

**Design of Layered Optical Filters for Optical Communication Applications in Visible, Infra-red and Terahertz Bands using Different Materials and Meta-Materials** 

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## What is Optical Filter?

- Optical filters are multilayer optical components that transmit, reflect or absorb electromagnetic waves at certain frequencies.
- Layer configuration and used materials of the multilayer structure determines the characteristics of the filter.



Figure 1: Example of Optical Filter

# **Solution Methodologies**

•  $M_l = D_l P_l D_l^{-1}$ 

•  $P_l = \begin{bmatrix} e^{j\phi_l} \\ 0 \end{bmatrix}$ 

#### **Drude Model**

$$n_M = \sqrt{1 - \frac{w_p^2}{w^2 - j\gamma w}}$$

- Drude model is to calculate refractive index of metal layer.
- Transfer Matrix Method is used to find reflected, transmitted and absorbed power ratios of the filter.

## **Transfer Matrix Method**

$$M_{l} = D_{l}P_{l}D_{l}^{-1}$$

$$D_{l} = \begin{bmatrix} 1 & 1 \\ n_{l} & -n_{l} \end{bmatrix}$$

$$P_{l} = \begin{bmatrix} e^{j\phi_{l}} & 0 \\ 0 & e^{-j\phi_{l}} \end{bmatrix}$$

$$M = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix}$$

$$P_{l} = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix}$$

### **Results and Discussion**

### **Project Description**

- In this project, new metal-dielectric multilayer optical filters is designed.
- Designed filter consists a thin metal layer as its entrance layer and has two block of layers that are configured according to Lucky and Thue-Morse series.



## **Design of Filter Blocks**

**Thue-Morse Series:** 

$$T_0 = 0$$
  
 $T_1 = 01$   
 $T_2 = 0110$   
 $T_3 = 01101001$ 

**Thue-Morse numbers** are already in the binary form however lucky numbers are decimal. Thus, chosen Lucky numbers are converted to BCD numbers.



Figure 3: a. Transmission, Absorption, Reflection vs Wavelength (T=1), b. Transmission, Absorption, Reflection Vs Wavelength (T=2), c. Transmission, Absorption, Reflection Vs Wavelength (T=3), d. Transmission, Absorption, Reflection Vs Wavelength (T=4)

In this project, new metal-dielectric hybrid optical filter is designed according to Lucky numbers and Thue-Morse series and with current materials.

\*Results showed that when Thue-Morse block is repeated, multi reflection and absorption bands occur between 650-750 nm. Also, absorption between 760-800 nm becomes more stable. When T=I, transmission behavior of the filter is quite low however, between 760-800 nm wavelengths absorption characteristic is well.

### $T_4 = 0110100110010110$

#### **Lucky Numbers:**

	23	8 4	5 6	67	89	10 11	12 13	14 15	16 17	18 19	20 21	22 23	24 25	26
Ι	3	3	5	7	9	11	13	15	17	19	21	23	25	
Ι	3			7	9		13	15		19	21		25	
Ι	3	3		7	9		13	15			21		25	

## **Filter Parameters**

0110100110010110					
0010 0001 0010 0101					
$n_{\rm L}$ =1.45 $n_{\rm H}$ =4.234 $n_{\rm S}$ =1.52					
$\lambda_0 = 700 \text{ nm}$					
5 nm					
$d_{\rm H,L} = \lambda_0 / (4n_{\rm H,L})$					

## **Published Conference Papers**

- B. Göral, U. Alan, M. F. Ay, Ç. S. Gürel, "Fibonacci-Thue Morse Çok Katmanlı Fotonik Kristal Optik Filtre Yapısının Yansıma Özelliklerinin İncelenmesi", in X. URSI-Türkiye 2021 Bilimsel Kongresi, Kocaeli, Turkey (2021).
- □ M. F. Ay, U. Alan, B. Göral, Ç. S. Gürel, "Analysis of Reflection from Triple Thue-Morse Photonic Crystal Structure", İlk Bildiriler Konferansı 2021, Ankara, Turkey (2021).
- B. Göral, U. Alan, Ç. S. Gürel, "Metal-Dielectric Hybrid Optical Filter Design Using Thue-Morse And Lucky Series," in Engineers of Future International Student Symposium., Zonguldak, Turkey (2021).

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#### General filter structure (T represents the repeat number of Thue-



#### Air/Cr/(HLLHLHHLLHHLHLH)<sup>T</sup>/(HHLHHHHHHHHHHHHHH)/Glass

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