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Quantum Oscillations in Insulators

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Abstract: ***In Quantum physics, many discoveries have been made by scientists be it the evolution of atomic clocks where the atomic structure and its energy level with the classical concept of relativity is used, on this account recently, the physicist of Princeton has discovered an interesting phenomenon-an unexpected quantum behavior in an insulator. It is called quantum oscillation. This also leads to a big distinction between metals and insulators as before this day, no insulator has experienced quantum oscillation. Throughout the report, we talked about the research of Princeton on how they discovered that insulators can also show quantum characteristics due to certain factors, the factors are discussed in the presentation, the terms behind them, and last but not least the future aspects of the materials that can be classified under the same category. If this scenario becomes true then there is a possible chance that there is an underlying quantum world in an insulator***

Keywords: Evolution of atomic clocks, Concept of relativity, Metals, Insulators, Quantum oscillation

1. What used to exist

If we talk about the fermi gaps (the level which separates occupied electrons from unoccupied ones), generally for the metals it is on the surface of the metal but for the insulators there is a long gap between the *fermi surface* and insulator. Now:

Since nature never lacks imagination, there are indeed new types of insulators and in order to bridge the gap, the presence of *Fermions* **(**charged neutral particle excitations) forms a neutral *condensate* between the Fermi surface and insulators.

List of keywords: 1. Fermi surface 2. Fermions 3. condensate

Composition of tungsten ditelluride

(Jia, Y., Wang, P., Chiu, CL. et al. Evidence for a monolayer excitonic insulator. Nat. Phys. 18, 87–93 (2022). 'Tungsten Ditelluride (WTe2), a transition compound whose properties have actually made possible the occurrence of phenomena of the quantum world
Let us talk about certain terminologies involved:
● This metal could exist both as metal and an insulator: If it is a thick material then it acts like a metal but when it is exfoliated as monolayered, it is an insulator

By mono layering the metal:
They prepared it by using standard scotch tape to exfoliate it into a single atom in a single layer.

- It creates an excitonic insulator:
- In the case of an insulator, when a *photon* is absorbed in a semiconductor, the formation of *excitons* occurs.
- Excitons are charged neutral particles in a 2-Dimensional insulator:

Reasoning: WTe2 is a *transitional metal* due to which the various characteristics were observed in the experiment.

List of keywords: 1. transitional metal 2. Photon 3. Excitons

2. Process /Methodology

'(Kittel, Charles)' Since it is a theory that was developed during experimental setup, the following methods were used.

When WTe2 was put against electromagnetic radiation, its *resistivity* was measured under tungsten ditelluride.

To their surprise, the resistivity of the insulator, despite being quite large, began to oscillate as the magnetic field was increased, indicating the shift into a quantum state.

In effect, the material-a very strong insulator was exhibiting the most remarkable quality of metal

The quantum properties observed:

Tang, S., Zhang, C., Wong, D. et al. Quantum spin Hall state in monolayer 1T′-WTe2.
Nature Phys 13, 683–687 (2017).

The monolayer insulating state develops due to intrinsic electronic correlations," "Combining this with the fact that the state appears exactly at charge neutrality, meaning that the number of electrons and holes are exactly equal, it became obvious that the monolayer insulator is an excitonic insulator.

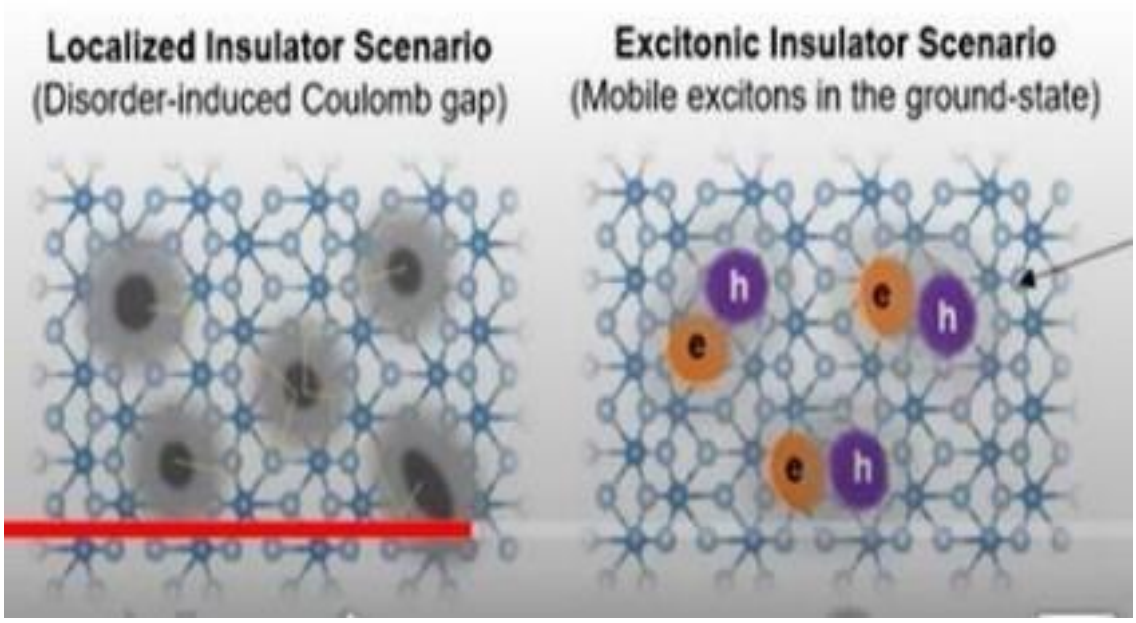

Figure 3.1

Explanation: (The left picture explains the state of WTe2 due toexisting *coulombic forces* and the right picture explains the state of the insulator during the formation of excitons)
List of keywords: 1. Resistivity 2. monolayer 3. coulomb forces

3. The Research Finding

Works Cited
'(Princeton Department of Physics. "discovery of quantum behavior in insulators." *nature*, 2021,)'

The Princeton physicists discovered a wholly new quantum world hidden in insulators, they used tungsten ditelluride which they converted into a *2-dimensional material, and* certain precisions were done to it that

The transformation of the WTe2 into a *monolayered* metal led to exhibiting various quantum properties. The conclusions drew the hypothesis of a neutrally charged quantum matter that is present over there.as per the *free electron theory,* it was felt that the electrons are arranging themselves to produce a new kind of quantum matter but the researchers led to the discovery of 'neutral *fermions* responsible for this dynamic quantum effect.

Currently, an investigation is going on whether this new particle they perceive is valid or not.

The scientists as well as the students like us are keenly interested in observing the existence of this phenomenon which would make us rewrite the mathematical proof of the scenario in insulators.

List of keywords:1. Free electron theory 2. Fermions 3. Monolayered metal

The Shortcomings
The research findings though very promising had a bunch of shortcomings which we have discussed as follows:-

1) There is no existing theory that can accommodate Wu's finding, quantum oscillations in insulators are not supposed to exist according to our current mathematics so if these findings are correct, we will have to rewrite almost all of our physics.
2) The hypothesis proposed by Dr. Wu and his colleagues proposes the existence of a new kind of particle, the neutral fermions, which conflicts with all the existing theories regarding charged fermions like Charged neutral fermions. But it is still too early to claim anything and this field requires a lot more research before any conclusion can be reached. List of keywords: 1. charged neutral fermions

4. Conclusion

In this dynamic field, there can never be a conclusive endto the quantum oscillations in insulators but throughout this paper,

This is only the starting point. If the hypothesis is true then future researchers will find other insulators with this surprising quantum property. If these neutral fermions actually do exist then it will revolutionize *quantum computing*. the question arises how? Well, it uses fermions for holding information and these neutral fermions will hold double the information of *charged fermions*. This information might even lead to the *development of humanity's first-ever supercomputer.*
So, to conclude we can say that

"With enough focus, this discovery might be the first step of taking our civilization to the next stage."

List of keywords: 1. quantum computing 2. development of humanity's first-ever supercomputer-'a future aspiration from this phenomena 3.. charged fermions

Declaration

Ethics Approval and consent to participate –
I, Katyani Gupta consent to participate in the publication process and accept the decision of the journal.

Consent for Publication:
I, Katyani Gupta the author consent to publish my review paper in this journal.

Availability of Data and material-
The author (Katyani Gupta) ensures that the data and material provided here are authenticated.

Competing interests-
There are no competing interests as ensured by the author, it is a review of the study and is desired to be published in the journal

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Author's contributions:
The author is responsible for writing the data and content for the paper, the charges for the publication and declare the authenticity of this review journal .

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*I **Katyani Gupta**<2k20/EP/62>, a student of bachelor in technology in engineering physics in the DELHI TECHNOLOGICAL UNIVERSITY, declare that the project titled <QUANTUMOSCILLATIONS IN INSULATORS is authentic and a review of the analysis of this*

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