Review of: "Foundations of quantum mechanics revealed by the conservation laws"

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In this paper, the author revisits some basis of quantum mechanics and recalls some issues that used to be forgotten. He also provides relativistic arguments that can be used to solve the problem of energy conservation.

After several readings of the paper, my opinion is mitigated. The topic definitely deserves interest, recalling some historical elements is good, and the recall that quantum theory must be understood relatively is excellent.

But, there are too many issues. Some elements are too vague, others are clearly wrong or outdated. I also disagree more or less with some assertions. Here is a list of remarks and comments.

- The abstract and the conclusion are quite disconnected. Also, the abstract refers to elements not present in the paper, e.g. "Applying the calculus of variations to the Schrödinger wave equation reveals that the wave function is incomplete because it requires twice the allowable action minimum." There is no Schrödinger equation in the paper.
- There is a problem of integration measures in Eq. (2) and (3). There is also a misprint in (4).
- After the quote by Feynman, I'm not really sure to understand the position of the author on the subject. Clearly, Feynman's claim is outdated because the old debate on the true nature of photons is considered closed by many physicists. This is due to Haroche's experiments on photon counting during the years 2000-2010 (see e.g. https://www.nobelprize.org/uploads/2018/06/haroche-lecture.pdf). With these experiments, photons can be measured non-destructively, and their quantum states can be reconstructed using some tomography techniques. Then, there is no need for emission/absorption by atoms to have photons or electromagnetic interaction. An atom can provide energy to the electromagnetic field and it is sufficient to describe the process. There is no need for a second atom/electron.
- In Sec. 2.3, the sentence "energy measurement is all-important so he disregards considerations of momentum" is curious, Feynman was well aware of the role of momentums in light-matter interactions. See for example is book "Quantum Mechanics and Path Integrals", chapter 9, or any book on quantum field theory or quantum optics that uses Feynman path integral techniques.
- In Sec. 2.4, I disagree with several assertions.
    - “photons are not a part of quantum mechanics”. I'm not counting the number of references where photons are described very well by quantum mechanics, both theoretically and experimentally. Just to cite one: Haroche's book: “Exploring the Quantum: Atoms, Cavities, and Photons”.
    - In stopped-light experiments, there is a shortcut in the interpretation. Actually, there is, strictly speaking, no stored

photon, but there is a polariton. In stopped light experiments, there is a transfer of quantum information, carried by photon states into a polariton state. This process is reversible. For a precise description of the process, I suggest to refer on the first theoretical study on the subject: “Fleischhauer, M. and Lukin, M.D., 2000. Dark-state polaritons in electromagnetically induced transparency. *Physical review letters*, *84*(22), p.5094.”. In this paper, they also clearly say: “In this process, pulse shape and the quantum state of the light pulse are mapped onto collective states of matter in which they are stored. ” Stopped light experiments do not show that photons can be localized and stored into a medium, but that their quantum properties can be transferred into a medium.

  - I do not think that stopped light experiments show a problem with the theory, it was first predicted theoretically, and experiments seem to agree well with the theory.

- Equation (2) is wrong. Classical paths are given by $\delta S =0$, not $S=0$. This can be easily verified with a harmonic oscillator.
- In sec. 3.2, the sentence “The actual path of the electron, the one chosen by nature, is the one whose action is minimum”, is misleading. Quantum mechanics allows superpositions of paths. Also, I'm not sure that this sentence is very useful here. I do not understand what is its purpose.
- Still in sec. 3.2, the paragraph “Energy is absorbed by atoms […] yields the reduced Planck’s constant ħ.” is very difficult to understand in detail. Also, I suspect that there are some miss understandings. Ground and excited states are not described by surfaces but by space densities. Moreover, what's the precise meaning of “adopts the circular path 2πr of an orbital”? is “r” still a path? If the modelization is really non-standard, I think that the theoretical model must be more clearly explained.
- Same remark for Eq. (3) as for Eq. (2). Just saying that now the action is equal to $\hbar$ do not change anything to the problem. This can be verified easily by redefining the action with a constant term. This changes the values of the extremums but not their position in configuration space, and thus, it does not change anything to the physics or the mathematical model
- I do not see how sec 3.3 solves the problem. Maybe a clear definition of £ can provide a better insight into the problem. What's really new from standard QED? Why the photon is modeled by $\phi i,\mu$? In usual notation, this is a quantity intrinsic to the electron, not of the E.M. field.
- In Sec. 3.4, the sentence “In relativistic theory the emission of energy is described with a Lagrangian (T-V) as a four-dimensional localization of fields £(ϕi, $\phi i,\mu$), while in non-relativistic theory it is described with a Hamiltonian (T+V) as the potential of a point electron.” Strictly speaking, this is not true, both Lagrange and Hamilton approaches can be used in relativistic models, although the Lagrange method is more straightforward.
- In sec. 3.4, the last paragraph “The non-relativistic Hamiltonian model […] combined action of a particle and an associated localized field.” proposes a novel interpretation of why we observe energy levels in an atom, but this interpretation cannot be inferred directly from the material presented previously. This idea is interesting (although quite improbable), but concrete calculations must be performed to show its relevance. If this effect is possible, it must be clearly visible with a specific choice of Lagrangian. The localization effect must be inferred from the model, and if the model is viable, it must return the energy levels of an atom and the correct electron densities.
- Still in Sec. 3.4, the sentence " A physical separation exists between the matter and energy of an excited state due to

field boundaries." does not make any sense.

- More generally, I do not think that the problem of energy conservation in quantum mechanics is due to emission/absorption by electrons or some kind of similar effect. These kind of processes are well described with relativistic and non-relativistic models. (see e.g. the Jaynes-Cumming or the Rabi-model). The problem of energy conservation is rather related to the measurement problem, which is not conservative. This is the key point, not the emission/absorption of photons by atoms. Note that this issue is also pointed out in ref [1].

To conclude, the paper needs strong revisions. Some ideas of the author deserve interest, but strong theoretical motivations are required, with detailed calculations showing their relevance.