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ORIGINAL PAPER

# Design of a Selective Filter Based on One-dimensional Superconductor Photonic Crystal

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**Abstract**
In this paper, we present a new design and analysis of one-dimensional superconductor photonic crystal (1D-SPC).The transmission spectrum and dispersion relation of this structure are obtained by the use of the transfer matrix method and Bloch theorem. The defective layers existence allows obtaining a new composite structure with tunable optical properties. Considering the transmission matrix of each layer, we can obtain the transmission matrix of the entire structure. The obtained results are presented in terms of the transmission spectra for both TE and TM modes. Numerical results of the effects of temperature, superconductor layer's thickness, and incident angle on the transmission spectra are presented. We discuss the effect of defect layers inserted between 1D-SPC structure on the transmission spectra. The number of defect modes can be controlled by adjusting the number of defect layers in the structure. The proposed approach is approved by comparison of computed results with previous published data.

**Keywords** Transmission · Photonic crystals · Superconductor · Photonic band gap

## 1 Introduction

The one-dimensional binary dielectric super-lattice has become attractive to optical engineering because of its multiple useful features, such as its ability to control and manipulate the propagation of electromagnetic waves in limited spaces [1]. This structure is now known as one-dimensional photonic crystal (1D-PC), which constitutes an important topic in optical physics over the last two decades [2–6]. The one-dimensional photonic crystal (1D-PC) structures have a number of useful properties, employed as dielectric reflecting mirrors, optical switches, optical limiters, and optical filters [6–9]. By using dielectric materials in (1D-PC) structure, it may be inevitable to face the inherent loss issue arising from the metallic extinction coefficient. To treat this loss problem, it is possible to replace the dielectric by superconducting materials [10–13].

One-dimensional superconductor photonic crystal (1D-SPC) has a certain advantage over (1D-PC) structure, such as the tenability of its PBG due to the temperature dependence of the London penetration depth. Therefore, a considerable number of researches have been devoted to the characterization of these structures [10–13]. It has been demonstrated experimentally and theoretically that (1D-SPC) structures have large omnidirectional photonic band gaps (PBGs). Thus, there is a possibility to build the selective filter based on one-dimensional superconductor photonic crystal (1D-SPC) structure, and to control some specific parameters of this filter through structural parameters variation. The control of defect modes in narrow-band filters is one major interest for the application of (1D-SPC) structure. In general, the existence of a defective layer within the (1D-SPC) structure can produce a transmission peak in the transmission spectrum; this peak is very similar to the defect states generated in the forbidden band in case of doped semiconductor. In the previous studies, the defect layer has been realized by changing physical parameters such as the thickness of one of the layers, adding another medium to the structure, or by removing a layer from 1D-SPC structures.

Nowadays, the photonic crystals numerical modeling is based on calculations of transmission and reflection coefficients. For this purpose, several mathematical methods are

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available. The transfer matrix method (TMM) and Block theorem are considered to be a more efficient method because of the simplicity of its algorithm and its ability to model complex structures [14].

In this paper, we combine the transfer matrix method (TMM) with the Block theorem in order to find the characteristics of transmission spectra and photonic band gap of one-dimensional superconductor photonic crystal (1D-SPC) structures. The effects of the temperature, thickness of the superconductor layer, and the incident angle on the width of the photonic band gaps (PBGs) are investigated. By introducing a defective layer into the (1D-SPC) structure, it would be possible to generate very narrow defect modes inside a band gap; the number of these defect modes is associated with the number of defect layers.

The considered structures are Air/$(SD_1)^6D_2(D_1S)^6$/Air), (Air/$(SD_1)^6D_2\ D_1D_2\ (D_1S)^6$/Air), and (Air/$(SD_1)^6D_2\ D_1D_2D_1D_2\ (D_1S)^6$/Air, in which both layers $D_1$ and $D_2$ are dielectrics and layer $S$ is a high temperature superconducting. Several simulation scenarios using Matlab will be given to show the performance of this approach. The accuracy of the analysis is approved by comparison of the computed results with real experimental measurement published data.

## 2 Theoretical Model

Let us first consider the (1D-SPC) structure consisting of alternating multilayer of the form $(SD)^N$ as described in Fig. 1, there are 2N layers made up of superconductor S and dielectric material D. Each layer must have a thicknesses $d_l$ and refractive index $n_l$. We suppose that the incident electromagnetic wave comes from the air to the layer S and layer D, the layers

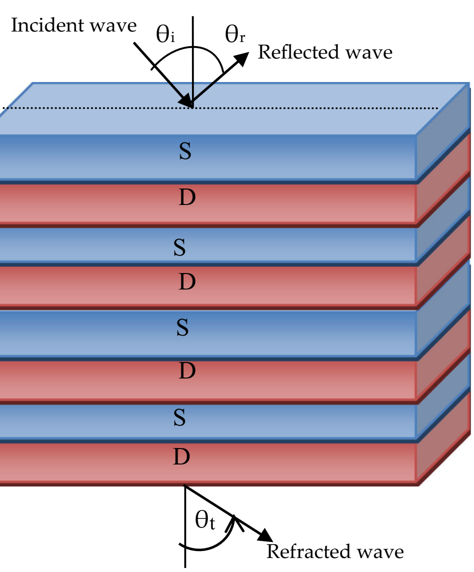


**Fig. 1** Structure of one-dimensional superconductor photonic crystal (1D-SPC)

are on the $x$-$y$ plane and the $z$ direction is normal to layer interface.

The refractive index profile ($n_l = \sqrt{\varepsilon_l}$) of superconducting (S) and dielectric (D) mediums can be given as:

$$\begin{cases} n_1 = \sqrt{\varepsilon_1} = \sqrt{\varepsilon_S} & 0 < z < d_1 \\ n_2 = \sqrt{\varepsilon_2} = \sqrt{\varepsilon_D} & d_1 < z < d_2 \end{cases} \tag{1}$$

where $\varepsilon_s$, $\varepsilon_D$, $n_1$, $n_2$, $d_1$, and $d_2$ denotes respectively the relatives permittivity, refractive indices, and thicknesses of S and D mediums.

In (Eq. 1), it is assumed that the magnetic permeability of the (1D-SPC) structure is equal to that in free space. Because $\varepsilon_l$ is a periodic function of z, the dielectric constant can be written as:

$$\varepsilon_l(z) = \varepsilon_l(z + d) \tag{2}$$

where $l$ is number of layer and $d = d_1 + d_2$ is period

Based on Maxwell's equations and Boundary conditions, the transverse components of the electrical (E) and magnetic (H) fields in the first layer, for TM polarization, are given by:

$$H_{ly} = A_l e^{i(\omega t - k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} + B_l e^{i(\omega t + k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} \tag{3}$$

$$E_{lx} = \eta_l \cos\theta_l \left( A_l e^{i(\omega t - k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} - B_l e^{i(\omega t + k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} \right) \tag{4}$$

$$E_{lz} = -\eta_l \cos\theta_l \left( A_l e^{i(\omega t - k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} + B_l e^{i(\omega t + k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} \right) \tag{5}$$

The transverse components of the electrical (E) and magnetic (H) fields of the Maxwell equations in the first layer, for TE polarization, are given by:

$$E_{ly} = A_l e^{i(\omega t - k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} + B_l e^{i(\omega t + k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} \tag{6}$$

$$H_{lx} = -\frac{\eta_l}{\cos\theta_l} \left( A_l e^{i(\omega t - k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} - B_l e^{i(\omega t + k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} \right) \tag{7}$$

$$H_{lz} = \frac{\eta_l}{\cos\theta_l} \left( A_l e^{i(\omega t - k_l(Z_l.\cos\theta_l + X_l.\sin\theta_l))} + B_l e^{i(\omega t + k_1(Z_l.\cos\theta_l + X_l.\sin\theta_l))} \right) \tag{8}$$

In the above formulations, $A_1$ and $B_1$ are the amplitudes of the *incident and reflected* waves in the first layer, $\theta_l$, $k_l$, and $\eta_l$ are the ray angle, wave numbers, and intrinsic impedances of first layer, respectively.

Where the wave numbers and intrinsic impedances are:

$$k_l = \omega\sqrt{\varepsilon_0 \mu_0 \varepsilon_l \mu_l} \tag{9}$$

$$\eta_l = \frac{k_l}{\omega \varepsilon_l \varepsilon_0} = \sqrt{\frac{\mu_0 \mu_l}{\varepsilon_0 \varepsilon_l}} \tag{10}$$

where $\varepsilon_0$, $\mu_0$, $\varepsilon_l$ , and $\mu_l$ are the free space permittivity, free space permeability, relative permittivity, and relative permeability ($\mu_l = 1$), respectively.

Using the boundary conditions and the condition of continuity of E and H fields at the interfaces of $z = 0$ and $z = d_1, d_2, d_3, \ldots d_{2N}$ $z = d_1, d_2, d_3 \ldots \ \ldots . d_N$, we can find out the relationship between the fields (1D-SPC) structure consisting of l layer, this relation is already exposed by [15, 16]:

$$\begin{bmatrix} E_1 \\ H_1 \end{bmatrix} = M_1 M_2 \ldots\ldots M_N \ldots . M_{2N} \begin{bmatrix} E_l \\ H_l \end{bmatrix} \tag{11}$$

The matrix $M_{l\text{-}1}$ of the $1^{\text{th}}$ layer can be written in the form:

$$M_{(l-1)} = \begin{bmatrix} \cos\left(\delta_{(l-1)}\right) & i\gamma_{(l-1)} \sin\left(\delta_{(l-1)}\right) \\ i\,\gamma_{(l-1)}{}^{-1} \sin\left(\delta_{(l-1)}\right) & \cos\left(\delta_{(l-1)}\right) \end{bmatrix} \tag{12}$$

$\delta_{(l-1)}$ and $\gamma_{(l-1)}$ being the matrix parameters as a function of the incident angle of light, the optical constants and the thickness of the layer are expressed as:

$$\delta_{(l-1)} = k_{(l-1)}.d_{(l-1)}.\cos\theta_{(l-1)} \tag{13}$$

$$\gamma_{(l-1)} = \begin{cases} \dfrac{\eta_{(l-1)}}{\cos\theta_{(l-1)}} & \text{TEmode} \\ \eta_{(l-1)}\cos\theta_{(l-1)} & \text{TMmode} \end{cases} \tag{14}$$

Notice that $\theta_{(l-1)}$ is related to the angle of incidence $\theta_0$ by the Snell-Descart law equation:

$$n_{(l-1)} sin\theta_{(l-1)} = n_0 sin\theta_0 \tag{15}$$

From the two fluid models, we find that the refractive index of the superconductor is

$$n_1 = \sqrt{\varepsilon_{r1}} = \sqrt{1-(\omega_{th}/\omega\ \ )^2} \tag{16}$$

where $\omega_{th}$ is the threshold frequency of the superconductor; where it is given by [17–20]:

$$\omega_{th}^2 = \frac{1}{\mu_0 \varepsilon_0 \lambda_L^2} \tag{17}$$

where $\lambda_L$ is the temperature-dependent London penetration depth and it is given by

$$\lambda_L^2 = \frac{\lambda_0^2}{1-\left(\frac{T}{T_C}\right)4} \tag{18}$$

where $\lambda_0$ is the penetration depth at $T = 0$ K, $T$ is operating temperature, $T_C$ is the critical temperature of the superconductor.

The dielectric layer having the refractive index in the form:

$$n_2 = \sqrt{\varepsilon_{r2}} \tag{19}$$

Considering the transmission matrix of each layer, we can obtain the transmission matrix of the entire structure. For one number of multilayer's, the corresponding transfer matrix can be defined as a product of matrices and is obtained from the symmetric PBG structure,

$$M = \prod_{k=1}^{(2N)} M_k = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} \tag{20}$$

The designed (1D-SPC) structure with a defect layer is depicted in Fig. 2. Here, the host symmetry (1D-SPC) structure with the configuration (Air/$(SD_1)^N D_2 (D_1 S)^N$/Air) is made up of superconductor S and dielectric materials $D_1$ and $D_2$. The product of matrices of (1D-SPC) structure with defect layer can be then written as follows [19]:

$$M = \prod_{k=1}^{(2N+1)} M_k = \left(M_S M_{D1}\right)^N M_{D2} \left(M_{D1} M_S\right)^{(2N+1)}$$
$$= \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} \tag{21}$$

where $M_S$ is the transfer matrix of the first superconductor layer, $M_{D1}$ is the transfer matrix of the dielectric layer, $M_{D2}$ is the transfer matrix of the defect dielectric layer, $m_{11}$, $m_{12}$,

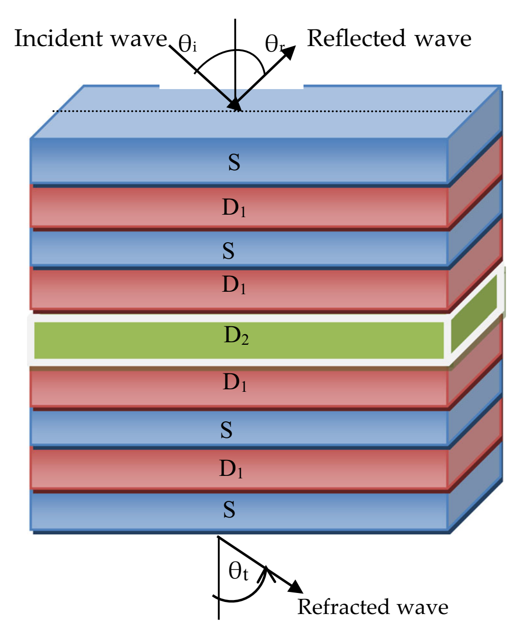


**Fig.2** (1D-SPC) structure containing a defect layer

$m_{21}$, and $m_{22}$ are the complex numbers.

The transmittance t and reflectance r are defined as the ratios of the fluxes of the transmitted and reflected waves, respectively, to the flux of the incident wave. After a few derivations, the total reflection and transmission coefficients are given by [21–22]:

$$r = \frac{\left(m_{11}+p_s^{-1}m_{12}\right)p_0^{-1} - \left(m_{21}+p_s^{-1}m_{22}\right)}{\left(m_{11}+p_s^{-1}m_{12}\right)p_0^{-1} + \left(m_{21}+p_s^{-1}m_{22}\right)} \tag{22}$$

$$t = \frac{2.p_0^{-1}}{\left(m_{11}+p_s^{-1}m_{12}\right)p_0^{-1} + \left(m_{21}+p_s^{-1}m_{22}\right)} \tag{23}$$

Here $p_0$ and $p_s$ are the first and last medium of the structure which are given by

$$p_s^{-1} = \begin{cases} \dfrac{\eta_s \cos\theta_s}{Z_0} & \text{TEmode} \\ \dfrac{\eta_s}{Z_0 \cos\theta_0} & \text{TMmode} \end{cases} \tag{24}$$

$$p_0^{-1} = \begin{cases} \dfrac{\eta_0 \cos\theta_0}{Z_0} & \text{TEmode} \\ \dfrac{\eta_0}{Z_0 \cos\theta_0} & \text{TMmode} \end{cases} \tag{25}$$

where $Z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$.

In general, wave propagation in periodic media can be described in terms of Bloch waves [23]. For a determination of the dispersion surfaces of a periodic crystal, it is necessary only to integrate the wave field through a periodic media. According to Bloch theorem, fields in a periodic structure satisfy the following equations:

$$E(z+d) = e^{-ikd}E(z) \tag{26}$$

The parameter $k$ is called the Bloch wave number or dispersion relation. In order to determinate $k$, we can use the relation between the electric field amplitudes of two layers. From Eq. (20), we obtain:

$$\begin{bmatrix} E_1 \\ H_1 \end{bmatrix} = M_1 M_2 \begin{bmatrix} E_2 \\ H_2 \end{bmatrix} \tag{27}$$

We can put the product matrix as:

$$M_1.M_2 = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} \tag{28}$$

$Tr[M_1. M_2]$ is the trace of the transfer matrix characterizing the wave scattering in a periodic structure, is given by;

$$Tr[M_1.M_2] = M_{11} + M_{22} = 2\cos(kd) \tag{29}$$

where

$$M_{11} = \cos(\delta_1)\cdot\cos(\delta_2) - (\gamma_1/\gamma_2)\sin(\delta_1)\sin(\delta_2) \tag{30}$$

$$M_{22} = \cos(\delta_1)\cdot\cos(\delta_2) - (\gamma_2/\gamma_1)\sin(\delta_1)\sin(\delta_2) \tag{31}$$

Substituting Eqs. (30) and (31) into Eq. (29), we obtain the following Eq. (32):

$$\cos(kd) = \cos(\delta_1)\cdot\cos(\delta_2) - \left(\frac{\gamma_2^2+\gamma_1^2}{2\gamma_1\gamma_2}\right)\sin(\delta_1)\sin(\delta_2) \tag{32}$$

The quantity cos(kd) determines the band structures or photonic bandgap structures of the (1D-SPC) structure. In the region where $|\cos(kd)| < 1$, $k$ takes a real value and this leads to propagating Bloch waves (passband). In the region where $|\cos(kd)| > 1$, the value of $k$ become complex which consists of an imaginary and a real part corresponding to the evanescent and propagating Bloch waves. The band edges are the regions where $|\cos(kd)| = 1$

## 3 Numerical Results

For the following numerical results, the simulations were carried out using the theory described in the previous section. Figures 3, 4, and 5 show the variation of transmission spectra of (1D-SPC) structure as function of the different thickness values ($d_S$) of high-temperature superconductor layer. Also, the proposed structure is restructured as $(S_nD_n)^m$ where $n = 1\ldots m$, $m$ is chosen as 6. We have kept constant the refractive index of the layers ($n_S = n_{YBa2Cu3O7} = \sqrt{\varepsilon_{r1}} = \sqrt{1-(\omega_{th}/\omega)^2}$ and $n_D = n_{InAs} = 3.3842$). The thickness of the layer was taken as $d_S = 30$ nm, $d_D = 80$ nm, $d_S = 50$ nm, $d_D = 80$ nm and $d_S = 80$ nm, $d_D = 80$ nm. The superconducting layer was assumed to be made of YBa2Cu3O7 thin films thickness $d_S$. The superconducting material characteristics are $\lambda_0 = 200$ nm and $T_c = 92$ K. The operating temperature is ($T = 4.2$ K).

From Figs. 3, 4, and 5, we have clearly observed that the proposed structure shows various band gaps (or stop band). The width of photonic band gap changes with respect to the change of superconductor layer's thickness; it is limited at 286.8 to 353.6 nm for $d_S$ = 30 nm, whereas for about $d_S$ = 50 nm and $d_S$ = 80 nm, it goes to 99.2 nm and 123.1 nm, respectively. The width of the PBGs is more sensitive to the increasing of the superconductor layer's thickness. On the other hand, it is possible to modify the photonic band gap

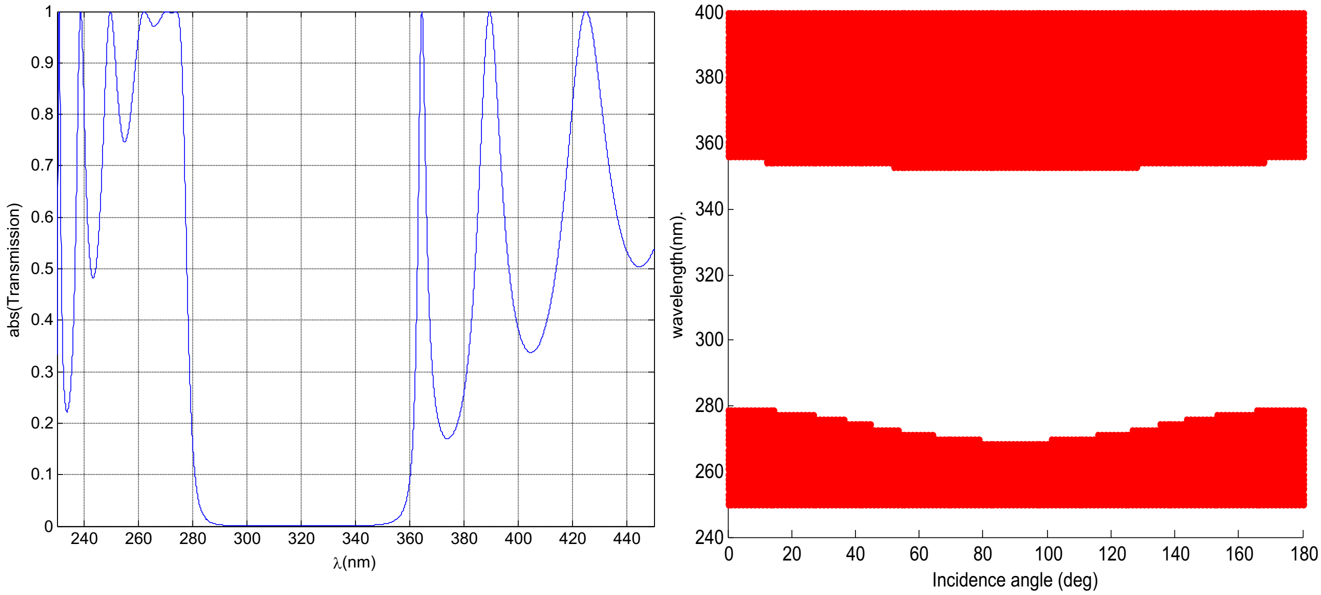


**Fig. 3** Transmission spectra projected band of (1D-SPC) structure versus the wavelength $n_D = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{\varepsilon_{r1}} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $d_S = 30$ nm, $d_D = 80$ nm, $T = 4.2$ K, $T_C = 92$ K, $\lambda_0 = 200$ nm, and $N = 12$

(PBG) of the structure by varying the incident angle. The red region indicates ranges of the transmission, and the empty space regions represent the band gap (PBG). As the incidence angle increases, the band gap width was also found to be increased and shifted to higher wavelength regions. Finally, we conclude that the superconductor thickness is a significant parameter in this structure [19, 22].

The dependence of transmission spectra with respect to the angle of incidence for TE and TM modes is shown in Figs. 6 and 7. Some features are worth for noting, the transmission spectrum is strongly increased with the increase of the temperature and the incidence angle for TE and TM modes, the same behavior ( $= 0°$) is found by Chien-Jang Wu [21].

To investigate the relationship between the number of defect layers and defect modes, we have plotted the transmission spectra depending on the wavelength. A range of refractive indices was selected: $n_{D1} = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{\varepsilon_{r1}} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $n_{D2} = n_{SrTiO3} = 2.437$, and $d_S = d_{D1} = d_{D2} = 80$ nm. The layer's thickness was taken as

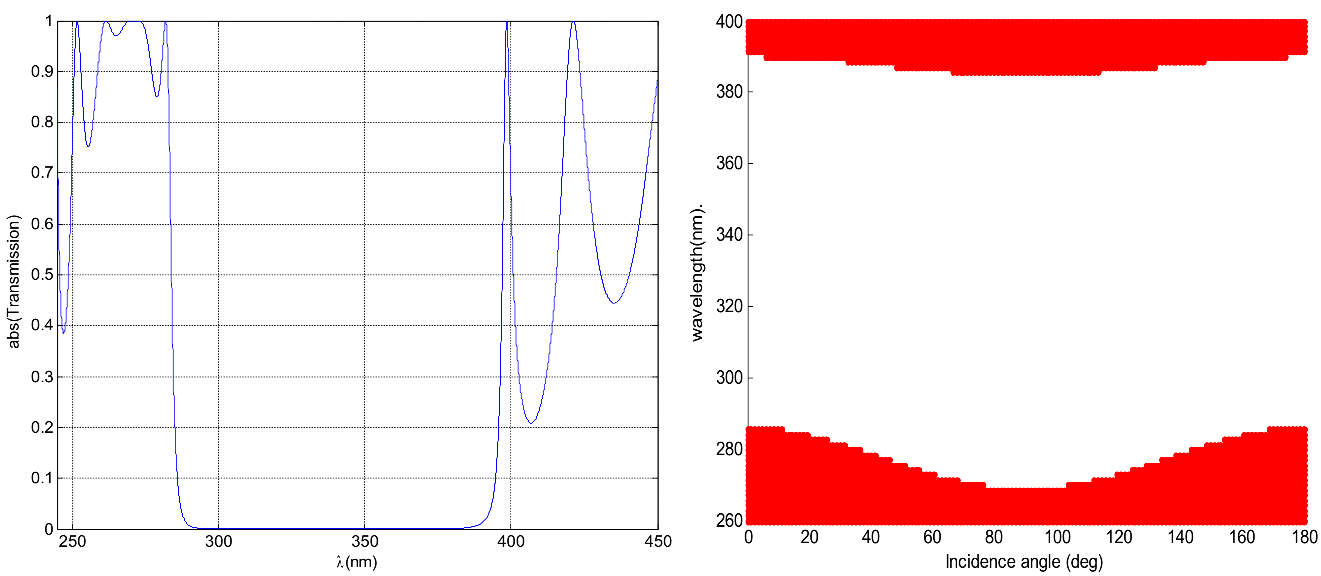


**Fig. 4** Transmission spectra and projected band of (1D-SPC) structure versus the wavelength $n_D = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{\varepsilon_{r1}} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $d_S = 50$ nm, $d_D = 80$ nm, $T = 4.2$ K, $T_C = 92$ K, $\lambda_0 = 200$ nm, and $N = 12$

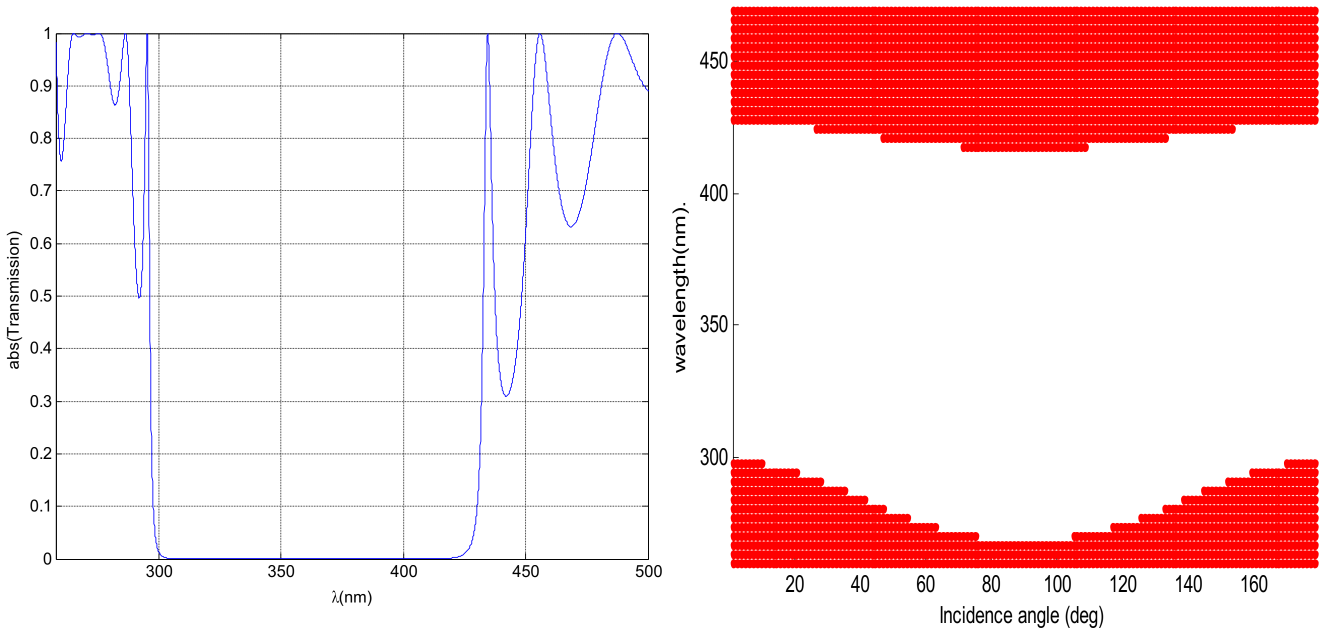


**Fig. 5** Transmission spectra and projected band of 1D-SPC structure versus the wavelength $n_D = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{\varepsilon_{r1}} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $d_S = 80$ nm, $d_D = 80$ nm, $T = 4.2$ K, $T_C = 92$ K, $\lambda_0 = 200$ nm and $N = 12$

follows: $d_S = d_{D1} = d_{D2} = 80$ nm. The effect of defective layers on the transmission spectra for a normal incidence (0°) are illustrated in Figs. 8 and 9. Also, the variation tendencies of the quality factor, the resonance wavelengths, and the width of the photonic band gap are presented. For the resonant structures, we notice that the ability is expressed in terms of quality factor $Q$. This last one is defined as $Q = \lambda/\Delta\lambda$, where $\lambda$ is resonance wavelength and $\Delta\lambda$ is the line-width of the resonance peak.

In Fig. 8, we have plotted the transmission spectra of the symmetric (1D-SPC) structure with the configuration $(\mathrm{Air}/(SD_1)^6 D_2 (D_1 S)^6/\mathrm{Air})$, the values obtained for the TE

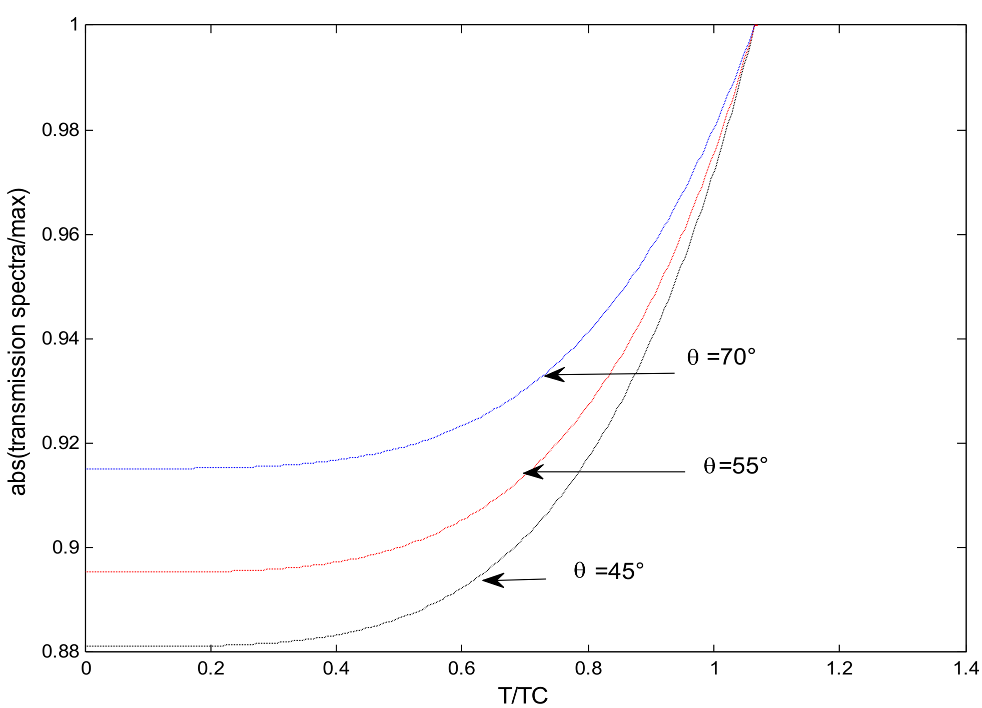


**Fig. 6** Transmission spectra of 1D-SPC structure calculated as a function of temperature. $\lambda = 320$ nm $n_D = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $d_S = 30$ nm, $d_D = 80$ nm, $T_C = 92$ K, $\lambda_0 = 200$ nm, and $N = 20$, TE mode

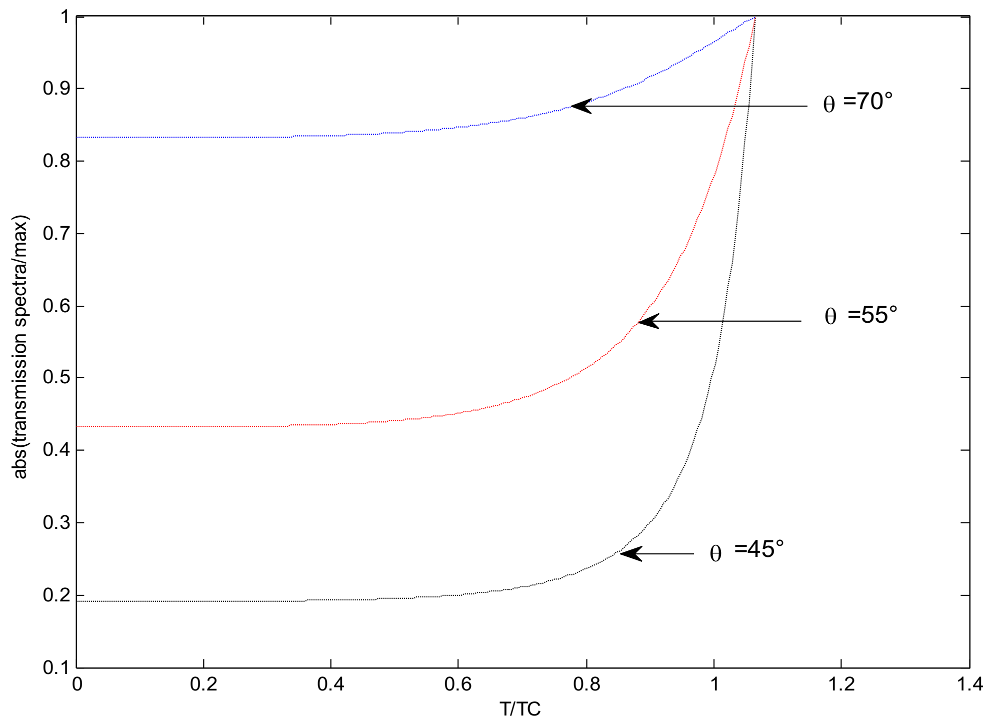


**Fig. 7** Transmission spectra of 1D-SPC structure calculated as a function of temperature. $\lambda = 320$ nm $n_D = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $d_S = 30$ nm, $d_D = 80$ nm, $T_C = 92$ K, $\lambda_0 = 200$ nm, and $N = 20$, TM mode

and TM modes are similar. The resonant peak is at the design wavelength of $\lambda_c = 365.6$ nm and the quality factor of $Q = 2437.3$. In addition, we can observe from Figs. 9 and 10 that the (1D-SPC) structure with the configurations (Air/(SD$_1$)$^6D_2$ $D_1$ $D_2$ $(D_1S)^6$/Air) and (Air/(SD$_1$)$^6D_2$ $D_1$ $D_2$ $D_1$ $D_2$ $(D_1S)^6$/Air) show the existence of two and three defect modes respectively within the photonic band gap (PBG); the resonant peak is located at the design wavelength of $\lambda_1 = 345.7$ nm and $\lambda_2 = 393.8$ nm with quality factor values of $Q_1 = 3457$and $Q_2 = 1969$, for the *(Air/(SD$_1$)$^6D_2$ $D_1$ $D_2$ $(D_1S)^6$/Air)* configuration, and $\lambda_1 = 336.9$ nm, $\lambda_2 = 336.3$ nm, and $\lambda_3 =$

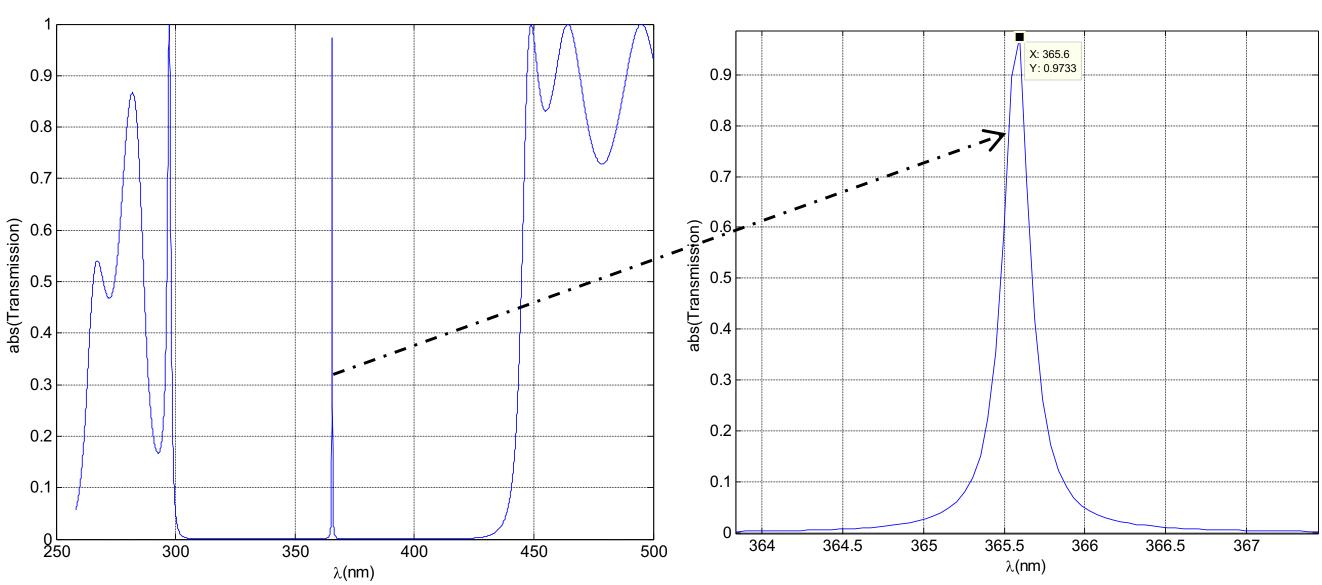


**Fig. 8** Transmission spectra of (Air/(SD$_1$)$^6D_2(D_1S)^6$/Air) configuration calculated as a function of temperature. $n_{D1} = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{\varepsilon_{r1}} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $n_{D2} = n_{SrTiO3} = 2.437$, $d_S = d_{D1} = d_{D2} = 80$ nm, $T_C = 92$ K, $\lambda_0 = 200$ nm, and $T = 4.2$ K

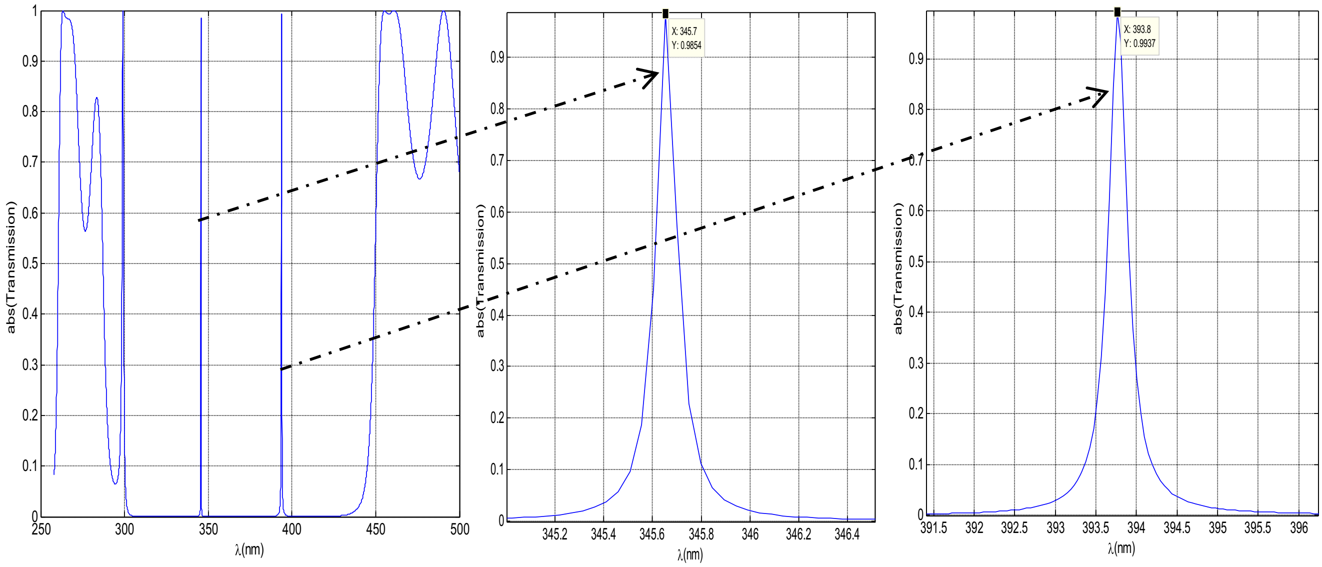


**Fig. 9** Transmission spectra of (Air/(SD$_1$)$^6$$D_2$ $D_1$ $D_2$ $(D_1S)^6$/Air) configuration calculated as a function of temperature. $n_{D1} = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $n_{D2} = n_{SrTiO3} = 2.437$, $d_S = d_{D1} = d_{D2} = 80$ nm, $T_C = 92$ K, $\lambda_0 = 200$ nm, and $T = 4.2$ K

409.1 nm, $Q_1 = 7486.7$, $Q_2 = 5605$, and $Q_3 = 1549.6$ for (Air/(SD$_1$)$^6$$D_2$ $D_1$ $D_2$ $D_1$ $D_2$ $(D_1S)^6$/Air) configuration. Our results imply that the number of defect mode can be increased by the adding of defect layers in structure.

## 4 Conclusions

In summary, a new design and analysis of one-dimensional superconductor photonic crystal (1D-SPC)

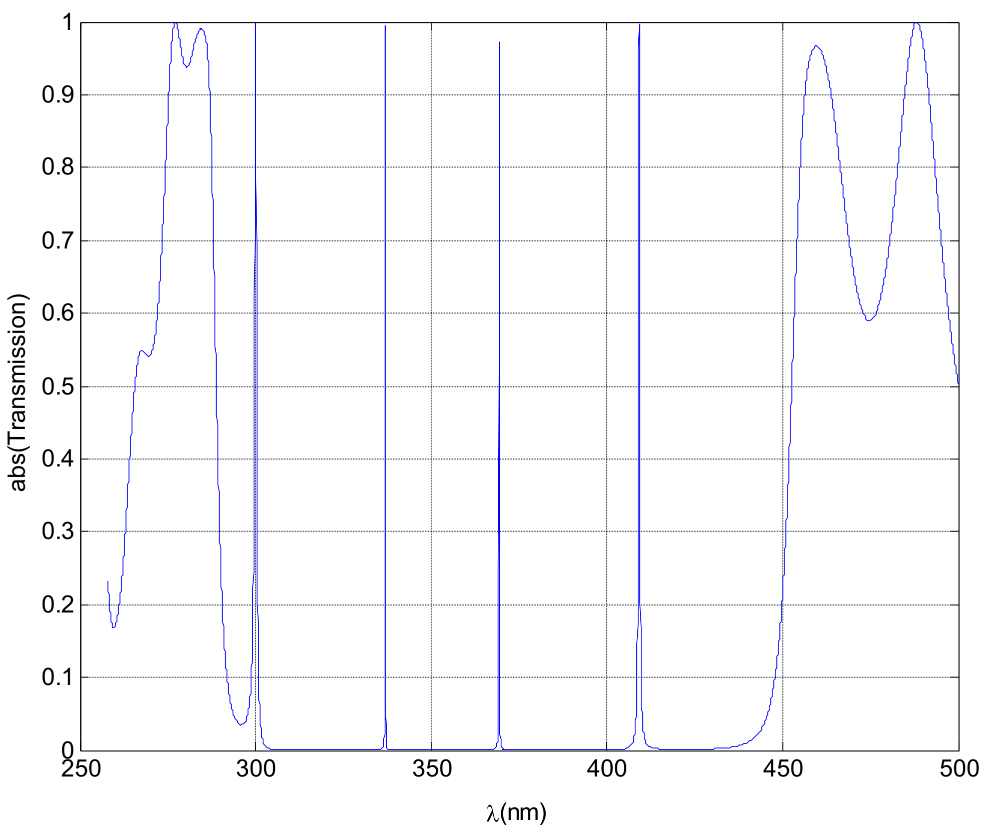


**Fig. 10** Transmission spectra of (Air/(SD$_1$)$^6$$D_2$ $D_1$ $D_2$ $D_1$ $D_2$ $(D_1S)^6$/Air) configuration calculated as a function of temperature. $n_{D1} = n_{InAs} = 3.3842$, $n_S = n_{YBa2Cu3O7} = \sqrt{1-(\omega_{th}/\omega\ )^2}$, $n_{D2} = n_{SrTiO3} = 2.437$, $d_S = d_{D1} = d_{D2} = 80$ nm, $T_C = 92$ K, $\lambda_0 = 200$ nm, and $T = 4.2$ K

are presented in this work. Theoretical results in terms of the transmission spectra for the various one-dimensional superconductor photonic crystal configurations were presented, and theoretically investigated by combining the transfer matrix method (TMM) and the Block theorem. Current simulations show that the width of the photonic band gap can be adjusted by modifying the superconductor layer's thickness and incidence angle. In case of fixed temperature, increasing the superconductor layer's thickness, also incidence angle could increase the width of the phonic band gap. In addition, the transmission spectrum at different incidence angles increases monotonically with temperature increase. Moreover, due to the existence of a defective layer, it is apparently shown that there is a very narrow passband within the photonic band gap. The number of defect modes can be controlled by adjusting the number of defect layers in the structure. Therefore, the proposed structure configurations may be of potential use and interest in many applications such as optical communication selective filters. The obtained results have been compared with the published data available in the literature and good agreement and correspondence that have been found.

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