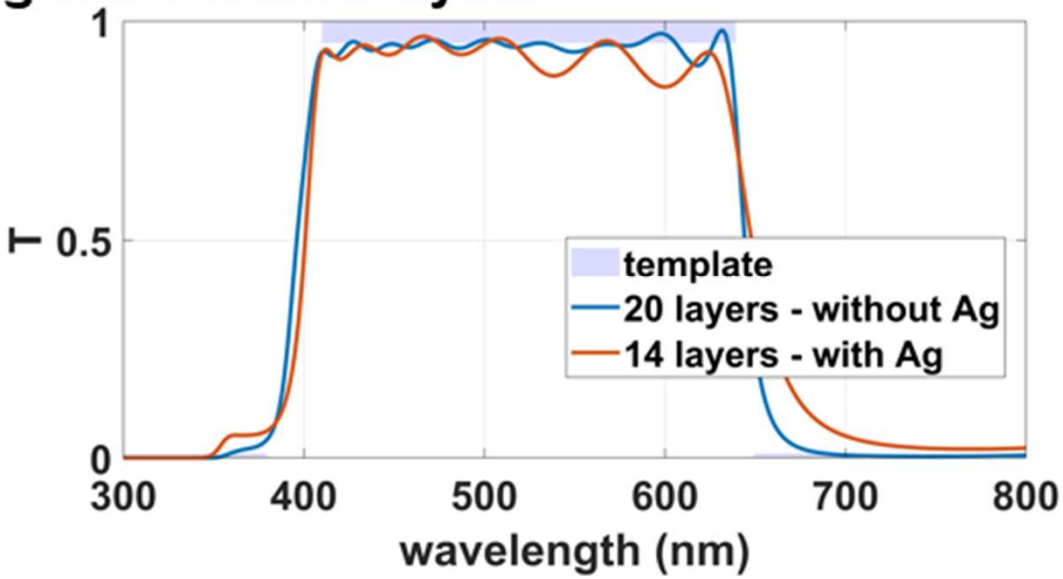

Figure 9 : Comparison between two multilayer filters. The first one is composed only of SiO_2 and TiO_2 on a BK7 substrate. The second one (orange) is composed of SiO_2 ,TiO_2 and Silver (Ag) on a BK7 substrate.

5. CONCLUSION

- We used **Levenberg-Marquardt** gradient algorithm, **"needle" algorithm** and **genetic algorithm** to simulate three multilayer filters taking account the requirements of Gaia satellite spectral bandwidths [3,4]. The algorithms were developed under Matlab platform.
- These filters are made of alternating layers of **SiO_2 and TiO_2 on a 2 mm thick BK7** substrate (Filter A with 10 layers on each sides of the substrate, filter B : 20 layers, filter C : 30 layers).
- The use of **absorbing substrates and thin metallic layers** can reduce the number of layers in the case of Filter B.

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[2] Page title: « Reseau Amateurs Professionnels pour les Alertes Scientifiques (RAPAS) ». Available at: http://rapas.imcce.fr/. Consulted on: 2 mars 2024.
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