QUANTUM ELECTRONICS IN QUANTUM COMMUNICATIONS

We show below the virtual model of a bosonic superconducting cosmic string (**fig. 1**) compared to our actual model of a **quantum electronic system** (**fig. 2**) that enables the creation of quantum generator for flexible (folded) quantum nano-computers, and space computer and TV displays in quantum telecom and cyberspace based on three fundamental laws of physical-chemical kinetics: (1) **the law of entire equilibrium**, (2) t**he law of the duality of elementary processes** (or the equality of direct and reverse transition probabilities), and (3) **the law of equal *a priori* probabilities**. It is shown that said three laws follow from the law of the symmetry of time, and furthermore, that the first and third of these laws are both derivable from the second.

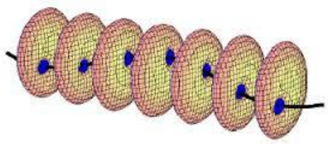


Fig 1. **Cosmic bosonic string**

Accordingly, and contrary to the common bosonic string model in **fig 1**, we model the ultracold hollow cylindrical superstring (**fig 2**) as a space-time piercing quantum tube with Casimir effect in interacting Bose-Einstein condensate inside a cylindrical tube (ref. 2 on p. 6) in overlapping counter-rotating magnetic fields (**fig. 3 here, and fig. 4**) and in **quantum fusion** in quantum entanglement and tunneling **(ill. 1)**.. (Compare with the space-time piercing characteristics of neutrinos and their left-right counter-spinning ability).

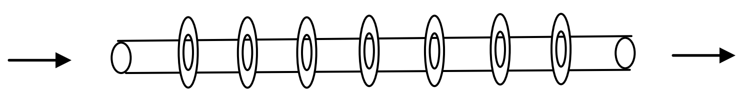


Fig. 2 **superstring**

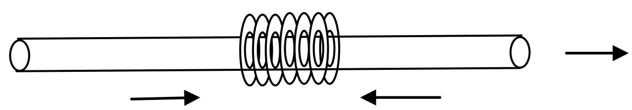


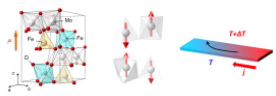
Fig. 3

Ill. 1

Our tunneling superstring system in fig. 2 consists of open left entry to trap fermionic atoms in the vacuum vortex core. There, quantum Hall***** effect (QHE) is realized in a 2d electron gas subjected to a strong perpendicular magnetic field (**fig. 3 and ref. 6, 7**) under the influence of the nuclear spin fields that are then harmonized in vertex by shifting counter-rotating magnetic fields in **dynamical Casimir effect** (**ref. 2, 3, 4**) to unify them in a superimposed magnetic field in quantum squeezejunction (**fig. 3** above). The unified matter is then superconducted via superstring's open right exit in **superpropagation** due to induced Casimir and Zeeman effects and Feshbach resonance, making helium and hydrogen to interact in nuclear fusion: **hydrogen** nuclei into **helium,** whereby the matter of the fusing nuclei is converted to **heavy or dark photon** (high energy)**.**

"Giant thermal Hall effect in multiferroics."Nature Materials

T. Ideue, T. Kurumaji, S. Ishiwata, and Y. Tokura . University of Tokyo.



The system in fig 3 functions similar to musical squeezebox harmonika or accordion (ill. 2) which expands and contracts its bellows by using trapped air to create pressure and vacuum and produce musical sounds.

Ill. 2. Accordion

Similar to accordion functions, our **quantum harmonic system** in fig. 3 shifts external magnetic fields back and forth over ultracold Majorana fermions trapped and compressed in the rotating tube of the superconducting superstring. In the lab such system can be modeled as a carbon tube (**ref. 5)** with Bose-Einstein condensate (**ref. 2, 4**) with graphene membrane (**ref. 7**) integrated within the counter-rotating **ferror- or nanomagnets*** sliding back and forth over the tube and its trapped ultracold particles similar to Casimir plates. Note that graphene membrane is impermeable to standard gases, including helium. To make this system work as a modular cold fusion reactor, we would direct the particles beam from our **quantum harmonic generator** into the chamber with liquid helium and neon to interact there with solar neutrinos.

*****Greek scientists from the University of Crete and the Foundation for Research and Technology-Hellas (FORTH), in collaboration with U.S. scientists from Ames Research Center of NASA, have discovered a new way to create small magnets by using short laser light pulses.

The discovery of the phenomenon called **Quantum Femto-Magnetism** was made by the University of Crete physics professor Ilias Perakis and his group in Greece, in co-operation with Ames Laboratory and Iowa State University physicist Jigang Wang and his team in the USA. 2016 Nobel Prize winner Duncan *Haldane* discovered how topological concepts can be used to understand the properties of **chains of small magnets**.

Our quantum model in fig 3 above represents the classical and quantum motion of photons, etc. in a rotating string. The spin motion per Bargmann-Michel-Telegdi equation is considered in the rotation tube and rotating system in acceleration of charged particles. In fact, neutral particles photons, neutrons, etc. can be accelerated by rotating tube. The specific characteristics of the mechanical systems in the rotating framework follow from the differential equations describing the massive body in the noninertial systems. (Landau, 1965). Let the Lagrange function of a point particle in the inertial system be as follows:

$$L_o = \frac{m v_0^2}{2} - U \qquad (1)$$

with the following equation of motion

$$m \frac{D v_o}{dt} = \frac{\partial U}{\partial r'} \qquad (2)$$

where the quantities with index 0 correspond to the inertial system. The Lagrange equations in the noninertial system is of the same form as that in the inertial one, or,

$$\underline{d} \quad \underline{\partial L} = \underline{\partial L} \qquad (3)$$

However, the Lagrange function in the noninertial system is not the same as in eq. (1) because it is transformed. Specific extraordinary properties of our quantum vacuum tube in fig. 3 is that it simultaneously revolves, and rotates around its axis **due to the forces acting on the electron in the Hydrogen atom and the centrifugal force (which appears to be the result of conservation of angular momentum),** creating thereby atomic vortex and superfluidity of trapped supercold gaseous helium, which in quantum Hall effect becomes superfluid in percolation of its housing tube and acts thereby as a lubricant and coolant for external magnets sliding over our quantum tube in fig. 3. Note that bosonic quasi-particles, known as exciton-polaritons, can be created in Bose-Einstein condensate (BEC) through strong coupling between bound electron-hole pairs and the photon field. Recently, a non-equilibrium BEC and superfluidity have been demonstrated in such structures.

Our quantum tube in fig. 3 is encapsulated by hydrogen solution in Feshbach resonance, creating thereby a dual quantum model in coherent entanglement (ref. 1) i.e., subquanta within quanta. Such a quantum-subquanta introvert-extrovert duo is the building block of universal quantum web predicted by Einstein, so our quantum model on macroscale explains the phenomenon of wave particle duality in perpetuum mobile of the in-and-out flows of matter and energy of a black hole with curved horizon due to rotation and inflated gases in corona of matter where energy circulates in a **Möbius band** (superconductive and polarized under magnetic field) in a partially visible and mostly invisible spectrum (**dark matter**). Compare with charged particles that have been caught in the magnetic field of earth and that can move on a Möbius band.

Alfred Goldhaber of Stony Brook University in New York says that if black holes have charged plasma swirling around them, a photon's slowed movement through the plasma could make it behave as if it has mass.

Hence, our model and physical system in fig. 3 materializes the **quantum vacuum and quantum space theories** where superfluid vacuum is constructed from quanta. The assumption that the vacuum is a superfluid (or a BEC), enables us to derive Schrödinger's non-linear wave equation, also known as the Gross-Pitaevskii equation, from first principles. Furthermore, by treating the vacuum as an acoustic metric, it becomes the analogue for general relativity's curved spacetime within regimes of low momenta.

This kaleidoscopic matter explains the mystery of mass generation, the question of how the Higgs boson gets its mass, because it manifests the mass generation similar to gap generation mechanism in superconductors or superfluids. In other words, mass becomes a consequence of symmetry, vectoring quantum **vortices** formed in vacuum condensate.

Because our ultracold superstring in fig. 2 above is nonrelativistic, it is not constrained to the multidimensional space-time in which superstrings are usually studied in high-energy physics. So, our string is the actual **harmonic condensed matter system**, where superconductviity in **macroscopic quantum phenomena** can be studied experimentally, and quantum energy teleported.

It means that in our above shown quantum model, physical/molecular data of the object can be photonically compressed, tunneled via our quantum tube and then amplified/reassembled at a given destination. See **ref. 2**.

The eternal question "why cosmic strings aren't detected by gravitational waves" is answered in assumption that in a quantum state such mini strings never meet or spark and function at zero point gravity, in anti-gravity or repelling gravity. Such cosmic mini strings create mini black holes that can't be detected by gravitational waves. When twin superstrings of matter create a macroscale black hole, as explained in our **Theory of Unified Matter** in ch. IV, we might detect them by gravitational waves.

Ref. 1:

Streltsov, A. *et al.* Measuring quantum coherence with entanglement. *Phys. Rev. Lett.* 115, 020403 (2015):

A team of researchers from India, Spain and the UK has mathematically proved that it is possible to convert an amount of 'quantum coherence' in a system into an equal amount of 'quantum entanglement'. The team, which included Alexander Streltsov from ICFO-The Institute of Photonic Sciences, Barcelona, Spain, and Gerardo Adesso from the University of Nottingham, provided a mathematically rigorous approach to resolve this question using a common frame to quantify quantumness in terms of coherence and entanglement. They show that any non-zero amount of coherence in a system could be converted to entanglement via incoherent operations.

Ref. 2

Shyamal Biswas, Saugata Bhattacharyya.
Amit Agarwal
03/2015

ABSTRACT

"We explore **Casimir effect** on an interacting Bose-Einstein condensate (BEC) inside a cylindrical tube. The Casimir force for a confined BEC comprises of a mean field part arising from the inhomogeneity of the condensate order parameter, and a quantum fluctuation part which results from the phononic Bogoliubov excitations of the BEC. Considering Dirichlet boundary conditions for the condensate wave function as well as for the Bogoliubov excitations we explicitly calculate the Casimir force and scaling function. For low densities of the condensate, the mean field part dominates over the quantum fluctuation part, while for high densities, as the BEC order parameter becomes homogenous, the quantum fluctuations start playing a more dominant role."

Ref. 3

Observation of the dynamical Casimir effect in a superconducting circuit:

C. M. Wilson,

G. Johansson,'

A. Pourkabirian,

M. Simoen,

J. R. Johansson,

T. Duty,

F. Nori & P. Delsing

Nature **479**, 376–379, (17 November 2011) doi:10.1038/nature10561

One of the most surprising predictions of modern quantum theory is that the vacuum of space is not empty. In fact, quantum theory predicts that it teems with virtual particles flitting in and out of existence. Although initially a curiosity, it was quickly realized that these vacuum fluctuations had measurable consequence, producing the Lamb shift of atomic spectra and modifying the magnetic moment of the electron. This type of renormalization due to vacuum fluctuations is now central to our understanding of nature. However, these effects provide indirect evidence for the existence of vacuum fluctuations. From early on, it was discussed whether it might be possible to more directly observe the virtual particles that compose the quantum vacuum. Forty years ago, it was suggested that a mirror undergoing relativistic motion could convert virtual photons into directly observable real photons. The phenomenon, later termed the dynamical Casimir effect, has not been demonstrated previously.

Here we observe the dynamical Casimir effect in a superconducting circuit consisting of a coplanar transmission line with a tunable electrical length. The rate of change of the electrical length can be made very fast (a substantial fraction of the speed of light) by modulating the inductance of a superconducting quantum interference device at high frequencies (>10 gigahertz). In addition to observing the creation of real photons, we detect two-mode squeezing in the emitted radiation, which is a signature of the quantum character of the generation process.

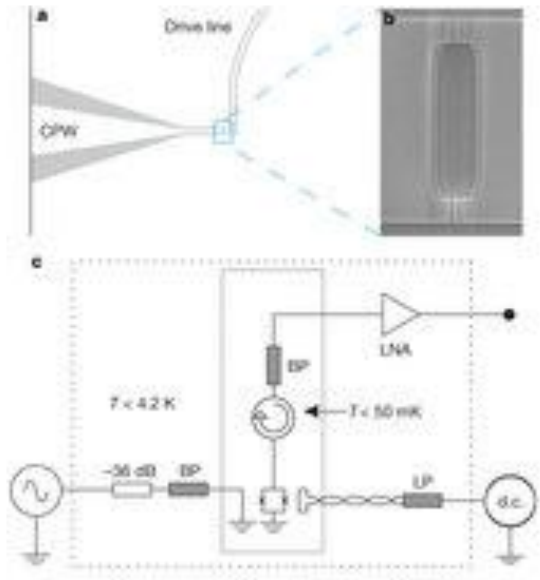


Figure 4. Experimental overview

a, Optical micrograph of sample 2. Light parts are Al, which fills most of the image, while the dark parts are the Si substrate, visible where the Al has been removed to define the transmission lines. The output line is labelled CPW and the drive line enters from the top. Both lines converge near the SQUID (boxed). **b**, A scanning-electron micrograph of the SQUID. The SQUID has a vertical dimension of 13 μm and a normal state resistance of 218 Ω (170 Ω) implying $L_J(0) = 0.23$ nH (0.18 nH) for sample 2 (sample 1).

A simplified schematic of the measurement set-up. The SQUID is indicated by the box with two crosses, suggestive of the SQUID loop interrupted by Josephson junctions. A small external coil is also used to apply a d.c. flux bias through a lowpass filter (LP). The driving line has 36 dB of cold attenuation, along with an 8.4–12 GHz bandpass filter (BP). The filter ensures that no thermal radiation couples to the transmission line in the frequency region were we expect DCE radiation. (For sample 1, the last 6 dB of attenuation were at base temperature.) The outgoing field of the CPW is coupled through two circulators to a cryogenic low-noise amplifier (LNA) with a system noise temperature of $T_N \approx 6$ K. At room temperature, the signal is further amplified before being captured by two vector microwave digitizers. The dashed boxes delineate portions of the set-up at different temperatures, T, which are labeled.

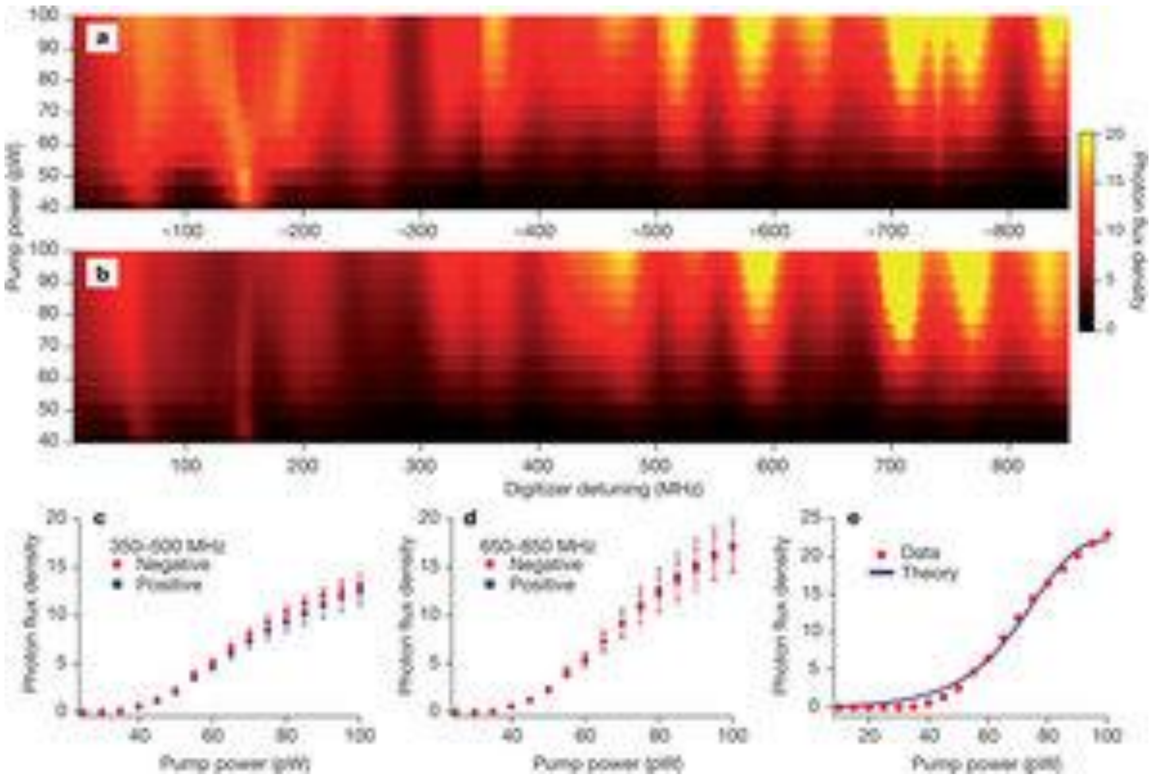


Figure 5. Photons generated by the dynamical Casimir effect.

Here we show the output flux of the transmission line while driving sample 1 at f_d = 10.30 GHz. **a**, **b**, Broadband photon generation. We plot the dimensionless photon flux density, n_{out} (photons s^{-1} Hz^{-1}), which is the measured power spectral density normalized to the photon energy, $\hbar\omega$, as a function of pump power and detuning, $\delta\omega/2\pi$. Panel **a** shows negative detunings (axis reversed), while **b** shows positive detunings. The symmetry of the spectrum is apparent. Positive and negative detunings are recorded simultaneously. The plots are stitched together from several separate scans, between which we have changed image rejection filters at the input of the analyzers. **c**, **d**.

The photon flux density for positive and negative detunings averaged over frequency (at fixed power) for two different symmetric bands, showing the symmetry of the spectrum. Error bars, s.d e., A section through **a** at $\omega/2\pi$ = −764 MHz, along with a fit to the full theory.

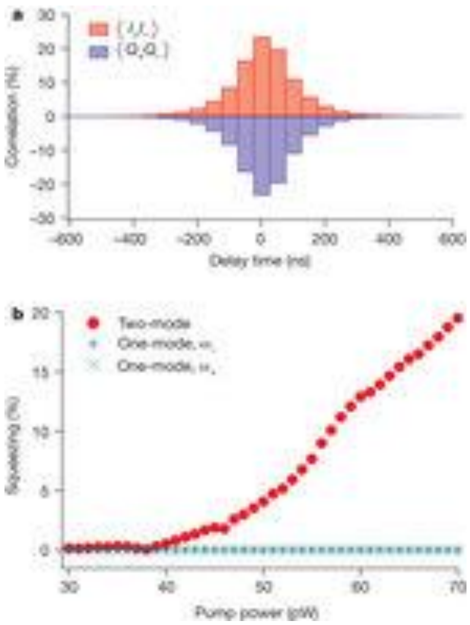


Figure 6. Two-mode squeezing of the DCE field.

<u>Ref. 4</u>

Viewpoint: Modeling Quantum Field Theory

Jeff Steinhauer, Department of Physics, Technion–Israel Institute of Technology, Technion City, Haifa 32000, Israel, November 26, 2012• *Physics* 5, 131

An analog of the dynamical Casimir effect has been achieved, where phonons replace photons, and thermal fluctuations replace vacuum fluctuations.

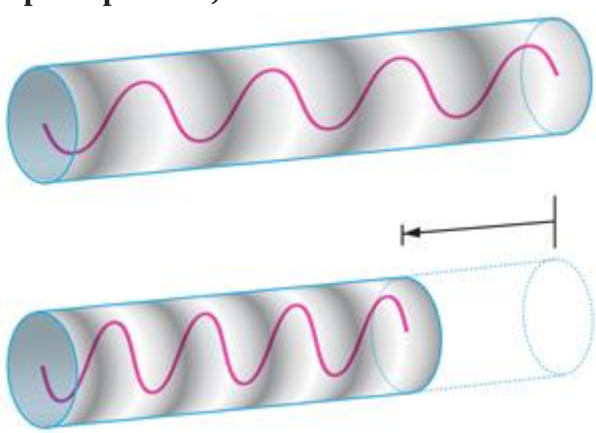


Figure 7. A resonator for the dynamical Casimir effect. The initial length of the resonator is shown in the upper illustration. The sine wave represents one of the modes of the resonator, initially populated by vacuum fluctuations. The length of the resonator is suddenly changed (lower illustration).

The wavelength and frequency of the sinusoidal mode changes rapidly. The change is nonadiabatic, so the vacuum fluctuations are amplified, creating real photons.

Empty space is constantly fluctuating with virtual photons, which come into existence and vanish almost immediately. While these virtual photons are all around us, they cannot be observed directly. However, in a special kind of environment with spatial or temporal inhomogeneity, virtual photons can become real, observable photons by means of a variety of effects.

The challenge can be made easier by using a condensed-matter analog to the vacuum and its photon modes [1]. In *Physical Review Letters*, Jean-Christophe Jaskula and colleagues at the University of Paris-Sud, France, report that they have created such an analog for the dynamical Casimir effect, in which a rapidly changing resonator (Fig. 1 in this ref 1) produces real particles [2]. In addition to being a condensed-matter system, their observation is an analogy in another way: The real particles they observe originate from thermal fluctuations rather than quantum fluctuations of the vacuum. Their work opens the door for the observation of the quantum vacuum version, in their condensed-matter analog system.

The phenomenon studied by Jaskula and co-workers was studied previously by Engels and colleagues [3], but the interpretation was strictly classical. The real particles created were referred to as Faraday waves, oscillatory patterns that appear at half of the driving frequency. Now, Jaskula and colleagues [2] show that the waves have pair correlations in momentum space, thus making the connection with quantum-mechanical pair production and the dynamical **Casimir effect.**

In the Schwinger effect, for example, a homogeneous electric field can pull apart pairs of oppositely charged virtual particles [5]. The electric field should be strong enough to give an acceleration of *mc*3/ħ, where *m* is the mass of the particles. Thus, to produce an electron-positron pair, an electric field of 1018V/m is required, giving an acceleration of 1029 m/s2 . To put this in perspective, if this acceleration were maintained in the laboratory reference frame, the electron would reach the speed of light from rest within a distance of 10−13m .

The event horizon of a black hole can also convert pairs of virtual particles (such as photons) to real particles, which are referred to as Hawking radiation [6]. One of the members of the pair has negative energy, and the other positive. Within the event horizon, the negative energy photon of the virtual pair can exist indefinitely, allowing the positive energy photon to exist also.

This real photon travels away from the black hole as Hawking radiation. On the other hand, virtual photons can be detected by accelerating the detector of the photons (the Unruh effect) [7]. In the reference frame of the detector, the virtual photons of the vacuum will appear to be a thermal distribution of real photons. In other words, the virtual photons are Doppler shifted into reality. A detector accelerating at 1020m/s2 would measure a radiation temperature of only 1K.

Another way to detect the virtual photons is to rapidly change the nature of the vacuum. In the dynamical Casimir effect, a resonator has a discrete spectrum of eigenmodes [8]. These modes are populated with the virtual vacuum fluctuations. One such mode is illustrated in Fig. 1. Suddenly, the length of the resonator is changed very rapidly, at a speed which is a significant fraction of the speed of light (the experimental challenge). The change is too fast to be adiabatic, so the population of the virtual vacuum fluctuations is amplified. The extra population consists of real, observable particles.

As we can see, it is a challenge to convert virtual particles into real, observable particles. In all cases, the experimental parameters which must be achieved are formidable. But what if we could replace the speed of light with the speed of sound? In a Bose-Einstein condensate, phonons could play the role of the photons, and the condensate itself could play the role of the quantum vacuum. This is the idea of the condensed-matter analog [1]. Following the suggestion of Carusotto *et al.*, Jaskula and colleagues used a cigar-shaped Bose-Einstein condensate as a resonator for the analog of the dynamical Casimir effect [2].

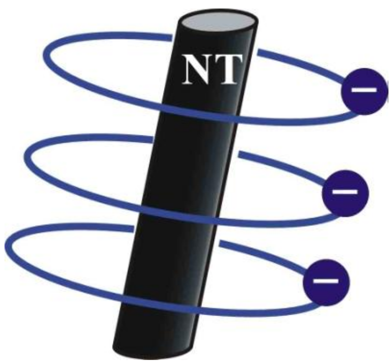
In the experiment of Jaskula *et al.*, the Bose-Einstein condensate was confined by focused laser light. The atoms forming the condensate were attracted to the bright light like insects to a lamp. In one experiment, the authors suddenly increased the laser intensity by a factor of 2 , which caused an abrupt increase in the speed of sound in the condensate, and a sudden decrease in the resonator length, as indicated in Fig. 1. Each thermally populated mode was unable to follow the sudden change adiabatically. This resulted in the production of pairs of phonons with equal and opposite momenta, and a wide distribution of momenta was observed. In another experiment, the laser intensity was modulated sinusoidally, with a variation of about 10% . This resulted in pairs of phonons with frequencies equal to half of the modulation frequency, thus demonstrating the connection between the dynamical Casimir effect and parametric down-conversion of nonlinear optics. The ongoing study of the dynamical Casimir effect is part of our effort to convince ourselves that empty space is truly filled with virtual particles. If they are really there, then we want to see them in the real vacuum, as well as in a Bose-Einstein condensate analog of vacuum.

References

1. W. G. Unruh, "Experimental Black-Hole Evaporation?" Phys. Rev. Lett. **46**, 1351 (1981)
2. J-C. Jaskula, G. B. Partridge, M. Bonneau, R. Lopes, J. Ruaudel, D. Boiron, and C. I. Westbrook, "Acoustic Analog to the Dynamical Casimir Effect in a Bose-Einstein Condensate," Phys. Rev. Lett. **109**, 220401 (2012)
3. P. Engels, C. Atherton, and M. A. Hoefer, "Observation of Faraday Waves in a Bose-Einstein Condensate," Phys. Rev. Lett. **98**, 095301 (2007)
4. C. M. Wilson, G. Johansson, A. Pourkabirian, M. Simoen, J. R. Johansson, T. Duty, F. Nori, and P. Delsing, "Observation of the Dynamical Casimir Effect in a Superconducting Circuit," Nature **479**, 376 (2011)
5. R. Brout, S. Massar, R. Parentani, and Ph. Spindel, "A Primer for Black Hole Quantum Physics," Phys. Rep. **260**, 329 (1995).
6. S. W. Hawking, "Black Hole Explosions?" Nature **248**, 30 (1974)

7. W. G. Unruh, "Notes on Black-Hole evaporation," Phys. Rev. D **14**, 870 (1976)
   V. V. Dodonov, "Current Status of the Dynamical Casimir Effect," Phys. Scr. **82**, 038105 (2010). I. Carusotto, R. Balbinot, A. Fabbri, and A. Recati, "Density Correlations and Analog Dynamical Casimir Emission of Bogoliubov Phonons in Modulated Atomic Bose-Einstein Condensates," Eur. Phys. J. D **56**, 391 (2010)

<u>Ref: 5.</u> Quantum electronic orbits discovered around carbon nanotubes



Formation of tubular electronic states around carbon nanotubes is demonstrated in recent experiments by M. Zamkov and collaborators.

Using two-color photoelectron emission researches can populate and subsequently observe the special group of electronic states with wave functions enclosing a carbon nanotube. These cylindrical “electronic tubes” constitute a new class of “image” states due to their **quantized angular motion**. The electron rotation about the axis of the nanotube gives rise to a centrifugal force that virtually detaches the electron charge-cloud from the tube's body. By experiencing the lattice structure parallel to the tube's axis these rings can act as powerful scanning probes of nanotube electronic properties. The first images show such electronic orbits schematically. The lower images gives a calculated shape of the radial part of the electronic wave function. This work represent the first experimental evidence for the existence of stable image-potential states orbiting carbon nanotubes. The measured lifetimes are found to be significantly longer compared to n = 1 image state on graphite. This facts indicates a qualitative difference in electron decay dynamics between carbon nanotubes and planar **graphene** layers. Electrons orbiting nanotubes can be used in novel computing and memory devices and possibly qubits.

Reference: M. Zamkov, N. Woody, B. Shan, H. S. Chakraborty, Z. Chang, U. Thumm, and P. Richard James R. Macdonald Laboratory, Department of Physics, Kansas State University, Manhattan, Kansas 66506-2604, USA Phys. Rev. Lett. 93, 156803 (2004)

<u>Ref. 6</u>

Abstract

We demonstrate a possibility for exciton Bose-Einstein condensation in individual small-diameter (∼ 1--2 nm) semiconducting carbon nanotubes. The effect occurs under the exciton-interband-plasmon coupling controlled by an external electrostatic field applied perpendicular to the nanotube axis. It requires fields ∼ 1 V/nm and temperatures below 100 K that are experimentally accessible. The effect offers a testing ground for fundamentals of condensed matter physics in one dimension and opens up perspectives to develop tunable coherent polarized light source with carbon nanotubes.

Received 9 May 2013
Revised 30 December 2013

Authors & Affiliations

I. V. Bondarev[*] and A. V. Meliksetyan

Department of Math & Physics, North Carolina Central University, Durham, North Carolina 27707, USA
[*]Corresponding author: ibondarev@nccu.edu

Ref. 7 Impermeable Atomic Membranes from Graphene Sheets

J. Scott Bunch, Scott S. Verbridge, Jonathan S. Alden, Arend M. van der Zande, Jeevak M. Parpia, Harold G. Craighead and Paul L. McEuen*. Cornell Center for Materials Research, Cornell University, Ithaca, New York 14853

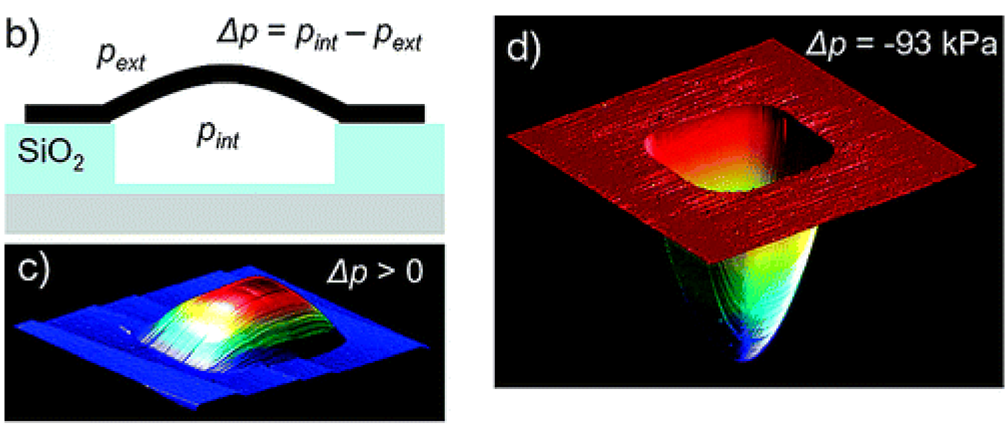
Nano Lett., 2008, 8 (8), pp 2458–2462
DOI: 10.1021/nl801457b
Publication Date (Web): July 17, 2008

* Corresponding author. E-mail: mceuen@ccmr.cornell.edu

The conduction and the valence band in graphene touch at two inequivalent points (K and K′) at the corners of the Brillouin zone. Around those two points (termed "Dirac points"), the energy dispersion relation is linear and the electron dynamics appears thus "relativistic" where the speed of light is replaced by the Fermi velocity of grapheme (≈ 106 F v m/sec) [1-4]. Such a unique electronic band structure has profound implications for the quantum transport in graphene. Indeed, it has recently been observed that high mobility grapheme samples exhibit an unusual sequence of quantum Hall (QH) effects **.V. Dubonos, A. A. Firsov, Nature 438, 197 (2005), Y. Zhang, Y.-W. Tan, H. L. Stormer, P. Kim, Nature** 438, 201 (2005)

In a magnetic field, B , **perpendicular** to the graphene plane, the Landau levels (LL) have an energy spectrum E n e v n B n F= sgn( ) 2 h 2 , where e and h are electron charge and Plank's constant, and the integer n represents an electron-like (n > 0) or a hole-like (n < 0) LL index. The appearance of an n = 0 LL at the Dirac point indicates a special electron-hole degenerate LL due to the exceptional topology of the graphene band structure. Of particular interest are the QH states near the Dirac point where strong electron correlation may affect the stability of this single-particle LL due to many-body interaction. **N. M. R. Peres, F. Guinea, and A. H. C. Neto, cond-mat/0512091**

<u>Abstract</u>

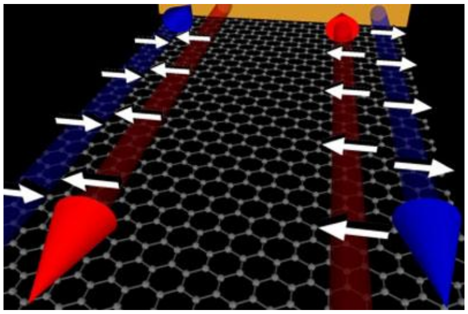


"We demonstrate that a monolayer graphene membrane is impermeable to standard gases including helium. By applying a pressure difference across the membrane, we measure both the elastic constants and the mass of a single layer of graphene. This pressurized graphene membrane is the world's thinnest balloon and provides a unique separation barrier between 2 distinct regions that is only one atom thick."

Ref.: 8 Graphene + magnetic field creates exotic new quantum electronic states

Could make graphene suitable for quantum computing for high-priority computational tasks

December 26, 2013



On a piece of graphene (the dark horizontal surface with a hexagonal pattern of carbon atoms), in a strong magnetic field, electrons can move only along the edges, and are blocked from moving in the interior. In addition, only electrons with one direction of spin can move in only one direction along the edges (indicated by the white-on-blue arrows), while electrons with the opposite spin are blocked (as shown by the white-on-red arrows). (Credit: A. F. Young et al.)

MIT research has found additional potential for graphene that could make it suitable for exotic uses such as quantum computing.

Under an extremely powerful magnetic field and at extremely low temperature, the researchers found, graphene can effectively filter electrons according to the direction of their spin, something that cannot be done by any conventional electronic system.

The trick:

- Turn on a powerful magnetic field perpendicular to the graphene flake. That causes current to flows only along the edge, and flows only in one direction — clockwise or counterclockwise, depending on the orientation of the magnetic field — in a phenomenon known as the quantum Hall effect.
- Turn on a second magnetic field — this time in the same plane as the graphene flake. Graphene's behavior changes yet again: electrons can now move in either direction around the conducting edge; electrons that have one kind of spin move clockwise while those with the opposite spin move counterclockwise.

Making circuits and transistors

"We created an unusual kind of conductor along the edge, virtually a one-dimensional wire." says Andrea Young, a Pappalardo Postdoctoral Fellow in MIT's physics department and the paper's lead author, The segregation of electrons according to spin is "a normal feature of topological insulators," he says, "but graphene is not normally a topological insulator. We're getting the same effect in a very different material system."

What's more, by varying the magnetic field, "we can turn these edge states on and off," Young says. That switching capability means that, in principle, "we can make circuits and transistors out of these," he says which has not been realized before in conventional topological insulators.

There is another benefit of this spin selectivity, Young says: It prevents a phenomenon called "backscattering," which could disrupt the motion of the electrons. As a result, imperfections that would ordinarily ruin the electronic properties of the material have little effect. "Even if the edges are 'dirty,' electrons are transmitted along this edge nearly perfectly," he says.

A graphene based quantum computer

Professor Pablo Jarillo-Herrero, the Mitsui Career Development Associate Professor of Physics at MIT, says the behavior seen in these graphene flakes was predicted, but never seen before. This work, he says, is the first time such spin-selective behavior has been demonstrated in a single sheet of graphene, and also the first time anyone has demonstrated the ability "to transition between these two regimes."

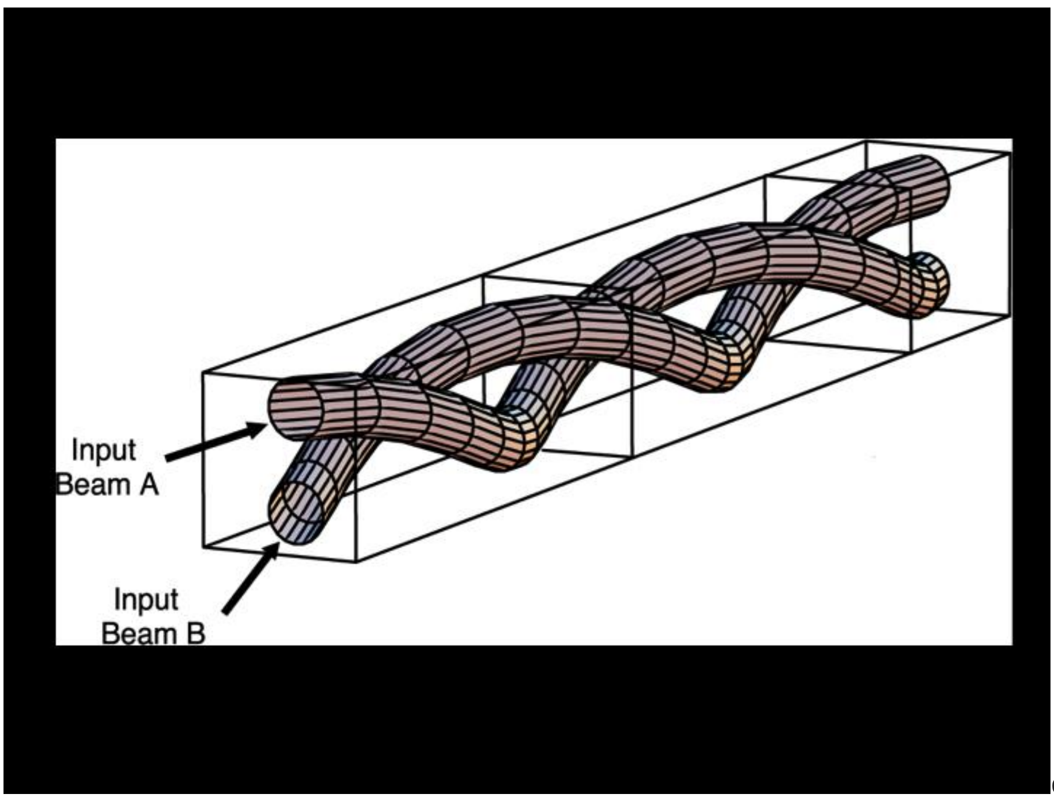
That could ultimately lead to a novel way of making a kind of quantum computer, Jarillo-Herrero says, something that researchers have tried to do, without success, for decades. But because of the extreme conditions required, Young says, "this would be a very specialized machine" used only for high-priority computational tasks, such as in national laboratories.

Ray Ashoori, a professor of physics, points out that the newly discovered edge states have a number of surprising properties. For example, although gold is an exceptionally good electrical conductor, when dabs of gold are added to the edge of the graphene flakes, they cause the electrical resistance to increase. The gold dabs allow the electrons to backscatter into the oppositely traveling state by mixing the electron spins; the more gold is added, the more the resistance goes up.

This research represents “a new direction” in topological insulators, Young says. “We don’t really know what it might lead to, but it opens our thinking about the kind of electrical devices we can make.”

The experiments required the use of a magnetic field with a strength of 35 tesla — “about 10 times more than in an MRI machine,” Jarillo-Herrero says — and a temperature of just 0.3 degrees Celsius above absolute zero. However, the team is already pursuing ways of observing a similar effect at magnetic fields of just one tesla and at higher temperatures.

Philip Kim, a professor of physics at Columbia University who was not involved in this work, says, “The authors here have beautifully demonstrated excellent quantization of the conductance,” as predicted by theory. He adds, “This is very nice work that may connect topological insulator physics to the physics of graphene with interactions. This work is a good example how the two most popular topics in condensed matter physics are connected each other.”



e

3D spiral light wave concept to constitute the photonic display in the NextGen electronic devices.

Light beam pairs propagate and spiral about each other in the crystal.

In re: by the rules of inertia, light particles would wiz off of an atom in a rotating three dimensional path. Is an electromagnetic wave 2-dimensional or 3-dimensional? The current "up-and-down" concept does not convince. If we look at a standard spring, we can see that it is a spiral/helix. We can also see that the side of the spring resembles a sine/cosine wave. So is an energy "wave" actually just a spiraling particle acting as a photon and appears to be an "up-and-down" wave only when viewed from the side? If true, this would explain at least two phenomena: 1.

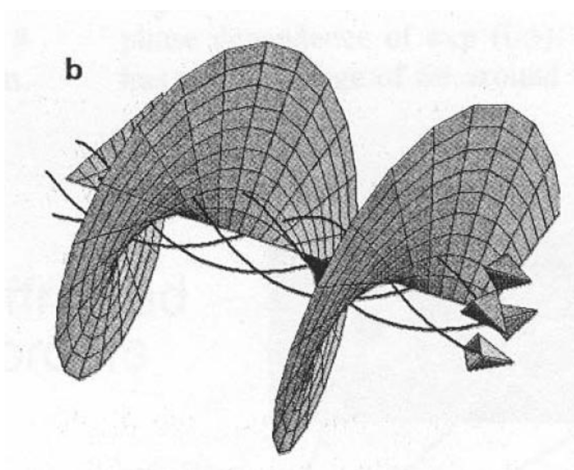
When the amplitude of a "wave" is doubled, the energy is quadrupled. In the formula for area of a circle (what would be the frontal cross-section of a spiral/helix), if one doubles the radius of the circle from 1cm to 2cm it goes from pi*cm^2 to 4pi*cm^2. Clearly, the so-called two dimensional wave acts as a circle when its amplitude is altered. 2. The side-view of EM radiation shows the standard sine wave and the path of the wave. The wave has the fastest vertical motion near the **x-axis** and slow vertical motion near the top and bottom. This would lead one to believe that the particle is traveling forward and backward in space relative to the side view, characteristic of spiral motion.

It is much like a ferry's wheel. If one arranges himself so that he is in-line with the wheel, the vertical speed of the cars is evident. The cars have the highest vertical motion right at 0 degrees on the wheel.

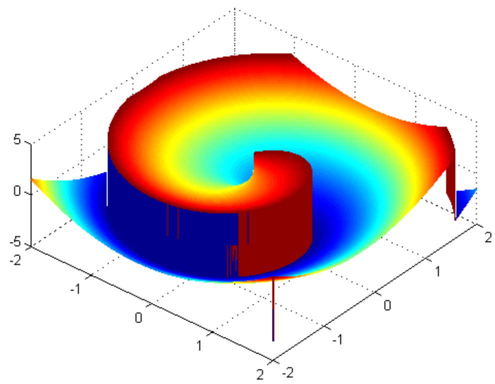
Once they near the top, their vertical speed is negligible. This is proven by the fact that at only 30 degrees, the sine measure is already at .5 radii. So if the motion of the particle on display screens exhibits slower speed at the crests and troughs of the sine wave, then there must be circular motion. If the wave is as we know it now, the particle would remain at a constant velocity on the display screen, completing a 45-->135 degree segment in the same time as a -45-->+45 degree segment. There are some interesting implications if this is true. The particle would always be traveling in the same direction, only around a helix. Is frequency determined by the angle of the particle in relation to the helix? Or its velocity... Or both? Is there an attracting body which holds the photon together? If the photon itself is traveling at the speed of light relative to the surroundings, then what is the velocity of the particle relative to the surroundings (vector creating a small, but important, amount of forward-velocity)?

Coupling nanoscale emitters with optical antennas enable comprehensive control of photon emission in terms of intensity, directivity and polarization. Highly directional emission of circularly polarized photons is possible from quantum dots coupled to a spiral optical antenna. The structure of the spiral antenna imprints spin state to the emitted photons. Thereby, a circular polarization extinction ratio of 10 is obtainable. Furthermore, increasing the number of turns of the spiral gives rise to higher antenna gain and directivity, leading to higher field intensity and narrower angular width of emission pattern in the far field. For a five-turn Archimedes' spiral antenna, field intensity increase up to 70-fold simultaneously with antenna directivity of 11.7 dB can be measured in the experiment. The highly directional circularly polarized photon emission from such optically coupled spiral antenna may find important applications in single molecule sensing, quantum optics information processing and integrated photonic circuits as a nanoscale spin photon source.

Consider spiral photons in Laguerre-Gauss (LG) beams. LG beams are not true hollow beams, due to the presence of magnetic fields and gradients of electric fields on beam axis. This approach paves the way to an analysis at the quantum level of the spatial structure and angular momentum properties of singular light beams.



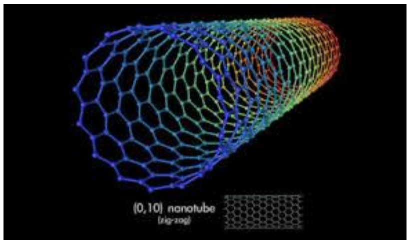
The spiraling pointing vector for LG beams



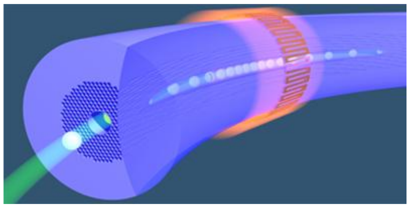
Phase dislocation on axis

Neutral edge transport

The quantum Hall effect takes place in a two-dimensional electron gas under a strong magnetic field and involves current flow along the edges of the sample. For some particle-hole conjugate states of the fractional regime, early predictions suggested the presence of counter-propagating edge currents in addition to the expected ones. When this did not agree with the measured conductance, it was suggested that disorder and interactions will lead to counter-propagating modes that carry only energy-the so called neutral modes. In addition, a neutral upstream mode (the Majorana mode) was expected for selected wave functions proposed for the even-denominator filling 5/2.



Carbon nano tube



Particle guided in hollow-core PCF approaching a thermal hotspot, shown at several different positions