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Maximum Stabilization System Operation Control With Second Order Short Pass Optical Filters and Filter Transient Time Response Analysis

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***Abstract*— This paper has presented the RLC second order short pass optical filters for more stable system operation control based on its corner wavelength and filter circuit components for different optical transmission spectrum regions. Signal transmission filtering quality, filter signal bit error rate, filter gain, time response, settling time, peak time, delay time, output signal voltage and damping ratio are the major interesting design parameters for different categories of signal filtering under the same operation considerations.**

***Index Terms*— Signal filtering, Time response, Settling time, Rise time, Unit step input, and Peak Time.**

I. Introduction

Light is known to have both particle-like and wave-like characteristics. Optical thin film theory is based principally upon the wavelike characteristics of light. Key among these are reflection, refraction, and interference. All boundaries between media in which lightwaves travel create a division of reflected and transmitted portions of the energy [1]. Those lightwaves not reflected are transmitted across the boundary to a medium with different electric and magnetic properties. These differences cause a refraction, or a change in the speed and angle of the lightwaves. A material's refractive index is derived by comparing the velocity of a lightwave in that medium to the velocity in a vacuum. The amount of light reflected is related to the difference between the refractive indices of the media on either side of the boundary; greater differences create greater reflectivity. If there is an increase in refractive index across the boundary, the reflected lightwave undergoes a phase change of 180º; if there is a decrease, no phase change occurs. An optical thin-film coating is a stack of such boundaries, each producing reflected and transmitted components that are subsequently reflected and transmitted at other boundaries. If each of these boundaries is located at a precise distance from the other boundaries, the reflected and transmitted components are enhanced by interference [2].

The importance of optical applications in the middle ultraviolet (UV) spectral region between about 200 and 320 nm continues to increase with the advent of new excitation light sources in this range, also identified as the ultra violet (200 to 400 nm), visible (400 nm to 700 nm), and near infrared region (NIR) (700 nm- 1600 nm) bands. Examples of new sources include more efficient mid UV lasers, and more conventional broadband sources such as high pressure mercury and xenon arc lamps with improved efficiency and longer lifetimes [3]. A major impediment that continues to make the mid-UV an optically challenging spectral region is the lack of durable optical filters with adequate performance. However, optical filters constructed from thin-film coating materials that have relatively low absorption and spectral dispersion yet high reliability at these short wavelengths would have significant advantages over components such as the diffraction gratings used in monochromators and spectrophotometers. In general, grating-based systems are not as selective and do not achieve as much throughput as filter based systems, and only filters allow direct imaging [4]. Until recently, optical filters for the mid UV have exhibited poor performance in terms of transmission, spectral selectivity and durability. Optical filters made with soft-coated thin-film materials and/or multiple laminated absorbing and transparent glass substrates cannot withstand the intense energies of illumination at mid-UV wavelengths [5].

The paper is organized in the following sections. Section II has explained the mathematical model equations of RLC short pass filter circuit analysis in more details and its transient time response. Section III has presented the simulation results and performance analysis of RLC short pass optical filter and its transient time response parameters. Finally, section IV has presented the summary of transient time response and filter transmission characteristics for different optical transmission spectrum regions operation.

II. Filter Modeling Analysis

II. 1. RLC short pass filter

RLC short pass Filters can be designed by using inductor, L, capacitor, C, and resistor, R, as shown in Fig. 1. RLC short pass filters output is taken from capacitor side.

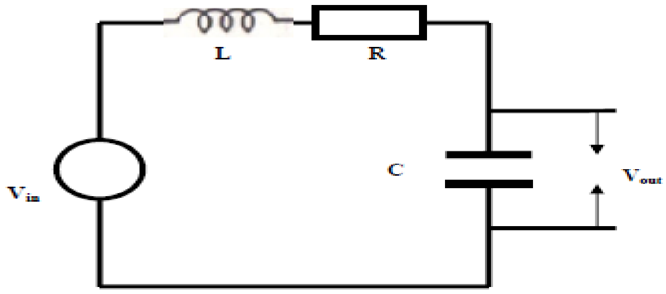

Fig. 1. An RLC short pass filter.

The RLC short pass filter gain can be expressed as the following formula [5]:

$$|G| = \frac{f_c^2}{\sqrt{(f_c^2 - f^2)^{2n} + \frac{f^2 f_c^2}{Q_{(f_c)}^2}}} \quad (1)$$

Where n is the filter order and is taken as unity, and the short pass filter circuit signal quality Q as a function of the corner frequency is given by:

$$Q_{(f_c)} = \frac{2\pi f_c L}{R} \quad (2)$$

In the same way, the filter signal quality can be rewritten as a function of operating signal wavelength λ and cut off wavelength or corner wavelength, λ_c as the following expression [6]:

$$Q_{dB} = 10 \log \left(\frac{2\pi c L}{\lambda_c R} \right) \quad (3)$$

Where L is the filter circuit inductance and R is the filter circuit resistance. Therefore the filter circuit bit error rate (BER) can be defined as the following expression [7]:

$$BER \approx \left(\frac{2}{\pi . Q} \right) . \exp\left(\frac{-Q}{8} \right) , \quad (4)$$

Equation 1 can be rewritten as a function of as a function of operating signal wavelength λ and corner wavelength λ_c as the following expression [8]:

$$|G| = \frac{1}{\lambda_c^2 \sqrt{\left(\frac{1}{\lambda_c^2} - \frac{1}{\lambda^2} \right)^{2n} + \frac{1}{\lambda_c^2 \lambda^2 Q^2}}} \quad (5)$$

Therefore the RLC short pass filter circuit gain can be expressed in dB units as the following formula:

$$|G|_{dB} = 20 \log_{10} |G| \quad (6)$$

II. 2. TRANSIENT TIME RESPONSE OF RLC SHORT PASS FILTER

The RLC short pass filter transfer function (Gain) can be expressed as the following formula [9, 10]:

$$\frac{v_{out}}{v_{in}} = \frac{\frac{1}{LC}}{S^2 + S\left(\frac{R}{L} \right) + \frac{1}{LC}} \quad (7)$$

If the input is unit step function, then the output in time domain as a function of time constant, t, can be:

$$v_{out} = \frac{e^{-\frac{\xi}{\sqrt{LC}} t}}{\sqrt{1-\xi^2}} Sin\left(\left(\frac{c}{\lambda_d} \right) t + \phi \right) V_{in} \quad (8)$$

Where $\lambda_d=\lambda_c/(1-\xi^2)^{1/2}$ is the damping wavelength, t=RC is the time constant, ϕ is the phase shift, t is the time constant and ξ is the damping ratio which can be given by the following formula based on the second order short pass RLC filter circuit:

$$\xi = \frac{\lambda_c R}{2 c L} \quad (9)$$

Where c is the speed of light (3×10^8 m/sec). Moreover the phase shift of filter circuit, ϕ can be expressed as [9]:

$$\phi = Tan^{-1} \left(\frac{\sqrt{1-\xi^2}}{\xi} \right) \quad (10)$$

As well as the rise time T_r, and settling time T_s, of the filter circuit can be given by [11, 12]:

$$T_r = \frac{\lambda_d}{c} Tan^{-1} \left(\frac{1-\xi^2}{\xi} \right) \quad (11)$$

$$T_s = \frac{4 \lambda_c}{\xi c} \quad (12)$$

In the same way, the delay and peak times, T_d, and T_p are described by the following expressions [13, 14]:

$$T_d = \frac{(1+0.7 \xi) \lambda_c}{c} \quad (13)$$

$$T_p = \frac{\pi \lambda_c}{c \sqrt{1-\xi^2}} \quad (14)$$

III. PERFORMANCE ANALYSIS AND DISCUSSIONS

Optical short pass filters have been deeply investigated in the ultraviolet, visible near infrared (NIR) spectrum regions to enhance it performance operation characteristics such as frequency response, filter gain, signal quality, and signal filter bit error rate over wide range of the affecting operating parameters as shown in Table 1.

Table 1. Proposed operating parameters for short pass optical filter circuit [1, 5, 12, 15].

Operating parameter	Symbol	Value
Ultraviolet signal wavelength	λ_{UV}	200 nm-400 nm
Visible signal wavelength	λ_V	400 nm-700 nm
Near infrared signal wavelength	λ_{NIR}	700 nm-1600 nm
Resistance	R	10 KΩ- 100 KΩ
Inductance	L	0.1 µH- 1 µH
Capacitance	C	1 nF-20 nF
Corner wavelength in Ultra violet band region	λ_{CUV}	220 nm-300 nm
Corner wavelength in Visible band region	λ_{CV}	440 nm-600 nm
Corner wavelength in near infrared region	λ_{CNIR}	950 nm-1350 nm
Filter order	n	1
Input signal voltage	V_{in}	1 Volt

Based on the modeling equations analysis, and the series of the Figs. (2-31), the following features are assured:

i) Figs. (2-4) have assured that filter signal quality increases and filter signal bit error rate decreases with increasing filter circuit inductance and decreasing filter circuit resistance for different corner wavelengths in optical transmission spectrum regions. Filter signal quality has higher values and filter signal bit error rate has lower values in the operation at ultraviolet corner wavelength in comparison with visible and near infrared corner wavelengths.

ii) As shown in Figs. (5-7) have indicated that filter signal gain increases with increasing operating optical signal wavelength until filter reaches its maximum value at corner wavelength for different optical transmission regions. Filter signal gain has presented higher values in corner ultraviolet wavelength in comparison with visible and near infrared corner wavelengths.

iii) Figs. (8-10) have demonstrated that filter circuit damping ratio increases with increasing both filter circuit resistance and its corner wavelength for different optical transmission regions under study considerations. Filter circuit damping ratio has presented lower values in corner ultraviolet wavelength in comparison with visible and near infrared corner wavelengths.

iv) As shown in Figs. (11-13) have indicated that filter phase shift decreases with increasing both filter circuit resistance and its corner wavelength for different optical transmission regions under study considerations. Filter phase shift has presented higher values in corner ultraviolet wavelength in comparison with visible and near infrared corner wavelengths.

v) Figs. (14-19) have assured that filter rise and settling times decrease with increasing both filter circuit resistance and its corner wavelength for different optical transmission regions under study considerations. Filter rise and settling times have presented higher values in corner ultraviolet wavelength in comparison with visible and near infrared corner wavelengths.

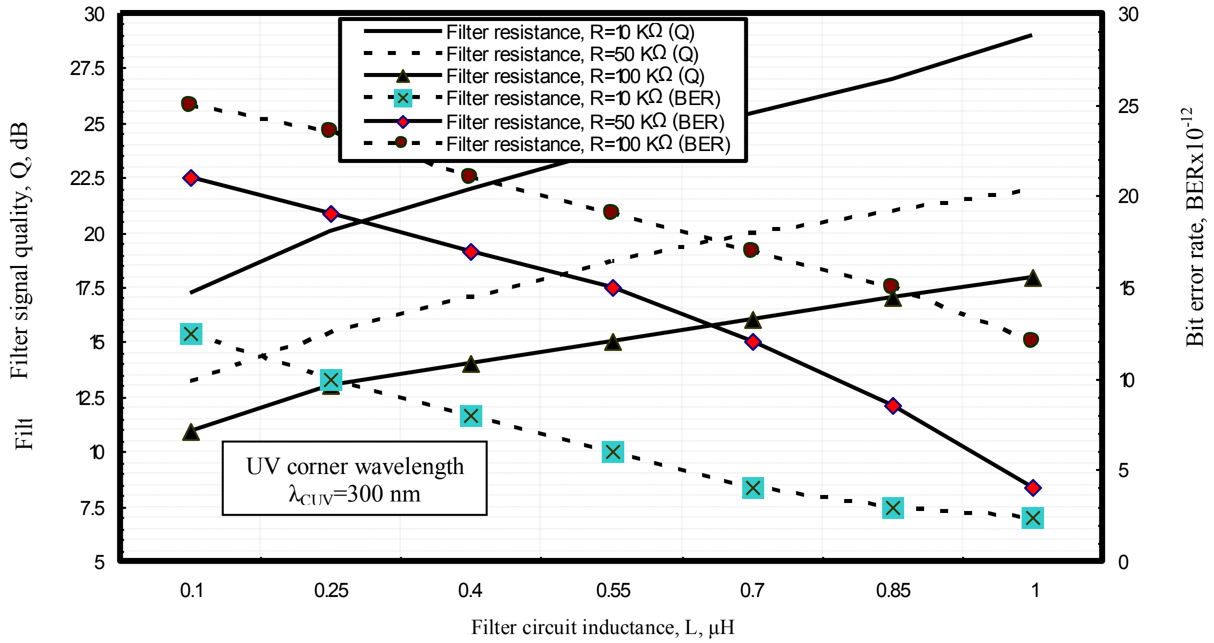

Fig. 2. Signal quality factor and bit error rate in relation to filter circuit inductance and resistance with ultraviolet corner wavelength (λ_{CUV}=300 nm) at the assumed set of the operating parameters.

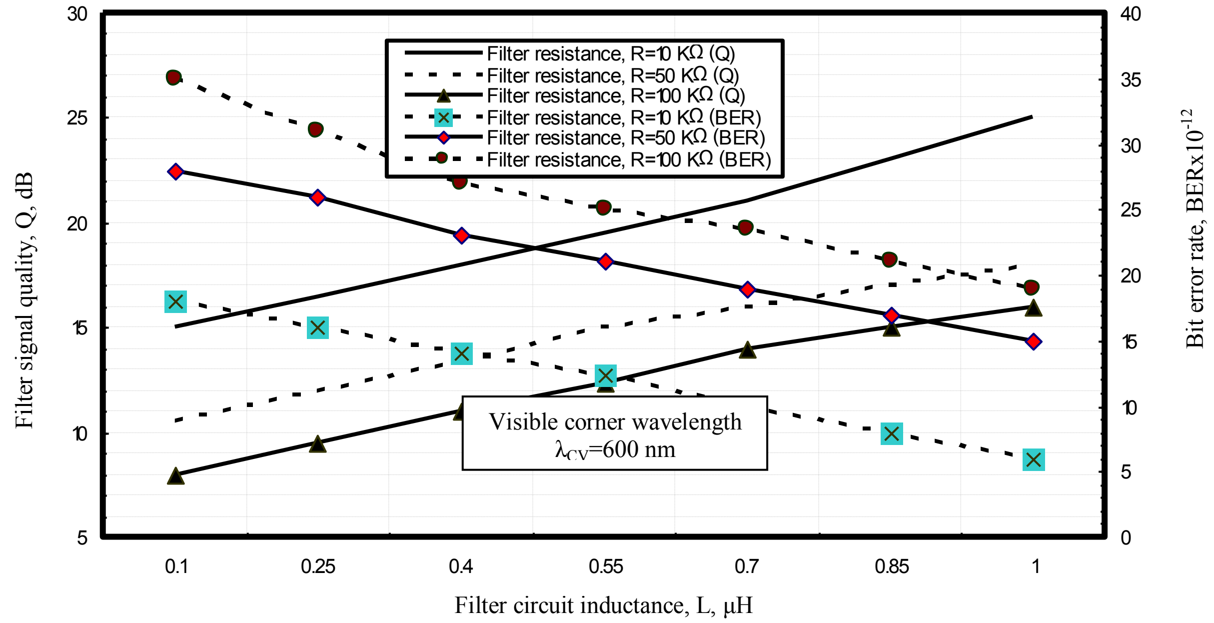

Fig. 3. Signal quality factor and bit error rate in relation to filter circuit inductance and resistance with visible corner wavelength (λ_{CV}=600 nm) at the assumed set of the operating parameters.

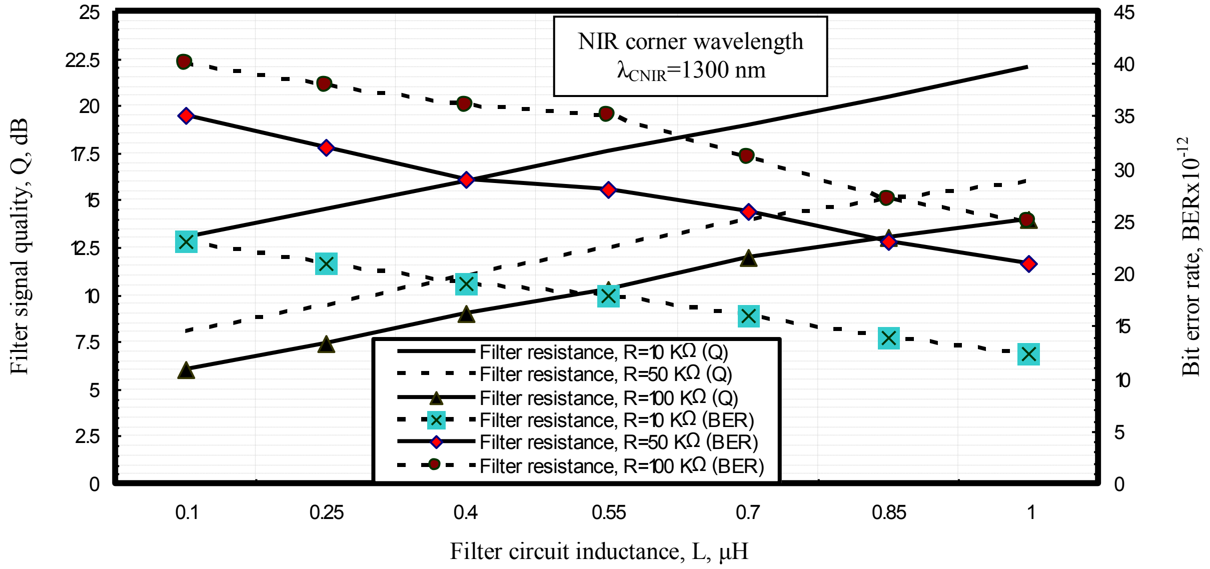

Fig. 4. Signal quality factor and bit error rate in relation to filter circuit inductance and resistance with near infrared corner wavelength (λ_{CNIR}=1300 nm) at the assumed set of the operating parameters.

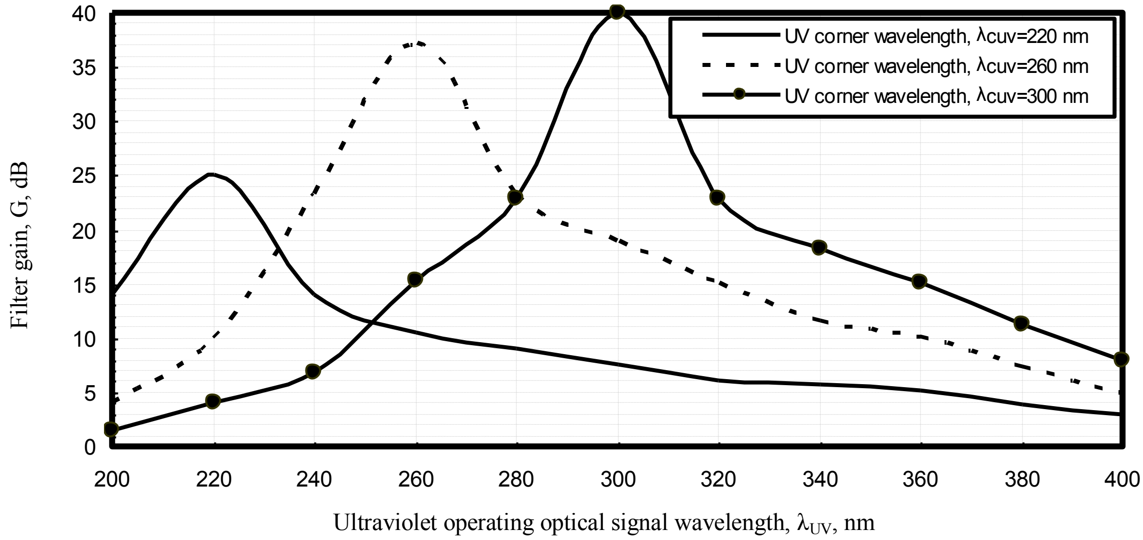

Fig. 5. Variations of filter gain versus variations of ultraviolet operating optical signal wavelength and ultraviolet corner wavelength at the assumed set of the operating parameters.

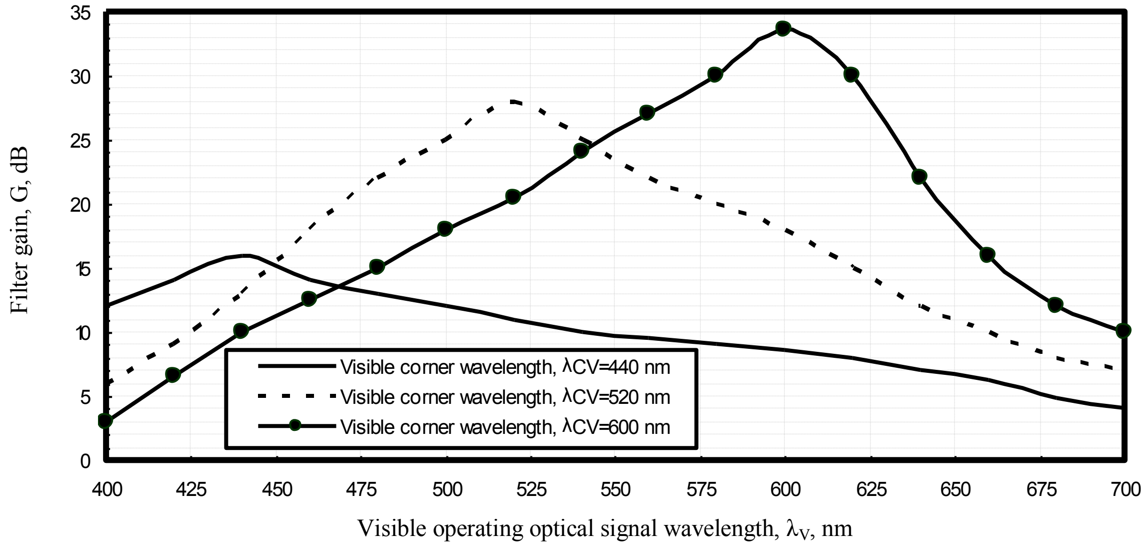

Fig. 6. Variations of filter gain versus variations of visible operating optical signal wavelength and visible corner wavelength at the assumed set of the operating parameters.

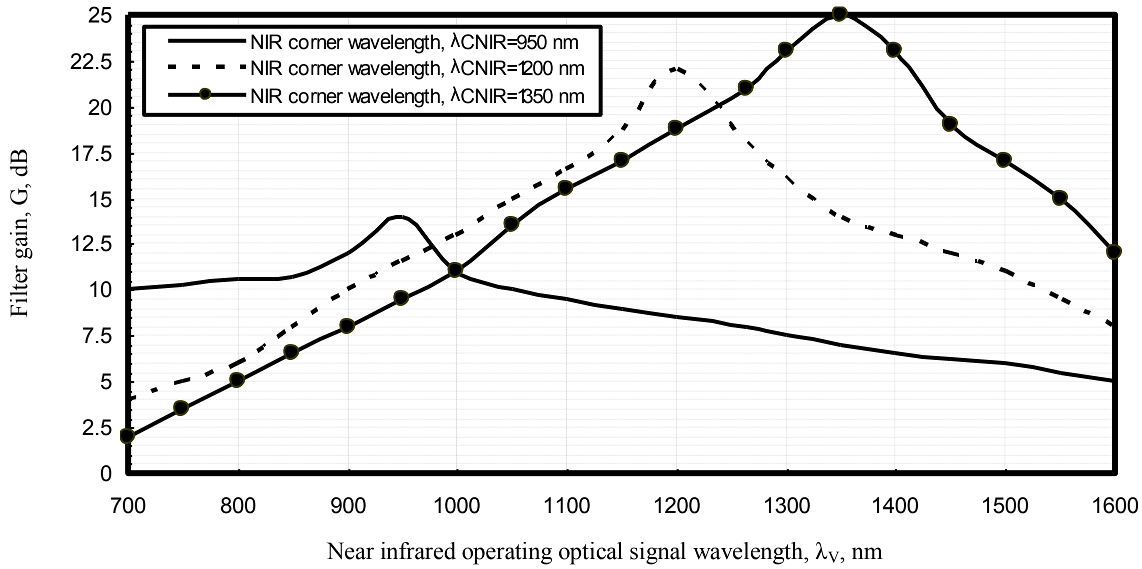

Fig. 7. Variations of filter gain versus variations of near infrared operating optical signal wavelength and near infrared corner wavelength at the assumed set of the operating parameters.

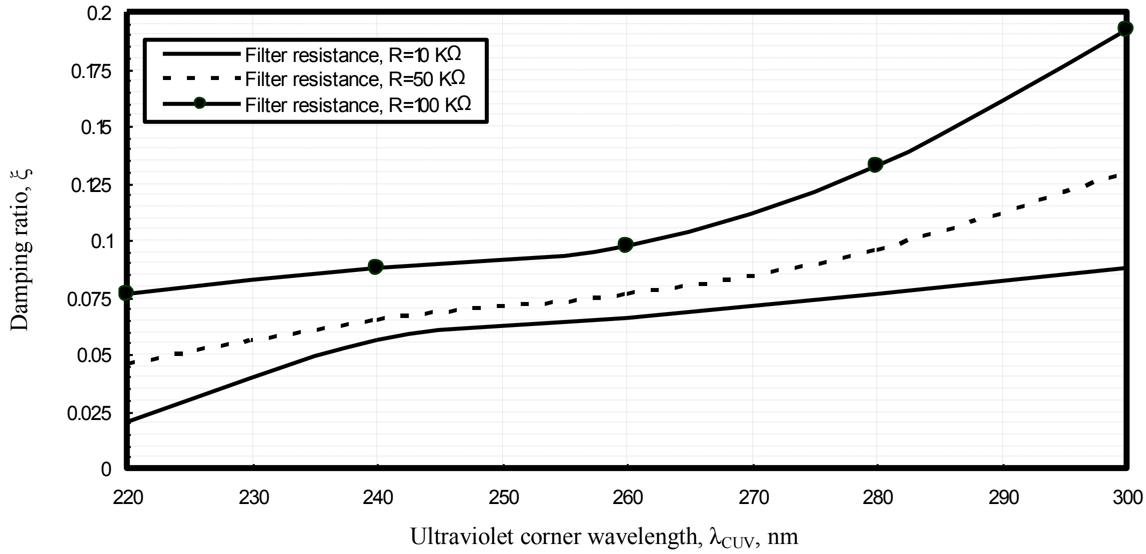

Fig. 8. Filter damping ratio in relation to ultraviolet corner wavelength and filter resistance at the assumed set of the operating parameters.

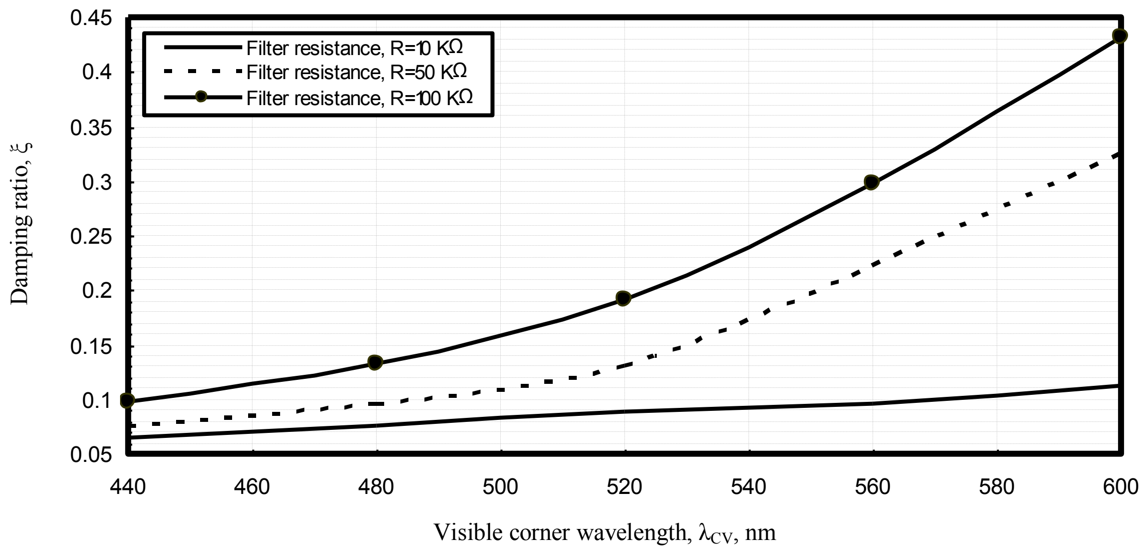

Fig. 9. Filter damping ratio in relation to visible corner wavelength and filter resistance at the assumed set of the operating parameters.

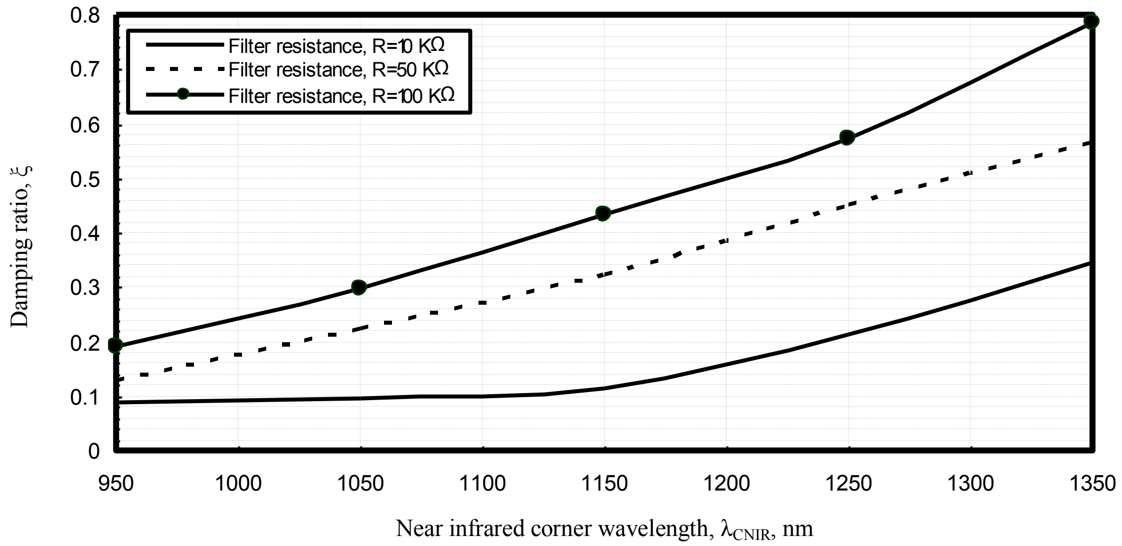

Fig. 10. Filter damping ratio in relation to near infrared corner wavelength and filter resistance at the assumed set of the operating parameters.

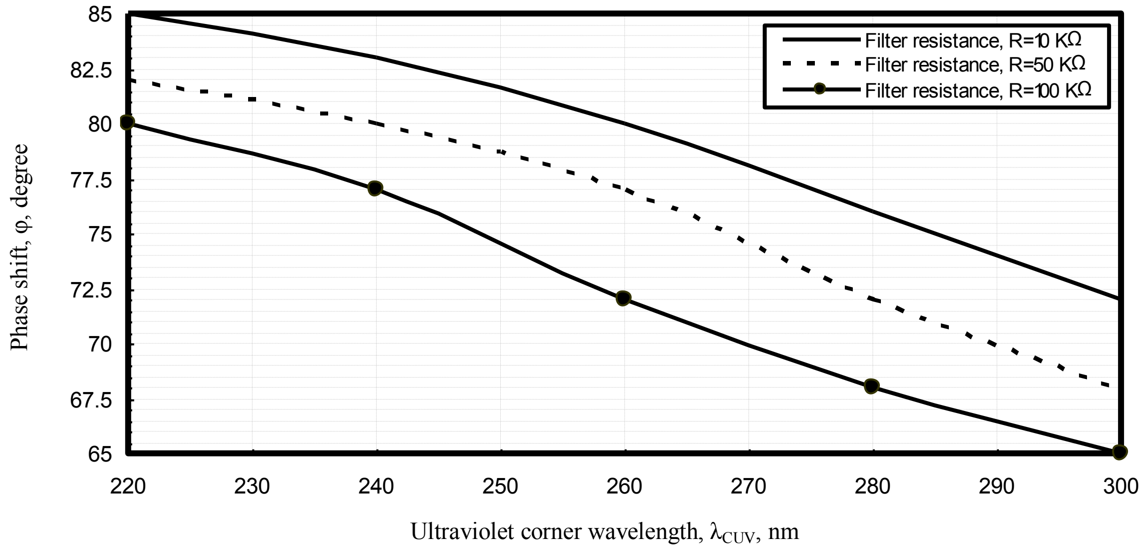

Fig. 11. Filter phase shift in relation to ultraviolet corner wavelength and filter resistance at the assumed set of the operating parameters.

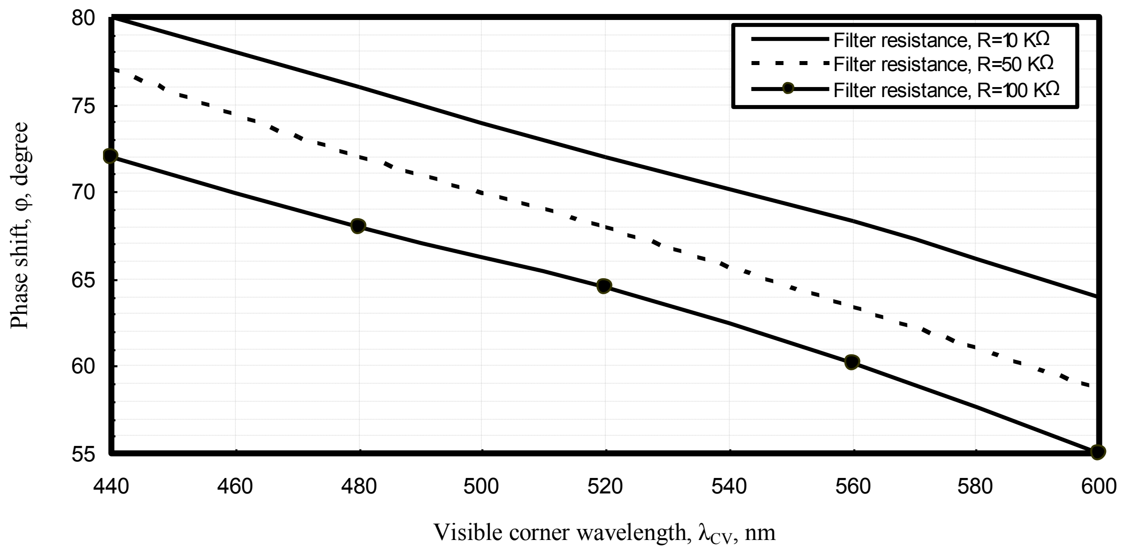

Fig. 12. Filter phase shift in relation to visible corner wavelength and filter resistance at the assumed set of the operating parameters.

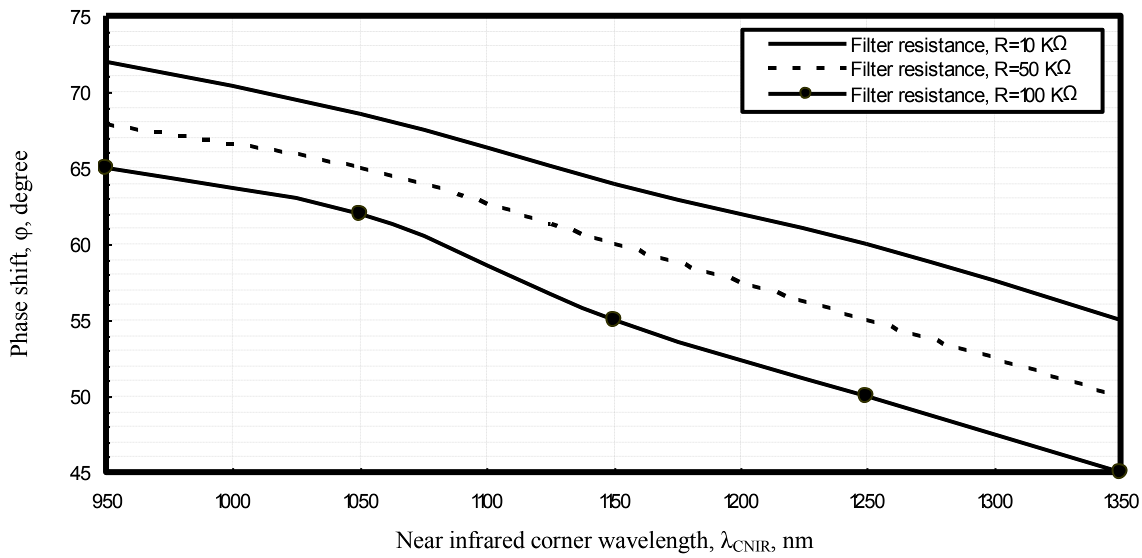

Fig. 13. Filter phase shift in relation to near infrared corner wavelength and filter resistance at the assumed set of the operating parameters.

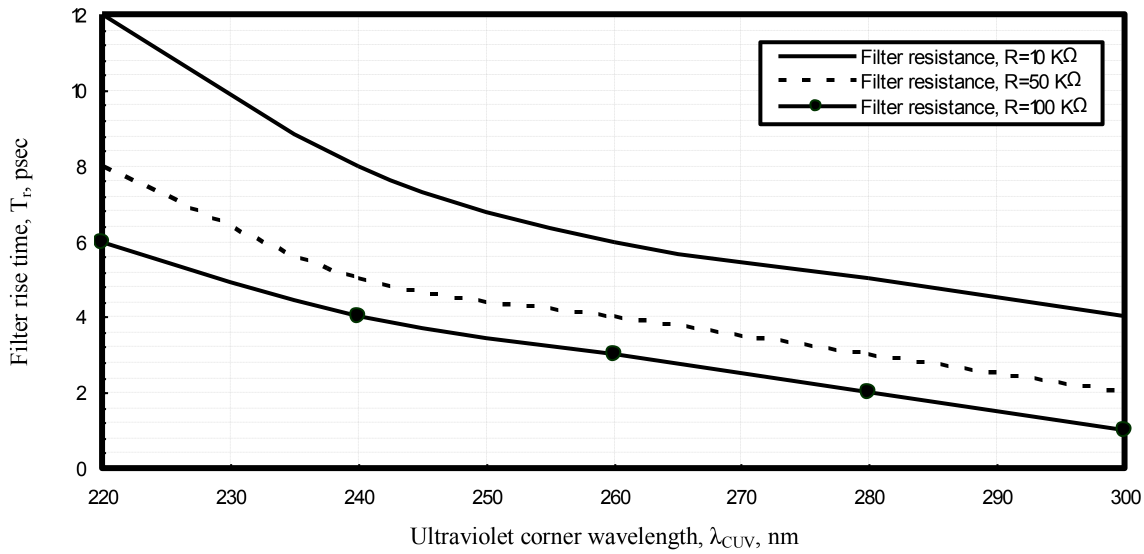

Fig. 14. Filter rise time in relation to ultraviolet corner wavelength and filter resistance at the assumed set of the operating parameters.

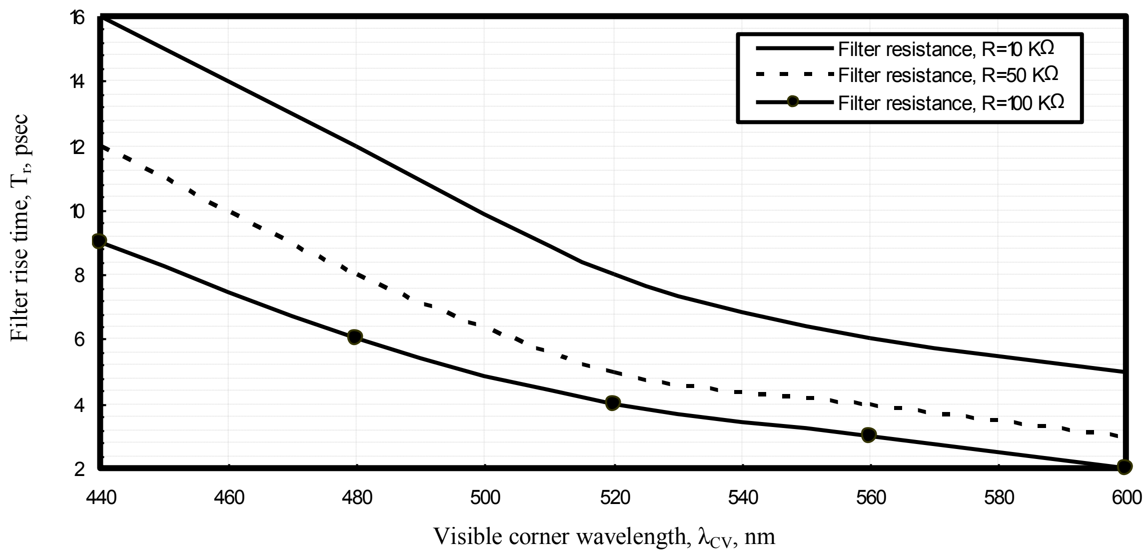

Fig. 15. Filter rise time in relation to visible corner wavelength and filter resistance at the assumed set of the operating parameters.

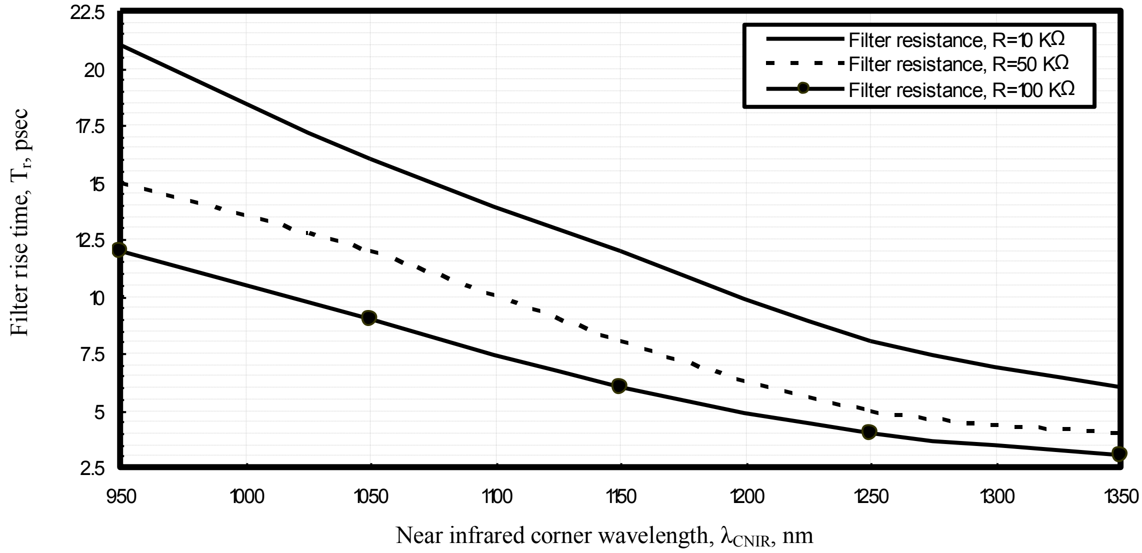

Fig. 16. Filter rise time in relation to near infrared corner wavelength and filter resistance at the assumed set of the operating parameters.

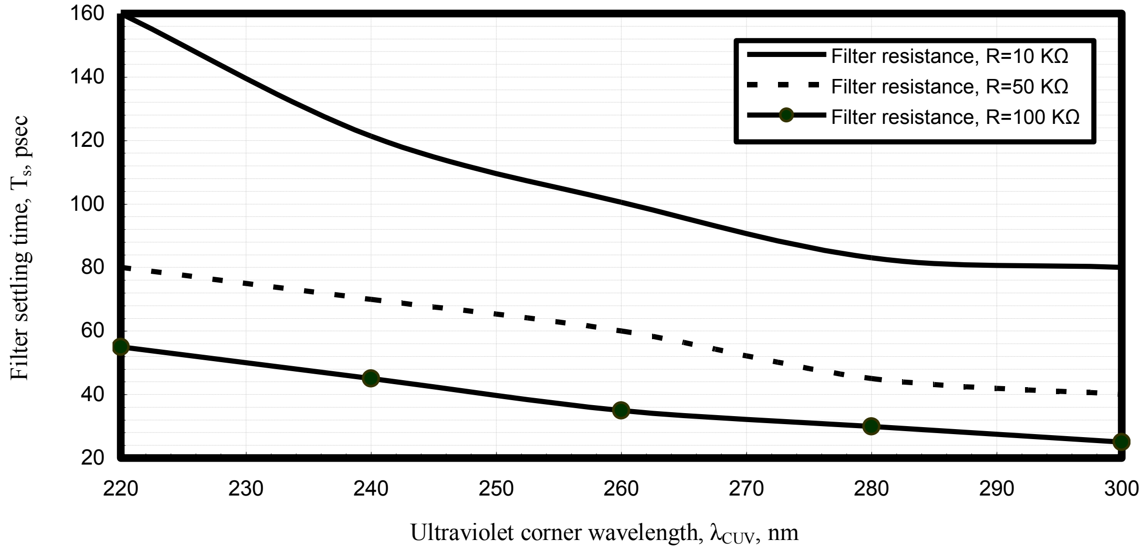

Fig. 17. Filter settling time in relation to ultraviolet corner wavelength and filter resistance at the assumed set of the operating parameters.

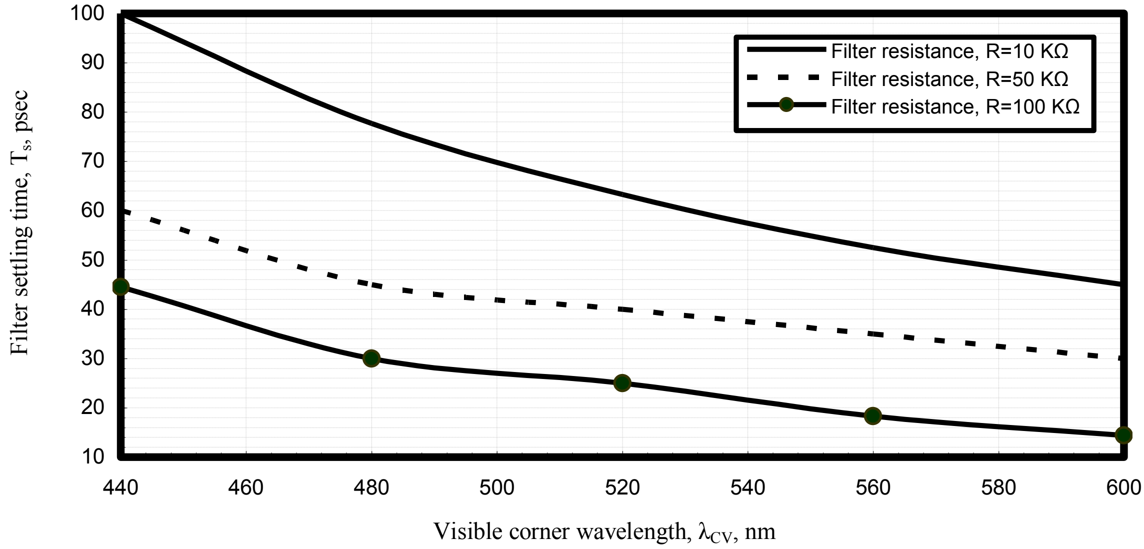

Fig. 18. Filter settling time in relation to visible corner wavelength and filter resistance at the assumed set of the operating parameters.

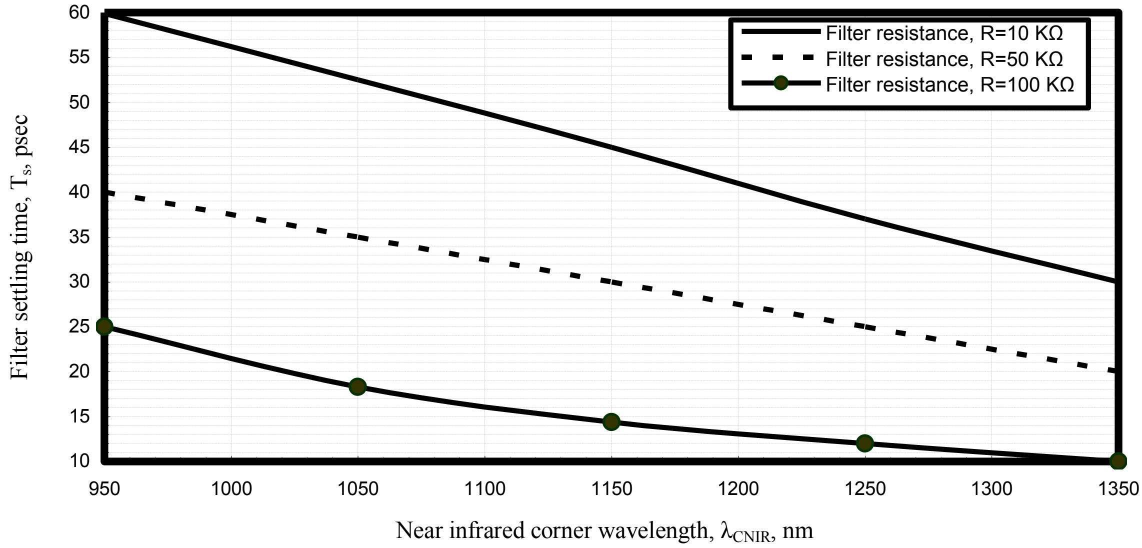

Fig. 19. Filter settling time in relation to near infrared corner wavelength and filter resistance at the assumed set of the operating parameters.

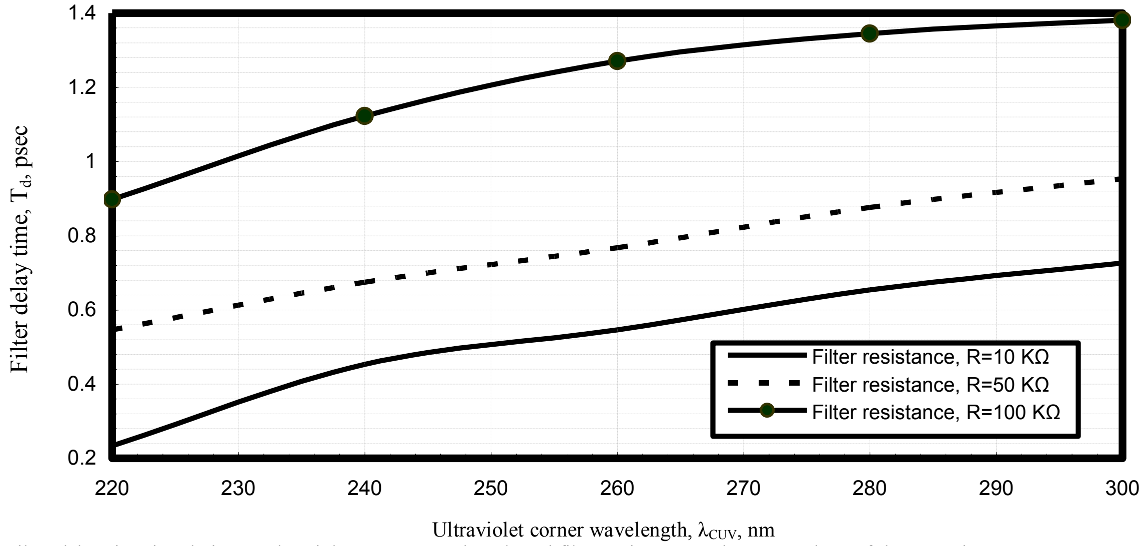

Fig. 20. Filter delay time in relation to ultraviolet corner wavelength and filter resistance at the assumed set of the operating parameters.

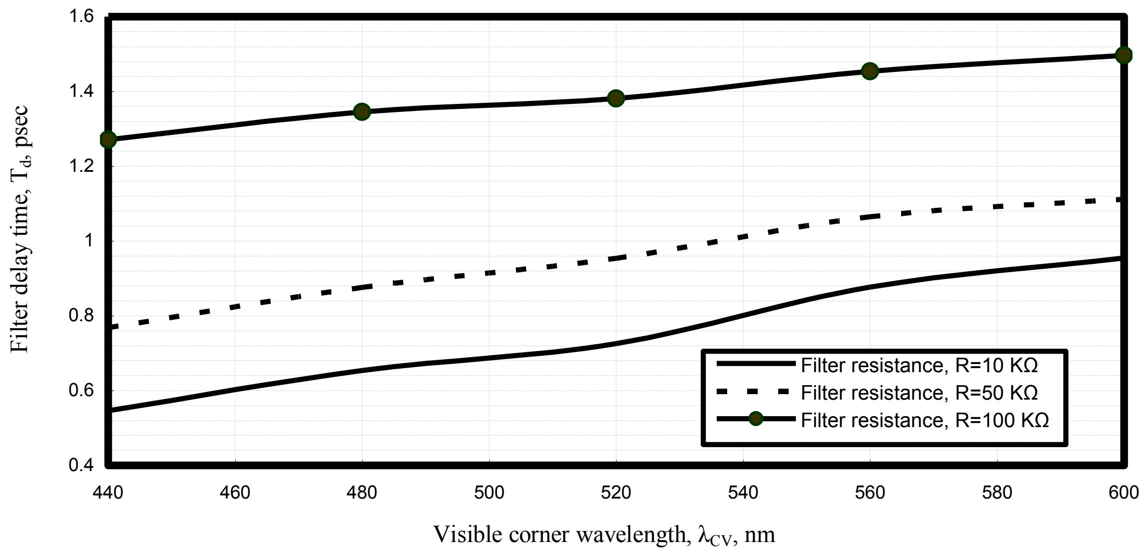

Fig. 21. Filter delay time in relation to visible corner wavelength and filter resistance at the assumed set of the operating parameters.

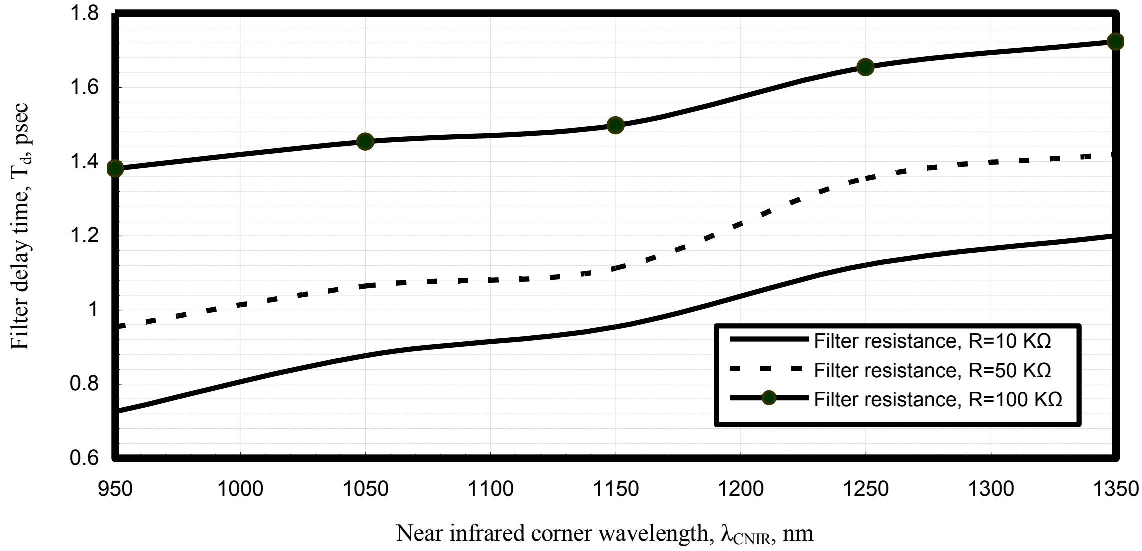

Fig. 22. Filter delay time in relation to near infrared corner wavelength and filter resistance at the assumed set of the operating parameters.

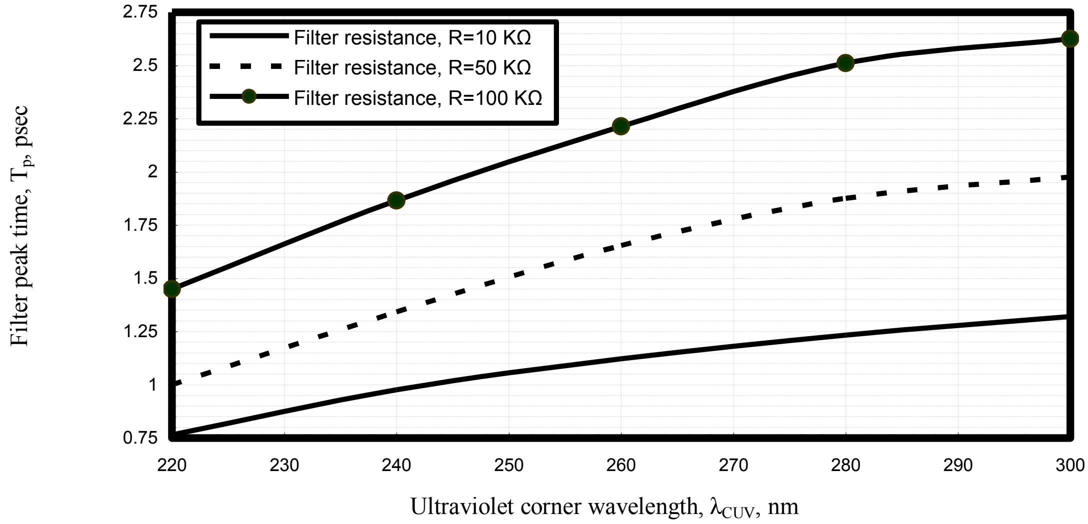

Fig. 23. Filter peak time in relation to ultraviolet corner wavelength and filter resistance at the assumed set of the operating parameters.

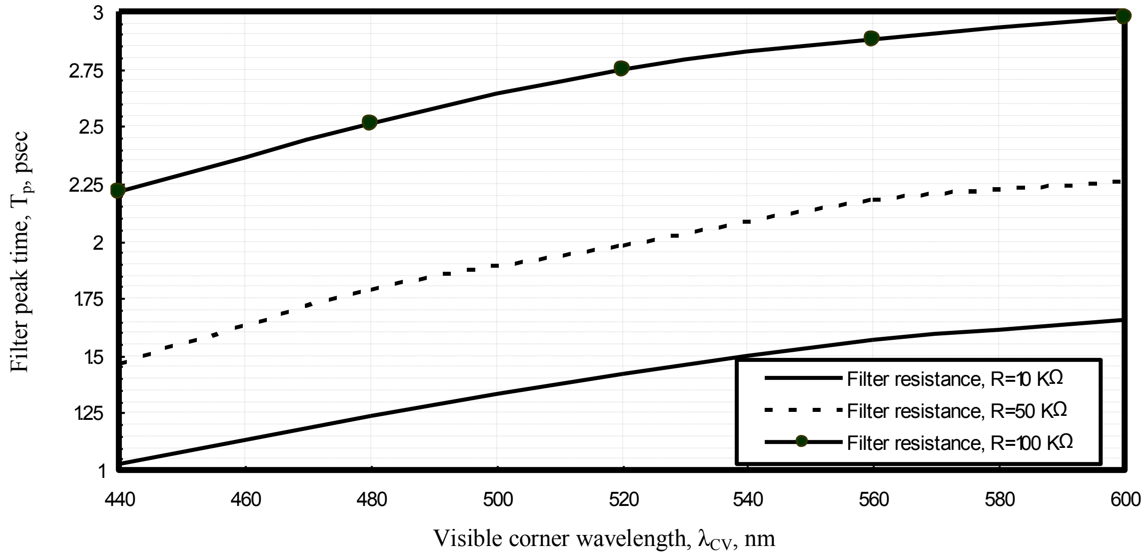

Fig. 24. Filter peak time in relation to visible corner wavelength and filter resistance at the assumed set of the operating parameters.

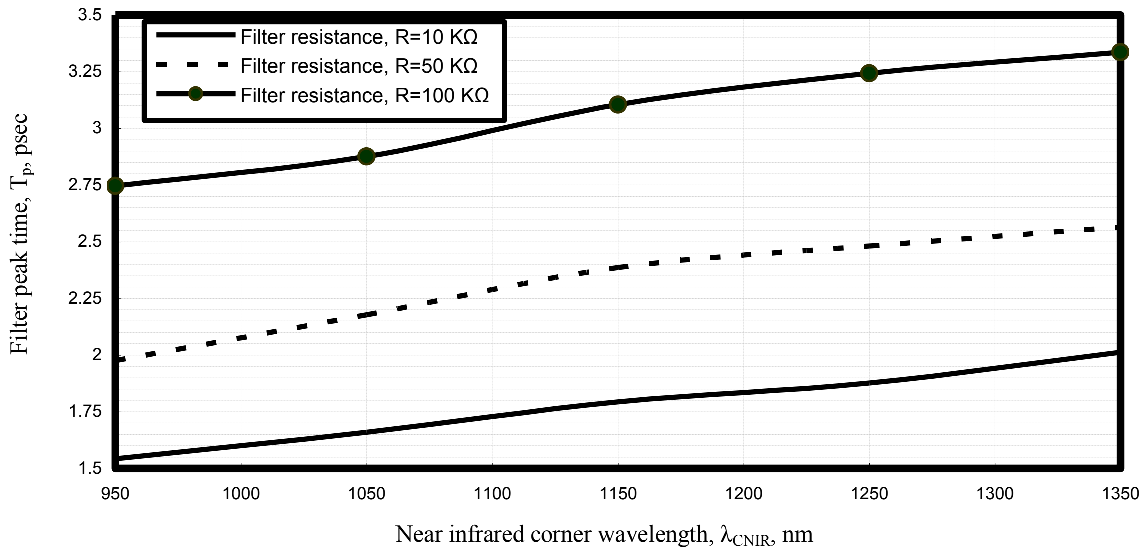

Fig. 25. Filter peak time in relation to near infrared corner wavelength and filter resistance at the assumed set of the operating parameters.

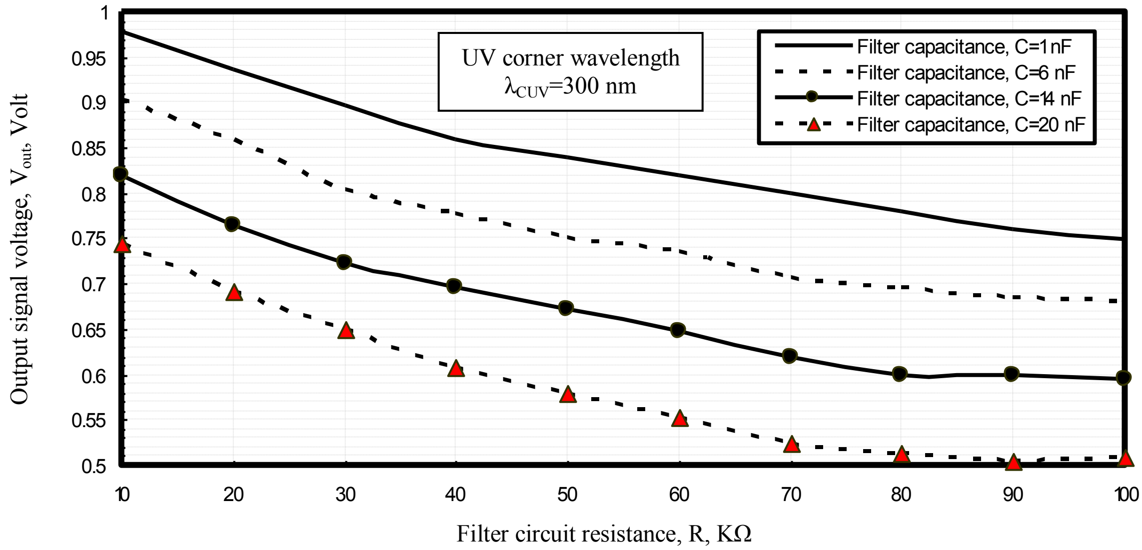

Fig. 26. Variations of output signal voltage against variations of filter circuit resistance and capacitance with ultraviolet corner wavelength at the assumed set of the operating parameters.

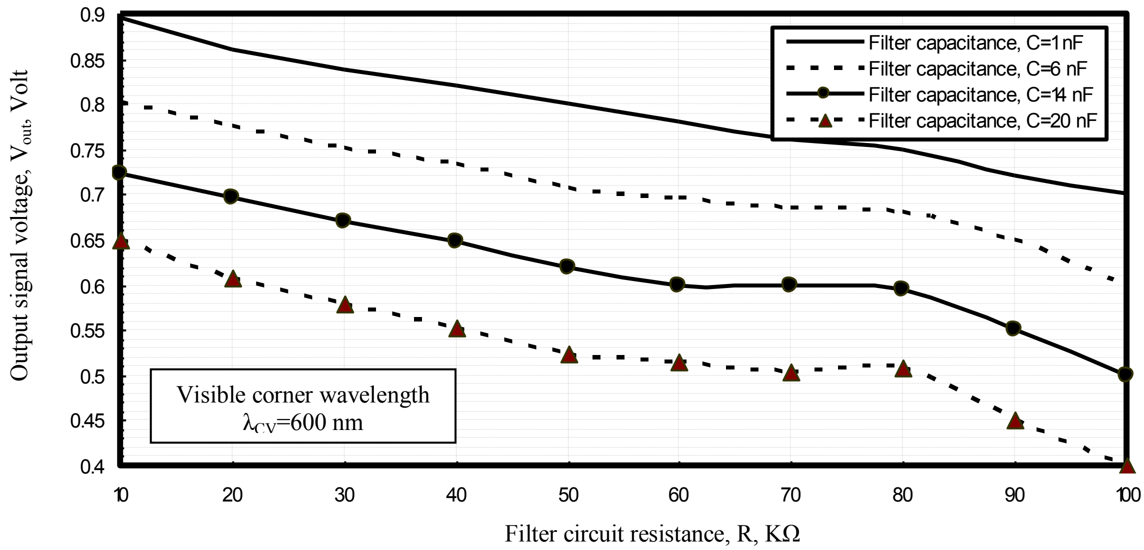

Fig. 27. Variations of output signal voltage against variations of filter circuit resistance and capacitance with visible corner wavelength at the assumed set of the operating parameters.

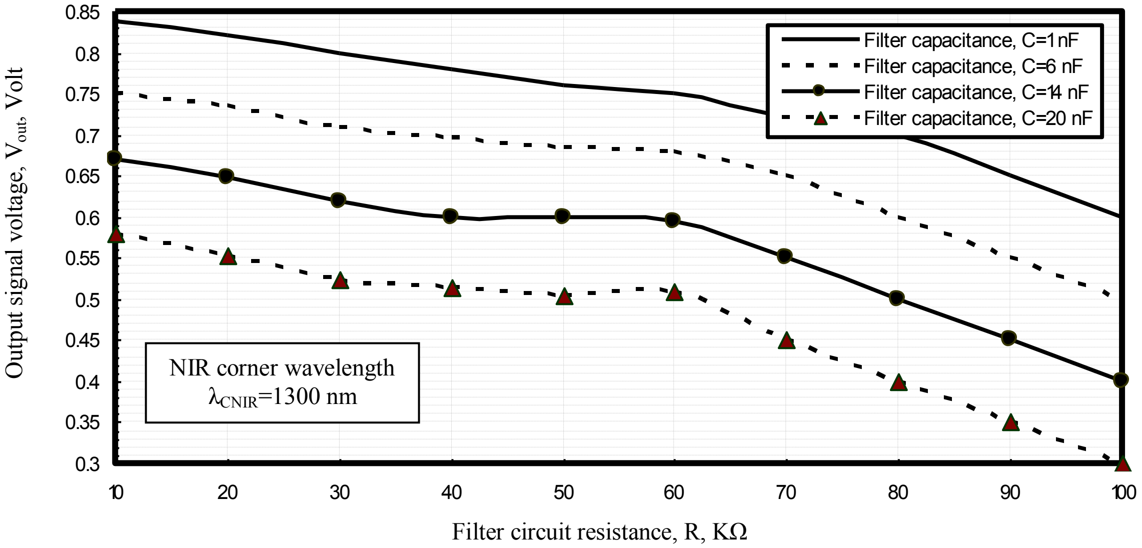

Fig. 28. Variations of output signal voltage against variations of filter circuit resistance and capacitance with near infrared corner wavelength at the assumed set of the operating parameters.

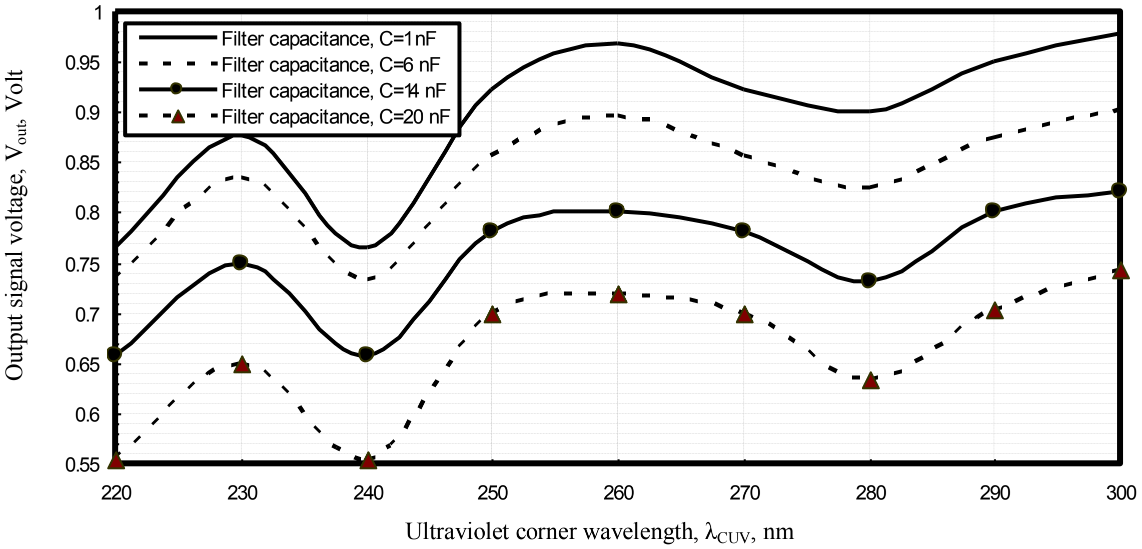

Fig. 29. Variations of output signal voltage against variations of ultraviolet corner wavelength and filter capacitance at the assumed set of the operating parameters.

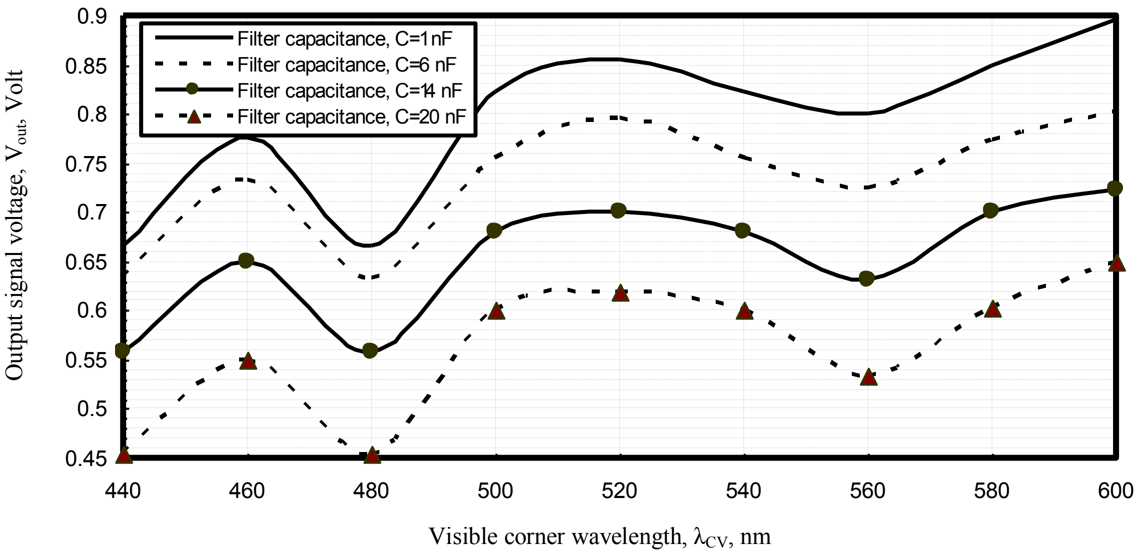

Fig. 30. Variations of output signal voltage against variations of visible corner wavelength and filter capacitance at the assumed set of the operating parameters.

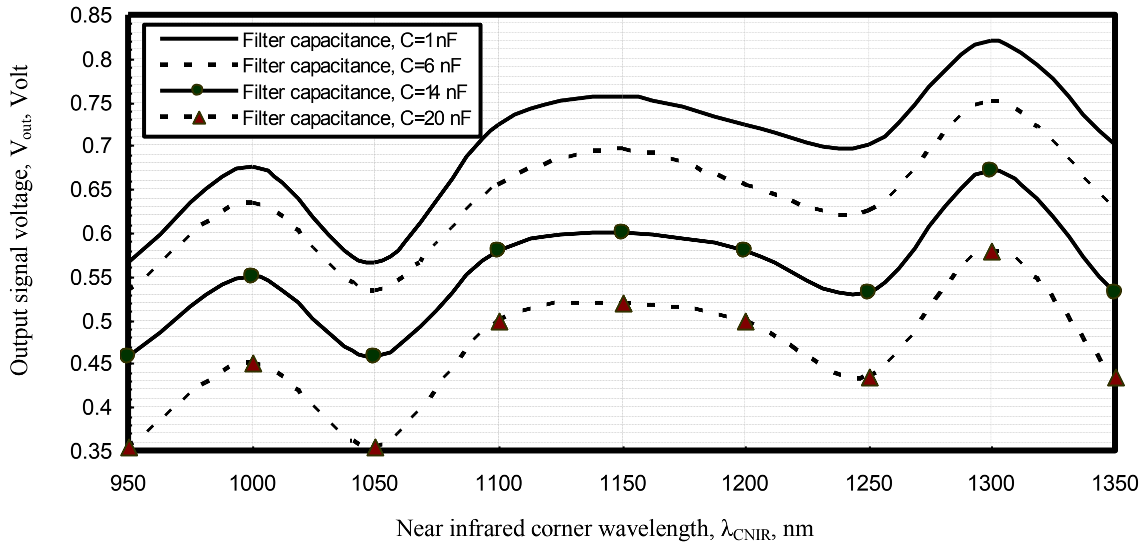

Fig. 31. Variations of output signal voltage against variations of near infrared corner wavelength and filter capacitance at the assumed set of the operating parameters.

vi) As shown in Figs. (20-25) have demonstrated that filter delay and peak times increase with increasing both filter circuit resistance and its corner wavelength for different optical transmission regions under study considerations. Filter delay and peak times have presented lower values in corner ultraviolet wavelength in comparison with visible and near infrared corner wavelengths.

vii) Figs. (26-31) have assured that filter output signal voltage decreases with increasing both filter circuit resistance and capacitance for different corner optical transmission wavelength regions under study considerations. Filter output signal voltage have presented higher values in corner ultraviolet wavelength in comparison with visible and near infrared corner wavelengths.

IV. CONCLUSIONS

In a summary, the short pass RLC filter model has been investigated over wide range of the affecting parameters. It is theoretically found the dramatic effects of the variations of filter resistance, inductance and capacitance on its gain, filter signal to noise ratio and filter bit error rates. By choosing suitable values of RLC circuit elements, this results in the filter transient time responses can be optimized for undamped condition. Table 2 has summarized the filter transmission characteristics and its transient time response.

Table 2: Transient time response and transmission specifications of short pass RLC filters (Under damping case).

Transient time response parameters	RLC short pass filters (R=10 KΩ, L=1 μH, and C=1 nF)		
	UV band region (λ_{CUV}=300 nm)	Visible band region (λ_{CV}=600 nm)	NIR band region (λ_{CNIR}=1300 nm)
Filter gain, G, dB	40 dB	33.65 dB	25 dB
Signal quality factor, Q, dB	29 dB	25 dB	22
Bit error rate, BER	$2.43X10^{-12}$	$6.35x10^{-12}$	$10.65x10^{-12}$
Damping ratio, ξ	0.0875	0.1132	0.345
Phase shift, ϕ, degree	72 degree	64 degree	57.5 degree
Rise time, T_r, psec	4 psec	5 psec	7 psec
Settling time, T_s, psec	80 psec	45 psec	35 psec
Delay time, T_d, psec	0.726 psec	0.954 psec	1.185 psec
Peak time, T_p, psec	1.32 psec	1.654 psec	1.954 psec
Output voltage, V_{out}, volt	0.978 Volt	0.896 Volt	0.82 Volt

REFERENCES

[1] V. M. Lubecke, K. Mizuno, and G. M. Rebeiz, "Micromachining for Terahertz Applications," IEEE Trans. Microwave Theory & Tech., Vol. 46, No. 11, pp. 1821-1831, Nov. 1998.

[2] Ahmed Nabih Zaki Rashed, "High Speed Transmission Performance Operation Efficiency of Optical Dichronic Communication Filters," International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), Vol. 3, No. 3, pp. 642-654, March 2014.

[3] P. Arcioni, M. Bozzi, G. Conciauro, and L. Perregrini, "Design and Optimization of Quasi Optical Frequency Multipliers," Intern. Journal of Infrared and Millimeter Waves, Vol. 20, No. 5, pp. 913-928, May 1999.

[4] D. A. Weitz, W. J. Skocpol, and M. Tinkham, "Capacitive Mesh Output Couplers for Optically Pumped Far Infrared Lasers," Optics Letters, Vol. 3, No. 1, pp. 13-15, July 1978.

[5] R. D. Rawclie and C. M. Randall, "Metal Mesh Interference Filters for the Far Infrared," Applied Optics, Vol. 6, pp. 1353-1358, 1967.

[6] B. A. Munk, Frequency Selective Surfaces: Theory and Design. New York: Wiley Interscience, 2000.

[7] R. Belikov and O. Solgaard, "Optical Wavelength Filtering by Diffraction from A surface Relief," Optics Letters, Vol. 28, No. 6, pp. 447–449, 2003.

[8] S. Sumriddetchkajorn, "Micromechanics Based Digitally Controlled Tunable Optical Beam Shaper," Optics Letters, Vol. 28, No. 9, p. 737, 2002.
[9] W. Noell, P. A. Clerc, L. Dellmann, B. Guldimann, H. P. Herzig, O. Manzardo, C. R. Marxer, K. J. Weible, R. Dandliker, and N. de Rooij, "Applications of SOI Based Optical Mems," IEEE Journal of Selected Topics in Quantum Electronics, Vol. 8, No. 1, pp. 148–154, 2002.
[10] M. P. de Boer, D. L. Luck, W. R. Ashurst, R. Maboudian, A. D. Corwin, J. A. Walraven, and J. M. Redmond, "High Performance Surface Micro machined Inchworm Actuator," Journal of Microelectromechanical Systems, Vol. 13, No. 1, pp. 63–74, 2004.
[11] N. A. Hall and F. L. Degertekin, "Integrated Optical Interferometric Detection Method for Micromachined Capacitive Acoustic Transducers," Applied Physics Letters, Vol. 80, No. 20, pp. 3859–3861, 2002.
[12] N. Neumann, M. Heinze, H. Stegbauer, K. Hiller, and S. Kurth, "Micromechanical Tunable Fabry Perot Filter for Ir Gas Analysis," Technisches Messen, Vol. 72, No. 1, pp. 10–15, 2005.
[13] O. Manzardo, R. Michaely, F. Schadelin, W. Noell, T. Overstolz, N. De Rooij, and H. P. Herzig, "Minature Lamellar Grating Interferometer Based on Silicon Technology," Optics Letters, Vol. 29, No. 13, pp. 1437–1439, 2004.
[14] H. Sagberg, M. Lacolle, I. R. Johansen, O. Lovhaugen, R. Belikov, O. Solgaard, and A. S. Sudbo, "Micromechanical Gratings for Visible and Near Infrared Spectroscopy," IEEE Journal of Selected Topics in Quantum Electronics, Vol. 10, No. 3, pp. 604–613, 2004.
[15] G. Griffel, "Synthesis of Optical Filters Using Ring Resonator Arrays," IEEE Photon. Technol. Lett., Vol. 12, pp. 810–812, July 2000.

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