Photonics Technology Will Transform the Software and Hardware of Telecommunications

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***Abstract*—Optics is the old and venerable branch of physics that involves the generation, propagation and detection of light. Three key developments achieved are responsible for rejuvenating the optical and its growing importance in modern technology, Laser, low loss optical fibers, transmitting signals. Surge the term Photonics, reflecting the important link between the applied optics and electronics. Electronics and control involves flow of electric charge in a vacuum or matter, involving control Photonics photon in free space or in the field. Both disciplines relate clearly since electrons typically control the flow of photons, and photons control the flow of electrons. Photonics thus the term reflects the importance of nature of the photon of light in the description of the operation of many optical devices. Photonic chip that may be a precursor of the programmable quantum processors can be generated, manipulated and measured entirely on a chip. As a result of these developments, new disciplines and new terms that describe them, electro-optics, optoelectronics, quantum electronics, quantum optics, light wave technology among others emerge. That is why this work with practical applications of this ultra-futuristic technology so that we look at the future of technological development in this field is presented.**

***Index Terms*—optics, photonics, electronics, laser**

I. Introduction

Optics is the old and venerable branch of physics that involves the generation, propagation and detection of light. Three key developments made in the last 40 years are responsible for the rejuvenation of optics and their growing importance in modern technology with a revolution:

- The invention of the laser
- The production of low-loss optical fibers
- Signal transmission

This has taken on increased importance not only in physics but in other sciences, engineering, industry and daily life [1]. As the dominant factor is the discovery and development of many forms of laser. The remarkable properties of the coherent radiation from a laser device have led to a wealth of new techniques in physics and nonlinear optics, cooling and grouping of atoms, electro dynamics of femtosecond optical. It has also engendered a deep understanding of optical radiation involved in coherence and quantum optics and optical coherence techniques have tended a major impact on atomic physics [2]. As a result of these developments, new disciplines emerge and new terms that describe:

- Electro-optic is usually reserved for optical devices in which electrical effects play an important role (laser, electro-optical modulators and switches)
- Optoelectronics typically refers to devices and systems that are essentially electronic in nature, but involve light (light emitting diode devices, liquid crystal display and arrangements of photo detectors).
- Quantum Electronics used in connection with devices and systems that are mainly based on the interaction of light with matter (Laser and used for optical amplifiers and optical wave mixing nonlinear optical devices).
- Quantum Optics studies and coherent quantum properties of light.
- Lightwave technology is used to describe devices and systems that are used in optical communications, optical signal processing and optical metrology.

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Although there is no complete agreement on the precise use of these terms, there is general consensus on its meaning.

II. Experimental Development

In analogy with electronics, in recent years the term Photonics arises, reflecting the important link between the applied optics and electronics, wrought by the growing role that materials and semiconductor devices play in photonic systems [3]. The field of optics is large and continues to maintain high potential for exploitation. Electronics and control involves flow of electric charge in a vacuum or matter, involving control Photonics photon in free space or in the field. Both disciplines relate clearly since electrons typically control the flow of photons, and photon electron flow control. As in modern optics is now given equal emphasis on aspects of photon wavelength of the optical radiation, this Photonics term reflects the importance of both aspects in understanding new developments that the laser has brought to the field, the development of fiber optical and semiconductor technology for optical emitters and detectors [4]. Thus the term Photonics reflects the importance of the nature of photon of light in the description of the operation of many optical devices.

III. Results and Discussion

Theoretical basis of photonics

A. *Wave Equations and Non-Linear Anisotropic*

The electric displacement vector birthday in the media:

$$D(r,t)=E_0E(r,t)+P_L(r,t)+P_{NL}(r,t) \qquad (1)$$

Operating analogously to the isotropic case

$$\nabla^2E-\nabla(\nabla\bullet E)-\frac{1}{c^2}\frac{\partial^2E}{\partial t^2}-\mu_0\frac{\partial^2PL}{\partial t^2}=\mu_0\frac{\partial^2P_{NL}}{\partial t^2} \qquad (2)$$

Note that the nonlinear source term contribution acts as:

- In the linear regime is necessary that: PNL -0
- There are situations in which the dielectric susceptibility tensor depends on the electric field E. This gives rise to another kind of nonlinearities which cannot be described by a nonlinear polarization.

$$n_0=\sigma I_0(N_{D_0}-N_{A_D}^-);\frac{\partial n_0(t)}{\partial t}\approx\frac{\partial N_{D_0}^+}{\partial t};N_{D_0}^+\approx N_A^-$$

- One of the best examples is not photorefractive nonlinearity.
- In this case: $\varepsilon L=\varepsilon L(E)$

B. *Medium Crystal Symmetry*

- Crystalline materials can be classified into 32 classes crystal point groups or grouped in seven crystallographic systems:
- Cubic, trigonal, tetragonal, hexagonal, orthorhombic, monoclinic and triclinic[5].
- From the optical point of view any crystal belongs to one of the following 3 groups: isotropic, uniaxial, and biaxial.
- Classification is determined by the symmetry of the tensor diagonalizable:

$$\varepsilon L=\varepsilon_{ij}^L$$

- The principal axes of the tensor are designated as principal dielectric axes.
- In a non-dissipative medium density electric power inside thermodynamic equilibrium conditions is:

$$U_E=\frac{1}{2}E*D=\frac{1}{2\varepsilon_0}\left(\frac{D_X^2}{\varepsilon_X}+\frac{D_Y^2}{\varepsilon_Y}+\frac{D_Z^2}{\varepsilon_Z}\right) \qquad (3)$$

- The main axes are associated with the index ellipsoid Fig. 1:

$$\frac{X^2}{s_x}+\frac{Y^2}{s_y}+\frac{Z^2}{s_z}+1 \qquad (4)$$

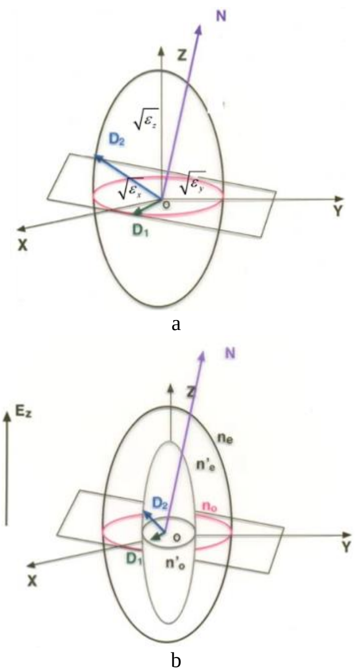


Figure 1. a. Ellipsoid of indices, b. Special case: Media uniaxial.

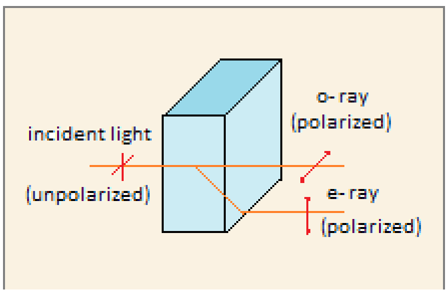


Figure 2. Interaction of light with a medium birefringent.

Degree of birefringence:

$$\eta_e=\sqrt{\varepsilon_{\parallel}}\ ;\ \eta_0=\sqrt{\varepsilon_{\perp}}\ ;\ \Delta_\eta=\eta_e-\eta_0 \qquad (5)$$

C. *Electro-Optical Effect Linear and Quadratic*

- Certain materials change their optical properties when subjected to electric fields.

- Electro-Optical Effect

The change that occurs in the refractive index as a result of applying a constant or alternating electric field at lower frequencies. Birefringence of the medium was changed in Fig. 2. The variation of the refractive index n due to the application of the field is Electro-optical effect linear and quadratic Table I.

$$\Delta(\frac{1}{n^2}) = rE + gE^2 \tag{6}$$

The first term corresponds to the linear electro-optic effect Pockels

The second term corresponds to the quadratic electro-optic effect or electro-optic Kerr effect is a non-linear third-order process.

Voltage necessary to produce the Pockels effect is an order of magnitude lower than needed for producing quadratic effect[6].

TABLE I. SOME CONSTANTS OF ELECTRO-OPTICAL

Some		Electrooptical		Constant
Material	Cystalsymmetry	r(10^{-12}m/V)	λ(μm)	Refractiveindex
$LiNbO_3$	3m	r_{13}= 8.6 r_{33}= 30.8 r_{22}= 3.4 r_{51}= 28	0.63	n_x = n_y= 2.286 n_z= 220
$LiTaO_3$	3m	r_{13}= 7.9 r_{33}= 35.8 r_{22}= 1 r_{51}= 20	0.63	n_x = n_y= 2.176 n_z= 2.180
GaAs	43m	r_{41}= 1.2	0.9	n_x=n_y=n_z= 3.42
HgS	32	r_{11}= 3.1 r_{41}= 1.4	0.63	n_x = n_y= 2.885 n_z= 3.232
CdS	6mm	r_{13}= 1.1 r_{33}= 2.4 r_{51}= 3.7	0.63 0.63 0.59	n_x = n_y= 2.46 n_z= 2.48
KDP	42m	r_{41}= 8.6 r_{63}= 10.6	0.55	n_x = n_y= 1.51 n_z= 1.47
ADP	42m	r_{41}= 28 r_{63}= 8.5	0.55	n_x = n_y= 1.52 n_z= 1.48
SiO_2 (Quartz)	32	r_{11}= 0.29 r_{41}= 0.2	0.63	n_x = n_y= 1.546 n_z= 1.555

D. *Matrices Electro-Optics for Crystal Symmetrie*

$$\overset{3m}{\begin{pmatrix} 0 & -r_{22} & r_{13} \\ 0 & r_{22} & r_{13} \\ 0 & 0 & r_{33} \\ 0 & r_{51} & 0 \\ r_{51} & 0 & 0 \\ -r_{22} & 0 & 0 \end{pmatrix}} \overset{43m}{\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ r_{41} & 0 & 0 \\ 0 & r_{41} & 0 \\ 0 & 0 & r_{41} \end{pmatrix}} \overset{42m}{\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ r_{41} & 0 & 0 \\ 0 & r_{41} & 0 \\ 0 & 0 & r_{63} \end{pmatrix}}$$

$$\overset{6mm}{\begin{pmatrix} 0 & 0 & r_{13} \\ 0 & 0 & r_{13} \\ 0 & 0 & r_{33} \\ 0 & r_{51} & 0 \\ r_{51} & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}} \overset{32}{\begin{pmatrix} r_{11} & 0 & 0 \\ -r_{11} & 0 & 0 \\ 0 & 0 & 0 \\ r_{41} & 0 & 0 \\ 0 & r_{41} & 0 \\ 0 & -r_{41} & 0 \end{pmatrix}}$$

E. *Effect Kerr*

It is a third-order process. Own electric field alters the optical properties of the medium. The variation of the refractive index depends on the intensity of the electric field spread in between.

$$n \approx n_0 + \frac{3}{4c\varepsilon_0 n_0} x^{(3)} I \tag{7}$$

$$\Delta n = \frac{3}{4c\varepsilon_0 n_0^2} x^{(3)} I = n_2 I \tag{8}$$

$$n(I) = n_0 + \Delta n(I) = n_0 + n_2 I \tag{9}$$

Initially a homogeneous medium becomes inhomogeneous due to the presence of light, following the same dependency (local) the spatial or temporal wave profile.

It can lead to nonlinear optical phenomena as individual autofocus and optical solutions.

F. *Fundamentals of Photo-Refractory Effect*

Material refractive photo: A means is conductive and electro-optical picture. Their optical properties are characterized by the electro-optical tensor the photo refractive effect is defined by four processes:

- Photoionization Fig. 3: As a result of the intensity of incident light at a particular frequency broadcast. Part of donor impurities is ionized.
- Dissemination: Generation and transport of free carriers in the energy bands (conduction and valence)
- Recombination Fig. 3: Re-trapping of free carriers by the donor impurity.

- Generating an electric field: load redistribution and create a very strong electric field (about 104 V / cm) Fig. 4 Space charge field of refractive index modulation load.

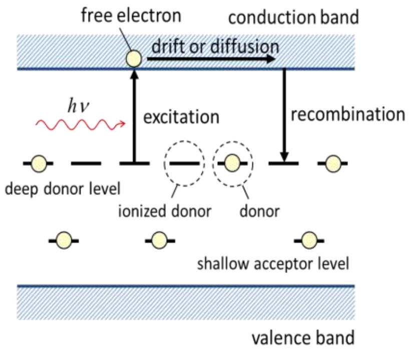


Figure 3. As a result of the intensity of incident light at a particular frequency broadcast. Part of donor impurities is ionized.

Fig. 3 a) Photoionization: Impurities of Fe_2+Fe_3 impurities pass rate +

c) Recombination: The Fe^+_3ions are converted into ions Fe^+_2.

Parameters involved in the process are:

N_D: donor density

N^+_D: density of donor'sphotoionized

N^-_A:photoionizedaceptor density

n: electron density

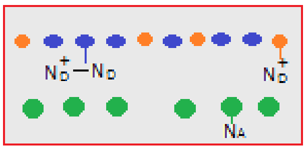


Figure 4. The generating an electric field and the spatial distribution of the loads.

G. *Microscopic Analysis: Network Formation Index*

The space charge field E modulates the refractive index via electro-optical effect:

$$\Delta\left(\frac{1}{n^2}\right)_{ij} = \sum_k r_{ijk}E^k + \sum_k s_{ijk}E^k E^l \tag{10}$$

In most cases the photorefractive materials Pockels effect is responsible for the modulation index. Induces a variation:

$$\Delta n_{ij} = -\frac{1}{2}n_0^3\sum_{k-1}^{3} r_{ijk}E^k \tag{11}$$

No need lighting with very intense beams. Example: low power lasers <1W for modulation index between 10^{-4} y 10^{-3}.When the direction of the electric field is parallel to a principal axis of the crystal Fig. 5 and is operated under conditions of partial coherence can be a scalar unit:

$$\Delta n = -\frac{1}{2}n^3\Delta\left(\frac{1}{n^2}\right) = -\frac{1}{2}n^3 rE' \tag{12}$$

A modulated intensity is obtained:

$$I = I_0\left[+m\cos\left(\bar{K}_{-}\bar{r} - \bar{\Delta}\varphi\right)\right] \tag{13}$$

Refractive index, electro-optical coefficients and magnitude of the effect of some photo-refractive materials [7].

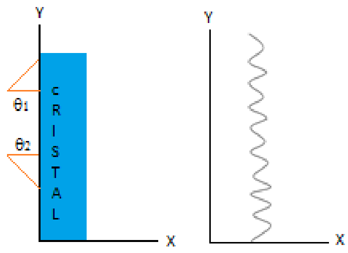


Figure 5. We assume that the diffraction of light by the network is generated index Bragg regime.

- Basic differential equations: Equation Kukhtarev

Formulation introduced by Kukhtarev in 1979, describes a basic model for temporal variation in the number of donors in the presence of a phenomenon photoionization. An initial balance equation is established: Ionized donor variation ratio = donors created - proportion of recombined the proportion of donors generated is proportional to the incident intensity and the number of non-ionized donors. photoionization cross section coefficient defined:

$$G = \sigma I(N_D - N_D^+) \tag{14}$$

The temporal evolution of photoionized donors is:

$$\frac{\partial N_D^+}{\partial t} = G - \frac{n}{\tau}t < 10^{-9}s \tag{15}$$

It also fulfills:

$$\frac{\partial N_D^+}{\partial t} = \frac{\partial N_A^-}{\partial t} \tag{16}$$

First-order solution to Eq. of Khutarev

$$\frac{\partial n_0}{\partial t} + \Upsilon_R n_0 N_{A_D}^- = \sigma I_0(N_{D_0} - N_{A_D}^-); \frac{\partial n_0(t)}{\partial t} \approx \frac{\partial N_{D_0}^+}{\partial t}; N_{D_0}^+ \approx N_A^- \tag{17}$$

$$n_0 = \sigma I_0(N_{D_0} - N_{A_0}^-)\tau_s\left[1 - e^{-\frac{t}{\tau_s}}\right] \tag{18}$$

τ_s half-life of e^-

- Numerical behavior of the temporal evolution of the electron density in the first approximation

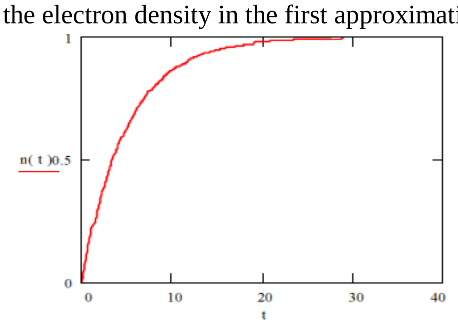


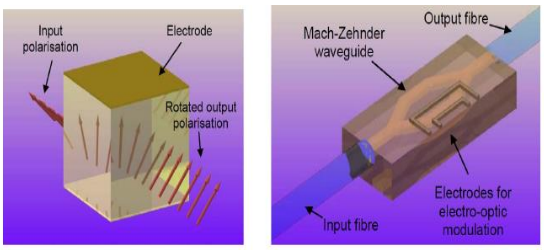
Figure 6. The numerical behavior of the temporal evolution of the electron density in the first approximation.

For a solution of first order linearization is introduced into the system of equations Fig. 6.

It is assumed that the fundamental process parameters have no spatial dependence.

It is assumed that the half-life of the electrons is practically equal to the time of recombination.

Examples of non-linear devices LiNbO3 Fig. 7



a b

Figure 7. a. Electro-optical device. b Electro-optical modulator.

Definition: a liquid crystal is a state of matter intermediate between solid and liquid, see Fig. 8.

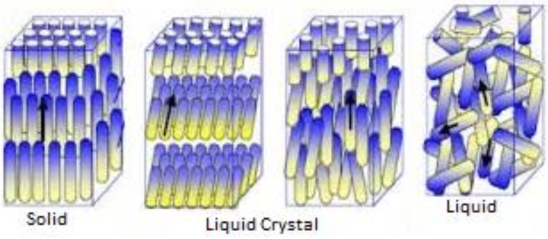


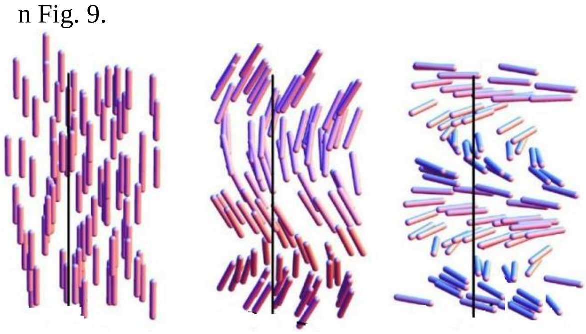
Figure 8. The liquid crystal.

The most common is called nematic liquid crystal:

1) The set of molecules are oriented, but each molecule lacks positional order. The direction of alignment of the molecules defines a nematic director: n.
2) Not ferroelectric.
3) Have a permanent dipole moment.

Electrical properties of liquid crystals:

1) Molecules form a permanent dipole moment.
2) The effect of the action of an electric field E is studied on the structure of the liquid crystal
3) is induced polarization P = (ε-1) ε0 E
4) The degree of polarization depends on the mutual orientations between the electric field and the director n Fig. 9.



Field not parallel n Field parallel n Field perpendicular to n.

Figure 9. The optimal orientation is obtained when the E vector is parallel to the direction of the vector n.

Electric displacement:

Energy per unit volume associated with the field:

$$D = \varepsilon_1 E + (\varepsilon_2 - \varepsilon_1)(\mathrm{nE})\mathrm{n} \tag{19}$$

$$F = -\frac{1}{4}\pi \int D \bullet dE = -\frac{\varepsilon 1}{8\pi} E^2 - (\varepsilon_2 - \varepsilon_1)(\mathrm{nE})^2 \tag{20}$$

Polarization in terms of susceptibility X:

$$\vec{P} = \vec{P}_L + \vec{P}_{NL}$$

$$P = \epsilon_0 \left[x^{(1)} E + x^{(2)} EE + x^{(3)} + \ldots \right] \tag{21}$$

$$P(t) = \sum_{i-1}^{N} pi(t) \tag{22}$$

$$P^{(n)}(\omega) = \epsilon_0 \, x^{(n)}(\omega_1, \omega_2, \ldots, \omega_n) \mathrm{E}(\omega_1) \mathrm{E}(\omega_2) \ldots\ldots \mathrm{E}(\omega_n) \tag{23}$$

For a liquid crystal with linear behavior:

$$\begin{pmatrix} Px \\ Py \\ Pz \end{pmatrix} = \varepsilon_0 \begin{pmatrix} x_\perp & 0 & 0 \\ 0 & x_\perp & 0 \\ 0 & 0 & x_{||} \end{pmatrix} \tag{24}$$

Electric susceptibility tensor of a nematic liquid crystal

$$\begin{pmatrix} P_x \\ P_y \\ P_z \end{pmatrix} = \varepsilon_0 \begin{pmatrix} x_\perp & 0 & 0 \\ 0 & x_\perp & 0 \\ 0 & 0 & x_{||} \end{pmatrix} \begin{pmatrix} E_x \\ E_y \\ E_z \end{pmatrix} \tag{25}$$

$$\vec{\varepsilon} = \varepsilon_0 (\vec{1} + \vec{x})$$

Degree of anisotropy:

$$\Delta\varepsilon = \varepsilon_{||} - \varepsilon_\perp \tag{27}$$

Properties:

Structural changes depending on the temperature and the application of an electron. It confers the ability to operate as an electro-optical device Fig. 10.

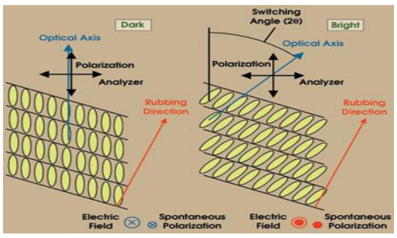
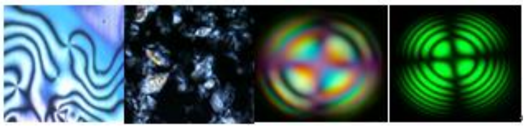


Figure 10. The light modulating liquid crystals.

Textures phasenematic



a b c d

Figure 11. Conoscopic image with: (a). texture of schlieren. (b). homeotropic texture. (C). with white light. and (d). Green light

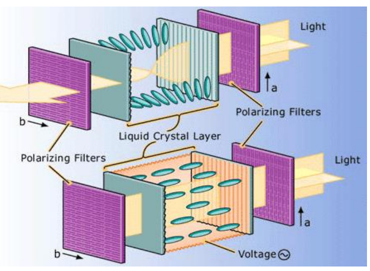


Figure 12. Textures nematic coli cell polarize polarizer twisted nematic electric field textures phase.

Almost flat cell CL, located between two crossed polarizers. Images observed with a microscope Fig. 11 and Fig. 12.

Absorption of photons, see Fig. 13 and Fig. 14.

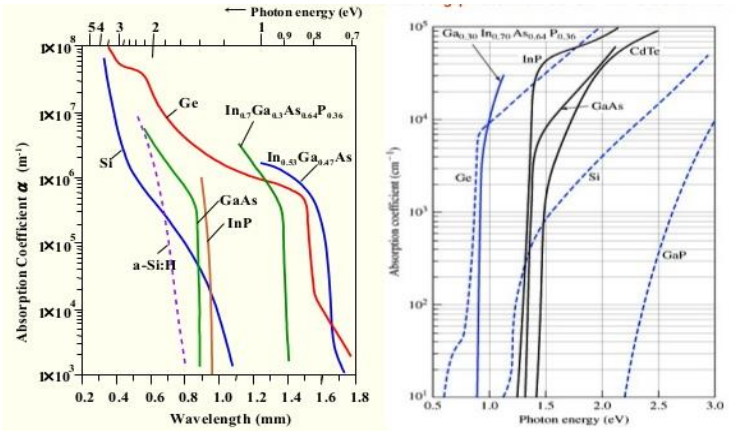


Figure 13. Absorption coefficient (a) vs. wavelength (2) for various semiconductors (Data selectively collected and combined from various sources).

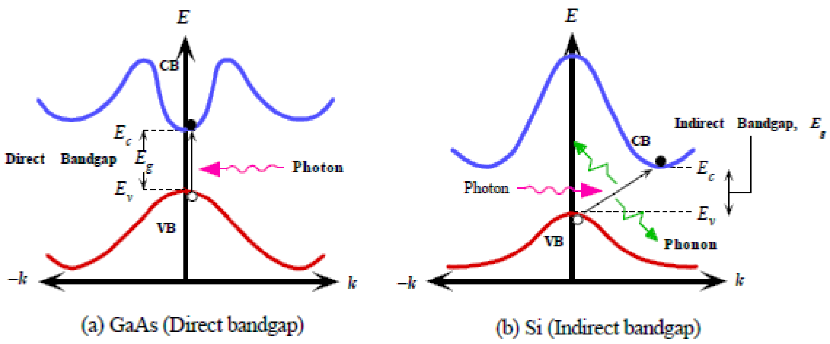


Figure 14. (a) Photon absorption in a direct bandgap semiconductor. (b) Photon absorption in an indirect bandgap semiconductor (VB, valence band; CB, conduction band).

- Fundamental parameters of quantum efficiency and responsivity

Quantum efficiency

$$n = \frac{NumberofEHPgeneratedandcollected}{Numberofincidentphotons} = \frac{\frac{I_{ph}}{e}}{\frac{P_0}{hv}} \quad (28)$$

Responsivity Fig. 14.

$$R = \frac{Photocurrent(A)}{IncidentOpticalPower(W)} = \frac{I_{ph}}{P_0} \quad (29)$$

Responsivity (A/W)

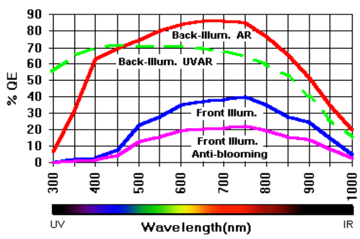


Figure 15. Wavelength (nm) Responsivity (R) vs. wavelength (2)for an ideal photodiode with QE = 100% (i = 1) andfor a typical commercial Si photodiode.

H. Spatial Light Modulators

Object beam modulation [9]:

Operation necessary for storing encoded in 2-D (1 page)

Types of spatial light modular (Spatial Light Modulators, SLM):

Liquid crystals (twisted nematic):

Parameters: frame rate (frame rate): 30 ms.

Spatial resolution: 1.024X1.024 pixels. Pixel Size: 15-8p, m

Ferroelectric crystals: 100p, s, similar spatial resolution.

Deformable mirrors (Deformable Mirror Devices, DMD): 2KHz, 850X600 pixels, high contrast: 800: 1

In general, the sampling operates SLM (discretized) the optical signal (*). The transfer function is:

$$t(x,y) = \sum_{n-1}^{N}\sum_{n-1}^{N} a_{xyz} rect\left(\frac{x}{p} - m\right) rect\left(\frac{y}{p} - n\right)$$

$$a_{xyz} = \{1,0\}; \text{binarizedsignal} \quad (30)$$

Detectors

Charge Coupled Devices (CCD)

Spatial resolution: pixels 1.024X1.024

Quantum Efficiency Fig. 15: 70%

$$P(\bar{r},t)\Delta t = \alpha c S \Delta t \langle \hat{I}(\bar{r},t) \rangle \quad (31)$$

σ: quantum efficiency (photoelectrons / photon)

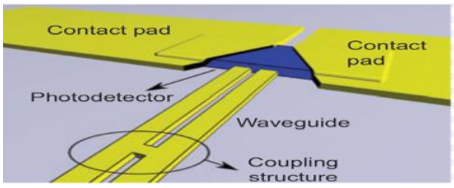


Figure 16. The parameters involved in the quantum efficiency.

Read speed: 15 Mpixels / s, using 64 parallel channels

APS CMOS Fig. 16 (Complementary Metal-Oxide Semiconductor, Active Pixel Sensor)

Developed at the Jet Propulsion Laboratory (Ca, USA)

It is characterized by capturing digital input signals and non-digital and convert them into digital output signals. Pixel size: 5 uM

High speed reading: 524 Mpixels / s

Use silicon microtechnology structure chip.

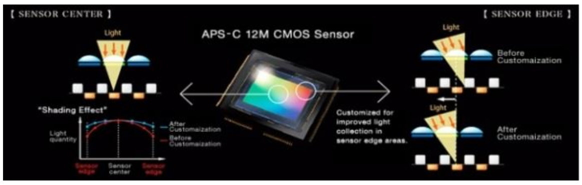


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Figure 17. a. APS CMOS chip structure. b. An enlarged view of the structure. c. Operational response

IV. CONCLUSIONS

In conclusion, photonics is another branch of science which has greatly helped to advance technology as it has many applications, we can say that we are not very accustomed to using in daily life photonic devices, but increasingly photonic applications are more present around us.

The fact that photons to be "lighter" than electrons, cause less heat to dissipate and are not subject to the restrictions caused by the capacitances, inductances and resistances that can be created.

An approximate model for the estimation of non-intrinsic photonic efficiencies heterogeneous photocatalytic reaction systems based on a parameter of photon efficiency independent intrinsic type reactor was developed; and the product of two functions, one photon energy absorption and other absorption correction effect of catalyst loading, and the geometry of the initial substrate concentration. The postulates were validated using dichloroacetic acid as a standard substance. It was found that the model is highly predictive for photonic efficiencies photodegradation processes of this component with smaller relative errors 1.8%

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