PHOTONICS-SCIENCE AND ENGINEERING OF THE LIGHT

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Rezumat. *Studiul prezintă apariția și dezvoltarea fotonicii în contextul fenomenelor complexe de generare, amplificare și detecție a radiațiilor electromagnetice din spectrul optic, unde fenomenele specifice opticii, coerența atomică și autoorganizarea sunt reprezentative. Aplicațiile inginerești ale fotonicii în toate domeniile de activitate sunt prezentate în strânsă relație cu dezvoltarea fără precedent a tehnologiei, culminând cu remarcabilele realizări din domeniul nanotehnologiilor. De aceea, problema armoniei universale a naturii găsește o abordare dinamică și, în special, problema fundamentală a cunoașterii capătă noi dimensiuni.*

Abstract. *The study presents the emergence and the development of photonics in the context of the complex phenomena of generation, amplifying and detection of the electromagnetic radiations from the optical spectrum, where the phenomena of specific optic and atomic coherence self-organization are representative. The engineering applications of photonics in all the fields of activity are presented in a close relationship to the unprecedented technological development culminating in the remarkable accomplishments from the field of nanotechnologies. Thus, the question of the universal harmony of nature finds a dynamic approach, and especially this fundamental problem of knowledge acquires therefore new dimensions.*

Keywords: Photonics, self-organization, engineering applications of photonics, nanotechnologies, universal harmony

1. Introduction

In 1900, Max Planck introduced in physics the assumption of “quanta” that highlight the discreet exchange of energy in nature, the linkage between energy of quanta and frequency of electromagnetic radiation which it represents being given by the Planck constant. Based on this hypothesis Planck explained properly spectral distribution of the black body radiation.

In 1905, Albert Einstein postulated the existence of the “photon” in the form of a particle of light with energy $\varepsilon = \hbar\omega$ and momentum, managing to correctly explain the photoelectric effect and the Compton Effect.

The hypothesis of photons in physics provides an essential element of quantum physics, the dual nature wave-corpuscle of the radiation, which was extended in 1921 by Louis de Broglie and for material particles.

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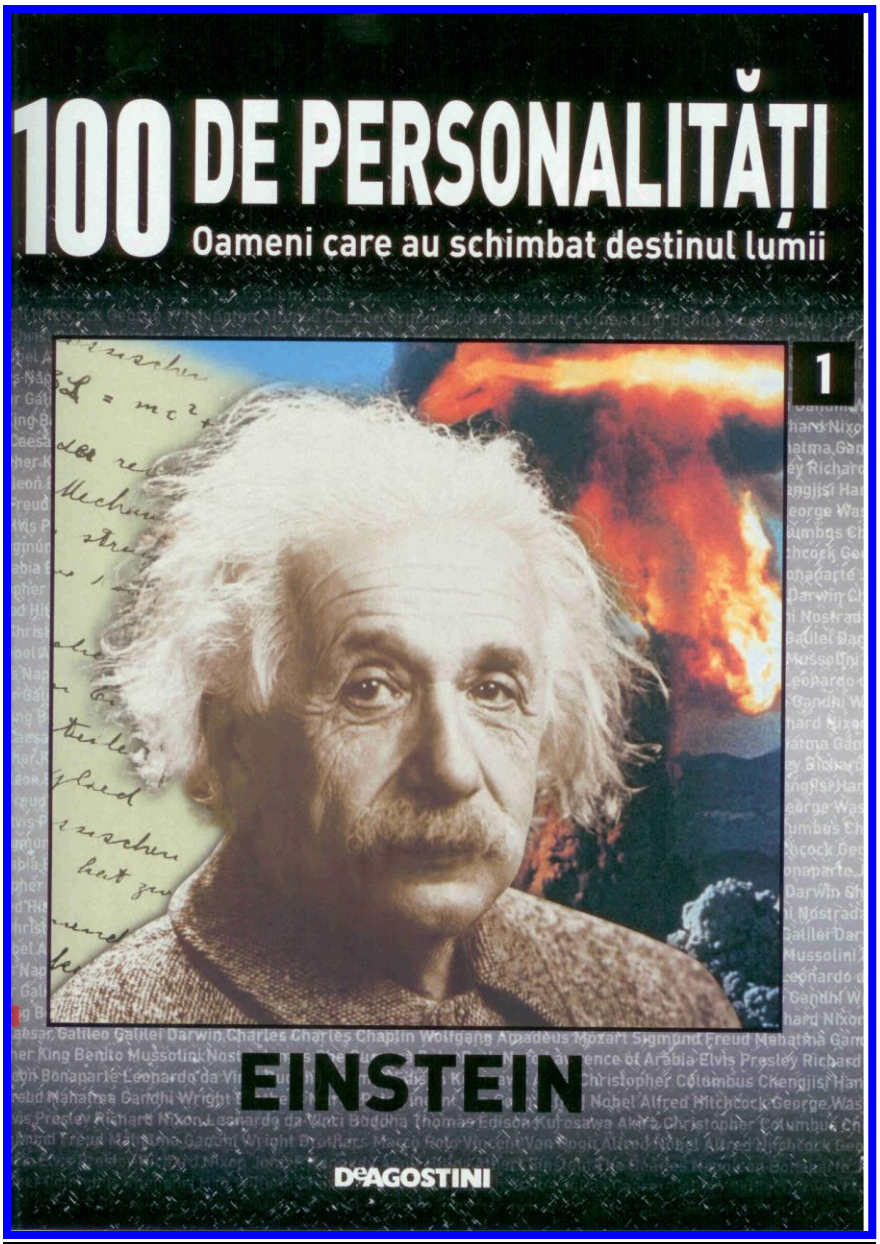
Also, in the year 1905, Einstein elaborated the *theory of relativity* in which the postulate of the *constant speed of light* had fundamentally changed the conception on the time and space. The development of the atomic physics through the formulation of the Bohr's atomic model in 1913, involving the existence of the stationary states of the atomic systems, related to the quanta assumption of Planck and photon hypothesis of Einstein, contributed to the development of a new theory on the interaction of radiation with the substance – the quantum theory.



Einstein discovered in the year 1916 the *stimulated emission* of the radiation as a process by which the electromagnetic radiation can be amplified achieving coherent radiation as a result of the atom behavior as a controlled actively oscillator in such an interaction.

Stimulated emission represents only the necessarily condition for the amplification of radiation. Calculations showed also the need to create in a system an inversion of population, which violate the Boltzmann is law of the systems distribution on the atomic energy levels.

It had been created what we call today a *dissipative structure* allowing photons self organization by the appearance of the correlations between them, behavior characteristic to optical coherence. The system must be forced to operate far from the thermal equilibrium, with a quantity of energy transferred to system for creating the inversion of population, the dissipative processes due to constraints on the system being inevitable.

Since the creation of the inversion of the population is not possible in the normal conditions, the realization of the laser, namely a device for light amplification by stimulated emission of radiation has delayed until 1960, in spite of the progresses of quantum physics, due to the great personalities as Louis de Broglie, Werner Heisenberg, Max Born, Erwin Schödinger, Paul Dirac, Wolfgang Pauli, Enrico Fermi and others.

Achievements important of the physics such as control of the nuclear fission reaction or the discovery of the television and of the transistor are previously to the laser, which shows comparatively the major difficulty which had be removed as the atomic system to be obliged to receive energy as to pass in a state with inversion of population.

First appearance of the ruby laser in 1960, using the atomic properties of the meta stable levels of Cr^{3+} ion for the creation of the population inversion and optical resonant cavity for ensuring the positive reaction in the coupled system, atomic oscillator consisting of active medium and optical oscillator consisting of resonant optical cavity had represented a decisive moment in the born and development of the *Photonics* as the field of the science and engineering of light, by possibility of the photons control concerning all them properties of which the coherence being essential.

We can exemplify in this regard two of the most spectacular developments.

- Developing of the lasers devices in entire optical spectrum, from ultraviolet to microwave, with the unlimited possibilities of applications in all fields.

- The emergence and development of optical systems for processing and transmission of information – significantly being the transmissions of data and optical communications.

The construction of the Romanian first laser took place at the Institute of Atomic Physics (IFA) in 1962, by Professor Ion Agârbiceanu, who inaugurated in Romania the *"era of photonics",* with remarkable developments in IFA as well as and in various universities and institutes in the country.

2. Photonics area of the science and technology of information

Photonics represents a step of maturity of science and engineering of light, with all possible interconnections, as determined by the progress of science and technology at the beginning of the millennium.

Keywords such as: laser, optical and atomic coherence, quantum or nonlinear optics, optical modulation or demodulation, photo detection, integrated optics, optical guide, optical bi-stability, coherent optical amplifier, synergetic, dissipative structure, self organization, super radiance, soliton, self induced transparency, mode - locking, Q-switch, quantum well, quantum confinement, photonic crystals, lasers cascade, nanotechnology etc., suggests us the fascinating, mysterious and delicate area of the Photonics.

To highlight the need of photonics it is enough to mention a few issues regarding the unprecedented development of the information technology, which determines global changes:

• if in a century so far have been installed in the world the first 700 million phone lines, the number of these lines will be doubled in the next 15 to 20 years, which means a 630,000 phone lines each week;

• if the present world has 200 million cable TV subscribers in the next 15 to 20 years their number will increase to 300 million. The phenomenally increasing of the Internet is illustrated as follows:

• 5 million e-mail messages in the following minutes;

• Internet traffic doubling in the next 100 days;

• over 100 million new users of Internet networks in each year;

• over 37 million people daily use over 830 million Web pages on the Internet.

To meet these requirements, the only solution is the Photonics. Communications systems on optical fibre have developed explosive in recent years: from the rate of 2.5 Gb/s în1992 at the rate of 40Gb/s in 1996 and beyond

100Gb/s in the near future. For example, cable TRANSPACIFIC (TPC-6) was designed to carry data with speed of 100 Gb/s.

Although the few years ago was not possible to imagine that light carrier can transmit data of the rate of 1 Tb/s, have already been conducted experiments with transmission speeds of 320Gb/s on a single carrier frequency and transmission on a single fiber the rate of 328 Gb/s using the multiplexing techniques.

But optical communications is only one example of the increasingly role of photonics today. During the paper this role will be demonstrated with other applications and developments.

3. Models and equations

A synthetic presentation of the most important is given in Table 1.

Table 1. Models and equations

Type of analyze	Models and formalisms	Description possibilities
I. QUANTUM	-Quantum Langevin equations -Matrix density equations -General Fokker-Planck equations	-The width of the spectral line, fluctuations, coherence, photon statistics
Meaning over the pumping and relaxation processes		
II. SEMI-CLASSICAL	-Based on quantum equations -Own equations (Lamb theory, etc.)	Frequency changes, modulation effects ultra short pulses, photon echo, super radiance, harmonic generation, other nonlinear effects, time dependence of population pulsations etc.
Neglecting of all phase relations		
III. THERMODYNAMIC	-Based on semi classical equations -Own equations (balances for populations and photons).	The threshold condition, output power, giant laser pulses, laser cascades, the coexistence and competition of the oscillating modes, etc.

Below is presented also a schematic correlation between optical and atomic coherence phenomena (Fig. 1).

A representative formalism for modeling of the coherence phenomena is given by Maxwell-Bloch equations describing the interaction of electromagnetic fields with an atomic two-level medium in a cavity Fabry-Perot.

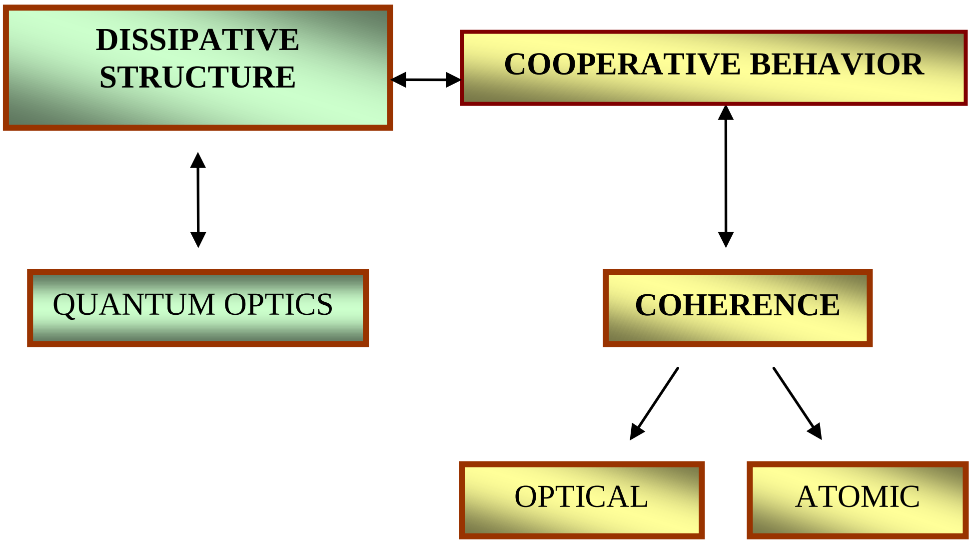


Fig. 1. Schematic correlation between optical and atomic coherence phenomena.

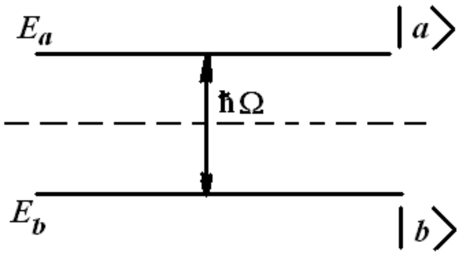


Fig. 2. A two-level atomic system.

Let us consider a two level atomic system designed by $|a\rangle$ and $|b\rangle$ states (Fig. 1), and $\hat{H} = \hat{H}_A + \hat{W}$ the Hamiltonian, $\hat{H}_A$ being the atomic Hamiltonian and $\hat{W}$ the interaction part of $\hat{H}$. For electric dipole transitions, we can write:

$$\hat{W} = -e\,x\,E(\vec{r},t) = \hbar\hat{V} \tag{1}$$

$\vec{r}$ being a point in the atom and $\hat{V}$ is a normalized interaction operator.

The interaction of the atomic system with a resonant coherent field determines an atomic transition having the frequency:

$$\Omega = \frac{E_a - E_b}{\hbar} \tag{2}$$

E_a and E_b being the energies corresponding to the states $|a\rangle$ and $|b\rangle$.

Under the influence of perturbation, in the system being initial in the state $|a\rangle$ at the moment $t = t_0$ can occur induced transitions in the state $|b\rangle$, so that at a moment $t > t_0$, the atomic wave function can be expressed as a linear superposition of the wave functions $\Psi_a(x)$ and $\Psi_a(x)$ as:

$$\psi(x,t) = a(t)\psi_a(x) + b(t)\psi_b(x) \tag{3}$$

Consequently, the corresponding Schrödinger equation become:

$$i\hbar \frac{\partial \psi}{\partial t} = \left(\hat{H}_A + \hat{W}\right)\psi = i\hbar\left[\dot{a}(t)\psi_a(x) + \dot{b}(t)\psi_b(x)\right] \tag{4}$$

The superposition of states (3) represents a new approach which takes into account the possibility of atomic cooperation in the developed formalism.

By considering the column vector:

$$|\psi_t\rangle = \begin{bmatrix} a(t) \\ b(t) \end{bmatrix} \tag{5}$$

for the equation (3) and introducing the vector $\vec{r}$ with the components:

$$\begin{aligned} r_1 &= ab^* + a^* b \\ r_2 &= i\left(ab^* - a^* b\right) \\ r_3 &= |a|^2 - |b|^2 \end{aligned} \tag{6}$$

the equation of motion for the vector $\vec{r}$ take the form:

$$\frac{\mathrm{d}\vec{r}}{\mathrm{d}t} = \vec{\omega} \times \vec{r} \tag{7}$$

The vector $\vec{\omega}$ has the components determined by the interaction operator $\hat{V}$ so that:

$$\left\langle \hat{H} \right\rangle = \frac{1}{2}\vec{\omega}\vec{r} \tag{8}$$

By analogy with the spin systems, described by the Bloch equations, the vector $\vec{r}$ is called *pseudo spin* and is responsible for atomic coherence between the atoms of the ensemble, so must be considered in the Maxwell-Bloch equations correspondingly.

For the *n* - photon interactions, Maxwell-Bloch equations have the form:

$$\begin{aligned} \dot{P} &= -\gamma_\perp P + 2gE^n D \\ \dot{D} &= -\gamma_{||}(D - D_0) - g\left[\left(E^*\right)^n P + E^n P^*\right] \\ \dot{E} &= -K(E - E_I) + ngP\left(E^*\right)^{n-1}. \end{aligned} \tag{9}$$

In the above equations, P correspond to the operator of total atomic polarization, D to the operator of total atomic population inversion and E to the operator of the cavity field; $E_I = \frac{E}{K}$ is a quantity proportionally with amplitude of the incident field *E*, g is the coupling coefficient corresponding to the matrix elements for multiphoton transitions (with n photons), D_0 is the population inversion due to incoherent pumping of the atoms ($D_0 = N/2$ for total inversion) and *K* is the decay rate for the cavity field. The decay rate of the collective atomic dipole is here denoted by $\gamma_\perp$ and the decay rate for the atomic population inversion is denoted by $\gamma_{||}$.

The Maxwell-Bloch equations are general for modeling the interactions:

- n - photon laser $(E_I = 0, D_0 > 0)$;
- n - photon laser with injected signal $(E_I \neq 0, D_0 > 0)$;
- n - photon optical bistability $(E_I \neq 0, D_0 < 0)$.

To study the indirect interaction of the atoms in the presence of the radiation field we define the *pseudo angular momentum* $\langle \vec{R} \rangle = \frac{1}{2}\vec{r}$ under $\vec{r}$ is the pseudospin vector defined above.

For an ensemble of *N* atoms, the quantities

$$\hat{\mathsf{R}}_i = \sum_{k=1}^{N} \hat{R}_i^k \qquad (i = 1,2,3) \tag{10}$$

represent the components of the operator “pseudo angular momentum collective”, the commutation relations of the angular momentum being satisfied.

Let be N_+ the atomic systems in the state $|a\rangle$ and N_- the atomic systems in the state $|b\rangle$. The equation with *eigen* functions and *eigen* values of the Hamiltonian operator $\hat{H}_0$ has the form:

$$\hat{H}_0|\psi\rangle = \hbar\omega_0 \hat{\mathsf{R}}_3|\psi\rangle = m\hbar\omega_0|\psi\rangle \tag{11}$$

where $m = \frac{N_+ - N_-}{2}$ and $N = N_+ + N_-$ so that:

$$|\psi\rangle = \prod_{i=1}^{N} |\psi_i\rangle = (+ + - - ... + - +) \tag{12}$$

The *eigen* value $m\omega_0$ of the $\hat{H}_0$ is degenerate of the order g_m:

$$g_m = \frac{N!}{(N_+)!(N_-)!} = \frac{N!}{\left(\frac{N}{2}+m\right)!\left(\frac{N}{2}-m\right)!} \tag{13}$$

corresponding to the possibilities of excitation of the N atomic system, independently of what atoms are excited. The maximum degenerescence is obtained for $m = 0$ so, according to expression (12) exist a great number of final states compatible with a given initial state.

We design by $|r, m\rangle$ the common states of the commutative operators $\hat{R}^2$ and $\hat{H}_0$ according to the equations:

$$\hat{R}^2 |r, m\rangle = r(r+1)|r, m\rangle \tag{14}$$

$$\hat{H}_0 |r,m\rangle = \hbar\omega_0 \hat{R}_3 |r,m\rangle = \hbar\omega_0 m |r, m\rangle \tag{15}$$

which define the quantum number r, named *cooperative quantum number*, similar to the internal atomic quantum number j of the atom. We have put into evidence in this way *the atomic Dicke states*, corresponding in the field theory to the *Fock states*.

By considering the complete set of the Dicke states, we can evaluate the spontaneous emission rate $I(r, m)$ of the system being in the state $|r, m\rangle$, which is proportional with the square of the matrix element $\langle r, m|\hat{R}^+|r, m\rangle$. It results:

$$I(r, m) = (r+m)(r-m+1)I_0 \tag{16}$$

where I_0 is the spontaneous emission rate for a single excited atom $(r = m = 1/2)$.

If all atoms are excited initially $(r = m = N/2)$, one obtains:

$$I(N/2, N/2) = NI_0 \tag{17}$$

that is the atoms radiate independently, without interference effects.

Four maximum g_m, it results $m = 0$ or $m = 1$ and for $r = N/2$ one obtains:

$$I\left(\frac{N}{2}, 0\right) \cong \frac{N^2}{4} I_0 \tag{18}$$

This kind of states having the radiation rate proportional with N^2 is called

superradiante states and correspond to the in phase oscillation of all excited atoms, resulting in a huge electric dipole moment:

$$\vec{P} = N\vec{d} \tag{19}$$

where $\vec{d}$ is the electric dipole of the individual atoms. This behavior is a cooperative one, the coherence between atoms being demonstrated. The photon echo is a very interesting effect of the atomic coherence which can be experimentally proved. The self-induced transparency of the substance is another example of manifestation of the atomic coherence, the optical delay lines in the seconds range being an important application.

4. Optical transmission systems

The block diagram of an optical system for information transmission is given in figure 2.

Fig. 3. Block diagram of an optical communication system.

In contrast with the microwave carrier frequency which is in the range 1 - 10 GHz, the optical carrier frequency is typically of the order of 100 THz, so the information capacity of the optical transmission systems is larger by a factor of 10^4.

Taking into account that only about 1% of the carrier frequency can be used as modulation bandwidth, it results a potential of information bit rate of 1 Tb/s that is a strong motivation to develop the light wave systems.

The optical transmitter role, to convert electrical signal into optical signal capable to be launched onto optical fiber on the channel is realized mainly by modulation of an optical carrier obtained from an optical source (usually a laser device) with the electrical input data in a suitable format (analog, digital or pulse modulation type).

Semiconductor laser diodes in the quantum well structure (QWL) are used preponderantly as optical sources being compatible with optical fiber channel so that the directly modulation by injection current is preferable in this case although an external electro-optical or acoustic-optical modulator is used in different applications.

In the future, the bit rate limitation by electronics can be avoided by complete optical transmission systems implementation of which are in the experimental study today.

The transmission channel is represented for optical communications systems by fiber-optic, the free-space channel applications being limited by atmosphere scattering.

Five generation of light wave systems was developed; the third generation use 1,53 μm systems, because the loss of silica fibers is minimum at that wavelength (less than 0,2 dB/km), the fourth generation of light wave systems make use of coherent amplification with erbium doped fiber amplifier (EDFA) and wavelength division multiplexing (WDM) for increasing the distance of transmission respectively the bit rate and, the fifth generation is concerned with optical soliton transmission systems to solve the fiber dispersion problem.

Particular attention must be paid to the erbium - doped fiber amplifier (EDFA) because their impact on the transmission systems was substantial.

In contrast to conventional optical repertoires where the signal received must be converted to electrical form for amplification then reconverted back into optical form, in an optical amplifier (EDFA type), the optical signal is amplified directly. Input signal consisting of photons with energies matching the $^4I_{13/2} - ^4I_{15/2}$ energy gap of the erbium ions in a glass host material of the fiber will stimulate the photons emission, in the medium having population inversion. The level $^4I_{13/2}$ is metastable so that the amplification is produced coherently by a laser mechanism.

The pump wavelengths frequently used for EDFA pumping are 980 nm and 1480 nm since they are high efficient and are obtainable also from a laser diode as the modulated laser signal having 1553 nm.

The optical receiver rolls to convert the optical modulated received signal into original electrical as output is realized by a photo detector and a demodulator, with afferent electronics. Compatibility with the whole systems is assured usually by large bandwidth semiconductor photodiodes operating at the transmission wavelength. The demodulator structure depends on the used modulation format at the transmission point.

Various sources of noise as quantum noise, shot noise, thermal noise, can corrupt the transmitted signal so that the performance of a light ware system are limited. Signal to noise ratio (SNR) or bit error probability (BER) are important parameters which characterize the performance of a transmission system. Corresponding to the information theory, the channel capacity of a communications system with noise is given by:

$$C = \Delta f_{ch} \log_2\left(1 + \frac{S}{N}\right) \tag{20}$$

where Δf_{ch} is the bandwidth of the transmission, N is the average power of noise and S is the average power of signal. Equation (20) estimates the maximum value of the channel capacity, in the best conditions of operation. Practically, the channel capacity is limited by the formula:

$$C \le C_{\max} = \left(\frac{S}{N_0}\right)\log_2 e \tag{21}$$

where N_0 is the spectral density of shot noise, which is present even in a perfect system, so the channel capacity cannot be increased indefinitely by increasing Δf_{ch}.

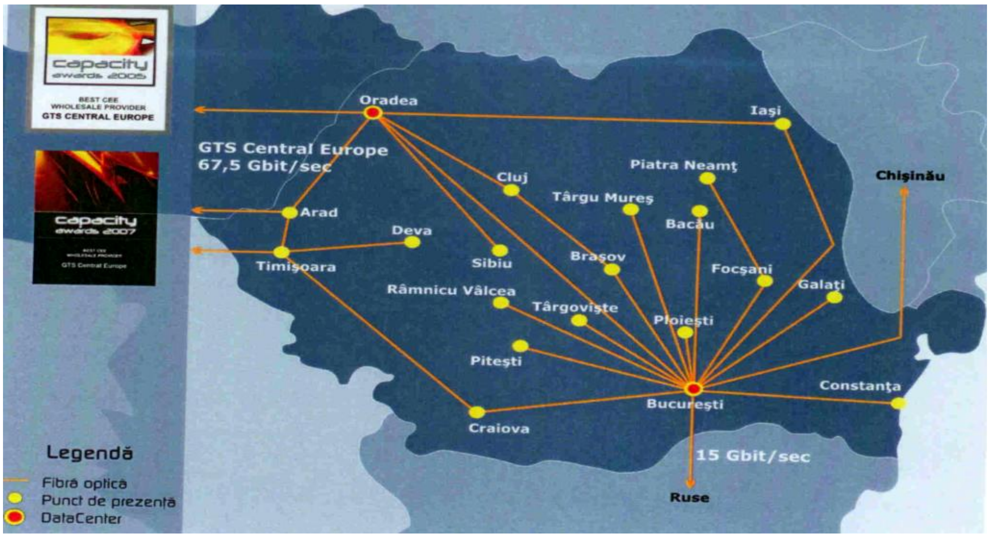


Fig. 4.

In Romania, Photonics is a strong developing process as partner of several European programs. For example: optical fibre network, integrated in the European communications system (Fig. 4 and Fig. 5).

GTS Telecom operates at the European level an external network at 82.5 Gbit/s.

The external network provide interconnection with the infrastructure group GTS Central Europe being implemented by own fiber-optic circuits through their presence points in Arad, Oradea, Timişoara and Giurgiu.

At the national level GTS Telecom operates a network of MPLS type, at 37.5 Gbit/s. with points of presence (POPs) open in the cities: Arad, Bucharest, Bacău, Braov, Cluj, Craiova, Constanţa, Deva, Focşani, Galaţi, Iasi, Oradea, Piatra - Neamţ, Ploieşti, Piteşti, Râmnicu-Vâlcea, Sibiu, Târgovişte , Timişoara, Târgu-Mureş. National network topology areof a "ring" type, with 100% redundant capacity in each node (POP) being provided IP connectivity services implemented by the company.

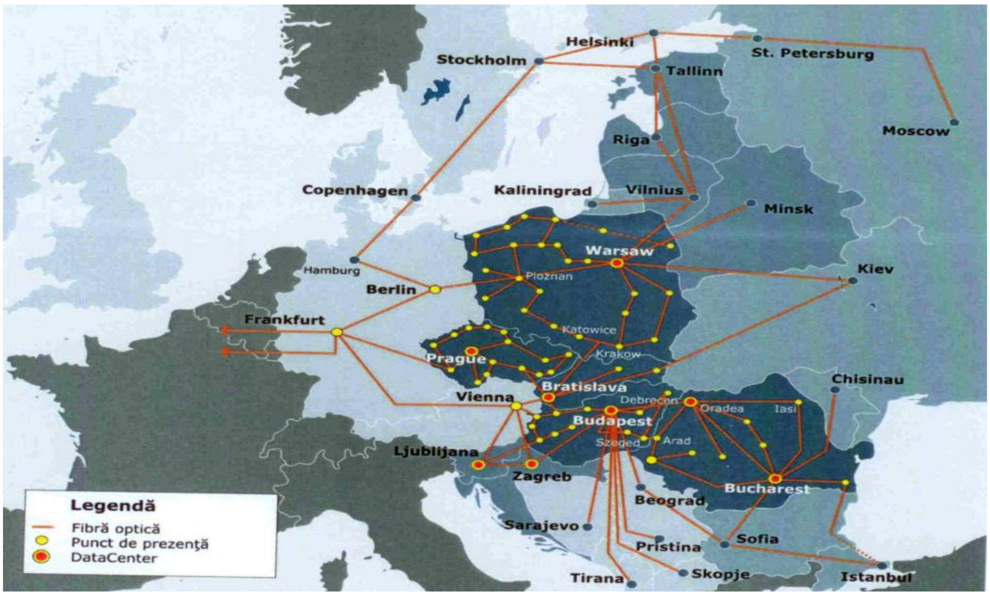


Fig. 5.

In Bucharest, GTS Telecom has and operates a metropolitan network of MPLS type of optical fiber with a transport capacity of 15 Gbit /s by which the company provide full coverage for the city of Bucharest.

5. Nanophotonics. Quantum well lasers

The term nanotechnology was introduced in 1974 by NORIO TANIGUCHI professor at the University of Sciences in Tokyo with referee to the silicon processing at the submicron scale.

Today, nanotechnology refers to the conception, design and development of devices with small dimensions in the range of 100 nm, that is close to the limit of physical technological achievement (a semiconductor chip is 90nm, a virus 75-100nm, a protein molecule 5-10 nm, DNA - 2nm.)

After MAURO FERRARI professor at the University of Texas, the operational definition of nanotechnology comprises three conditions:

- nano-scale sizes;
- artificial nature;
- existence of properties due to the nanoscopic size.

In the evolution of the semiconductor laser, quantum well laser represents an example of nanotechnology application in photonics.

The active zone of the quantum well lasers is realized as a periodical structure of two different semiconductor materials each with a thickness of a few single-atom layers, with different energy gap, but with the crystalline lattice of the similarly materials.

The spatial periodicity of the conduction and valence bands determines a periodic structure of the potential wells separated by corresponding barriers, in the both conduction and valence band as in figure 6.

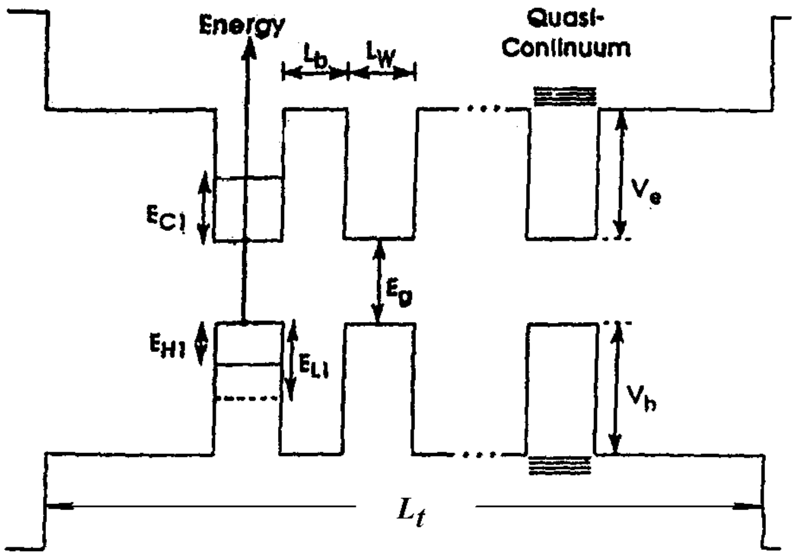


Fig. 6. The potential profile of quantum wells structure.

The well width is L_w and the barrier width is L_b, the total structure length being L_t. The height of the barriers for the electrons and holes are V_e respectively V_h, E_g being the gap energy in the well region.

The energy levels for electrons and holes are E_{Cn} in the conduction band and E_{Hl}, E_{Lm} the energy levels of the heavy holes and light holes respectively, in the valence band.

As an example, we consider a structure compose by $In_{0,53}Ga_{0,47}As$ as a semiconductor material for the wells and $In_{0,79}Ga_{0,21}P_{0,55}$ as a barrier semiconductor material.

If the geometrical dimension of the potential well is comparable or smaller than de Broglie wavelength ($\lambda \sim 200\,\text{Å}$) associated to the charge carriers and the height of the potential barrier are higher than thermal energy *kT*, "the quantum size effect" manifests and determines a discrete structure of the energy levels in the potential well as in figure 6.

The structures with multiple quantum wells (MQW) having thin barriers are called super lattice, because the periodicity of the quantum well are superposed on the periodicity of the crystalline lattice.

The energy levels of the charge carriers in the quantum well are obtained by a special technology named “the forbidden band engineering”.

Techniques as molecular beam epitaxy (MBE), metal - organic chemical vapor deposition (MOCVD), hot wall epitaxy (HWE) or liquid phase epitaxy (LPE) are developed as being suitable for obtaining semiconductor nanostructures.

A quantum well laser (QWL) is the most important application of this technique, but the designing and construction on a large scale of the photonic active and passive devices for integrated optics was developed as: optical modulators, solar cells, optical logic circuits, etc.

In the QWL, the emitted wavelength is dependent on the thickness of the material with smaller forbidden band, (the potential well).

For example, the GaAs/AlGaAs systems emitted wavelengths can be tuned by technology between 700 nm (red) to 850 nm (infrared).

Similarly for the InP/InGaAs, the accordability is in the band of 1,3 μm and of 1,5 μm, very important results to match the optical fiber with very low losses (the second and third windows of the silica fiber used in optical communications).

The smaller threshold current than in the conventional lasers and the very good frequency answer there are together with technological accordability the main controllable parameters of the QWL which determine the higher performances of the QWL as well as the designing flexibility.

This is way the QWL and another QW optoelectronics components are currently available at industrial level but their development is in full progress.

In addition to the quantum well lasers (QWL), which is the most important application, a wide range of other nanophotonic devices were designed based on these technologies. This is way we say that a *new photonic era* is developing based on nanoscience and nanotechnology.

6. Photonic crystals

In the realization of the optical microcircuits as an essential problem of the photonics it is necessary to confine and to maintain the light in some region of interest, by frontiers which interdict the propagation of the radiation with different spectral range. It can be shown by calculus that a medium having the 3D – periodically distribution of the electrical permittivity presents forbidden regions for the electromagnetic field having given spectral distribution. This type of structure named **photonic crystal**, can be used to perform various devices such as optical resonant cavities, optical guides, splitters, filters and optical demultiplexers, without the risk of interference with others components made on the same structure.

Being a periodical distribution of different media having the dimensions larger of more than 10^2 atomic diameters the mathematical model suitable for description of the characteristic interaction phenomena is given by the Maxwell equations.

That means, we have to find the algorithms capable to solve Maxwell equations for linear, nonmagnetic, without charges and currents distribution, having the electric permittivity as function of space position of the considered point. The finite domain time division (FDTD) method is an example of such instrument of calculus. The most known type of photonic crystal is represented by a basic medium having relative electric permittivity ε_{r1} in which on insert a matrix of cylinders having relative electrical permittivity ε_{r2}. It demonstrate that the forbidden frequency regions are function of geometric parameters of the structure as the transversal section of the cylinders, symmetries of their spatial distribution, the filing factor of the elementary cell but the roll of refractive index contrast is also important.

The design of the micro optical circuits with photonic crystal can be developed to realize the same functions as in microelectronics but at higher rate, for complete optical processing and transmission of information, the ultimate objective of photonics.

The fact that for a given frequency range photonic states may not exist has as a result: the impossibility of propagation of the incident waves inside the photonic crystal in a definite frequency range and also the interdiction of the photon emission spontaneously or stimulated in the photonic crystal.

Spontaneous emission control is possible because if no one mode is available for the emitted photon by de-excitation of the atom so that the radiant transition is prohibited.

This property may be used, for example, to increase energy efficiency in lasers, where spontaneous emission uses most of the pumping energy but also to increase the maximum voltage produced by photovoltaic effect.

Meanwhile, inside the crystal photonic presenting nonlinearities may propagates and solitons, property essential for optical communications.

“Photonic crystals are more quiet even than vacuum”, says Professor Eli Yablonovitch metaphorically, the man which discovered the photonic crystal in 1991.

Experimental results

Since the discovery of Yablonovitch photonic crystals have been investigated intensively worldwide, many universities and industrial laboratories performing researches in this regard.

In recent years, based on photonic crystal were designed and realized a series of devices of great importance in optical telecommunications and computers:

• non-linear optical components: limitators, transistors, diodes, delay lines mixers (U.S. Army Missile Command - the United States);

• microlasers with vertical cavities and low threshold current (SANDIA National Laboratory the United States);

• electroluminiscente diodes detectors and optical resonant cavities (IMEC - Belgium);

• 2D optical filters with a very high quality factor (Glasgow University - England, Massachusetts Institute of Technology - the United States);

• 3D photonic crystals at optical frequencies (University of California at Los Angeles, California Institute of Technogy the United States);

• photonic crystals in the form of fibre, operating in the range of wavelengths 800-1600 nanometers (University of Bath, Southampton University the England);

• new types of antennas, micro strip for microwaves, both in a photonic crystals as the substrate (University of California at Los Angeles-United States);

• optical wave guides with low losses(Massachusetts Institute of Technology - the United States).

Theoretical results

a) suppression of spontaneous emission of the photon and of the resonant interaction dipole-dipole resonances between two atoms;

b) the creation the bound states atom-photon;

c) eliminating the radiant combination electron-hole;

d) improving of super radiant effect;

e) propagation of solitaire waves in the prohibited band ("gap soliton").

Photonic crystals represent a point of "jump" in the evolution of the photonic devices.

As artificial materials like natural semiconductor crystal, photonic crystals are designed to transfer in photonic field, the theoretical and experimental results obtained in the engineering and physics of semiconductors.

Although involving different fundamental particles, the electron which is fermion (semiconductor materials) and the photon which is boson (photonic crystals), this major difference is favorable to photonic crystal.

In the next photos we present same example of papers concerning the beginning contributions to the developments of the Photonics in Romania.

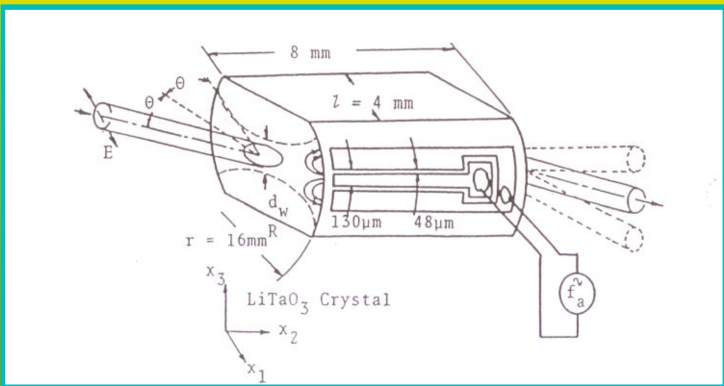
- **A MODULATOR USING AN ACOUSTIC FABRY - PEROT RESONATOR FOR A MODE-LOCKING OPERATION OF A GAS LASER**
-
- **AKIRA NISHIWAKI**

  Departament of Electronic Enginering, Chubu Institute of Technology, 1200 Matumoto-cho, Kasugai-shi, 487 (Japan)

  and

  PAUL E. STERIAN and SHUZU HATTORI

  Faculty of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya-shi 464 (Japan)(Received March 15, 1978; accepted September 6, 1978)



Perspective viev of the device tested, along with dimensions of the LiTaO, crystal.

Computer Physics Comunications

121 – 122(1999) 583 - 585

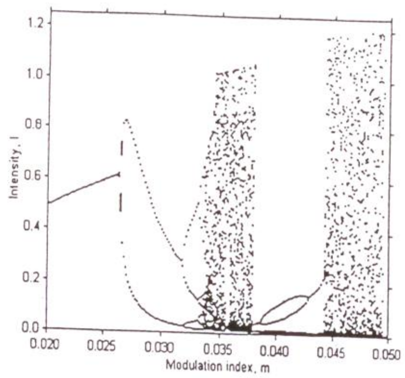


Fig. 1. Bifurcation diagram of the laser with modulated losses (modulation index is increasing). Typical dynamics are shown in Fig. 2.

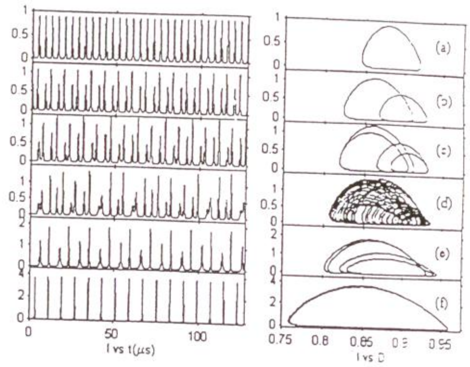


Fig. 2. Laser dynamics: temporal dynamics of the intensity (left) and $I-D$ phase plane diagrams (right). Results are shown for (a) $m = 0.025$, (b) $m = 0.030$, (c) $m = 0.033$, (d) $m = 0.037$, (e) $m = 0.040$, and (f) $m = 0.050$.

Variante simple de mode-locking avec applications dans la mesure du temps de réponse des dispositifs opto-électroniques

Revue Phys. Appl. **21** (1986) 277-282

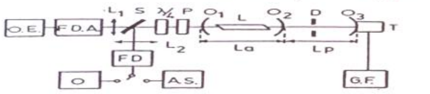
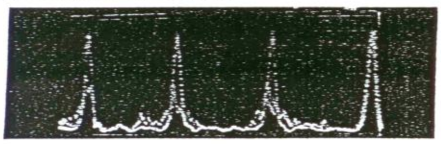


Fig. 1. — Schéma-bloc de réalisation et de mesure du régime mode-locking obtenu par le déplacement du miroir de la cavité couplée à la cavité d'un laser HeNe. L : laser; O_1, O_2 : miroirs de la cavité laser; O_3 : miroir de la cavité couplée; D : diaphragme; T : traducteur électromécanique (haut-parleur); G.F. : générateur de fonctions; P : polariseur; $\lambda/4$: lame quart d'onde; S : diviseur de faisceau; L_1, L_2 : lentilles; FD.A. : photodiode à avalanche au Si (TIXL55); FD : photodiode au Si (ROL22); O.E. : oscilloscope à échantillonnage; O : oscilloscope (0-50 MHz); A.S. : analyseur de spectre radio.



b)

Fig. 2. — Oscillogrammes du signal photodétecté obtenues sur l'oscilloscope à échantillonnage O.E. dans les conditions

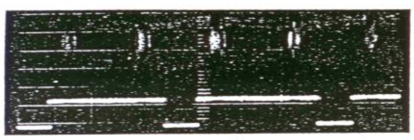


Fig. 7. — Signal fourni par le circuit monostable (en bas) se rapportant au signal photodétecté (en haut). (En bas : 5 ms/div. ; 5 V/div.) ; (en haut : 5 ms/div. ; 50 mV/div.)

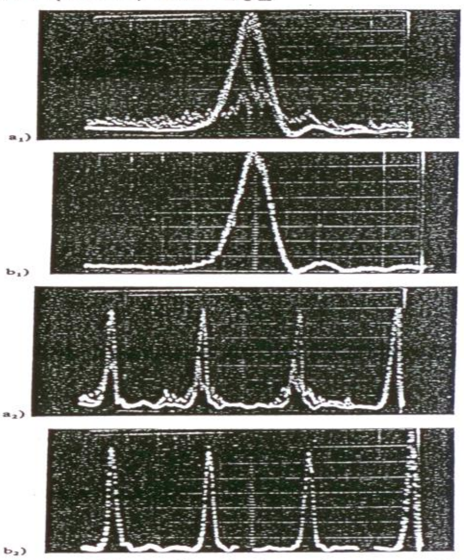
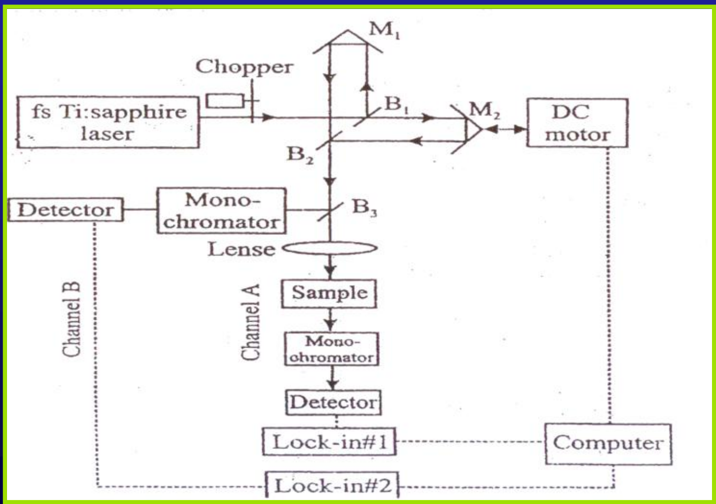


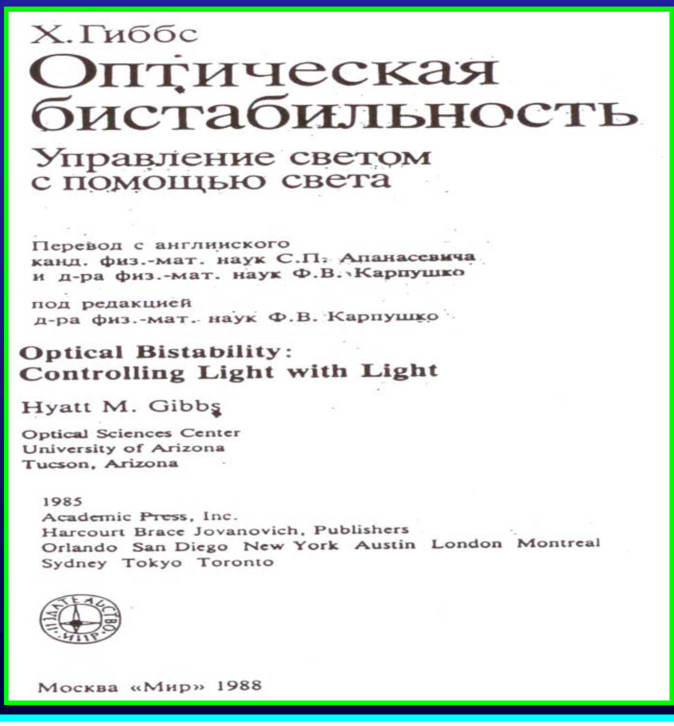
Fig. 8. — L'effet du schéma d'extinction du spot aux impulsions visualisées : a_1, a_2 : schéma d'extinction arrêté ; b_1, b_2 : schéma d'extinction en marche.

Caracterization of Nd:YAG crystal based on femtosecond optical excitation FSO-10

V. Ninulescu,[1,2] J.Y.Zhou,[1] P.E. Sterian, [2] and M. Dumitru[2]
[1]State Key Laboratory of Ultrafast Laser Spectroscopy, Zhongshan University, Guangzhou 510275, China
[2]"Politehnica" University of Bucharest, 77206, Romania



Experimental set-up for time-resolved wave packet dynamics spectroscopy



Х. Гиббс

Оптическая бистабильность

Управление светом с помощью света

Перевод с английского
канд. физ.-мат. наук С.П. Апанасевича
и д-ра физ.-мат. наук Ф.В. Карпушко

под редакцией
д-ра физ.-мат. наук Ф.В. Карпушко

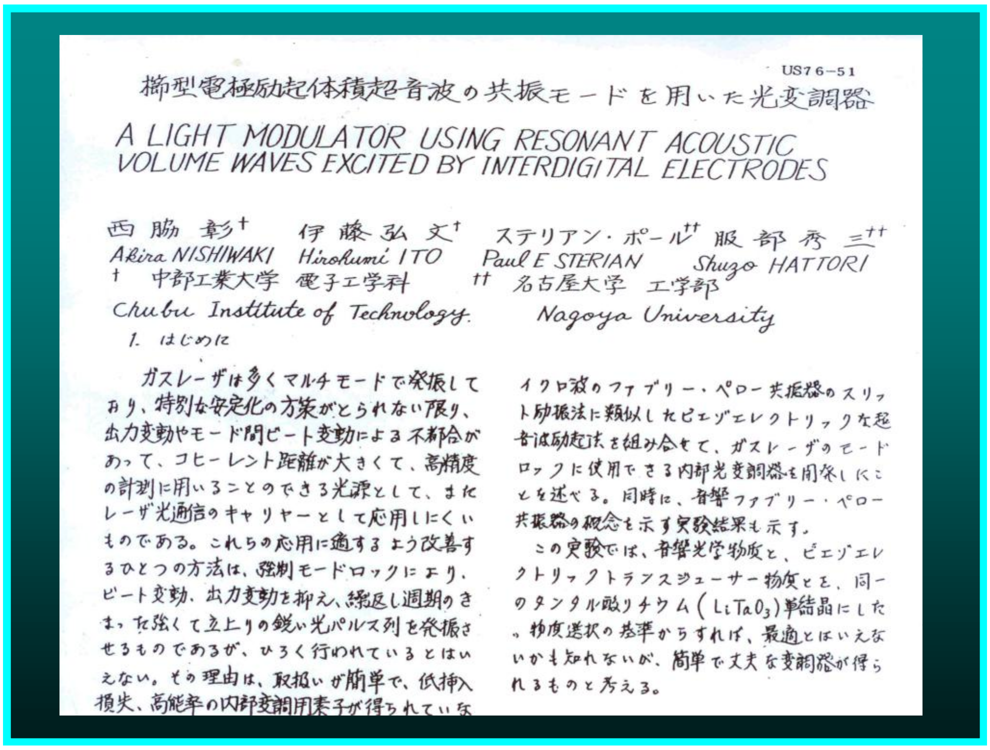
Optical Bistability:
Controlling Light with Light

Hyatt M. Gibbs

Optical Sciences Center
University of Arizona
Tucson, Arizona

1985
Academic Press, Inc.
Harcourt Brace Jovanovich, Publishers
Orlando San Diego New York Austin London Montreal
Sydney Tokyo Toronto

Москва «Мир» 1988



US76−51

擶型電極励起体積超音波の共振モードを用いた光変調器

A LIGHT MODULATOR USING RESONANT ACOUSTIC VOLUME WAVES EXCITED BY INTERDIGITAL ELECTRODES

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Chubu Institute of Technology. Nagoya University

1. はじめに

ガスレーザは多くマルチモードで発振しており、特別な安定化の方策がとられない限り、出力変動やモード間ビート変動による不都合があって、コヒーレント距離が大きくて、高精度の計測に用いることのできる光源として、またレーザ光通信のキャリヤーとして応用しにくいものである。これらの応用に適するよう改善するひとつの方法は、強制モードロックにより、ビート変動、出力変動を抑え、繰返し周期のきまった強くて立上りの鋭い光パルス列を発振させるものであるが、ひろく行われているとはいえない。その理由は、取扱いが簡単で、低挿入損失、高能率の内部変調用素子が得られていな

イクロ波のファブリー・ペロー共振器のスリット励振法に類似したピエゾエレクトリックな超音波励起法を組み合せて、ガスレーザのモードロックに使用できる内部光変調器を開発したことを述べる。同時に、音響ファブリー・ペロー共振器の概念を示す実験結果も示す。

この実験では、音響光学物質と、ピエゾエレクトリックトランスジューサー物質とを、同一のタンタル酸リチウム（$LiTaO_3$）単結晶にした。物質選択の基準からすれば、最適とはいえないかも知れないが、簡単で丈夫な変調器が得られるものと考える。

Conclusions

Photonics represents a maturity step of the science and engineering of the light, at a century from the photon hypothesis of Einstein.

The “universal” importance of the photonics results from the fact that the life of each of as is marked in one or another way by the power almost “mystical” of the light.

Annual Conference of European Photonics Platform, which took place in Brussels in December 2007 showed that currently, the engine of innovation activities in Europe is represented by PHOTONICS whose production is equivalent to that of microelectronics, which will exceed one in the near future.

We have in view the optical communications and computers, medicine, industry, agriculture and defense, cosmic navigation and genetic mutations, controlled fusion reactions and so on.

We can say that nanosciences and nanotechnologies had opened a new era in the evolution of the photonics as was appreciated by the professor MAURO FERRARI “At the nanoscale there is no difference between chemistry and physics, engineering and mathematics, biology and its sub-domains”.

After our appreciation is evident that: “The common factor, integrator, for the relevant areas mentioned above, when the differences between them disappear is *the information* and the progress factor is then represented by the science and technology of information”.

The emergence and development of the photonics was presented in the context of profound understanding of the mechanisms of generation, amplification and detection of electromagnetic radiation in the optical spectrum, phenomena of self organization and optical and atomic coherence being representatives.

Engineering applications of photonics in all areas of activity were presented in conjunction with the unprecedented technological development which culminated in the remarkable achievements in the field of nanotechnologies.

In this way the issue of universal harmony of nature has a dynamic approach, the fundamental problem of his knowledge having the new dimensions.

We can say that light has still many mysteries for science and for man generally, so that the paper is written in the context of trying common position of these factors in relation to the possibilities of the human being.