# Are lithium, phosphate, and Posner molecule fundamental for quantum biology?

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**Abstract**

In this article I compare the work of Fisher proposing that phosphate ion and calcium phosphate known as Posner molecule are fundamental for quantum neuroscience. Phosphate ion show nuclear spin could serve as qubit able to get enzymatically entangled and make possible a transfer of qubits. Posner molecule would serve as unit of quantum memory. I describe first what might be called Lithium mystery, which served as a motivation of Fisher and summarize also the TGD view about the role of Lithium. The model of Fisher for how phosphate ion and Posner molecule could play a central role quantum neural processing is described. I also summarize the TGD view about the situation suggesting that Posner molecule might indeed have deep role. What puts bells ringing is that ELF radiation at frequencies equal to multiples of 15 Hz cyclotron frequency for Calcium ion in endogenous magnetic field $B_{end} = .2$ Gauss was found by Blackman and others to have effects on vertebrate brain. Furthermore, the cyclotron frequency of phosphate ion in endogenous magnetic field $B_{end}$ corresponds to the 11 Hz at the top of alpha band defining a fundamental biorhythm. A further interesting observation is that the 6 spin states of phosphate ions could realize genetic code.

## Contents



## 1 Introduction

I encountered a very interesting Facebook link (see http://tinyurl.com/zyy3b4l) to the work of Mathew Fisher [J2] (see http://tinyurl.com/hd3t6sr) related to quantum biology, in particular to the possible role of Posner molecules. Posner molecules (see http://tinyurl.com/ya2vura9) are not some bio-chemical rarity. Betts and Posner, while examining the x-ray crystal structure of the bone mineral hydroxyapatite $Ca_{10}(PO_4)_6$ (see http://tinyurl.com/y7quv997), found that within each unit cell there were two calcium-phosphate clusters with atomic constituents $Ca_9(PO_4)^6$.

I attach below the abstract of the first article [J2] of Fisher.

> *The possibility that quantum processing with nuclear spins might be operative in the brain is proposed and then explored. Phosphorus is identified as the unique biological element with a nuclear spin that can serve as a qubit for such putative quantum processing - a neural qubit - while the phosphate ion is the only possible qubit-transporter. We identify the ■, $Ca_9(PO_4)^6$, as the unique molecule that can protect the neural qubits on very long times and thereby serve as a (working) quantum-memory.*
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> *A central requirement for quantum-processing is quantum entanglement. It is argued that the enzyme catalyzed chemical reaction which breaks a pyrophosphate ion into two phosphate ions can quantum entangle pairs of qubits. Posner molecules, formed by binding such phosphate pairs with extracellular calcium ions, will inherit the nuclear spin entanglement. A mechanism for transporting Posner molecules into presynaptic neurons during a ■ exocytosis, which releases neurotransmitters into the synaptic cleft, is proposed. Quantum measurements can occur when a pair of Posner molecules chemically bind and subsequently melt, releasing a shower of intra-cellular calcium ions that can trigger further neurotransmitter release and enhance the probability of post-synaptic neuron firing. Multiple entangled Posner molecules, triggering non-local quantum correlations of neuron firing rates, would provide the key mechanism for neural quantum processing. Implications, both in vitro and in vivo, are briefly mentioned.*

The model of Fisher [J2] (see `http://tinyurl.com/hd3t6sr`) for how phosphate ion and calcium phosphate known as Posner molecule could play a central role quantum neural processing is described. Fisher assumes that the nuclear spin $S = 1/2$ of phosphate ions could make possible long range correlations and allow long decoherence lifetimes in these degrees of freedom. Fisher emphasizes also the possible role of Lithium in quantum biochemistry.

About two years after writing the first version of this article, I learned about a second article about Posner molecules by Fisher, Swift and Van de Walle [J3] (see `http://tinyurl.com/ycyu5bj9`) describing a detailed study of Posner molecules. The abstract of the article gives idea about what is done.

> *We investigate ■, calcium phosphate clusters with chemical formula $Ca_9(PO_4)^6$. Originally identified in hydroxyapatite, Posner molecules have also been observed as free-floating molecules in vitro. The formation and aggregation of Posner molecules have important implications for bone growth, and may also play a role in other biological processes such as the modulation of calcium and phosphate ion concentrations within the mitochondrial matrix. In this work, we use a first-principles computational methodology to study the structure of Posner molecules, their vibrational spectra, their interactions with other cations, and the process of pairwise bonding. Additionally, we show that the Posner molecule provides an ideal environment for the six constituent $^{31}P$ nuclear spins to obtain very long spin coherence times. In vitro, the spins could provide a platform for liquid-state nuclear magnetic resonance quantum computation. In vivo, the spins may have medical imaging applications. The spins have also been suggested as ■ in a proposed mechanism for quantum processing in the brain.*

I also learned about the finding of M.Y. Simmons et al [D1] (see `http://tinyurl.com/ydx6v7xa`) about electronic qubits realized with phosphorus atoms serving as donors. This inspires the question whether also electronic qubits might be realized by using the valence electrons of $P$.

About two years after writing the first version of this article I ended up with a model of valence bond [L3] (see `http://tinyurl.com/ycg94xpl`) assuming that the electrons at valence bonds can have non-standard value of Planck constant $h_{eff} = n \times h$ (the hierarchy of Planck constants characterizing dark matter as phases of ordinary matter comes as a basic prediction of adelic TGD [L6, L7]). The starting point of the model was the surprisingly weak variation of the bond energy along the rows of the periodic table.

The model provides a vision about the role of valence bonds in biology and provides a precise identification for the notion of metabolic energy. The binding energies of bonds decrease with the value of $h_{eff}/h = n$ increasing along the rows of the periodic table, and the reduction of the binding energy can be identified as potential metabolic energy liberated in catabolism. The bonds

involving atoms towards the right end of the rows of the periodic table have highest metabolic energies, and are indeed the bonds appearing in nutrient molecules. Phosphate ion has especially high bond energy so that Posner molecules could be also ideal for storing metabolic energy.

In the sequel I will consider the proposal of Fisher from TGD view point. I will describe first the Lithium mystery, which served as a motivation of Fisher and also TGD view about the role of Lithium. I also present TGD view about the situation suggesting that Posner molecule might indeed have a deep role but perhaps also in different sense to that in Posner's proposal. ELF radiation at frequencies equal to multiples of 15 Hz cyclotron frequency for Calcium ion in endogenous magnetic field $B_{end} = .2$ Gauss was found by Blackman and others to have effects on vertebrate brain. Furthermore, the cyclotron frequency of phosphate ion in endogenous magnetic field $B_{end}$ corresponds to the 10 Hz alpha resonance frequency defining a fundamental biorhythm. This suggests that Ca ions and phosphate ions might form two separate cyclotron Bose-Einstein condensates at different magnetic flux tubes so that cyclotron energies. I will also represent a brief comment about the realization of electronic qubits with $P$ atom serving as a donor.

# 2 Lithium mystery

The starting point of Fisher was a very interesting finding challenging the hypothesis about life as mere bio-chemistry. Already in 1986, scientists at Cornell University examined the effects of the two isotopes of Lithium on the behavior of rats. Pregnant rats were separated into three groups. One group was given $Li^7$, one group was given the isotope $Li^6$, and the third served as the control group. Once the pups were born, the mother rats that received $Li^6$ showed much stronger maternal behaviors, such as grooming, nursing and nest-building, than the rats in either the $Li^7$ or control groups.

$Li^6$ therefore as has a positive effect on maternal behaviour unlike $Li^7$. The chemistry is exactly the same. According to the popular article, Fisher believes that the higher nuclear spin of $Li^6$ could give it special role.: in the article he talks about nuclear spin $J = 1/2$ which cannot be true since the spin must be even. As a matter fact, according to my Nuclear Physics by Howard $Li^7$ has nuclear spin of $J = 3/2$ units whereas $Li^6$ has nuclear spin $J = 1$ so that neither of the above claims is correct. Could the bosonic character of $Li^6$ nucleus provide an alternative explanation? In any case, the finding strongly suggests that magnetic fields are involved.

Lithium - presumably $Li^6$ - has also other positive effects. If the positive effects are indeed due to $Li^6$ isotope, the dose of Lithium could be reduced by using only $Li^6$ isotope. I attach here the abstract of the article that I wrote as a reaction to discussions with my friend Samppa who told about Lithium [L2] (see `http://tinyurl.com/j44epwp`).

> Lithium has been used for more than 50 years as a mood stabilizer in manic depression. During last years Lithium has been studied intensively and found that it can be used also in treatment of schizophrenia and many other brain disorders. The effectiveness of Lithium is however difficult to understand in the standard framework of biology. In TGD framework organism-environment pair of standard biology is replaced with the triplet magnetic body - organism -environment. Magnetic body uses biological body as sensory receptor and motor instrument. This suggests that the re-establishment of communications of brain with some level of the magnetic body is how lithium causes its positive effects. Magnetic body does not receive information about brain and cannot control it since dark Lithium ions and correspond- ing cyclotron radiation are not present. The disorders caused by the lack Lithium and other biologically important ions would therefore be something totally new from the perspective of standard neuroscience.

TGD explanation for the effects of Lithium relies on the notions of magnetic body and dark large $h_{eff} = n \times h$ photons, electrons, and ions and relies on cyclotron frequencies as frequencies assignable to the dark photons responsible for the communications between magnetic body and biological body. In this picture the charge of the ion and its total magnetic moment would be relevant rather than only nuclear magnetic moment characterizing also neutral atoms (which could also contribute to the magnetic moment of ion). Cyclotron frequencies would replace Larmor frequencies.

1. For $Li^6$ the cyclotron frequency is about 50.0 Hz in the endogenous magnetic field $B_{end} = .2$ Gauss explaining the quantal effects of em fields at ELF frequencies on vertebrate brain reported by the pioneers of bio-electromagnetism such as Blackman [J1] to occur at multiples of cyclotron frequency in this magnetic field for Calcium ion and also for other biologically important ions. For $Ca^{+2}$ ion the cyclotron frequency is 15 Hz. Thanks to the large value of $h_{eff} = n \times h$ dark photons would have energies above thermal threshold. An attractive hypothesis is that the energies are in the range of bio-photon energies (visible and UV).

2. In the case of $Li^6$ the dark photons would make possible communication to and control by the magnetic body relevant for maternal behaviors. Magnetic fields oscillating at 50 Hz frequency are known to have biological effects [K3]. The size of the corresponding magnetic body part would be obtained from the wavelength $\lambda = 2\pi R$ ($R$ denotes the radius of Earth) of the lowest Schumann frequency 7.8 Hz as $L = (7.8/50) \times R = .98 \times R$. This suggests that dark magnetic flux tubes assignable with Earth are involved: not however that the field strength is $2B_E/5$.

3. For $Li^7$ the dark photons would have cyclotron frequency about 42.9 Hz, which brings in mind the thalamocortical resonance with frequency around 40 Hz assigned to consciousness at the time when the use of the word "consciousness" ceased to be pseudo-science. The more abundant $Li^7$ (92.5 per cent) should be also important but could be associated with other kinds of biological functions.

# 3 Phosphate, Posner molecule, and cognition

Fisher as also other quantum biologists tries to understand quantum biology as an improvement of biochemistry. One assumes that standard quantum theory brings in small effects allowing to optimize biological functions. In the case of the avian navigation and also in many other situations the problem is that Earth's magnetic field is only 2 per cent of the minimum magnetic field at which the proposed radical-pair mechanism is found to work [L1] (see `http://tinyurl.com/jnxvdmf`). To my opinion much more radical approach challenging the basics of quantum theory itself is necessary.

Fisher wants to identify the quantum mechanism behind neural activity assumed to rely on nuclear spins. This is quite a demanding challenge. One should understand long coherence time for nuclear spins representing the qubits, discover a mechanism transporting the qubit through the brain to neurons, identify a molecular scale quantum mechanism entangling qubits, identify a chemical reaction inducing quantum measurement of the qubits dictating the subsequent neuron firing, and understand what happens in nerve pulse transmission from pre- to post-synaptic neuron at quantum level.

1. Fisher assigns fundamental qubit and the ability to develop lon lasting quantum entanglement with phosphate ion (see `http://tinyurl.com/zgbgtwy`). Phosphate ion would be qubit transporter. The transfer of phosphate ion from APT to a molecule is fundamental part of metabolism and the TGD proposal is that a transfer of negentropic entanglement (purely TGD based notion involving p-adic physics as correlate for cognition) is in question.

2. Enzyme catalyzed qubit entanglement would emerge in the reaction ATP→ AMP+PPi. PPi is diphosphate ion with entangled phosptate and the reaction PPi→ Pi+Pi would create two entanglement phosphates. The reaction rate is proposed to depend on whether the 2Pi state is spin single or spin triplet.

3. Quantum memory is assigned with so called Posner molecule $[(PO_4)^{-3})]_6Ca_9^{+2}$ made of 6 phosphate ions and 9 calcium ions would be the key player. Posner molecule belongs to a family of calcium phosphates having as building bricks $PO_4^{-3}$ and $Ca^{+2}$ ions (see `http://tinyurl.com/jftjmro`). Calcium phosphate is the principal form of calcium found in bovine milk and blood. 70 percent of bone consists of hydroxyapatite, a calcium phosphate mineral known as bone mineral. Tooth enamel is composed of almost ninety percent hydroxyapatite.

   Posner molecule is neutral since the charges of 9 Ca ions and 6 phosphate ions cancel each other: $9 \times 2 - 6 \times 3 = 0$. Geometrically Posner molecule can be described as a cube with

Calcium ions at corners and center and phosphate ions at the centers of faces. The nuclear spin of the Posner molecule assignable to phosphates is 0, 1, 2, or 3. Posner molecule has also reduced rotational degrees of freedom characterized by group $Z_3$ giving rise to pseudospin. Posner molecule would be a carrier of phosphate qubits giving rise to (working) quantum-memory realized in terms of entangled Posner molecules.

4. Fisher proposes the notion of quantum entangled chemical reactions. This notion does not make sense if one identifies chemical reactions as processes involving state function reduction as assumed in chemical kinetics. The notion could make sense if chemical reactions are identified as unitary time evolutions for entangled systems such as Posner molecules. In TGD framework the notion of entangled time evolutions could make sense in zero energy ontology (ZEO).

5. Nerve pulse tranmission from pre- to postsynaptic membrane would entangle neurons by entangling Posner molecules. Biochemistry is complex but to my opinion the proposed model is too complex to be feasible. My view is that the enormous complexity of the description based on biochemical reaction pathways reflects the failure to realize the presence of control level - magnetic body. Situation would be like trying to understand the functioning of computer program regarding it as mere physical phenomenon without any idea about its purpose.

# 4 TGD view

In the sequel Posner molecules are discussed from TGD perspective. The Larmor and cyclotron frequencies of phosphate ions are in alpha band for $B_{end} = .2$ Gauss playing a key role as endogenous dark magnetic field, whose flux tubes carrying dark ions. The 6 phosphate molecules of Posner molecule provide a realization of genetic code in terms of qubits.

## 4.1 Larmor and cyclotron frequencies of Posner molecule

In TGD framework both nuclear spins and angular moment of dark nuclei in the magnetic fields assignable to dark magnetic flux tubes would be important: Larmor frequencies would be replaced with the sums of Larmor - and cyclotron frequencies assignable to (usually) charged particles. It is interesting to look whether the cyclotron frequencies of phosphate and Posner molecule could teach something about their possible role.

1. Phosphate $PO_4^{-3}$ with mass number $31 + 4 \times 16 = 95$ has cyclotron frequency 9.5 Hz in the endogenous magnetic field $B_{end} = .2$ Gauss assumed in TGD model and therefore in alpha band. For smaller charges -2 and -1 one has frequencies 6.26 Hz and 3.13 Hz. In TGD framework the transfer of phosphate from ATP to the acceptor bio-molecule could be at the fundamental level transfer of NE from metabolites [K1, K2]. This could reduce to the transfer the ends of the associated flux tubes between the molecules.

2. Posner molecule is neutral since the charges of 9 Ca ions and 6 phosphate ions cancel each other: $9 \times 2 - 6 \times 3 = 0$. Being neutral Posner molecule as a whole does not couple to the magnetic field except through its total magnetic moment. TGD proposal that ions form Bose-Einstein condensates encourages however to consider the possibility that the building bricks of Posner molecule form separate Bose-Einstein condensates. One can ask whether this is possible also more complex calcium phosphates: could bones be much more than just passive building bricks?

   The simplest possibility is that 3 Cooper pairs of fermionic $PO_4^{-3}$ molecules (as is easy to check by noticing that phosphorus and oxygen atoms are bosons and there are surplus 3 electrons: note that phosphorus nucleus is fermion and oxygen nucleus a boson) form a Bose-Einstein condensate a their own circular portion of flux tube. 9 bosonic $Ca^{+2}$ ions would form similar Bose Einstein condensate at their own flux tube portion. The value of $h_{eff}$ proportional to the mass of the ion by $h_{eff} = h_{gr}$ hypothesis. The formation of Cooper pairs of phosphate ions would conform with the conjecture of Fisher that two phosphate ions can entangle.

3. The value of $h_{eff}$ proportional to the mass of the ion if $h_{eff} = h_{gr}$ hypothesis is accepted. The formation of Cooper pairs of phosphate ions would conform with the conjecture of Fisher that two phosphate ions can entangle.

   These observations put the bells ringing - with a frequencies of 10 Hz and 15 Hz, one might say. Unfortunately this frequency is not directly audible, so that I cannot hope that colleagues would hear the ringing! There are however some hopes: also 10 Hz and 15 Hz can be made audible as difference of frequencies fed to right and left ear! Maybe some experimentalist could get interested!

4. A further intriguing observation is that the Larmor frequency of P for $B_{end}$ is 10.96 Hz. This is marginally in alpha band. This suggests that also Larmor frequency of P is indeed important in bio-control by magnetic body.

5. An alternative and more realistic sounding hypothesis is $h_{eff} = h_{em}$. $h_{eff} = h_{em}$ would hold true when em interaction becomes non-perturbative. In this case NE would be short ranged and associated with atomic/molecular systems. At this moment one cannot exclude the possibility that only short range NE is involved with living matter.

   Short ranged NE could be associated with dark atoms for which the scale of binding energy behaves like $1/h_{eff}^2$ and is thus reduced for dark atoms [K4]. The creation of dark atoms would require metabolic energy. This metabolic energy could also be liberated as dark atoms transforms to ordinary atom. Metabolic electrons could be associated with dark atoms and also the dark atoms in nutrients could provide metabolic energy driving protons through the mitochondrial membrane against potential gradient and transforming ADP to ATP contains high energy phosphate bond, which would actually correspond to the presence of dark (say hydrogen -) atom. Phosphate containing the dark atom would carry the NE or be accompanied by dark magnetic flux tube.

   The simplest view about photosynthesis would be that the absorption of solar photons excites some atoms to dark states and that nutrients contain these dark atoms as stable enough entities. The contamination of nutrients could mean the decay of these dark atoms to the normal states.

6. The cyclotron frequencies of these Bose-Einstein condensates would be 9.5 Hz *resp.* 15 Hz in $B_{end} = .2$ Gauss. This model could allow to improve the understanding about why the radiation at harmonics of 15 Hz has effects on vertebrate brain and also about the realization of alpha rhythm as a control signal from magnetic body. Fisher proposes that in nerve pulse transition two Posner molecules fuse temporarily and produce a spray of $Ca^{+2}$ ions. This could make sense also in TGD framework.

## 4.2 A new step of progress after two years

Roughly two years after writing the first version of this article I ended up with a model of valence bond [L3] (see `http://tinyurl.com/ycg94xpl`) assuming that the electrons at valence bonds can have non-standard value of Planck constant $h_{eff} = n \times h$ (the hierarchy of Planck constants characterizing dark matter as phases of ordinary matter comes as a basic prediction of adelic TGD [L6, L7]). The starting point of the model was the surprisingly weak variation of the bond energy along the rows of the periodic table and the observation that the heating of Ruthenium leads to a mysterious disappearance of valence electrons known for decades: the interpretation would be that they are transformed to dark electrons [L5].

The model provides a vision about the role of valence bonds in biology and provides a precise identification for the notion of metabolic energy. The binding energies of bonds decrease with the value of $h_{eff}/h = n$ increasing along the rows of the periodic table, and the reduction of the binding energy can be identified as potential metabolic energy liberated in catabolism. The bonds involving atoms towards the right end of the rows of the periodic table have highest metabolic energies, and are indeed the bonds appearing in nutrient molecules. Phosphate ion has especially high bond energy so that Posner molecules could be also ideal for storing metabolic energy.

Posner molecule would be ideal for both control purposes and for metabolism.

1. There are 9 $Ca^{2+}$ ions and 6 $PO_4^{3-}$ ions with cyclotron frequencies of 15 Hz and 9.5 Hz respectively in the endogenous magnetic field $B_{end} = .2$ Gauss explaining the observations of Blackman [J1] about the quantal effects of ELF em fields on vertebrate brain: thus these molecules are ideal for control by and communication to magnetic body.

   Also the fact that the Larmor frequency of P is 10.96 Hz and marginally in alpha band, suggests that MB uses spin flips for control purposes. MB could control and coordinate all phosphate containing biomolecules usign this Larmor transition of P. This includes ATP, DNA, RNA, the tubulins of microtubules containing GTP and all biomolecules to which phosphate is attached. This would conform with the frequencies in alpha band as a universal biorhythm used by magnetic body to keep metabolism in synchrony in body scale.

2. The 6 phosphates with high energy phosphate bonds are in turn ideal for metabolism: P and O related valence bonds indeed have nearly maximal metabolic energy content in the proposed model of valence bonds based on $h_{eff}/h = n$ hierarchy [L3] (see `http://tinyurl.com/ycg94xpl`).

   **Remark:** Totally unrelated association: the magic number 6 appears also in the structure of cortex: could the six layers represent qubits and realize genetic code?

3. The 6 phosphates with high energy phosphate bonds are in turn ideal for metabolism: P and O related valence bonds indeed have nearly maximal metabolic energy content in the proposed model of valence bonds based on $h_{eff}/h = n$ hierarchy [L3] (see `http://tinyurl.com/ycg94xpl`).

   This suggests that bones might also serve as energy storages and - of course - as nutrients. Interestingly, in the evolution of humans the discovery of stones as tools to break down bones of prey animals to get bone marrow has been seen as a critical step leading to the growth of cortex requiring a lot of metabolic energy (to generate large $n$ valence bonds providing ability to generate negentropy).

What is interesting that ATP molecule - the basic metabolic currency - has triphosphate with total charge -4 as a building brick. Triphosphate is characterized by cyclotron frequency 4.8 Hz which is one half of the alpha band frequency. The diphosphate in ADP has cyclotron frequency 5.2 Hz. Note that the cyclotron frequency of $Fe^{2+}$ ion central in oxygen based metabolism is 10.7 Hz and in alpha band as also the Larmor frequency of P.

Note that in DNA the singly charged phosphates in XMPs, X = A, T, C, G, have cyclotron frequency, which is one third of this, that is 3.1 Hz. This frequency appears in EEG as a kind of resonance frequency during deep sleep. DNA nucleotides as whole have cyclotron frequencies around 1 Hz. In microtubules the phosphate of GTP can have three different charge states allowing frequencies 3.1,6.2 and 9.4 Hz. I have proposed that these charge states together with two different tubulin conformations give rise to a realization of the genetic code.

The proton cyclotron frequency 300 Hz has been already earlier assigned with ATP and the models for the lifelike properties of a system consisting of plastic balls involved cyclotron frequency of $Ar^+$ ion which is same as that of $Ca^{2+}$ ion and cyclotron frequency 300 Hz of proton [L4] (see `http://tinyurl.com/yassnhzb`). Also the two important frequencies associated with honeybee dance [L8] correspond to the cyclotron frequencies of $Ca^{2+}$ and proton (see `http://tinyurl.com/ycnst4z5`).

## 4.3 Phosphorus electrons as qubits

M.Y. Simmons et al [D1] (see `http://tinyurl.com/ydx6v7xa`) have found that $P$ atoms can serve as donors of electrons giving rise to very long-lived qubits (see `http://tinyurl.com/y88d7vhf`). I attach the abstract of the article here.

Substitutional donor atoms in silicon are promising qubits for quantum computation with extremely long relaxation and dephasing times demonstrated. One of the critical challenges of scaling these systems is determining inter-donor distances to achieve controllable wavefunction overlap while at the same time performing high fidelity spin readout on each qubit. Here we achieve such a device by means of scanning tunnelling microscopy lithography. We measure anti-correlated spin states between two donor-based spin qubits in silicon separated by 161nm. By utilising an

asymmetric system with two phosphorus donors at one qubit site and one on the other (2P1P), we demonstrate that the exchange interaction can be turned on and off via electrical control of two in-plane phosphorus doped detuning gates. We determine the tunnel coupling between the 2P1P system to be 200MHz and provide a roadmap for the observation of two-electron coherent exchange oscillations.

A controllable exchange interaction between electron spins is needed for the realization of 2-qubit quantum gate. The valence electron of $P$ atom rather than $P$ nucleus serves as a qubit. The qubits have unexpectedly long relaxation times (measured in seconds) and dephasing times. $2P$ (2 $P$ atoms) and $1P$ serve as electron donors. The distance of 2P and 1P is rather long - $16 \pm 1$ nm - 1.6 times the p-adic length scale $L(151)$ ($p$ is Gaussian prime $M_{G,151} = (1+i)^{151} - 1$ assignable to neuronal membrane. Exchange interaction occurs if there is an overlap between electron wave functions.

In TGD framework the electrons donated by phosphorus atoms and forming the qubits could be actually dark electrons with $h_{eff}/h = n$ larger than for atoms or normal valence bonds. This would scale up the domain of electron wave functions by $n^2$ and make possible the overlap. This also increases relaxation and dephasing times.

**Remark**: In living matter negatively charged phosphate ions for which $P$ atoms have received electrons (negative oxidation number) are important. In the experiment discussed $P$ atom loses electron and becomes a positive ion.

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