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Optical switching in ME containing nonlinear

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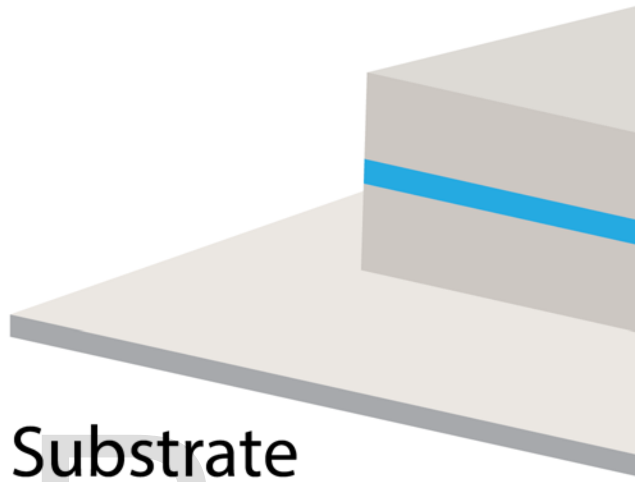

Abstract— Optical switching which used a grating structure as an external in this paper. ECTL consists of the laser cavity and switching cavity. The las a nonlinear optical material which used in the switching. A bistable beha study of this switching structure shows great advantages of smaller size Mechanical System (MEMS) technology. We show that a laser cavity di absorption coefficient can act as an absorptive switch, in which the on / c paper also studies the effect of the variations in the imaginary part of the re

Index Terms— Nonlinear materials, ECTL, MEMS, FDTD.

1 Introduction

Tunable lasers are used in many applications such as optical communications, biomedical applications, and environmental engineering [1-3]. There are a lot of technological options, but the External Cavity Tunable Laser ECTL has led itself to the top choice because of its advantages of simple configuration, high power and wide tuning range. The Littrow and Littman configuration are the popular conventional ECTL configurations [1, 4]. The development of MEMS technology has opened up a new opportunity to downscale a bulky tunable laser to a miniaturized device, while improving the mechanical reliability at lower fabrication cost. Several different approaches have been proposed in order to achieve active control of light in nanoscale optical devices [5-9]. These include thermally induced changes in the refractive index [5–7]. An alternative approach for active control of optical signals in devices is tuning the absorption coefficient. All optical switching based on non linear material effects is a promising technique for use in future optical communication systems [10]. In this paper, we introduce controlled ECTL by using nonlinear material between the laser cavity and external reflector (switching cavity) as shown in Figure 1. Where the switching cavity which is filled with an active material whose absorption coefficient can be modified with an external control beam (bias) [11-13]. We note that such structure acts as an absorption switch in which the on / off states correspond to the absence / presence of biasing. We select the length of the external cavity (switching cavity) depending on the value of the modulation depth; the ratio of the transmission in the on state to the transmission in the off state. We use two dimensional finite difference time domain (FDTD) solutions to calculate the transmission of the absorption switches. Perfectly matched layer (PML) absorbing boundary conditions are used at all boundaries of the simulation domain in order to eliminate the reflection of outgoing waves

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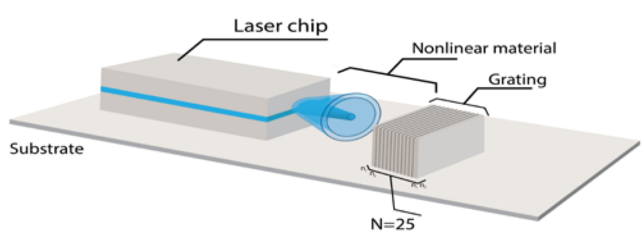


Fig. 1. Schematic diagram of the studied controlled ECTL source.

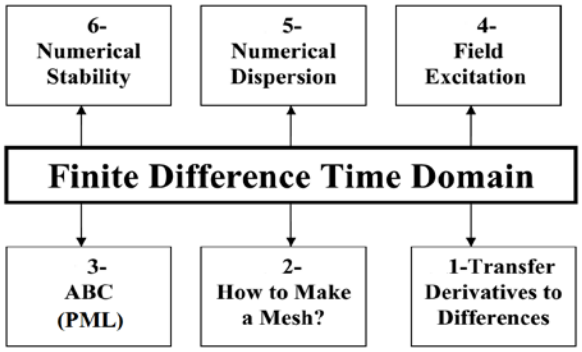


Fig. 2. Layout of FDTD method

2 Nonlinear Material

In order to achieve a variable transmission with and without an applied bias, the switching cavity should be filled with a material such that it exhibits an acceptable amount of change in its absorption coefficient. This is possible if the switching cavity is filled with an optically active material in which the refractive index expressed as n=n0+ik. Ge-rich SiGe multiple quantum wells (MQWs) or layers of Ge quantum dots (QDs) grown on a silicon matrix [15-18] are an examples of this type of materials. An electrically bias applied to such a structure shifts the absorption edge (and therefore κ) in Ge quantum wells as shown in Figure 3, resulting in a transmission contrast between the biased and unbiased states. Thus, the switching cavity in Figure 1 was assumed to be filled with a material with refractive index n= 4+iκ, where the real part is the bulk Ge refractive index.

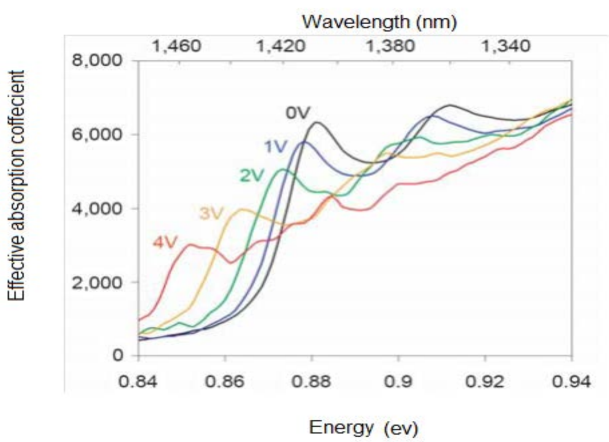


Fig. 3. Change in absorption coefficient spectra at 300K of a heterostructure comprising 10nm Ge quantum wells and 16nm Ge/Si0.15Ge0.85barriers on a relaxed Si0.1/Ge0.9 buffer [15].

3 System Model

The studied configuration of the MEMS controlled ECTL source is presented in Figure 1 with the grating which used as external mirror. The reflected wavelength from the grating is determined by the following expression:

$$\lambda = 2n_{eff}\Lambda \qquad (1)$$

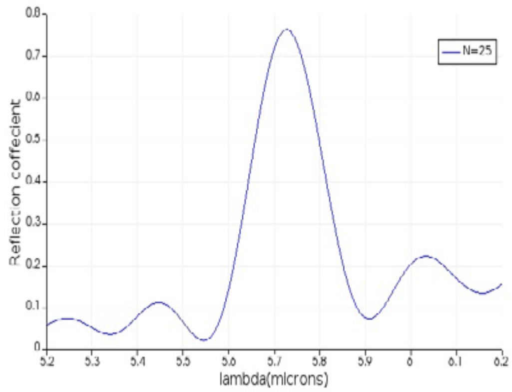
Where Λ is the grating period and n_{eff} is the effective modal index. In our calculations we assume that the output of the laser cavity is a circular Gaussian beam with a spot size of about 12 micrometers. The field distribution at the output of the laser diode can thus be expressed as [19-21]

$$E(x,y) = E_m \exp(-(x^2 + y^2)./w_0{}^2) \qquad (2)$$

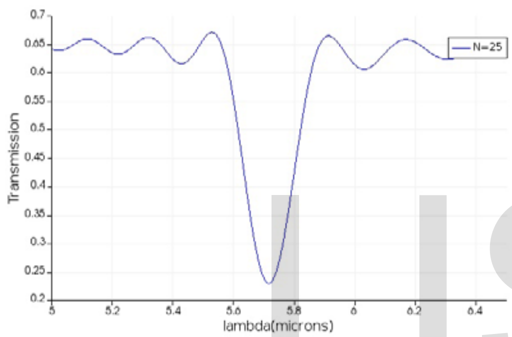
Where E_m is the field amplitude at the center of the beam, w_0 is the spot radius. The beam phase front is assumed at the emitting edge of the laser cavity. The laser source is emitting at different ranges of wavelengths. In our calculation we assume the length of the switching cavity about 10 micrometers and filled with a material with refractive index n = 4 + iκ. The imaginary part κ of the refractive index can be modified with an external control (bias) beam. In the absence of bias, the active material is transparent to infrared photons. In contrast, in the presence of bias, infrared photons are absorbed by an intraband transition in the material which are excited by the bias. The reflection and transmission are studied at two wavelengths. These two wavelengths are calculated based on equation 1. The first one equals 5.67μm while the second equals 1.62μm. For the first wavelength the refractive index of the first layer of grating is 4 while the refractive index of the second layer is taken as 4.1. The value of Λ is calculated using equation 1 and it is approximately equal 0.7μm. In this case, the number of periods (N=25). The values of the second wavelength are as follows: the first and second refractive indices equal 4 and 4.1 respectively, Λ equal 0.2 μm and the number of periods (N=25).

Figure 4 shows the reflection and transmission from grating in the absence of bias (k=0). First, we show the reflection from the grating as a function of the wavelength in the absence of the bias (k=0) as shown in Figure 4 (a). We show the transmission of the structure also in the absence of the bias as shown in Figure 4 (b). It is obvious from the results of Figure 4 (a) that the reflection coefficient increases at the reflected wavelength of the grating and the transmission in Figure 4 (b) decreases at the same wavelength. It is clear from figure 4 that a stop band filter appears at the resonance wavelength in figure 4 (a) while at that resonance notch filter appears in the counterpart figure of transmission. In another case, Figure 5 shows the reflection from the grating at k=0. 2 . This results can be explained as follows:

When the material filling the cavity is in its absorbing state in the presence of bias, the transmission of the grating decreases roughly. If the external cavity is long enough, the incident optical mode is almost completely absorbed in the cavity, then there is almost no transmission. Thus, we observe that such cavity structure can act as an absorptive switch, in which the on / off states correspond to the absence / presence of biasing.



(A)



(B)

Fig. 4. (a) Reflection coefficient of grating with wavelength for N equals 25 in the absence of the biasing. (b) Transmission of grating with wavelength for N equals 25 in the absence of the biasing.

Second case, The reflection and transmission of the grating at lambda= 1.62 micrometers in the absence of the biasing are calculated as shown in Figure 6.

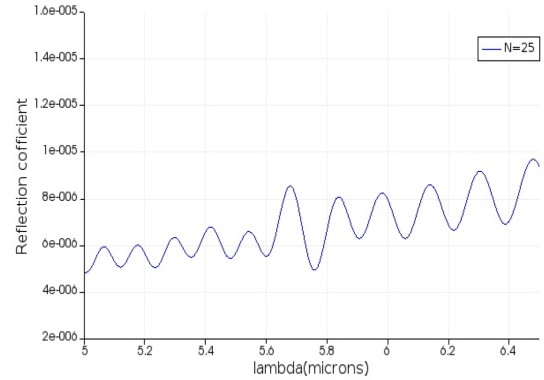
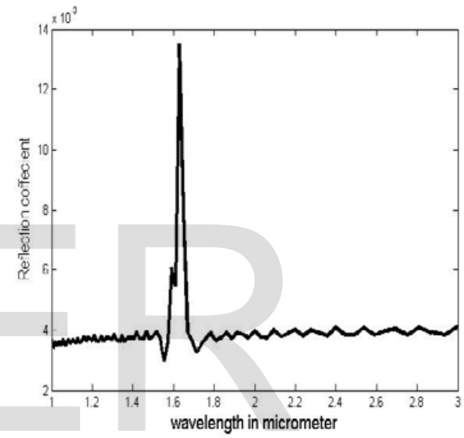
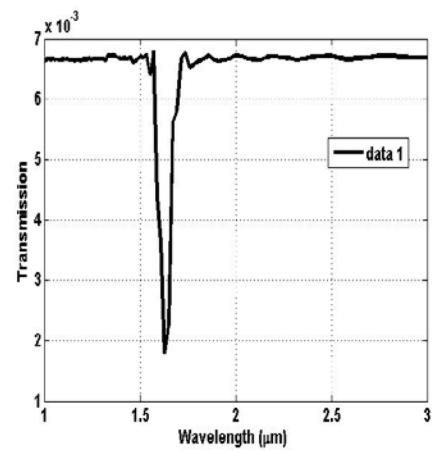


Fig. 5. Reflection coefficient of grating with wavelength for N equals 25 in the presence of the biasing k=0.2.



(A)



(B)

Fig. 6. (a) Reflection coefficient of grating with wavelength for N equals 50 in the absence of the biasing. (b) Transmission of grating with wavelength for N equals 50 in the absence of the biasing.

To insure the concept of absorption of the nonlinear material, Figure 7 plots the reflection coefficient versus wavelength at different values of k. It is clear from this Figure that If the imaginary part (k) of the refractive index is changed gradually or

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make sweeping on the k from 0 to 0.05. We can see a significant value of the reflection when k=0.01 and k=0.02. While for values of k greater than 0.03, the reflection approximately equals 0, as shown in Figure 7.

Finally the electromagnetic power distribution in the switching cavity is presented in Figure 8(a) / 8(b) for presence / absence of bias respectively. We show also the power distribution in the switching cavity in the absence and the presence of the biasing. It is clear that in the absence of biasing, corresponding to the off state where k=0, the incident optical mode is almost completely reflected at specific wavelength as shown in Figure 8 (a). In contrast, in the presence of biasing, corresponding to the on state where k=0.2, which means that all power are completely absorbed by the material as shown in Figure 8 (b). It is obvious in Figure 8 (b) there is no propagation for the power in the switching cavity and thus due to the absorption in the switching cavity. The type of material that used is very important parameter. Ge/SiGe quantum wells is used as an active material in the switching cavity. Due to the weak confinement of the electrons, the absorption of photons with energy equal to the interband transition energy can be reduced at very small values of the transverse electric field. So we observe strong electroabsorption in Ge quantum wells. The photocurrent spectra at room temperature for different diode reverse bias voltages are measured [22].The corresponding effective absorption coefficient spectra are analyzed in Figure 3.

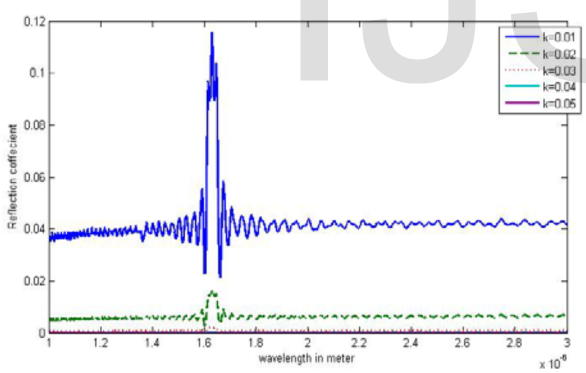

Fig. 7. Reflection coefficient of grating with wavelength for N equals 50 with different values of k.

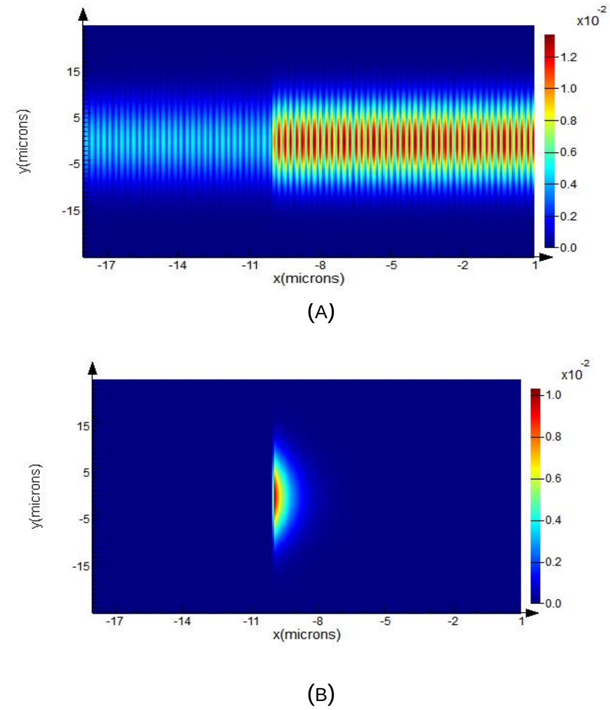

Fig. 8. (a) power distribution in the switching cavity in the absence of the biasing (k=0). (b) In the presence of the biasing (k=0.2).

4 Conclusion

In this paper, we first considered a switch consisting of two cavities laser cavity and switching cavity ended with a grating. The switching cavity filled with an active material whose absorption coefficient can be modified with an external control beam (bias). We found that such structure can act as an absorption switch, in which the on/off states correspond to the absence/presence of biasing. We observe that the material absorb all the power when k increase on 0.03. The active material considered in this paper is Ge/SiGe quantum wells. The properties of this material are studied. Our design opens the door to make controlled ECTL. this structure is useful in many applications in optoelectronic devices such as: optical modulator, MUX / DEMUX.

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References

[1] A. Q. Liu," Photonic MEMS Devices Design, Fabrication and Control", CRC Press, 2009.
[2] O. Solgaard, "Photonic Microsystems: Micro and Nanotechnology Applied to Optical Devices and Systems",Springer New York, 2009.
[3] Mohamed Gad-el-Hak, "MEMS design and fabrication", CRC press,2006.

[4] A. Q. Liu, and X. M. Zhang, "A review of MEMS external-cavity tunable lasers", Journal of Micromechanics and Microengineering, Vol. 17, No. 1, 2007.

[5] A. V. Krasavin, and N. I. Zheludev, "Active plasmonics: Controlling signals in Au/Ga waveguide using nanoscale structural transformations," Appl. Phys. Lett. 84(8), 1416–1418 (2004).

[6] T. Nikolajsen, K. Leosson, and S. I. Bozhevolnyi, "Surface plasmon polariton based modulators and switches operating at telecom wavelengths," Appl. Phys. Lett. 85(24), 5833–5835 (2004).

[7] A. L. Lereu, A. Passian, J.-P. Goudonnet, T. Thundat, and T. L. Ferrell, "Optical modulation processes in thin films based on thermal effects of surface plasmons," Appl. Phys. Lett. 86(15), 154101 (2005).

[8] G. A. Wurtz, and A. V. Zayats, "Nonlinear surface plasmon polaritonic crystals," Laser Photon. Rev. 2(3), 125– 135 (2008).

[9] C. Min, P. Wang, C. Chen, Y. Deng, Y. Lu, H. Ming, T. Ning, Y. Zhou, and G. Yang, "All-optical switching in subwavelength metallic grating structure containing nonlinear optical materials," Opt. Lett. 33(8), 869–871 (2008).

[10] Komarevskiy, Nikolay, et al. "Ultrasensitive switching between resonant reflection and absorption in periodic gratings." Progress In Electromagnetics Research 139,pp. 799-819, (2013).

[11] M. J. Dicken, L. A. Sweatlock, D. Pacifici, H. J. Lezec, K. Bhattacharya, and H. A. Atwater, "Electrooptic Modulation in Thin Film Barium Titanate Plasmonic Interferometers," Nano Lett. 8(11), 4058–4052 (2008).

[12] Changjun Min and Georgios Veronis, "Absorption switches in metal-dielectric-metal plasmonic waveguides," Opt. Express 17, 10757-10766 (2009).

[13] Changjun Min, Pei Wang, Chunchong Chen, Yan Deng, Yonghua Lu, Hai Ming, Tingyin Ning, Yueliang Zhou, and Guozhen Yang, "All-optical switching in subwavelength metallic grating structure containing nonlinear optical materials," Opt. Lett. 33, 869-871 (2008).

[14] A. Taflove and S.C. Hagness, "Computational Electrodynamics: the finite difference time-domain method". Artech House, Boston, 2000.

[15] Y. Kuo, Y. Lee, G. Yangsi, S. Ren, J. Roth, T. Kamins, M. D.A.B, and J. Harris, "Quantum-confined stark effect in ge/sige quantum wells on si for optical modulators," IEEE. J. of Sel. Top. in Quant. Elec., vol. 12, pp. 1503–1513, 2006.

[16] P. Chaisakul, D. Marris-Morini, M.-S. Rouifed, G. Isella, D. Chrastina, J. Frigerio, X. L. Roux, S. Edmond, J.-R. Coudevylle, and L. Vivien, "23 ghz ge/sige multiple quantum well electro-absorption modulator," Opt. Express, vol. 20, pp. 3219–3224, 2012.

[17] Y. Kuo, Y. Lee, G. Yangsi, S. Ren, J. Roth, T. Kamins, D. Miller, and H. J.S, "Strong quantum confined stark effect in germanium quantum well structures on silicon," Nat. Lett., vol. 437, no. 04204, p. 1334, Oct. 2005.

[18] Y.-H. Kuo, Y. Lee, S. Ren, Y. Ge, D. Miller, and J. Harris, "Quantum-confined stark effect electroabsorption in ge/sige quantum wells on silicon substrates," in Lasers and Electro-Optics Society, 2005. LEOS 2005. The 18th Annual Meeting of the IEEE, oct. 2005, pp. 284–285.

[19] Bahaa E. A. Saleh, and Malvin Carl Teich, "Fundamentals of photonics", Wiley, 2007.

[20] Ahmed Fawzy, Osama Elghandour, and Hesham F. A. Hamed, "Diffraction effects on a dual external cavity tunable laser ECTL source", PIERS 2015 Conference in Prague, Czech Republic, 6-9 July, 2015.

[21] Ahmed Fawzy, Osama Elghandour, H., F., A., Hamed.,"Performance Analysis on a Dual External Cavity Tunable Laser ECTL source", Journal of Electromagnetic Analysis and Applications,Vol.7, PP. 134-139.,2015.

[22] Roth, J.E., Fidaner, O., Schaevitz, R.K., Kuo, Y.H., Kamins, T.I., Harris, J.S. and Miller, D.A.,"Optical modulator on silicon employing germanium quantum wells," Optics Express, 15(9), pp.5851-5859,(2007).