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Logic Gates Through Three Core and Dual Core Nonlinear Directional Couplers Operating in Continuous Wave Mode

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ABSTRACT

We have studied and obtained logic gates through three-core nonlinear directional couplers and dual-core nonlinear directional couplers operating in continuous wave mode in which the laser signal has the same wavelength. In symmetrical three-core nonlinear directional couplers with its identical cores in a planar arrangement was studied using a control pulse applied to the first core. In dual core the structure was the asymmetric two core switching process was held in symmetrical triangular fiber couplers and three-core nonlinear directional couplers using the coupled mode of the nonlinear Schrodinger equation. The logic gates, AND, OR and NXOR were generated from the triangular three-core nonlinear directional couplers, while planar three-core nonlinear directional couplers produced logic gates AND, NAND, OR and XOR. For this two basic modes were considered. The first triangular structure with three symmetrical core were considered from an equilateral triangle and used a control signal applied to the first core. In the second model the symmetric cross structure with three cores in a parallel equidistant arrangement. We have obtained optical logic gates in a fiber coupler doped with erbium, leaded the resonant non linearity to change the refractive index which helped to reduce the device switching energy threshold.

KEYWORDS

Logic gate, Core, nonlinear, coupler, control pulse, symmetric, switching, directional, control signal, mode.

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INTRODUCTION

MeneZes et al. [1] studied triangular and planar coupler with two configurations operating in continuous regime and obtained AND, OR, NAND, NOR, XOR NXOR and NOT logic gates. They analysed the extinction ratio figure of merit of the logic gates. The triangular symmetric structure was composed of three cores in an equilateral triangle using a

control signal applied to the first core. The two configurations have a planar structure with three symmetrical cores in equidistant parallel arrangement with different control signal input positions.

Agrawal [2] made study of nonlinear optical field and on the propagation of short optical pulses inside optical fibers. The nonlinear Schrodinger equation was used for the nonlinear phenomenon of self phase modulation that leaded to the formation of solitons in the presence of anomalous dispersion. The study showed the importance of non-linear processes such as spin off of higher order soliton and the intrapulse Raman effect. They also studied the performance of three different dual core asymmetrical nonlinear directional couplers including an increase and a decrease in self phase modulation profile. A study of the extinction ratio of the device was made, observing the device's transmission characteristics through the cross channel.

Sobrinho et al. [3] studied four possible situations were analysed for two input logic gates, modulating the incoming pulses by time shift and allowing a variation of the modulation adjustment parameter offset coding.

Almedia et al. [4] made numerical study on transmission and switching solitons in asymmetric nonlinear directional couplers, developed with dispersion decreasing fiber. The coupler consists of two separate parallel fibers, on with a dispersion decreasing fiber profile and another with a constant profile and truth tables were obtained for logic gates AND, OR and XOR.

Meneze et al. [5] presented a numerical analysis of triangular nonlinear dual core fiber coupler, planar symmetric and asymmetric, propagating a soliton pulse, which used the nonlinear responses of Kerr effects, delayed and instant analysed to implement a optical half adder. For this purpose eight configurations were analysed with regard to fiber nonlinear directional coupler with two symmetric and six asymmetric configurations. In the simulation the symmetric asymmetric planar features with three cores in a parallel equidistant arrangement, three logic inputs and two output power. To compare performance of optical half adders the figure of merit of the logic gates were used.

Singhi et al. [6] made study with optical Boolean circuits implemented with a semiconductor optical amplifier and Mach-Zehnder interferometer that are simulated and analysed at 10Gb/s. They have proposed new designs for half-adder, half subtracted and 4bit decoder for various results and results of different bit rates. The designs consisted of data that serves as a pump generated by a clock wave laser and another acting as blocking probe laser mode. The results were useful for the design of other fully complex optical circuits that used the data ports as the basic building block.

Uthaya Kumar et al. [7] studied switching in three-core nonlinear directional couplers and logical operations using all optical control. To achieve results symmetrical trans-pacific cable models were used with planar geometry and other core with the equilateral triangular geometry and the use of Fourier series. The coupler direction characteristics were demonstrated by the curve. The chloroform filled the triangular core showed all logical operations i.e. OR, NOR, AND, NAND, XOR, XNOR and NOT with low input power.

Yaghoubi et al. [8] made study of all logic gates based on the theory of non linear directional coupler. The experiments they used two waveguides. These waveguides had similar properties in the material and length when applied to gates. Bream PROP software was used and they observed that the desired output signal power was reached, using incomplete coupling and half adder function was obtained from the AND and XOR gates.

Guo et al. [9] study was made for obtaining optical logic gates based on two kinds of refractive index, grating and polymer film doped with azo dye. To perform the study they used an interference recording method with two 532 nm laser beam in which the characteristics of the transient grating in films were recorded with different polarization states by monitoring the intensity of first order reading diffraction of the 632.8 nm laser beam. They found that the transient grating in polymeric films was established and deteriorated in seconds.

Saboia et al. [10] performed an analysis of a directional optical fiber coupler embedded in a photonic crystal was proposed, which was driven by an external control signal allowing switching cell work in fully optical switch. The method used for switching an external control signal of low power in the central coupling region which acted as a waveguide. They used the plane wave expansion method, a time domain finite difference, besides the binary method of propagation.

Sharifi et al. [11] used a general method to design all optical gate considering photonic crystal and functions based on the logical threshold concept with a regular pattern on the inputs. There was a cascade junction of the photonic crystal, performed by a power level threshold detector and a new method has been introduced to change the power level threshold for the design of various gates and logic functions. The power of inputs and out change the power level threshold for the design of various gates and logic functions. The powers of inputs and outputs ports and functions of the study was homogeneous and operated with a bit rate of 500 Gbit/s.

Goudazi et al. [12] studied an optical logic gate structure based on line defects and defect points in two dimensional photonic crystal. The process occurred in a square lattice of silicon photonic crystal bars. The device has two inputs and two output ports. They proved that the initial phase difference between the two input ranged was $\frac{\pi}{2}$, they interfered constructively or destructively to perform the logic functions. Rocha et al. [13] made study of propagating characteristics of soliton pulses of Pico seconds through odd-drop optical filters based on a uniform medium without losses and non-linear Gaussian grids couplers. For the temporal profiles, nonlinear coupled mode equations were considered. These devices were solved numerically and performed the extraction of an optical signal, since there was reflection of a pulse previously alternated between adjacent waveguides, where extraction efficiency occurred best at low power levels.

Rani et al. [14] reported the independent polarization of optical logic gates in silicon-insulator photonic crystal which consisted of two dimensional lattices of honey comb with two photonic air holes for transverse electric and transverse magnetic modes in the optical communication windows. The response time and the bit rate for the transverse magnetic polarizations at the wavelength 1.55 nm showed good results. Shaik and Ranges Wamy [15] studied new structures of all optical logic gates based on two dimensional photonic crystal square lattice type with silicon rods dipped in air have been proposed. The proposed structures were based on a waveguide T-shaped optimized edge. An additional input port was included in the structure, along with the actual input ports required for a logic gate. The result showed that the T-shaped waveguide operated as a NOT gate and appropriate change in the phase value of digital input 'I'.

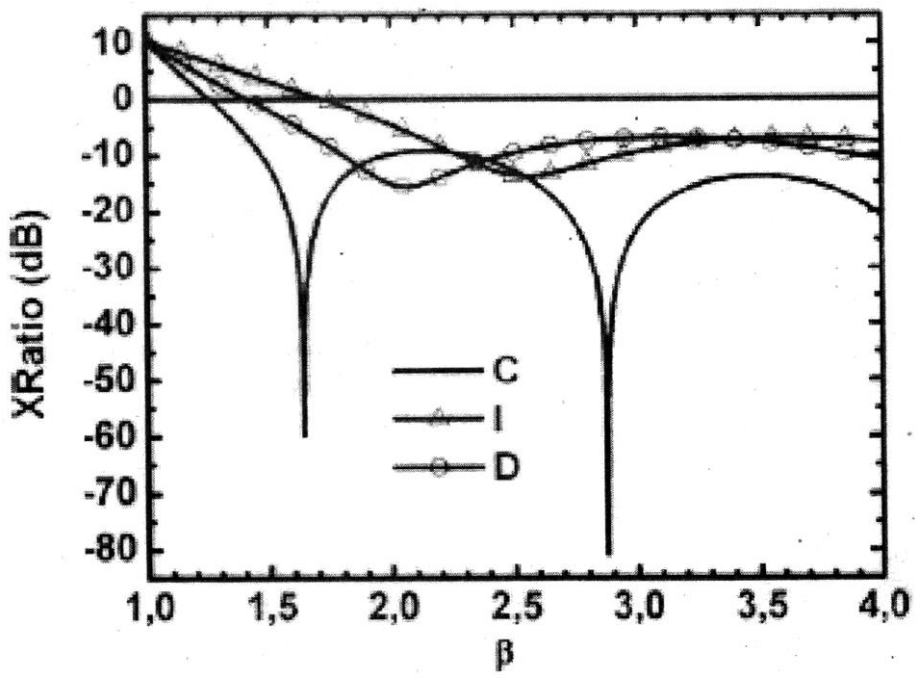
METHOD

We have studied the performance of three different dual core and three core asymmetrical non-linear directional fiber coupler including increase and decrease in the self phase modulation profile. A study of the extinction ratio of the device was made observing the device's transmission characteristics through cross channel. We have observed that the performance of logic gates AND, XOR and OR in the three couplers depended on the non linearity profile, concluding that to operate the asymmetric coupler as a logic gate that controlled the non linearity profile in order to optimize completely the characteristics of transmission and extinction coefficient. We have used different ways of pumping for obtaining of logic gates. The operation of an all optical logic gate based on symmetrical non linear directional coupler, operating with a pulse-position modulation. The performance of a symmetrical non linear directional coupler revealed logical functions AND and OR applied in the transmission and processing of signals in all optical thermally diffused mode system. This arrangement consisted of the symmetrical non linear directional coupler was developed with ultra short soliton light pulse of two pico seconds, which has been modulated using pulse position modulation which effectively served to break the device symmetry and generated logic gates. Four possible situations were analysed for two-input logic gates. A numerical study on

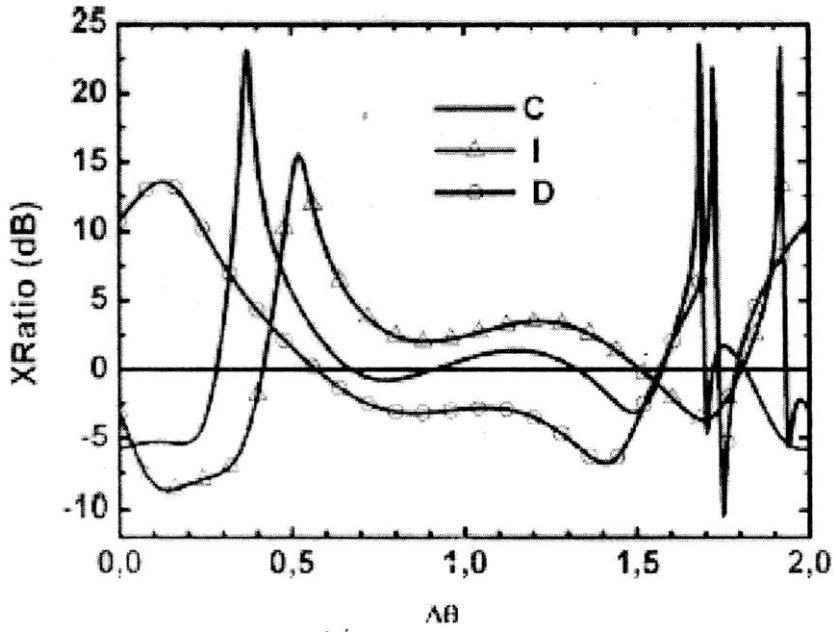
transmission and switching of fundamental solitons asymmetric non linear directional couplers developed with dispersion decreasing optical fiber.

RESULTS AND DISCUSSION

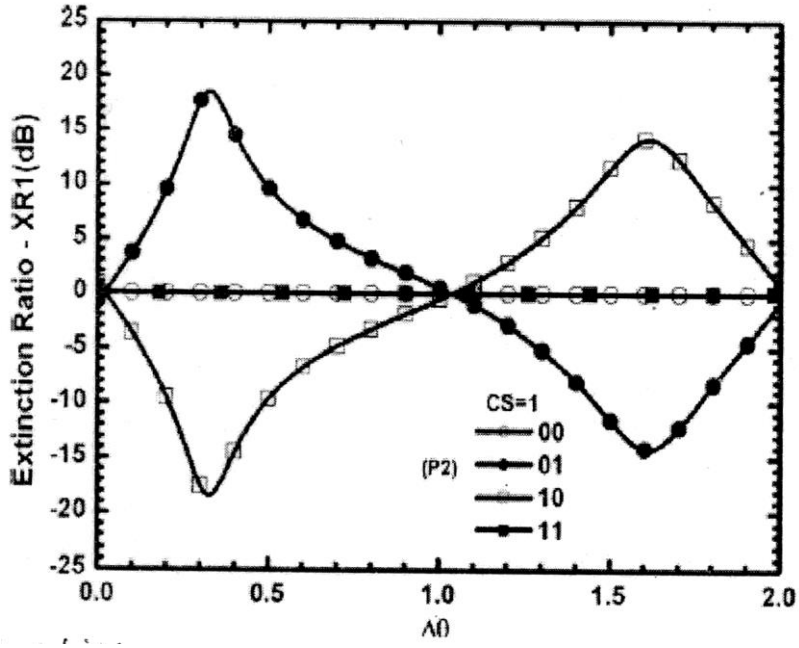
Graph (1) shows the result of extinction ration when the pumping was alone in channel two. Specially with beta equal to one, the output light was present an channel one. When beta increased, the extinction ration decreased indicating that the light returned to channel two, making possible the obtaining of logic gates. Graph (2) shows that when pumping for both inputs one and two, a strong presence of light was found in guide one and guide tow. We also found that the phase value $\Delta\varphi$ of extinction ration was increasing for two of the couplers with maximum value 23.40 dB was obtained for constant profile $\Delta\varphi = 1.68p$. Graph (3) shows that when $\Delta\varphi = 0.32\pi$ there are strong peak values where most of the output energy is switched to the output control 02 and 01. For control signal the extinction ratio values are near thus the energy fractions of outputs 01 and 02 are identical. Graph (4) shows that extinction values are always negative for any variation of $\Delta\varphi = \Delta\theta\pi$ with strong fluctuations. It shows that the switched power switches between outputs 02 and 01. Most of the energy is present in the channel 02. In phase value the signal is switched predominantly in 02. For crossed phase = $1(\Delta\varphi)$ the values of extinction ratio are alternated, sometimes positive and sometimes negative. Then it was found that three core nonlinear directional couplers provided AND, NAND, OR, XOR and NOT gates where as dual-core nonlinear directional coupler provided XOR, AND and OR gates. Graph (5) presents the unification of transmission curves as a function of input power to the instantaneous peak and cases of non linear delayed Kerr response between the switching powers. In nonlinear directional fiber couplers the critical power for the signal is completely transmitted to the core three then returns to the core two and finally to the core one.



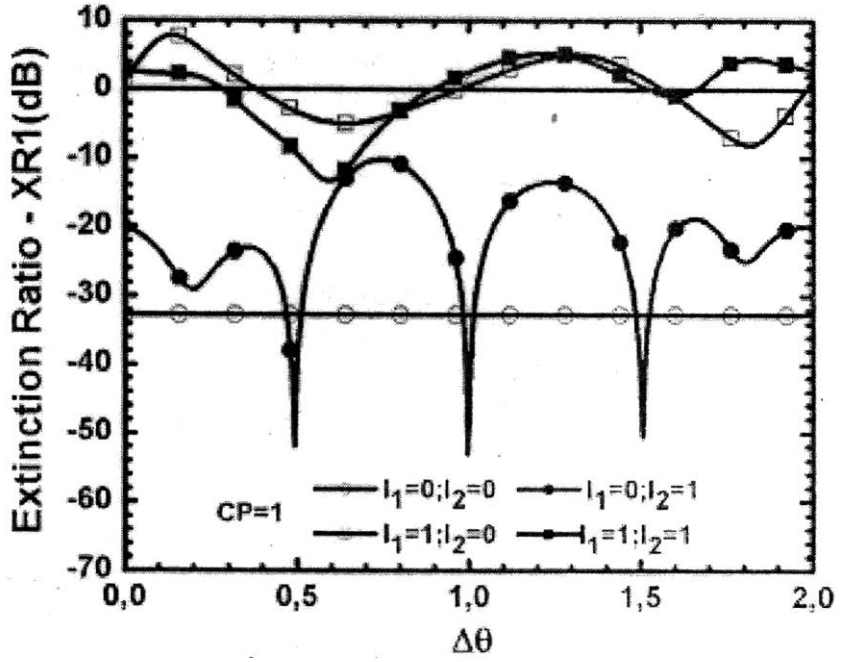
Graph 1: Extinction ratio with incident light, pumping for channel 2.



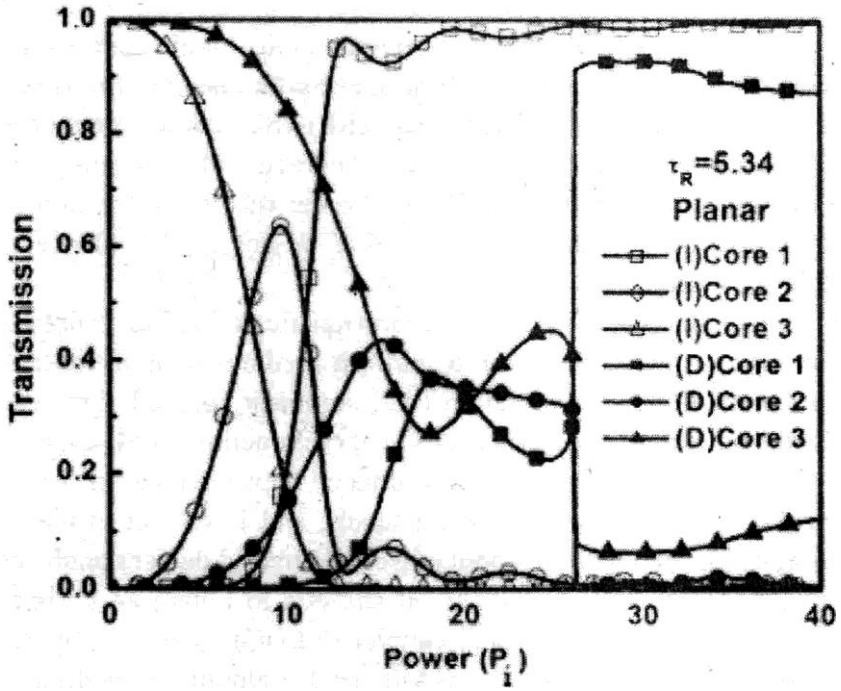
Graph 2: The phase extinction ratio is increasing for two of the couplers with maximum value.



Graph 3: Extinction values (dB) are near 0, thus the energy fractions of output O1 and O2 are identical



Graph 4: The values of extinction ratios are alternates, sometimes positive, sometimes negative.



Graph 5: Unification of transmission curves as a function of input power to the instantaneous peak in a nonlinear directional fiber coupler.

CONCLUSION

We have studied for obtaining logic gates through dual core and three core nonlinear directional couplers operating in continuous wave mode. The analysis was made for devices through their performances in linear and nonlinear regime, considering the various optical characteristics. We have observed the generation of all optical gates using optical fiber couplers. The non linear characteristics of the fiber and generation of optical codes using Bragg gating was studied. The study was made for obtaining of optical logic gates in fiber devices couplers, filters and interferometers in on off switching mode

including the use of figure of merit of the logic gates. We have found that application for the linear and nonlinear effects affected inherent to the fiber. These studies have applications in the obtaining of optical logic gates through the control of characteristics of the fibers such as nonlinearity profile, dispersion profile, control pulse, pumping pulse among others. The optical fibers are essential in the development of communications and data transmission with strong positive characteristics in bandwidth of data transmission as well as the transmission speed. Simulation was used in the analysis of effect of dispersion in optical logic gates. We have used semiconductor optical amplifiers. The dependence of output quality factor in input pulse energy, pulse width, semiconductor optical amplifier life time of the line width of the enrichment factor and power saturation were observed. It was found that the production of logic gates and half adders with relaxed nonlinearity in fiber couplers are useful for communications and transmission of data. The optical logic gates based on nonlinear optical fiber couplers present important characteristics such as security in information traffic, high transmission rate and capacity and optimizing effective data transport. The obtained results were compared with previously obtained results and were found in good agreement.

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Performance of Silica Single Mode Hollow-core Optical Fibers in Optical Communications

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ABSTRACT

We have studied the performance of silica single mode hollow-core optical fibers in optical communication. Silica single mode optical fibers form the core of high capacity telecommunication network. Hollow-core optical fibers have an air filled core surrounded with micro structured glass cladding allowing high level of light confinement. Light guiding mechanism of Bragg, photonic band gap and antiresonant fibers were considered. Nested antiresonant nodeless fibers and conjoined fibers are the two most promising antiresonant fiber designs for achieving ultra-low attenuation. Mode field adaptation using graded index multimode fiber; we have achieved record low insertions loss and also suppressed higher order modes. Deposition of anti-reflective coating allowed reducing unwanted back reflections. We have developed an approach for a hollow-core optical fiber of single mode interconnection based on a modified fiber array technology which solved the problem of back reflections by applying optical coating. Fundamental mode coupling was achieved by using mode theory adapters in the form of graded index multimode fibers.

KEYWORDS

Single mode, Hollow-Core Fiber, Optical Communication, Microstructured, Cladding, Photonic Band Gap, Antiresonant, Attenuation, Mode Field, Fiber Array, Optical Coating.

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INTRODUCTION

GAO et al. [1] presented that fusion splicing is method which is used for permanent, low-loss interconnection of solid core optical fibers. This method was applied to the hollow-core fibers of single mode fibers interconnection, but does not address back reflections angled-splicing of hollow-core fibers was proposed but it was proved to be quite lossy [2-3]. In telecommunications hollow-core fibers are new process for the attenuation of standard single mode fibers [4]. An 11Km long hollow-core fiber has been drawn by Chen et al. [5] while predictions of more than 100 KM long hollow-core fiber drawing were presented by Jasion et al. [6] for effective use hollow-core fibers in conventional fiber optic-systems, it is

essential to connect hollow-core fibers to solid core optical fibers in most cases of single mode fibers. Three main challenges existed for such an hollow-core fiber-single mode fiber interconnection (i) the air silica boundary causing unwanted back reflections (ii) state of the art low loss hollow-core fibers have a significantly larger mode field diameter compared to single mode fibers and (iii) hollow-core fibers with large mode field diameter are inherently multi modal, therefore higher order mode excitation must be suppressed to ensure only fundamental mode coupling.

Komanec et al. [7] developed an approach for a hollow-core fiber-single mode fiber interactions based on a modified fiber array technology which solved the issue with back reflections by applying optical coating, optical coating cannot be used in fusion splicing because of high temperatures. Fundamental mode coupling was achieved by using mode field adapters in the form of graded index multimode fibers. Wave guidance in a hollow-core has been existed which was shown by Thomson [8] and Lord Rayleigh [9] and presented the possibility of metallic waveguides.

Marcatili and Schmelter [10] proposed a hollow-core metal coated dielectric wave-guide for short range transmission of millimeter waves. Hidaka et al. [11] formed a hollow-core metal-coated fibers which were designed for the 10.63μm band to guide light from CO_2 lasers. These hollow-core fibers were made of pb-oxide glass and exhibited attenuation of 7.7 dB/m. Silica-glass based hollow-core fiber was presented by Nagano et al. [12] for CO_2 laser delivery with attenuation below 7.7 dB/m. Saito et al. [13] studied on hollow-core fibers appeared that were based on the silica-air design. Hollow-core fibers in the vicinity of 10μm were used to measure gas concentration where hollow-core fiber with a 1.5 mm inner core diameter of 1m length acted as a gas cell to analyse NH_3 content.

Sirkis et al. [14] presented an interferometric hallow core fiber based fiber where the hollow-core fiber was formed by a glass capillary with a 70μm inner diameter and length of 137μm.

Renna et al. [15] used simple glass capillary hollow-core fiber to transport atoms by optical forces. The main limitation originated from glass capillary attenuation proving the need for better light guidance.

Pennetta et al. [16] studied hollow-core photonic band gap fiber led to numerous application areas hollow-core fiber were afterwards advantageously used as gas sensing, gas filled lasers [17], fiber optic gyroscopes, high speed data transmission and many more [18].

Wheeler et al. [19] studied the attenuation of negative curvature Kagome hollow-core fiber was significantly higher than that of photonic band gap fiber, the band width was superior to that of photonic band gap fiber.

GAo et al. [20] presented conjoined tube fiber with minimal loss of 2dB/Km at 1512 nm was demonstrated.

METHOD

We have developed an approach for a hollow-core fiber combination with single mode fiber interconnection based on a modified fiber array technology which solved the back-reflections by applying optical coatings. The fundamental mode coupler was achieved by using mode field adapters in the form of graded index fibers. Hallow core fiber samples to current state of the art hollow-core nested antiresonant node less fibers with only 0.28dB/Km attenuation at 1550 nm were considered. Then we have considered the main hollow-core fiber guidance mechanisms from Bragg fibers. Photonic band gap fibers were followed to antiresonant fibers summarizing hollow-core fiber key properties. We have compared photonic band gap fibers and antiresonant fibers. The fusion splicing results were compared with modified fiber array technology. Advantages of interconnection technique were taken with regard to hollow-core fiber applications. An Omniguide fiber was presented with high refractive index glass and a low refractive index polymer microstructure. Omniguide fibers exhibited less than 1dB/m attenuation at 10.6μm while it was possible to get tens of meters of Omniguide fibers in a single draw. Then we have considered primarily placed on Bragg fibers from pure silica where rings were

held together by glass struts. Photonic crystal fibers allowed freedom in photonic crystal parameters tailoring such as the chromatic dispersion curve, zero dispersion wave length single mode cut off wavelength, mode field diameter which was modified by changing the design of the photonic fiber microstructure. Endlessly single mode photonic crystal fiber appeared, group velocity dispersion management became possible and super continuum generation was demonstrated using photonic crystal fibers with zero dispersion wavelengths at 800nm producing broadband radiation from visible to near infrared region. Optical networks the most important parameters are fiber attenuation in 1550 nm band and fiber transmission band width. The design of the photonic band gap fiber eventually limited the progress in achieving low attenuation and broadband performance the achieved band width was only 70 terahertz and an alternative hollow-core design was obtained. This was due to the negligible optical field overlap with the glass leading to low surface scattering losses.

RESULTS AND DISCUSSION

Fig (1) shows the negative curvature shape of first ring around the antiresonant fiber core which led to a decrease of fiber attenuation down to hundreds of dB/Km with a band width of 1000nm. The attenuation of this negative curvature Kagome hollow-core fiber was significantly higher than that of photonic band gap fiber, the band width was better to that of the photonic band gap fiber. Efforts on exploiting the negative curvature simultaneously reduced the microstructure complexity. These antiresonant fibers do not require a periodic lattice and works just on the principle of antiresonance. Among the lattice variants the tubular antiresonant fiber provided the simplest design and the best performance. The lowest current attenuation of a single ring tubular antiresonant fiber was found 7.7dB/Km at 750 nm. The obtained results were impressive in comparison to conventional single mode fibers. The potential of antiresonant fibers when including additional resonator inside of each existing tubes forming so called nested antiresonant fibers when including additional resonator inside of each existing tubes forming so called nested antiresonant node less fibers. The nested antiresonant nodeless fibers surpassed the attenuation of other hollow-core fibers types and eventually that of single mode fibers. This is due to the negligible optical field overlap with glass leading to low surface scattering losses. Antiresonant fibers suffered from significantly higher confinement losses and were addressed by the proposed nested antiresonant nodeless fiber designing by including more antiresonant elements. Fig (2) shows and advanced negative curvature fiber with non touching capillaries. These fibers eliminate the remaining glass nodes which are not in antiresonance. Antiresonance prohibits the aircore mode from overlapping with glass material. This leaded to low surface scattering and low material induced attenuation which is required for low propagation to achieve competitive losses to standard single mode fibers greater coupling suppression between the air core mode and the cladding modes are required. Graph (1) Shows a simplified formation of the photonic band gap as the photonic band gap fiber. The guided modes are expressed by the dispersion equation using the normalized frequency ν and rod radius *r* as

$$\nu = \frac{2\pi r}{\lambda}\left(n_1^2 - n_0^2\right)$$

Then it has set the air line as

$$w^2 = \left(\beta^2 - k_0^2\right)r^2 = 0$$

where β is the propagation constant in the direction of propagation and k_0 is the wave number in air. No modes can propagate above air line as they are in anti resonance with the rod modes and also they cannot propagate in the cladding. Graph (1) (a) shows that below the air line is continuum of plane wave like air modes. Graph (1) (b) shows that when rods are arranged in a symmetric or periodic fashion to form a single ring around the central rod, the dispersion equation changes and conditions broaden around the particular mode cut offs. The rod modes became expanded that they overlapped with the other rod modes and a spatial superposition occurred. Periodic forbidden bands appeared below the air line as shown in graph (1) (b). Graph (2) (a) shows the measured interference pattern of the fundamental mode LP_{01} with higher order modes for a 10-m long photonic band gap fiber. From this interference pattern using Fourier transform relative amplitude of

the propagation modes were calculated. Higher order mode propagation is shown in the graph (2) (b) and have found suppression of greater than 30dB for higher order modes. The field adapters based on graded index multimode fiber were used to match quality. The interference of higher order mode amplitude were found for various levels. Using arc discharge that heated the two fiber ends presented together to form a permanent robust, repeatable and low loss splice, because creating a permanent interconnection of two optical fibers is fusing splice. The appearance of Hollow-core fibers, modified splicing technique found emerged on maintaining the delicate microstructure, which were easily collapsed when it was over heated. Among hollow-core fibers the antiresonant fibers provided a homogeneous and low defect structure with substantial migration of high order modes became the most suitable choice to form gas cells. Advantage of silica hollow-core fibers for gas sensing is their transparency. We have found that using fiber array interconnection technology back reflections were suppressed. We have increased the reflection and allowed multipath propagation on hollow-core fiber attenuation and coating reflectivity. The fundamental mode excitation reduced the noise of the sensing system. The results were compared with previous results and were found in good agreement.

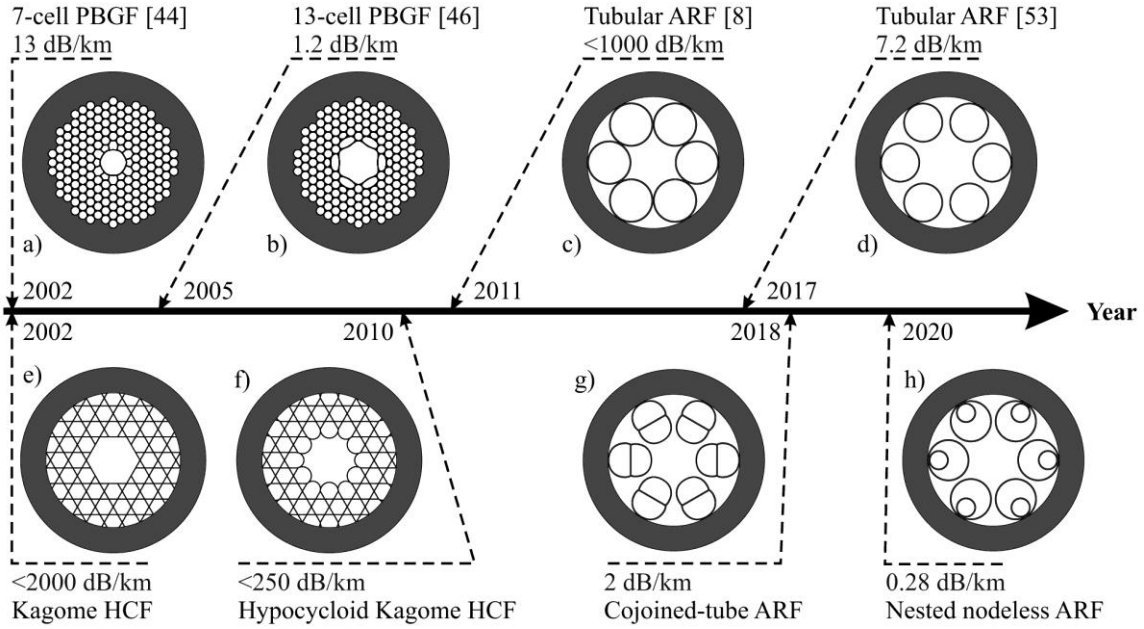


Figure 1: Timeline of the hollow-core optical fiber evolution including both fiber design and attenuation milestones, values are given for the wavelength of 1550nm.

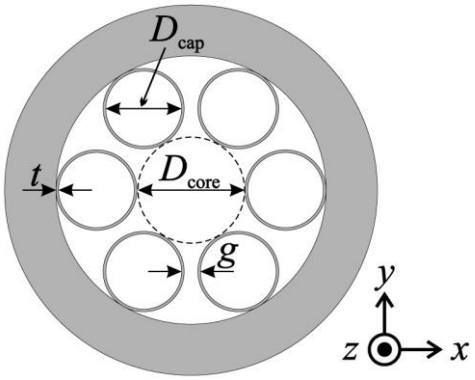
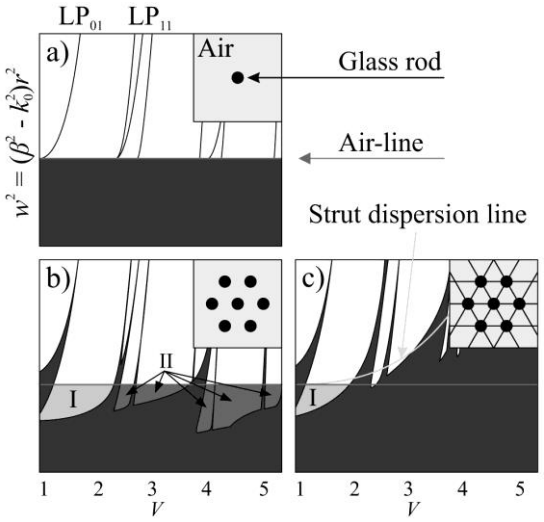
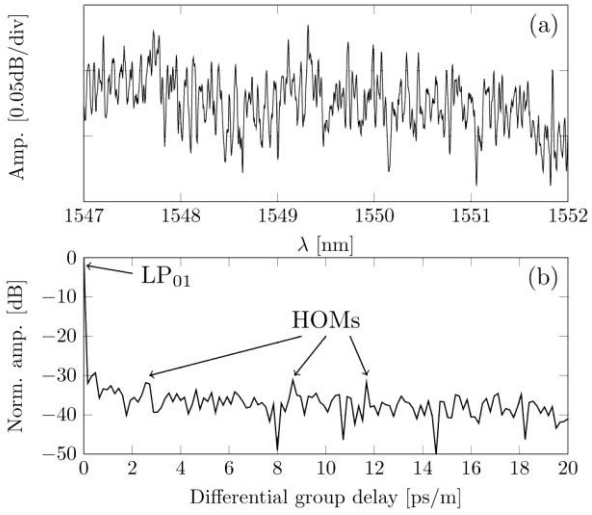


Figure 2: Tubular fiber structure with non-touching glass capillaries.



Graph 1: Formation of air guiding photonic band gap.



Graph 2: Higher-order mode interference pattern in a 10-m-long photonic band gap fiber.

CONCLUSION

We have studied the performance of silica single mode hollow-core optical fibers in optical communications. Light guiding mechanisms were presented and performances of hollow-core fibers were obtained. The interconnection techniques to standard optical fibers were compared with respect to possible hollow-core fiber applications. Fusion splicing results were presented with and alternative interconnection solution based on a modified fiber array technique newly developed by us. Cutting edge hollow-core fiber applications have advantages hollow-core fiber interconnection mode field adaptation using graded index multimode fiber. We have achieved record of low insertion loss and also suppressed higher order modes. Deposition of anti-reflective coating allowed us to reduce unwanted back reflections. To achieve sub -1dB insertion losses, the move to bridge fibers acting as model field adapters was necessary. Showing the potential of bridge fibers formed by thermally expanded core fibers, the splice loss of only 0.73 dB was found for an single mode fiber-expanded core-photonic band gap fiber interconnection. The obtained results were compared with previously obtained results and were found in good agreement.

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Neutrosophic Battery: An Introduction to High-Performance Battery Configuration

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ABSTRACT

Nowadays, great effort has been focused on various kinds of batteries commonly referred to as electric energy storage systems (EESS), such as lithium-related batteries, sodium-related batteries, zinc-related batteries, aluminum-related batteries and so on. Some cathodes can be used for these batteries, such as sulfur, oxygen, layered compounds. In the present article, let us consider the basic battery configuration, i.e. they are mostly composed of cathode and anode metals. Such a classic system can be considered as "two elements" model. Based on Neutrosophic Logic as developed by one of us (FS), we consider in this paper that actually we can extend it further to become a Neutrosophic battery system, consists of three-elements (or may be more), i.e. cathode-anode-catalyst system. The catalytic electrolyte method is found to be significant to achieve high-performance battery.

KEYWORDS Neutrosophic Battery, Electric Energy Storage Systems (EESS)

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INTRODUCTION

As it is known, the majority of energy usage in the world is predominated by fossil fuels. But it has resulted in many environmental problems, including ozone layers problem. Renewable energy sources have been promoted as an alternative to such fossil fuel sources. Among many kinds of renewable energy sources, solar energy has become the most favorite in many countries, along with water and wind. They are called WWS (wind, water, solar) energy. [4] Although it is still quite debatable, there is growing acceptance of potential contribution of renewable energy sources. Even there *are known projections* that renewable energy sources can be sufficient to meet future energy demands. See for instance Mark Jacobson's book from Stanford University [5]. Among those plentitude alternatives of renewable energy types, it is known that "Sun, wind and tides have huge potential in providing us electricity in an

environmental-friendly way." However, as Jianmin Ma et al., wrote: Its intermittency and non-dispatchability are major reasons preventing full-scale adoption of renewable energy generation. Energy storage systems will enable this adoption by enabling a constant and high-quality electricity supply from these systems, see [7]. But which storage technology should be considered? That is one of significant questions to be asked now-a-days. Nowadays, great effort has been focused on various kinds of batteries to store energy, lithium-related batteries, sodium- related batteries, zinc-related batteries, aluminum-related batteries and so on. Some cathodes can be used for these batteries, such as sulfur, oxygen, layered compounds. Now, let us consider the basic battery configuration, as composed of cathode and anode metals. Such a classic system can be considered as "two elements" model. Based on Neutrosophic Logic as developed by one of us (FS), we consider in this paper that actually we can extend it further to become a Neutrosophic battery system, consists of three-elements (or may be more), i.e. cathode-anode-catalyst system. The catalytic electrolyte method is found to be significant to achieve high-performance battery. Moreover, recently there is also research on "*interface engineering*." Therefore, the classic model of cathode- anode can still be improved further. This article is an introduction to this fast growing field in (physics-) chemistry engineering.

PROSPECT OF BATTERIES FOR ENERGY STORAGE

Let us cite from Nadeem *et al*.'s paper at IEEE Access: "It is an exciting time for power systems as there are many ground-breaking changes happening simultaneously. There is a global consensus in increasing the share of re-newable energy-based generation in the overall mix, transitioning to a more environmental-friendly transportation with electric vehicles as well as liberalizing the electricity markets, much to the distaste of traditional utility companies."

The generation affects distribution networks, renewables introduce intermittency, and liberalized markets need more competitive operation with the existing assets. All of these challenges require using some sort of storage device to develop viable power system operation solutions. There are different types of storage systems with different costs, operation characteristics, and potential applications. Understanding these is vital for the future design of power systems whether it be for short-term transient operation or long-term generation planning."[6] For instance, if we consider batteries for Large Scale EESS, then one obvious consideration is how to find quite abundance source in nature as well as cheap material. The effective use of electricity from renewable sources requires large-scale stationary electrical energy storage systems (EESS) with rechargeable high-energy-density, cheap batteries. While batteries using lithium, cadmium, lead-acid etc. have been widely used, notably there is an alternative source e.g. salt-water which is quite abundant in nature and known as electrolytes. In a recent paper, we reported a series of preliminary experiments on potential use of salt-water as cheap source of renewable battery with various kind of metals as anode and cathode. [4] Interestingly, a report by PreScouter (2018) also mentioned salt-water battery as one of potentially disruptive battery technologies. [2] They also wrote some key insights, such as follows: "Numerous chemistries are being developed to directly counter some of the disadvantages of Li-ion batteries, namely the high cost and sourcing for the raw materials, as well as degradation of the caused by dendrite formation in the solid-electrolyte interphase. Most of these technologies are still in either the prototype or research phase, and may not appear on the commercial market until at least 5-10 years from now (with notable exceptions, e.g. silicon-based chemistries). Most of these technologies are aiming to reduce the cost of energy storage and point to new opportunities in the energy sector."[2] Nonetheless, such a choice of salt-water battery (in German: "*salzwasser batterie*"), is not without hurdles. One of such a hurdle is low voltage produced in salt-water (EES) system. That is why nowadays we begin to consider several potential catalytic materials. Such a hurdle actually also leads us to the following new scheme of "Neutrosophic battery system," as we are going to discuss in subsequent section.

INTRODUCING NEUTROSOPHICBATTERY SYSTEM

As we wrote in Introduction section, let us consider basic battery configuration, as composed of ″cathode″ and ″anode″ metals. Such a classic system can be considered as ″two elements″ model. Based on Neutrosophic Logic as developed by one of us, FS [3], we consider in this paper that actually we can extend it further to become a Neutrosophic battery system, consists of three-elements (or may be more), i.e. cathode-anode-catalyst system. Definition of catalyst (/kad()lst/): ″a substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change.″ According to Merriam-Webster dic- tionary: ″a substance that enables a chemical reaction to proceed at a usually faster rate or under different conditions (as at a lower temperature) than otherwise possible.″ (cf. https://www.merriam-webster.com/dictionary/catalyst). The catalytic electrolyte method is found to be significant to achieve high-performance battery configurations. Moreover, recently there is also research on ″interface engineering.″ Therefore, the classic model of cathode-anode system can still be improved further. Although the use of catalyst was more known in fuel-cell research, see for instance [8], but recently it begins to be explored for applications in battery research, see for instance [9]. We admit that the proposed term ″Neutrosophic battery″ is still schematic as for now, but let us see the following diagram of configurations used in high-performance battery experiments, as follows (Figure 1).

Alternatively, one may consider the fourth element as extension of catalytic method to improve performance, i.e. interface. It is sometimes called as interface engineering; an example is as shown in the following diagram (Figure 2).

It is our hope that the above diagrams make clear what is the implication of the proposed new term ″Neutrosophic battery″ in actual experiments. It can be expected that high-performance battery research in the future shall include these additional elements.

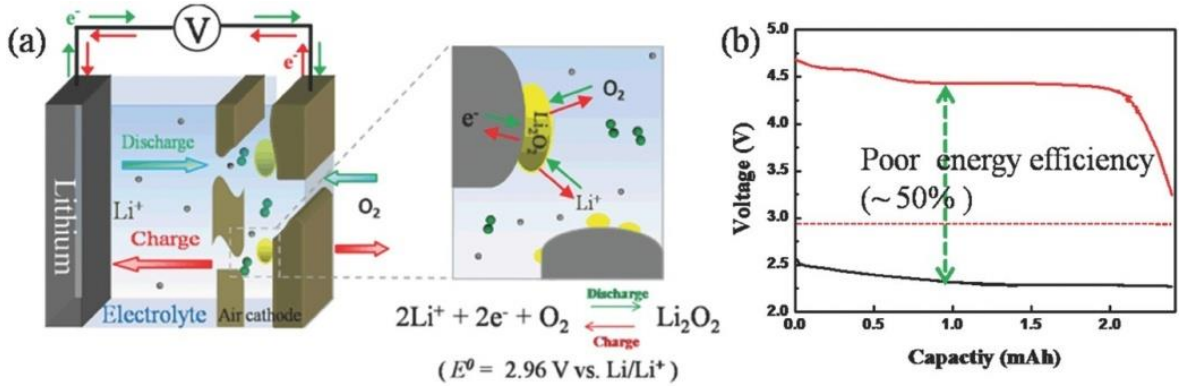

Figure 1: Sample configuration of electrocatalyst, from Chang's paper

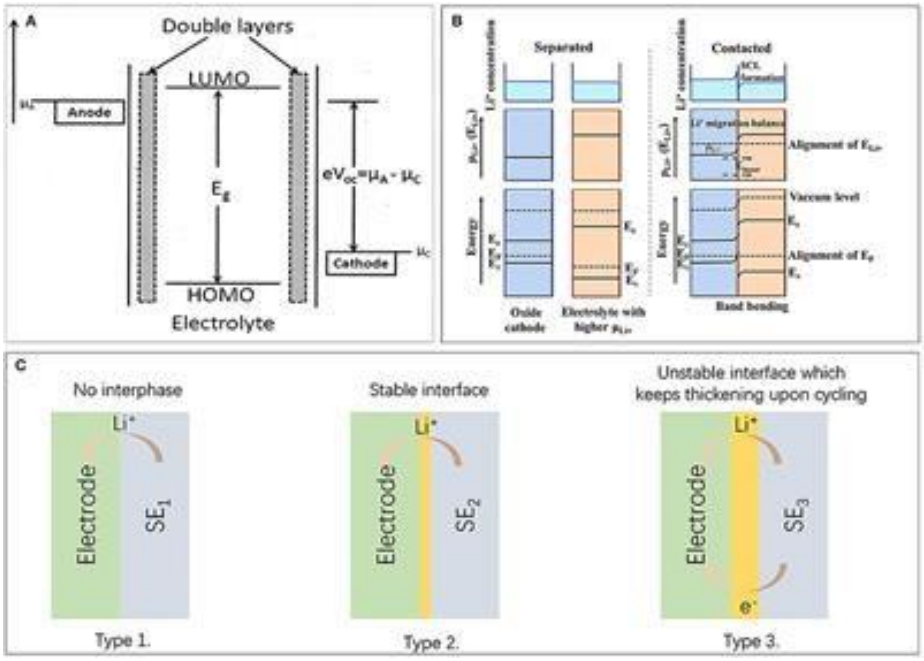

Figure 2: An example of interface in battery experiment.

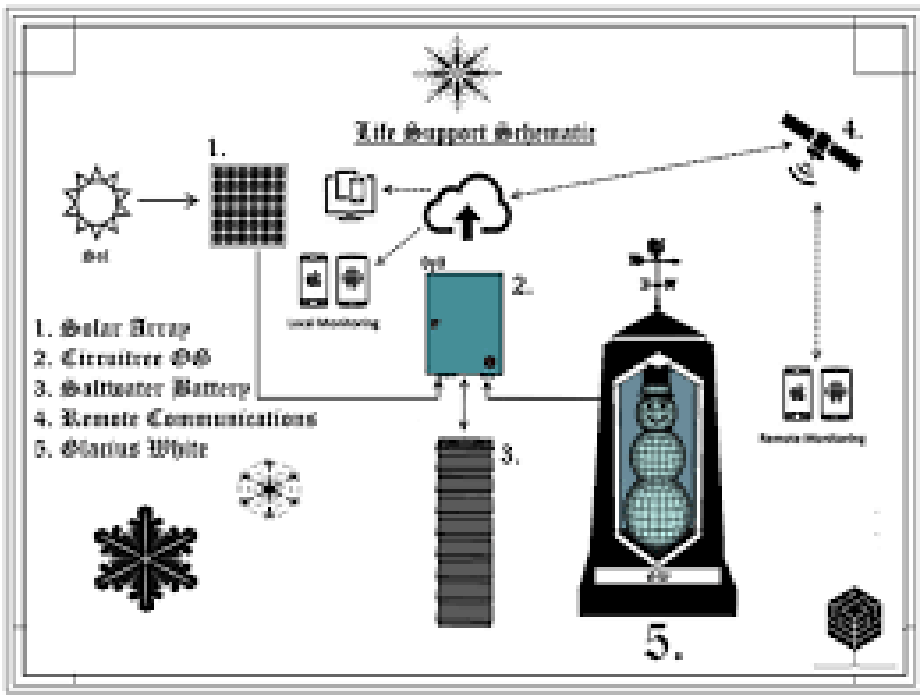

Figure 3: Example of Aquion Salt-Water battery for remote support.

COMMENTS ON INDUSTRIAL APPLICATIONS

As far as we can find in recent literatures, there are a number of companies which already put salt-water batteries into practical applications, including Aquion, SoNick, and also GreenRock. Nonetheless, there is news that it appears that Aquion battery went bankrupt then it restarts again recently. What is interesting here is that SWB (salt- water battery can also be used for powering off-grid house). See the following diagrams.

CONCLUDING REMARKS

There is growing acceptance of renewable energy contribution to meet world energy demands. However, intermittency problem of WWS requires solution to stabilize that intermittency i.e. battery as energy storage (EESS). Considering basic battery configuration, as composed of ″cathode″ and ″anode″ metals. Such a classic system can be considered as ″two elements″ model. Based on Neutrosophic Logic as developed by one of us (FS), we consider in this paper that actually we can extend it further to become a Neutrosophic battery system, consists of three-elements (or may be more), i.e. cathode-anode-catalyst system. The catalytic electrolyte method is found to be significant to achieve high-performance battery. Moreover, recently there is also research on ″interface engineering.″ Therefore, the classic model of cathode-anode system can still be improved further. We admit that the proposed term ″Neutrosophic battery″ is still schematic as for now, but we cited several other configurations used in high-performance battery experiments. It is our hope that the above diagrams make clear what is the implication of the proposed new term ″Neutrosophic battery″ in actual experiments. To conclude, it can be expected that high-performance battery research in the future shall include these additional elements. We hope that this introductory article can be found useful for young physicists/chemistry scientists.

Figure 4: Salt-water battery can power off-grid house.

Figure 5: A Swedish school implements salt-water battery. Source: *PV Magazine*.

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Comparative Relativistic Study of Change in Frequency of Hawking Radiation between XRBS and AGN

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ABSTRACT

The present paper gives the comparative study of change in relativistic frequency of Hawking radiation due to XRBs and AGN categories of black holes and concludes that the relativistic change in frequency of Hawking radiation due to XRBs is greater than to that of AGN category of spinning black holes.

KEYWORDS Hawking radiation, XRBs and AGN

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INTRODUCTION

The black holes are the product of supernova explosion due to dying stars of masses greater than 5 solar masses and perfect absorbers of every things. These do not emit anything; their temperature is absolute zero. The quantum mechanical effect suggests the emission of particles from black holes like a hot body at the temperature $\kappa/2\pi$, where κ is surface gravity of black holes [1,2,3]. The thermal emission of radiation from black hole leads to show decrease in the mass of the black hole and to its eventual disappearance [2]. Mahto et al. gave a model for the frequency/wavelength of radiation emitting from the black holes and have shown that the frequency or wavelength of radiation emitted from the black holes may be treated as the characteristics of black holes [4]. Mahto and Ranjan gave a model for the frequency and wavelength of Hawking radiation in terms of the event horizon using quantum theory of radiation, energy of Hawking radiation and the radius of event horizon of the spinning

black holes which may be regarded as the characteristics of spinning black holes [5].

In the present paper, we have presented the comparative study of change in relativistic frequency of Hawking radiation due to XRBs and AGN black holes and concluded that the relativistic change in frequency of Hawking radiation due to XRBs is greater than to that of AGN category of the black holes.

THEORETICAL DISCUSSION

The virtual particles called electrons and positrons are created on the event horizon of the black holes in which virtual particles like electrons fall into the black hole and others escape from black hole as Hawking radiation. The frequency of radiated photons is given by the following equation [6].

$$\nu = \frac{c^3}{16\pi GM} \tag{1}$$

Where G be the gravitational constant and c be the velocity of light. The constants G and c have their own significances as discussed in the reference [7].

The mass of black holes will vary with velocity as proposed by Albert Einstein's special theory of relativity as [8], because the spinning black holes have their spinning velocity from 50% to 99% of the velocity of light [9]

$$M = \frac{M_0}{\sqrt{1-V^2/c^2}} \tag{2}$$

Where M_0 is the rest mass and V be the spinning velocity of black holes. Combining Eq(1) and Eq(2) with proper mathematical proper operation, we get the relativistic frequency of Hawking radiation as follows [10,11]:

$$\nu_{rel} = \frac{c^3}{16\pi GM_0}\left[1-\frac{1}{2}(V/c)^2\right] \tag{3}$$

or

$$\left|\frac{d\nu_{rel}}{dV}\right| = \frac{1}{16\pi}\left(\frac{V}{M_0}\right) = 0.19625\left(\frac{V}{M_0}\right) \tag{4}$$

The above equation is used to calculate the maximum relativistic change in the frequency of radiation in terms of mass and spinning velocity of black holes.

The model represented by the equation (8) is applied for the black holes of masses M= $5M_\odot$, $10M_\odot$, $15M_\odot$ and $20M_\odot$ belonging to XRBs and for the black holes of masses M= $10^6 M_\odot$, $10^7 M_\odot$, $10^8 M_\odot$ and $10^9 M_\odot$ belonging to AGN [12] and compared relativistic change in the frequency of radiation of Hawking radiation in terms of mass and spinning velocity.

RESULT AND DISCUSSION

The present work gives the comparative study the relativistic change in the frequency of Hawking radiation due to both categories of black holes. The final expression for the proposed model is in terms of mass and spinning velocity of black holes, which means that the relativistic change in the frequency of Hawking radiation is dependent on the mass and spinning velocity. From the final expression, it is is clear that the relativistic change in the frequency is a function of mass and spinning speed of black holes. This model is applied for the black holes of masses M= $5M_\odot$, $10M_\odot$, $15M_\odot$ and $20M_\odot$ belonging to XRBs and for the black holes of masses M= $10^6 M_\odot$, $10^7 M_\odot$, $10^8 M_\odot$ and $10^9 M_\odot$ belonging to AGN. This shows that for the constant values of mass of black holes, the magnitude of the relativistic change in frequency increases with increase in velocity of black holes while increasing the mass of black holes, this change decreases. In both categories of black holes, the relativistic change in frequency of Hawking radiation w.r.t. spinning velocity for different masses of black holes existing in XRBs as well as in AGN have uniform variations and showing a definite relation between the rate of change in the frequency of Hawking radiation of black holes w.r.t. spinning velocity with corresponding values of spinning velocity of black holes, but the inclination of variations differ. The inclination of variations of XRBs is greater than AGN. It is clear that for the higher mass, the rate of variation of relativistic change in frequency of black holes with velocity is lower and vice – versa in both cases of black holes either XRBs or AGN.

From the theoretical discussions of our work, we finally conclude that the relativistic change

in frequency of Hawking radiation due to XRBs is greater than to that of AGN category of spinning black holes.

CONCLUSIONS

The following conclusions are drawn during the present research.

1. The relativistic change in frequency of Hawking radiation of black holes w.r.t. spinning velocity due to XRBs is greater than the relativistic change in frequency of Hawking radiation of black holes w.r.t. spinning velocity due to AGN
2. The non-spinning black holes of both categories of black holes give maximum change in the relativistic change in frequency of Hawking radiation of black holes than spinning black holes of both categories.
3. The relativistic change in the frequency of Hawking radiation is a function of the mass and spinning velocity.

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Fantasia in Warp Drive - Part II: Plausible Steps to Make A Workable Warp Drive Machine, Someday in the Near Future: Discussion and Remark

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ABSTRACT

There is a persistence interest among physicists, to investigate on possibility of FTL (faster than light) travels, even if those fields related to FTL are most likely categorized to fringe research. Especially after Alcubierre introduces a new notion called "warp drive" solution to FTL problem. For these writers, it is interesting because (one of us :) Smarandache's hypothesis says that there is no speed barrier of anything; by generalizing implications of EPR paradox, which is known in most QM experiments. But the question remains unsolved: how to make it possible? This short article reviews several progress in such a FTL drive, while it does not necessarily mean that we agree with Alcubierre nor GTR-based approaches. We will argue in terms of possible realization of trajectory in complex plane (i.e. Argand plane.)

KEYWORDS

FTL travel, warp drive, Alcubierre hypothesis, warp bubble, Argand plane, Smarandache hypothesis, interstellar travel possibility

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INTRODUCTION

This short article is intended -among other things - as anopen letter to Mr. Elon Musk, founder and chief of Tesla and SpaceX, as well as other scientists and experiment investigators in FTL drive. We admire him as one of great inventors in modern era. As we often hear, Mr.Musk wants to go to Mars as quickly as possible. Although we're rather skeptical if Mars will be our next destination for habitable planet, because it is already beyond Goldilocks zone, [1] nonetheless for experiment reasons…may be there are things we can learn if we get there. So we guess there

[1]Meaning of Goldilocks zone: "The habitable zone is the area around a star where it is not too hot and not too cold for liquid water to exist on the surface of surrounding planets." Ref. https://exoplanets.nasa.gov/faq/15/what-is-the-habitable-zone-or-goldilocks-zone/#:~:text=The%20habitable%20zone%20is%20the,the%20surface%20of%20surrounding%20planets.

are reasons to consider travelling to Mars is interesting.

Around several months ago, one of these writers wrote to him that if he plans to use "carbon capture method" to propel a rocket to go to Mars, that is more likely to fail, because CO2 only takes place around Earth atmosphere, not in outer space. And if he introduces certain nuclear engines to propel his starship, that may work, but it would take very long time to go to Mars (perhaps it would take months or may be a year or so). Therefore it leaves us to explore novel methods which so far belong to "fringe physics", something like warp drive machines.

For us, it is also interesting because one of us's hypothesis says that there is no speed barrier of anything; but the question remains unsolved: how to make it possible?

Other possible "real" warp drive machines in recent news

In 1994, physicist Miguel Alcubierre proposed an innovation that would permit quicker than light travel: warp drive, a theoretical method for avoiding around the universe's definitive speed limit by bowing the texture of the real world. It was an interesting thought - even NASA has been exploring it at the Eagleworks research facility - however Alcubierre's proposition contained issues that appeared to be unfavorable.[2]

He contended that the general relativity took into account "*warp bubbles*" - areas where matter and energy were organized so as to twist spacetime before the air pocket and grow it to the back in a manner that permitted a "level" region inside the air pocket to travel quicker than light. [2]

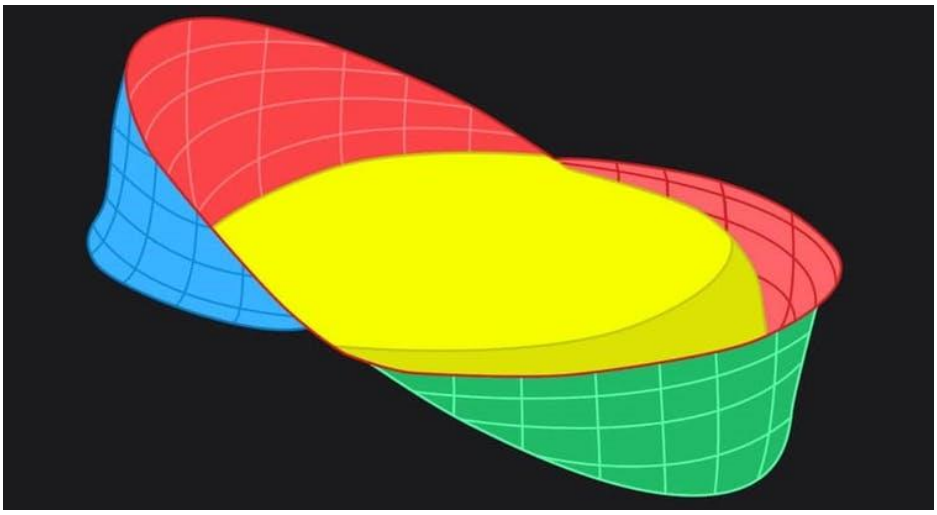

Illustration 1: Spacetime warp, as originally perceived by Alcubierre [2]

More awful, the negative energy necessities of Alcubierre's gadget are colossal. By certain appraisals, the whole energy in the realized universe would be required (however later work cuts the number down a little).Bobrick and Martire show a warp drive could be produced using positive energy (for example "ordinary" energy) or from a combination of negative and positive energy. All things considered, the energy necessities would in any case be gigantic.[4]

More recently, around December last year, Harold "Sonny" White, a NASA specialist at the Eagleworks Laboratory in Houston, Texas, distributed an examination paper with his group in July about the "conceivable design of the energy thickness present in a Casimir hole." As indicated in their report, the Eagleworks group went over

"*a miniature/nano-scale structure … that predicts negative energy thickness appropriation that intently matches necessities for the Alcubierre metric.*"[3]

White told a science and innovation magazine: "as far as anyone is concerned, this is the main paper in the companion surveyed writing that proposes a feasible nano-structure that is

anticipated to show a genuine, yet modest, *warp bubble*." White and his group intend to direct more analyses into the chance of more modest models to more readily comprehend the chances of a forthcoming warp drive. Maybe the Eagleworks Laboratory can take us from sci-fi to the real warp starship model.[3]

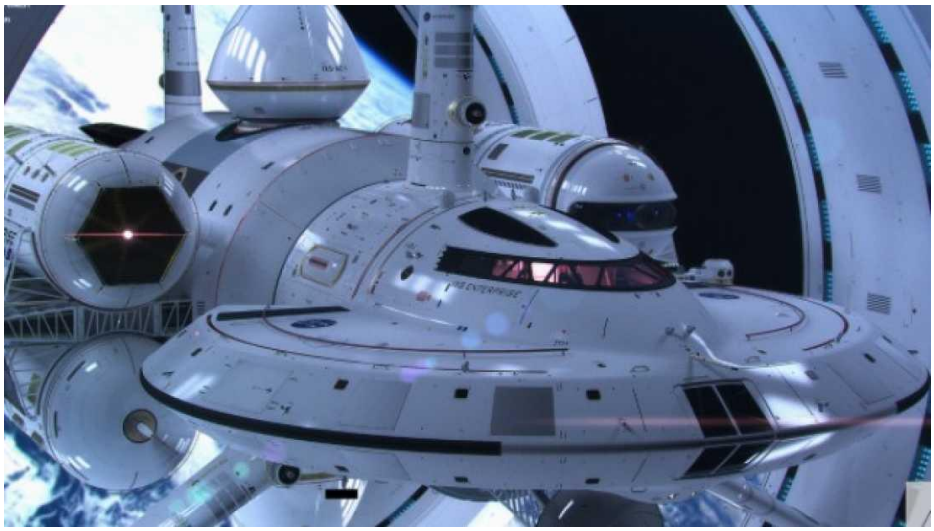

Illustration 2: NASA illustration [3]

A comment by a reader to that article goes as follows: "They did not 'accidentally' create a warp bubble in the lab, that's a very misleading headline. What this, and the big-think article in another comment, is stating that the math works, in a very small scale albeit, but the numbers support the theory of a warp-bubble. But that's it, the numbers look good for a theoretical idea. But, no one has built anything in a lab, and 'accidentally' created a warp bubble." [3]

Beam me up, Scotty…

Other physicist, named Dr. Erik Lentz, tried to solve the problem, inspired partially by **Star Trek.** Lentz specifically examined the assumptions leading to the negative energy requirements in Alcubierre's work. Like his colleague, Lentz began by analyzing spacetime, modeling the multidimensional substance as a stack of very thin layers. He found that Alcubierre had only considered comparatively simple "linear" relationships between the equations for shifting one layer onto the next. At this point, choosing more complex "hyperbolic" relations, which typically express rapidly changing quantities, results in a different warp bubble than the one obtained by Alcubierre.[4]

Other people, including Agnew, argues that LIGO etc. provide interesting clue on such a realizable technology based on GTR: "The LIGO discovery a few years back was, in my opinion, a huge leap forward in science, since it proved, experimentally, that space-time can 'warp' and bend in the presence of enormous gravitational fields, and this is propagated out across the Universe in a way that we can measure. …."[5]

As we shall see later on, this is not the case. But before we discuss our new hypothesis, let us discuss Asaro's solution. She is also a researcher, although you may find her names more related to sci-fi books, but may be there are things that we can learn.

Catherine Asaro's hypothetical solution to warp Drive[1]

Physicist and science fiction author Catherine Asaro is tracing the mathematical background of this problem and came up with a way to modify Einstein's equations in order to make them compatible with an FTL drive. Warp speed, according to her, might be achievable by using a fairly simple solution involving imaginary numbers.

Overcoming the distance between planets and stars is something that science fiction needed to do, as it would otherwise significantly restrict the plots of any film or novel. We all

know there's just no use trekking the stars when traveling from Earth to Mars takes half a year. To get around this issue at least some sort of warp drive is needed, allowing for faster-than-light travel.

Asaro explained at a panel at the Escape Velocity convention in Washington D.C. these days that most of the scientists base their FTL-research purely on Einstein's theory of relativity and **according to Einstein himself — there is no solution**. Asaro began by highlighting that:

"*The problem for light speed travel in sci-fi is you can never get to the speed of light […] As you approach the speed of light, your mass becomes infinite…* "

So okay — FTL travel might not be scientifically plausible right away, but Asaro was pretty determined to find some kind of mathematical justification for her own sci-fi novels. Therefore, she came up with a modified version of Einstein's equations as it's definitely a good idea to not ignore them. Instead she thought of speed as an imaginary number, a complex number defined by a real number multiplied by i, or the square root of -1.

And guess what — according to Asaro, this effectively solved the problem of FTL travel in some regard. Imaginary numbers don't have or need to have a physical equivalent in the real world. She opted to apply the same to the "complex speed," as she calls it in her paper published in the *American Journal of Physics.* What she did is treating the whole issue like a thought problem. The conclusion: If there were a physical equivalent to their imaginary number, it would theoretically allow FTL travel to work in real life.

Asaro wrote an essay for PBS explaining the thought process in even more detail:"I now had a framework based on relativistic physics that I could use to let my starships break the interstellar speed laws […] I called the process 'inversion' because if you are going faster than light, relativity predicts the constellations you see will be flipped around (ed) from their positions as seen at slower than light speeds."

…

For the time being, all of this remains the thought problem Asaro encountered, but who says we won't discover the physical analog for complex speed in real life now? Maybe we just can't fathom it yet.

On the other hand — imaginary numbers seems to suggest that that we can get back complex plane (Argand plane) without recourse to Einstein in even more ways than pure science.[2]

Another hint to a workable pathway: Solve it with 3D-symmetric plane

Let us recall one quote by one of great mathematicians of his time, J. Hadamard, something like this: "*a shortest path to a point (or to infinity) is through complex plane*."[2]

To put it in other words, we may consider that Asaro's idea may lead to something interesting…but the problem is: as we argue in a forthcoming paper, it is unlikely that the notion of *geometrodynamics* is true, and also the entire LIGO project.

To speak frankly, these authors wrote a number of papers in the past based on the notion of quaternion algebras and quaternion numbers. A senior math-physics professor once asked one of authors (VC): "Do you believe in such a universe of quaternion numbers?" At the time, he didn't think that much, because at the timeit seems like the simplest approach to find 6D-version of Maxwell equations." But it does not mean that we agree with the entire geometro-dynamics theories, includingAlcubierre hypothesis and also the remaining of GTR-based warp drive machine proposals so far.

As we wrote (cf. [8]):
"Therefore, it is understandable that the late John Wheeler himself, who coined term geometro-dynamics, later on abandoned many features of that approach. See J. Stachel's article: The rise and fall of Geometrodynamics, and also W. Misner. We can recall too, that there is senior professor in Germany who was brought to justice a few years ago, and then he admitted that there is no way to measure "spacetime curvature." This case file can be found in internet, related to LIGOproject. Actually, there are several criticisms on that observation project. … Of course, by

mentioning all of these, it does not mean that we are right all along, but let us face the truth as it is. Physics is more related to solid experimental evidences, not just made of tower of sand. ….Nonetheless, there is also possibility that the 6D geometry, or more exactly (3D, symmetric) can be found in nature, especially in quasicrystalline structure. Therefore all we can say is that may be this is still useful, although these 6D geometry may be seen more like a mathematical artefact. Zlabys *et al.* wrote their abstract as follows: "*Here we show that time and space crystalline structures can be combined together and even six-dimensional time-space lattices can be realized. As an example, we demonstrate that such time-space crystalline structures can reveal the six-dimensional quantum Hall effect quantified by the third Chern number*."[8]

CONCLUDING REMARK

To sum up our aforementioned arguments, what can be a simpler path toward making a working warp drive machine, are as follows:
(1) Find if it is possible at all to reconsider 6D (3D, symmetric) crystalline structure in such a way to allow "shortest path to infinity" - as J. Hadamard's famous phrase. (That is, our argument here is to do away from the geometro-dynamics approaches, such as Alcubierre's hypothesis.)
(2) Do experiments in small-scale version. We may call such experiments: *"lab scale warp drive" experiments (LSWDE)*. This is quite similar to what Harold White, a NASA specialist at the Eagleworks Laboratory, attempts to do with their warp bubble scenario.
(3) Computational simulation may be helpful, for instance, we shall check if the crystalline structure of the 3D space itself, can be related to Dr. Harold Aspden's space aether model.

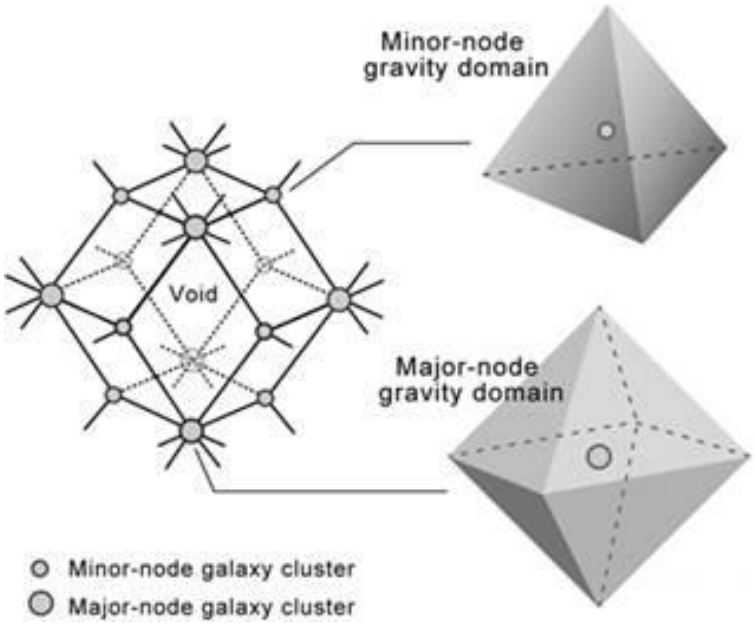

Illustration 3: Harold Aspden's space aether model

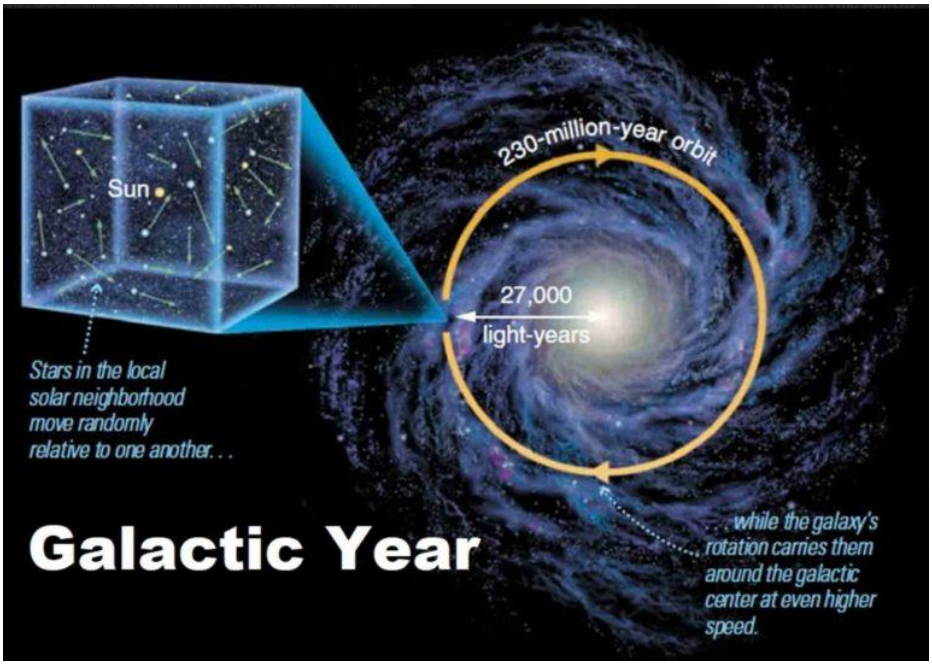

Illustration 4: Harold Aspden's space aether model.

(4) Once we find a "realistic" *small-scale version* / simulation of LSWDE, we can begin to be sure that what is required for small-scale version of warp drive machine, can be scaled up to larger prototype of WD.
(5) Then we can start to send *photon signal* or something like that to see if itis really workable warp drive as we sought for.

At this point, some readers may ask: why do we write this article? Just to make sense of all those nonsense?

Answer: No. You should know that mathematicians are more or less like a coffee making machine. As a wise word says: "A mathematician," the Hungarian mathematician Alfréd Rényi (1921-1970) used to say, "*is a machine for turning coffee into theorems*." Rényi's colleague Paul Erdős well embodied the statement. That is part of the reason we write this short article. Hopefully you will find something to learn from this short remark.

As with a question: how to generate required energy to travel over the complex plane? - we don't get an answer for that. May be, just may be, we can generate through extracting vacuum to become negative energy or negative masses. [7][9][10]

We write this remark quite short, and it is sketchy indeed. But, what is sketchy and seems like simple steps, can actually lead to human kind's real pathway to reach the stars, and go where we belong since the ancient past…along with the Galactic Federation.

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VC & FS

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Transport Properties of Square Lattice of Metallic Nanogranules Embeded in Insulator

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ABSTRACT

We have made theoretical studies of transport properties of square lattice of metallic nanogranules embedded insulting layers. We have developed an extension of the classical Sheng-Abeles model for a single layer of identical spherical particles located in sites of a simple square lattice with three possible charging states of granule and three kinetics processes, creation of a pair on neighbor granules, recombination of such a pair and charge translation from a charged to neighbor neutral granule. This model neglecting the effect of disorder within a layer and of multilayered structures, revealed a variety of possible kinetic and thermodynamical regimes. Effective kinetic equations for averaged charge densities were derived for the characteristics area of the granular sample, the contact areas beneath metallic currents leads and free area between these leads. From these kinetic equations, it was shown that the tunnel conduction in the free area did not produce any notable charge accumulation and the conduction regime was purely ohmic. Some conduction in the contact area became impossible without charge accumulation, leading to a generally non-ohmic conduction regime, since the contact area dominated in the overall resistance. The calculated I-V curves and temperature dependences were found in a good agreement with available experimental data and obtained theoretical results.

KEYWORDS

Transport, Lattice, Nanogranules, Embedded Insulator, Disorder, Kinetic Equations, Tunnel Conduction Charge Accumulation.

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INTRODUCTION

A number of physical mechanisms still need better understanding for transport phenomena in films are still a great challenge and, at present various studies address them [1-3]. The main reason is that granular systems reveled certain characteristics which cannot be obtained either in classical conduction regime, in metallic electrolyte or gas discharge conduction or in the hopping regime in doped semiconductors or in common tunnel

junctions. Their specifics are mainly determined by the drastic difference between the characteristics time of an individual tunneling event $\sim \frac{\hbar}{\varepsilon_F} \sim 10^{-5}$ seconds and the interval between such events on the same granule $\sim \frac{e}{jd^2} \sim 10^{-3}$ seconds at typical currents density $j \sim 10^{-3}\,\mathrm{A}/cm^2$ and granule diameter d ~ 5.0 nm. Other important moments are the sizable coulomb charging energy $E_C \sim \frac{e^2}{\varepsilon_{eff} d}$, typically ~ 10 meV and the fact that the tunneling rates across the layer may be even several orders of magnitude slower [4] than along it. The interplay of these factors leaded to unusual macroscopic effects including a peculiar slow relaxation of electric charge discovered in experiments on tunnel conduction through granular layers and granular films [5-6]. The specifics can be contrasted with well studied process of tunnel conduction in the variable range hopping regime [7]. The latter approach is more adequate for tunneling between atomic localized states, e.g. in doped semiconductors with shallow dopant levels where the hopping range is defined by the effective localization radius and can extend over many periods of crystalline lattice. Actually, nanostructured granular films are of a considerable interest for modern technology due to their peculiar physical properties like giant magneto-resistacne [8], coulomb blockade [9-10] or high density magnetic memory [11] properties that are impossible for continuous materials. Due to dynamical accumulation of charge and not to thermic excitation of charge carrier the conductance was obtained [12]. Kulik and Shekhter [13] presented tunnel conduction through granular media.

METHOD

We have considered a system of identical spherical metallic nanogranules of diameter d, located in sites of simple square lattice of period within a layer of thickness $b \sim a$ of insulating host with a dielectric constant ε. In the charge transfer process each granule can bear different number of σ of electrons in excess or deficit of the constant number of positive ions and the resulting excess charge σe defines a coulomb charging energy $\sim \sigma^2 E_C$.

At modulate temperatures $T \lesssim E_C / k_B$, the consideration can be limited only to the ground neutral state $\sigma = 0$ and single charged states $\sigma \pm 1$. Actually for low metal contents will separated small grains and typical granule size 'd' ~ 3 nm in a medium with effective dielectric constant $\varepsilon_{eff} \sim 25$, we estimated $E_C \sim 20\ meV$ and since the energy difference between single charged and double charged states is $3E_C$, the relative smallness of tunnel probability to this state was $\sim \exp(-3E_C / k_B T)$ and the effective temperature limitation was $T \lesssim 3E_C / k_B \sim 660\,K$. This assured the adopted single charge restriction for the whole temperature range upto at least room temperatures. For a three dimensional granular array, E_C was considered under the assumption of a constant ratio between the mean space 'S' and granule diameter 'd' in the form $E_c = e^2 f(s/d)/(\varepsilon d)$ where the dimensionless function .

$$f(z) = \frac{1}{\left(1 + \frac{1}{2z}\right)}$$

The complete dielectric response of three dimensional insulating host with the dielectric constant ε and metallic particles with the volume fraction $f < 1$ and diverging dielectric constant $\varepsilon_m \to \infty$ can be characterized by the effective value $\varepsilon_{eff} = \frac{\varepsilon}{(1-f)}$.

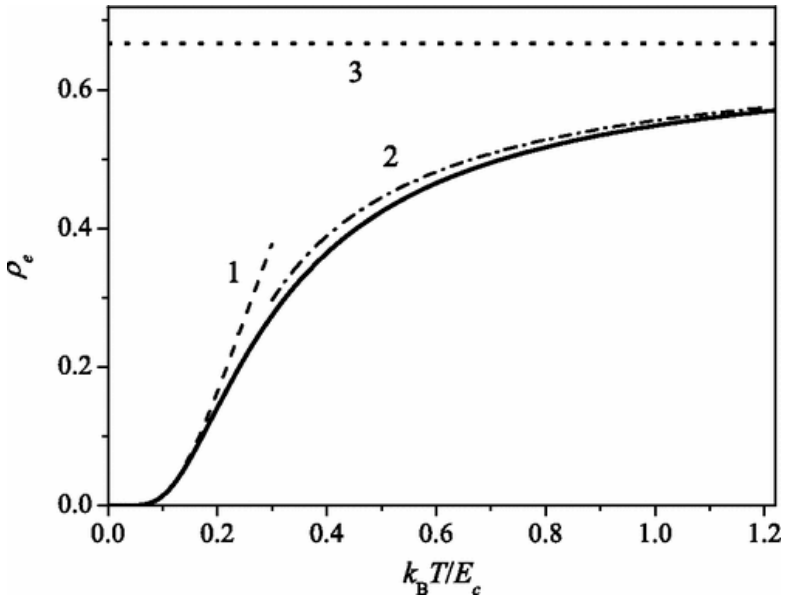
For planar lattice of granules, the analogous effective constant can be estimated, summing the energy $\frac{e^2}{(\varepsilon d)}$ of charged granule at the $n = 0$ site and energy of its interaction with electric dipolar moments $\approx \left(\frac{e}{\varepsilon_{eff}}\right)\left(\frac{d}{2n}\right)^3 n$, induced by the coulomb field from this charge in macroscopic dielectric approximation on all the granules at the sites $n = a(n_1, n_2)$.

$$E_c = \frac{e^2}{d}\left[\frac{1}{\varepsilon} - \frac{\alpha}{\varepsilon_{eff}^2}\left(\frac{d}{a}\right)^4\right] = \frac{e^2}{\varepsilon_{eff} d}.$$

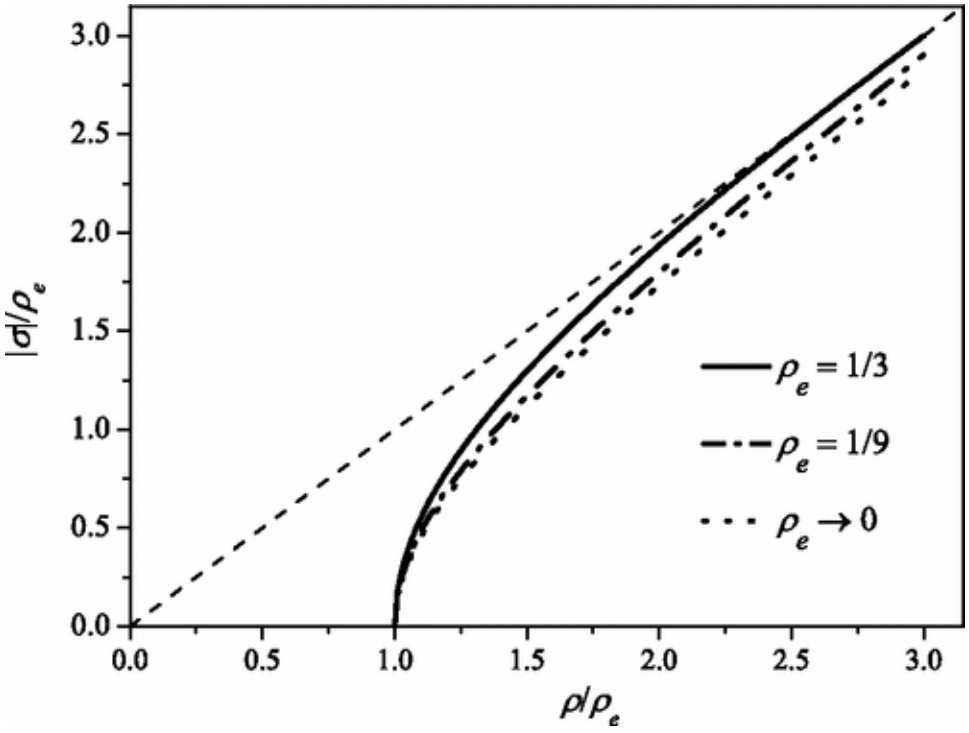
Where constant $\alpha = \frac{\pi}{4}\sum_{n \neq 0} n^{-4}$.

RESULTS AND DISCUSSION

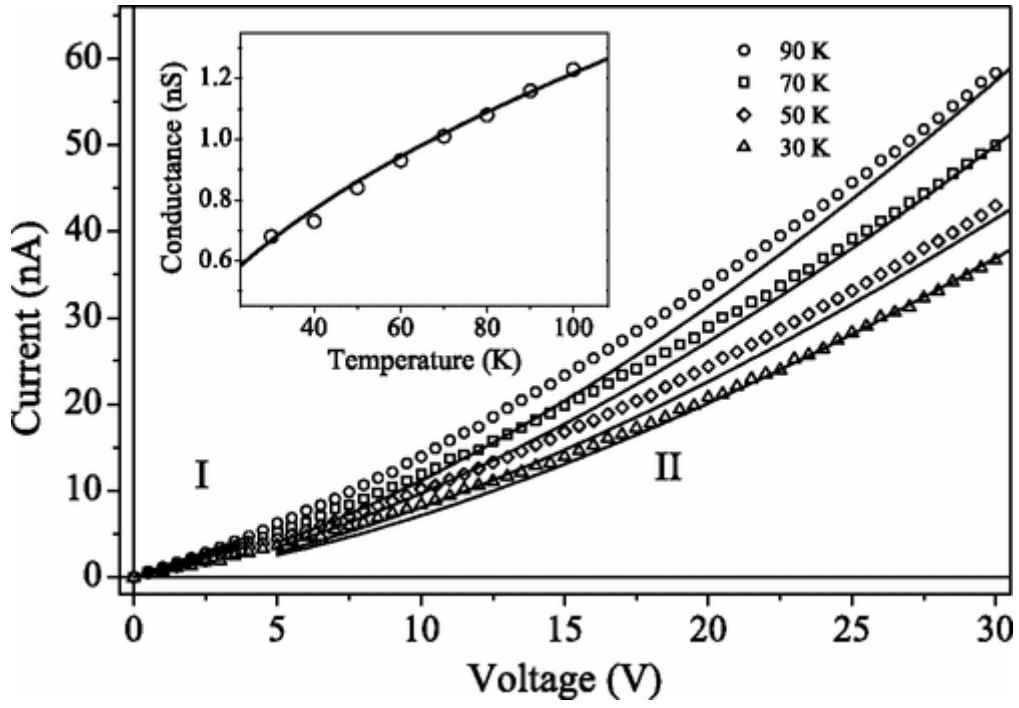
Graph (1) shows that in the presence of electric field $F_r \neq 0$ the local equilibrium is perturbed and the system generates current and generally accumulate charge. Graph (2) shows that for moderate temperatures, $T \lesssim E_C / k_B$, where the neglect of multiple charged state is justified, this dependence is reasonably close to the simplest low temperature form $\sigma = \sqrt{\rho^2 - \rho_e^2}$. It was found that the evident consequence of long range character of coulomb field in free area where possible due to screening effects by the metallic contacts and to the related short range fields. There is practically no charge accumulation and hence no diffusive contribution to the current in free area. Thus steady state of free area in out of equilibrium conditions is characterized by the ohmic conductivity g_e. The conduction in the overall system resulted from matching the considered process in contact and free area. To evaluate the global resistance of the circuit in series it is necessary to add the contributions of both areas to it. Choosing $T = 50K$ the ohmic conductance of the free area G_{FA} was calculated through the formula $G_{FA} = g(\rho_e) L'b / l \approx \omega 1.5 \times 10^{-18}$ seconds. In the contact area we have estimated the conductance using the formula $G_{CA} = \omega 8.0 \times 10^{-22}$ seconds. We have found that any choice of ω, the conductance of the contact area was about 4 orders of magnitude smaller than that of the free area and dominated the global resistance of the system. The effective value of the parameter V_0 giving the best fit to the experimental data notably higher than obtained by above formula for a single layer system. We have obtained the single value $V_0 \approx 0.5V$ whereas the bet fit for 10 layer experimental sample which is shown in graph (3). This difference was effectively accounted by the simple multiplicative factor $\alpha \approx 6$ the multilayer factor so $V_{\exp} = \alpha V_0$ assured both the agreement for regimes I and II of I-V curves and boundary $V \sim V_{\exp}$ between them, which is shown in graph (3). The obtained results were compared with previously results of theoretical and experimental works and were found in good agreement.



Graph 1: Equilibrium density ρ_e of charge carriers in the function of temperature (solid line). Curve 1 (dashed line) corresponds to the low-temperature asymptotics $\rho_e \approx 2\exp(-E_c / 2k_B T)$ and curve 2 (dashed-dotted line) to the high-temperature asymptotic $\rho_e \approx \rho_\infty - E_c / 9k_B T$, converging to the limit $\rho_\infty = 2/3$ (dotted line).



Graph 2: The charge density σ in function of the carrier density ρ for different temperatures (corresponding to different thermal equilibrium value ρ_e).



Graph 3: I-V characteristics for a granular sample at different temperatures, compared with the theoretical curves for Regimes I and II. (Inset) Temperature dependence of ohmi conductance G_0, measured data (circles) vs. calculated results.

CONCLUSION

We have studied the transport properties of square lattice of metallic nanogranules embedded in insulator. We have found that in this model with three possible charging states $\pm$ or 0 of a granule and three kinetic processes creation or recombination of pair and charge transfer between neighbor granules, the mean field kinetic theory was developed. We have also found the interplay between charging energy and temperature between applied electric field and the coulomb fields by the nano compensated charge density. The resulting charge and current distributions were found to be essentially differ in the free area, between the metallic contacts or in the contact area beneath those contacts. Thus the steady state *dc* transport is compatible only with zero charge density and ohmic resistivity. The obtained results were found in good agreement with previously obtained results.

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Characteristics of Coherent Photon Transport in Semiconductor Waveguide Cavity System

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ABSTRACT

We have studied the characteristic feature of coherent photon transport in a semiconductor waveguide. We have presented a semiconductor master equation formalism that accurately simulated coherent input or output coupling of semiconductor cavity quantum electrodynamics systems such as planar photonic crystals and micropillar cavities. The role of quantized multiphoton effects pointed out the possible failure of weak excitation approximation, which was found to fail even for low input powers and small mean cavity photon numbers. For increasing field strengths, possible failure of the semiclassical approach was taken into account. In the weak coupling regime, higher order quantum correlation effects, were shown to be significant. We have introduced the general theoretical technique to simulate coherent photon transport outside both the weak excitation approximation and the semi classical approximation. Electron-phonon interactions at a microscopic level were derived using polaron transformation. We have demonstrated that substantial deviations from the weak excitation approximation resulted for very small mean photon numbers. We have modified the master equation approach to include the mechanism of electron-acoustic scattering and studied the impact of electron-phonon interaction on incoherent scattering and coherent renormalization of the exciton cavity coupling rate, qualitative differences from simple Lorentzian decay model containing quantum dot were found. We have also studied the transmission of light in the strong coupling regime and simulated a phase gate. We have found that coupling to an acoustic phonon bath caused considerable qualitative changes in light propagation characteristics modeled by a simple pure dephasing process. We have used the model to simulate a conditional phasegate. The obtained results were found in good agreement with previously obtained results.

KEYWORDS

Coherent, Photon Transport, Waveguide, Simulation, Coupling, Photonic, Semiconductor Cavity, Micropillar Cavity, Quantization, Excitation, Interaction, Polaron Transformation, Acoustic Scattering, Lorentzian Decay, Quantum Dot.

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INTRODUCTION

There have been several successful demonstration of coherent light propagation effects in various semiconductor systems, including planar photonic crystals and micropillars. Bose et al. [1] measured the exciton-induced doublet, i.e. polariton splitting through waveguide mode transmission in a photonic crystal waveguide cavity system [2]. Loo et al. [3] probed the strong coupling in micropillar via coherent reflection. Young et al. [4] demonstrated first steps toward a conditional phase gate using light reflection from a micropillar common to the analysis of all of these experiments has been the application of the weak excitation approximation, where at most only one quantum was assumed. Young etal suggested that their experiments were likely at the single photon level for less than 0.1 photon per cavity lifetime, so they applied a weak excitation approximation solution [5]. These useful formalisms have been very successful and certainly help to clarify the basic physics of low intensity photon transport. The validity for the weak excitation approximation was taken and there can be quantum nonlinearities in the systems due to multiphonon correlations. Giant optical non linearities were studied by Auffeves-Garnier et al. [6], their semiclassical approach adiabatically eliminated the cavity mode and included effects outside the weak excitation approximation i.e. the Purcell regime, naturally with such a semiclassical approach. There is no influence from the higher lying levels of the anharmonic Jaynes-cumming ladder, so it cannot be applied in the strong coupling regime. Most photon transport approaches also neglect the details of electron-acoustic phonon scattering [7-11], apart from the inclusion of Lorentzian decay rate for the excition i.e. broadening of the zero phonon line. Several workers have shown that coherent excitation of semiconductor quantum dot systems can easily go into the anharmonic cavity quantum electrodynamics regime [12-13]. The ability to couple waveguides and cavities offers exciting opportunities for integrated quantum optical devices using solids [14-16]. In planar photonic crystals offer a technology platform, when quantum bits or qubits can be manipulated from quantum dots placed at field antinode positions within the cavity or waveguides [17-19]. Integrated semiconductor micropillar systems also shown promise for quantum optical applications [20-21] working at the few photon level. Sattar and Kumar [22] studied impedance concept for waveguiding devices from the microwave frequency regime to optics and plasmonics. The Expression were based on the electromagnetic eigen modes that were excited at the interface of a structure. Alam and Aparajita [23] studied mutual capacitive coupling and tunneling in the silicon single electron transistor coupled to a dopant atom. They observed a spectacular enhancement of the conductance through single electron transistor when transport occurred by resonant tunneling via the dopant atom. They have found that in certain range of temperature the mesoscopic fluctuations of coulomb blockade peaks were suppressed. Kumar and Ranjan [24] studied transmission through surface disorder waveguides in general and solid basis. Their results presented that desired properties on a waveguide through the roughness of its boundaries can be obtained. This surface scattering approach predicted that how mode specific scattering lengths in waveguides dependent on the details of system's surface roughness.

METHOD

We have considered that light propagation for a quantum dot cavity geometry, where the input and output fields can be indentified separately from the cavity regime in which the quantum dot was assumed to be embedded. For a continuous wave waveguide mode of a photonic crystal system, the classical weak excitation approximation reflectivity has been derived is given below

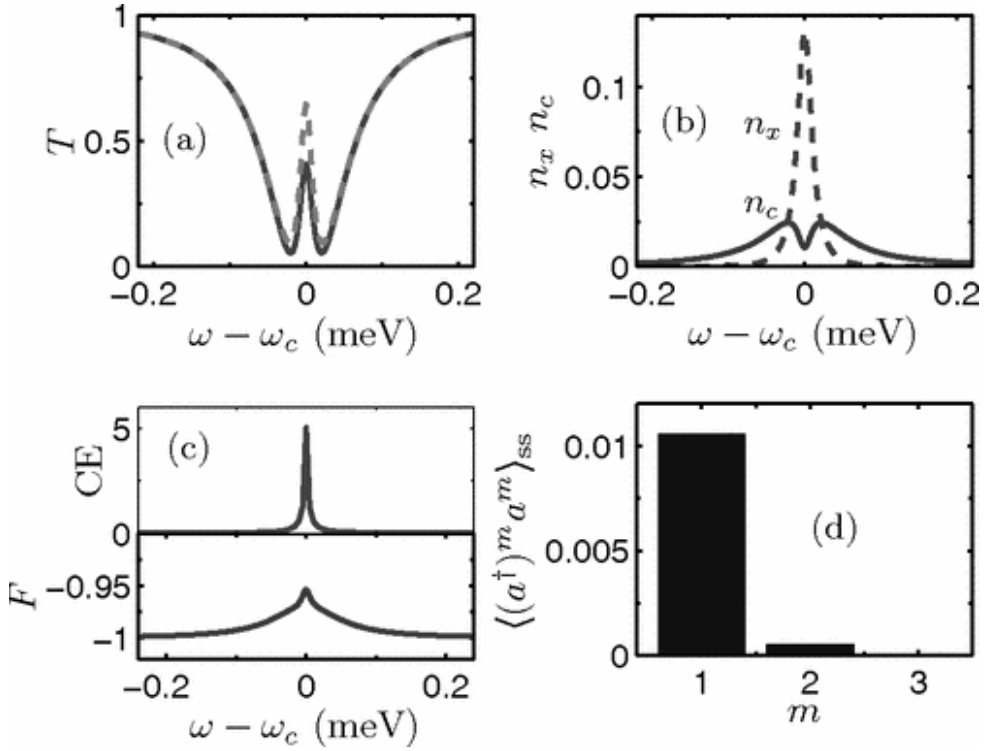
$$r_{pc}(\omega)=\frac{i\omega\Gamma_c}{\omega_c^2-\omega^2-i\omega(\Gamma_c+\Gamma_0)-\omega\Sigma(\omega)}$$

Where the self energy $\omega\Sigma(\omega)=\frac{\omega g^2}{\omega_x}-\omega^2-i\omega\Gamma_x^- \Gamma_0=2k_0$ is the cavity decay, $\Gamma_c\equiv 2k_c=2(k_l+k_r)$ is the cavity waveguide coupling rate, which is inversely proportional to the group velocity of the waveguide mode, ω_c is the cavity mode resonance, ω is the target exciton resonance of the quantum dot and $\Gamma_x^{'}=Y+Y^{'}$ is the total

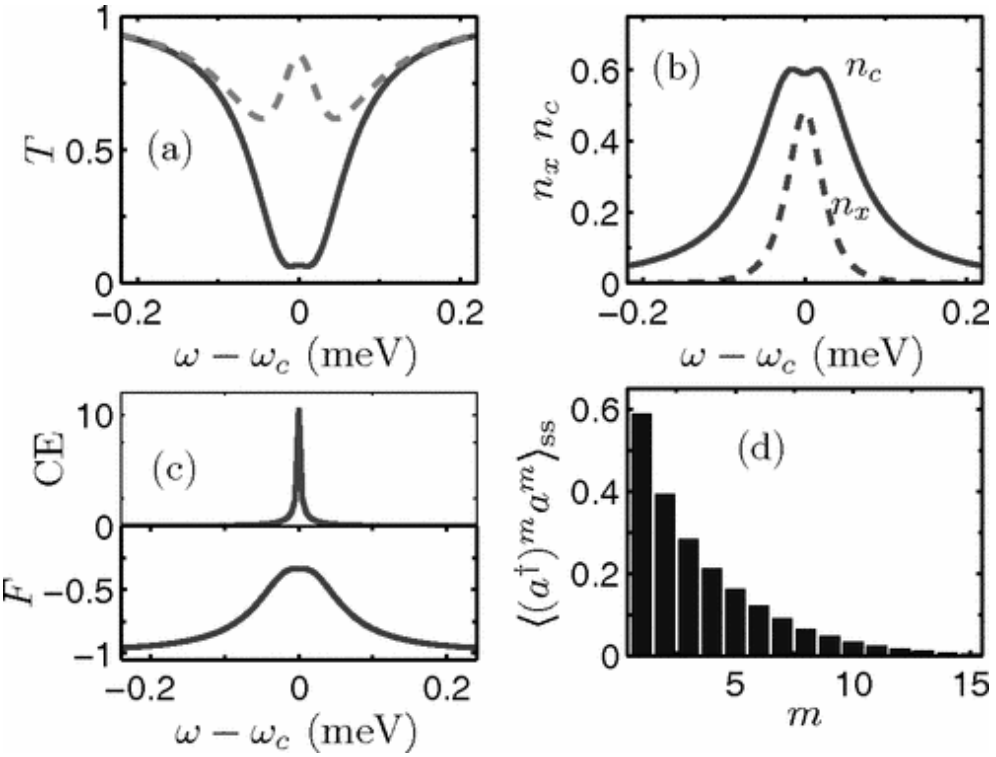
decay rate of the exciton, including radiative (Y) and non radiative, pure dephasing (Y') process. The total cavity decay rate in $\Gamma_c^t = \Gamma_0 + \Gamma_c$ and the exciton cavity coupling rate $g \propto \frac{d^2}{V_{eff}}$ is the effective mode volume. The corresponding transmissivity is simply $t = 1 + r$ and transmission through $R = |r|^2$ and $T = |t|^2$. Similar expressions have been derived by other group, e.g. with the dot resonance with cavity, then polariton doublet coincides with the vacuum Rabi splitting which was observed in transmission or reflection, the normal mode doublet occurred even if the dot is not in the strong coupling regime, through ultimately doublet feature is lost at high temperatures due to phonon micropillar system was similar and have $r_{\mu pill} = 1 - \sqrt{\eta pc}$, where η is a measure of in or out efficiency.

RESULTS AND DISCUSSION

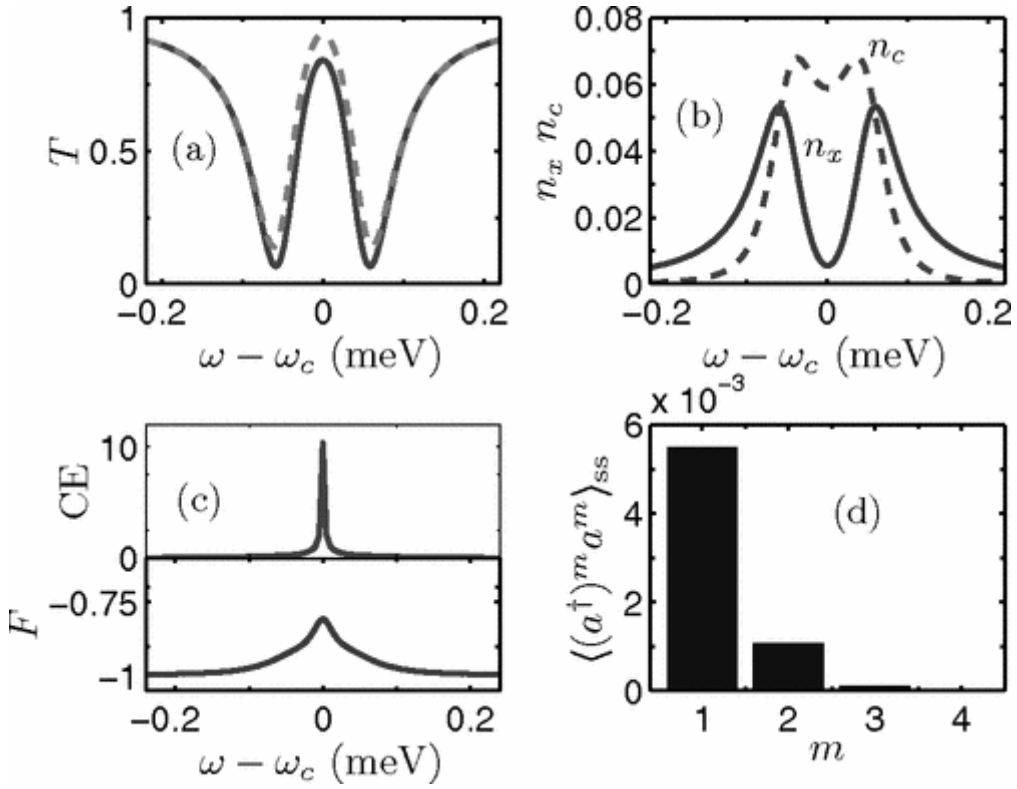
Graph (1) shows the weak coupling regime with $g = 20meV \approx 0.32\kappa_t$, using a fairly weak excitation field of $\eta_x = 0.5g$. This field value was chosen to be small enough that the cavity population is significantly lower than 0.1 but large enough a breakdown of the weak excitation approximation. We have also confirmed that this value of $\frac{g}{k}$ yielded to vacuum Rabi splitting. Graph (1)(a) shows the transmission versus detuning with as shown as dashed line and without the weak excitation as shown by solid line. We have also confirmed that the polariton doublet appeared even though are not in the strong coupling regime. The weak excitation approximation breaks down with qualitative differences of more that 40% near $\omega \approx \omega_c$ and with chosen value of g, the region of transparency is very weak, which is a consequence of the finite quantum dot broadening through Y and Y'. This observation is contrast with the results of ref (6), where such broadening were not included, these zero phonon line broadenings are essential to include for a realistic quantum dot system. Graph (1) (b) shows the exciton and cavity mode population, confirming that the largest cavity population is well below 0.1, the fundamental condition for the weak excitation approximation is not low number of photons but a negligible excitation of the dot and excitation population is evidently no longer negligible. Graph (1) (c) shows the correlation error. The non linear quantum aspects of this dot cavity coupling regime is shown in graph (2) which shows the increase in the pump value to $\eta_c = 2.5g$. The weak excitation breaks down dramatically as shown in graph (2)(a). Graph 2 (a) and 2 (d) further confirm that we are accessing a regime where both the weak excitation approximation and the semi classical approximations, even for a weakly coupled system. We have found anharmonic cavity quantum electrodynamics regime. Graph (2) (b) shows the corresponding population. A quantum dot cavity system in the weak to intermediate coupling regime with $g = 60\mu eV \approx k_t$ and $\eta_c = 0.25g$ have been found. Graph (3)(a) shows the transmission with dashed line and without solid line the weak excitation approximation, the population was found. Graph (3)(b) shows the semiclassical error and 3 (c) and 3 (d) dhows the Fano factor. Electron-phonon scattering is seen to manifest in a coherent renormalization in $g \to \langle B \rangle g$ as well as mediate incoherent scattering between the exciton and cavity. We have studied a conditional phase gate. Using a semiconductor micropillar system, conditional phase shifts of around 0.03 were found. In reflection conditional phase changes of around $\pm\frac{\pi}{4}$ were found. One photon resulted i.e. the weak excitation approximation tended to overestimate this value. Including the coupling to the photon bath was seen to qualitatively change the phase characteristics. The obtained results were compared with previously obtained results of theoretical and experimental works and were found in good agreement.



Graph 1: Transmission characteristics for a weakly-coupled Quantum Dot-cavity-waveguide system, with $g = 20meV \approx 0.32\kappa_t$ and $\eta_c = 0.5g$. (a) Transmission with (dashed) and without (solid) the Weak excitation approximation.



Graph 2: With the larger pump field $\eta_c = 2.5g$ multiphoton correlations.



Graph 3: For an intermediate to strongly coupled system, with $g = 60\mu eV \approx \kappa_t$ and $\eta_c = 0.25g$ ..

CONCLUSION

We have studied the characteristics of coherent photon transport in a semiconductor waveguide cavity system using semiconductor master equation technique. We have found that for the regime of coherent photon transport including multiphoton effects and photon scattering within the theoretical formalism in the weak coupling higher order quantum correlation effect were significant. We have demonstrated that for mean photon numbers much less than 0.1 adopted weak excitation i.e. single quantum approximation breaks down even in weak coupling regime. We also explored the role of electron-acoustic-phonon scattering and found that phonon mediated scattering played a qualitatively important role on the light propagation characteristics. A conditional phase gate at a phonon bath temperature of 20k in the strong coupling regime was present. The obtained results were found in good agreement with previously obtained results.

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