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A drop of quantum dots in the ocean of quantum computing

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The composition tunable and special size electronic feature of quantum dots makes promising feature of quantum dots and promising number of new technologies and applications. Understanding the research patterns and opportunities in the field of quantum dots, gives birth to advanced technologies. Nowadays it is essential to examine the transition in artificial atoms that is quantum dots to the next generation evolution and biosafety. The paper gives the analysis of scientific publications in the field of quantum dots. The quantitative and qualitative analysis of the research publication of quantum dots in quantum computing revealed the emerging sub-field and future development trends. The paper focuses on the relevant publications from 1986 to early mid of 2022, using Scopus and Web of Science research database. Using the popular search keywords, the analysis not only focuses on trends of the quantum dots in quantum computing but also points out future directions for the researchers.

Keywords: *Quantum dot, Quantum computing, Quantum machine learning, Qubits.*

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1. Introduction

The explicit use of 'quantum mechanical effects' in new technologies is trending now for the research and development team in the world. Quantum Physics is one of the greatest scientific breakthroughs of the 20th century (Abdurrahman et. al.,1018, p.41). It gives us a much deeper understanding of the physical world. Scientific breakthrough actually gives us the knowledge of subatomic particles, electrons, quarks and Biggs boson. The artificial atoms driving the periodic table of the element in everyday phenomena such as color of sky, the power of the sun, hardness of diamonds and even the nature of empty space (Dieterle et. al., 2021, p.033). For tech- nologies, Quantum Physics (Abdurrahman et. al.,1018, p.41) has already been a game changer and often in terms of technology, quantum physics has already transformed the development of the transistor, contemporary computers, MRI equipment, and the atomic clock and the things that really could not be possible without in depth understanding of the physical world that got from quantum theory. But in last 25 years or so a new technology revolution has built that is exploring to take advantage of quantum measurement and quantum wave phenomena such as superposition and entanglement (Brif et. al., 2010, p.075008). These phenomena have the potential to create entirely new technological concepts and also radical improvements in the performance of technologies such as computing communication and sensing. These mentioned application areas particularly have the huge impact on the ability of our military to gather, transmit and analyze information in battle space that really includes the entire globe and beyond into space. Probably the best-known example of quantum technology is quantum comput- ing. Quantum computing algorithm takes advantage of the wave like nature of matter of constructive interface a quantum system. So it can be selected out of the correct answer from a vast number of possible wrong answers (Mangini et. al., 2021, p.10002). The objects like atoms or electrons or protons have strong quantum effects because these are sort of the prototypical quantum objects. But the larger objects can show and have exhibited the wave like nature of matter from a quantum quark consisting of the atoms positioned in a crystal surface to a very cold cloud of atoms, when there is a Bose Einstein condensate (Dieterle et. al., 2021, p.033).

The purpose of this paper is to motivate researches to explore the emerging quantum journey. Section 1 discusses basics of quantum dots and the emerging trends. Section 2 highlights research design of the paper to find the relevant data from the research database. The research findings in section 3 to show the contribution and major work in the quantum dot field. The Section 4 concludes the overall analysis done in the paper with discussion and future direction for upcoming quantum enthusiastic researchers

1.1 *Basics of Quantum Dots*

Quantum dots are small particles of semiconductor crystal particles made up of thousands of atoms (Górski & Kucab, 2021,p.114459). Quantum dots (epitaxial) form a continuous crystal lattice with a sub- strate, that they are grown on (Duan et el., 2021). Dots are essentially solid crystal droplets, in some case indium arsenide semiconductor grown on a gallium arsenide substrate. Typical quantum dot is 10 or 15 nanometers in diameter and several nanometers in height (Górski & Kucab, 2021, p.114459). The advan- tage of well established tools of the semiconductor industry is to fabricate electronic and optical devices. For example, if we grow quantum dots inside transistor or a diode struc- ture and wire it up in the right way, then a device can be made that that allows us to inject individual electrons one by one into a quantum dot. The small size quantum dots are often known as artificial atoms (Gidwani et. al., 2021, p.102308). When an electron is confined in such a small space it can no longer move in. Its motion becomes quantized. It is taken on discrete values which form an orbital like energy level structure and it is analogous to the different orbits. An electron in spin has spin property because it can take on two values which are usually called spin up and spin down. This two-level property is an example of a quantum bit or qubit but unlike a digital bit in a classical computer. Qubit can exist in a quantum superposition state, which is a quantum combination of both things at once. For electron spin superposition considered as an error of its processing, the state a the intermediate angle between spin up and spin down (Wigger et. al.,2021, p.2000128).

The quantum dots are developed as a source of individual photon, which is important for quantum communication. The quantum communication provides a means for doing ultra-secure encryption. Communication is based on fundamental physical fact that it is impossible to copy a quantum wave function (Basso et. al., 2021, p. 7). So, if a sender and receiver have message or are sending a message it is intercepted by an eaves dropper. The quantum dots are actually an excellent source of single photons, although it is most common these days to use a laser (laser creates all or lot of photons). It laser is attenuated with filter then we get down to the level of individual photons. The problem is that the photon comes at random times and the communication would be more efficient if the photon come at regular times. Quantum dots can make a triggered quantum or a single photon machine gun. Single individual photons are actually entangled with each other and the entanglement is one of the Quantum Mechanics concepts. If two or more objects are entangled then their wave functions cannot be separated. Even if the objects are physically separated or no longer interacting with each other, a causal connection still remains between them. Research (Rudno-Rudziński et. al., 2021, p.942) has shown that it is possible to entangle an electron spin in a quantum dot with a photon been emitted by that quantum dot. The authors show (Basso et. al., 2021, p. 7) the process once done, then the same process can be iterated with the multiple interactions or times. If each photon is entangled with that spin then the photon will be entangled with each other.

Need of chain of entangled photons- One way of doing quantum computing is to use photons as qubits. The possibility of the ability to do quantum computing is very attractive, with photons in very compact silicon integrated photonic circuit device architecture (Chakravartyet. al., 2021, p.041303).The quest for quantum technologies is really a worldwide effort, especially big companies like Google, Microsoft, IBM, many universities, national labs, and intelligence agencies, which are actively supporting the effort.

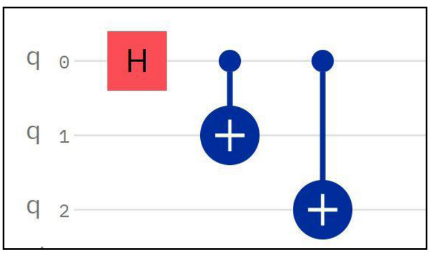

Figure 1

Illustrates Qubits on actual quantum framework and shows interaction between two qubits using CNOT gate. Circuit fetch from the IBM Q platform

1.2 *Quantum computing view from nuts and bolts angle*

In diagram (See Figure1) every horizontal line is like a timeline. The timeline is for the quantum bit or qubit. Every single qubit is an individual atom. The fact is that single information is started in an individual atom. The timeline is going from left to right. Each of these atoms has an electron like hydrogen atom. Electrons can be in a spherical orbital or an extended orbital. Basically, the electrons are in spin up or spin down (when it is up the n electron is in 1 state and when it is down then the electrons is in 0 state, like a bit of information. Each of the atoms has timelines. One of the two types of things either operation happens to individual atoms that would be called a gate on a single qubit. On initial state laser shines for certain amount of time and when the laser is turned off, an operation is done which is called H. The other more difficult thing in all different platforms to do is the Control Not (CNOT) (shown in Figure 2 with green highlight). The CNOT operation connects two different timelines i.e. interaction between the two qubits. The figure shows (See Figure 1) the sorts of circuits like to draw and the key challenge, which often in any technology is to realize the two qubit gates that connect two of the individual systems. Quantum dots are artificial atoms i.e. artificially confined electron systems. The underlying idea is that one can use the state of the electron systems to host qubits. Quantum dot has discrete energy states and one can use these states to store and manipulate Qubits, which contains information (Wigger et. al.,2021, p.2000128).

2. Research Design

2.1 *Data sources*

The bibliometric data used in this study are from two resources used: (1) The Scopus. Scopus is the multidisciplinary research database of envision research, peer-reviewed literature with tools to pursue, and scrutinize, (2) The Web of Science (WoS) database provided by Clarivate Analytics (Philadelphia, Pennsylvania, USA).

2.2 *Search Procedure*

In this paper, the quantum dot analysis considered the document type such as “Short Survey”, “Conference papers”, “Article”, and “Review”. It is observed that the total 273242 papers were published from 1986 to mid 2022. The various of search queries were used for collecting the relevant quantum dot data and finding the recent advancement in the QT research field (See Table 1). Various combinations of proximity operators, truncation, and quotation marks are used to test the relevant paper count and data collection. Our ultimate key goal is to have a high accuracy and adequate recall. With prudent formulation of formulated WoS and Scopus search query, paper achieves goal to focus on the relevant publications on quantum dots while excluding few irrelevant publications. The data was excluded which is not associated to the field of quantum dots i.e. quantum physics, quantum computing etc. The explorations were done on 1st Jan 2022 in the online version of the Scopus and WoS.

2.3 *Search Queries*

In the following (See Figure 2), we elucidate the Scopus personalized search queries for applicable sub research areas, in order to achieve high precision and maximum recall. Targeted combination search queries are used in the field for specific search. The suitable combination of proximity operators works differently on every keyword for specific search. The combination of AND and OR operators are used for the field specific search in WoS and Scopus research database.

Apply voltage on lithographically defined gate patterns on the surface, so roughly the parabolic confinement for the electrons at the center. To discuss the free electron regime by making gate voltages more negative of qubit spin (Wigger et. al.,2021, p.2000128)., such type of subfields can be merged with the query "Quantum Dot" AND" Superconducting" AND Qubits or "Quantum Computation". With the help of charge sensor (i.e. quantum point contact) the qubit spin and empty quantum dots concepts/explained (Kojima et. al., 2021, p. 68). Now we have system where trap electron and other bells and whistles are to detect the electron tunneling events, to achieve electron configuration of the dot. Using the mentioned secondary keywords search, the proposed spin state theory of dimension was highlighted; we have the 1231 relevant search query result using the secondary keyword "qubits" (See Figure 3).The spin states of electrons are trapped in the discarded structures. The quant or discarded structure can host qubits. The gated devices and scalable architecture are significant (Li et. al., 2019, p. 2011). That means, litho- graphic facilities are provided by the Micro Fabrication technology. With the help of the micro fabrication and the scalable architecture, we can make number of quantum dots and each of the dots can host bits of information (i.e. quantum information). Finally, do spin states and that spin states are taught to store information (that is the idea behind the spin states).The above explained idea is proposed by (law and dawn). There are mainly two kinds of quantum bit or qubit architecture, based on this proposal.

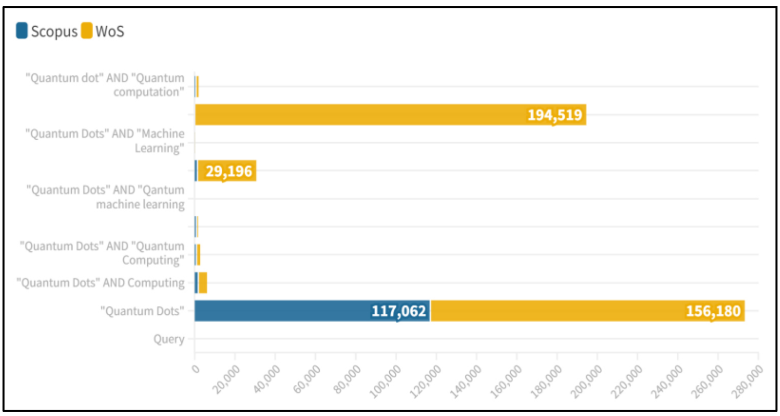

Figure 2

The primary search query results. Data fetch from Scopus and Web of Science research database. (Access on 1st Jan 2021)

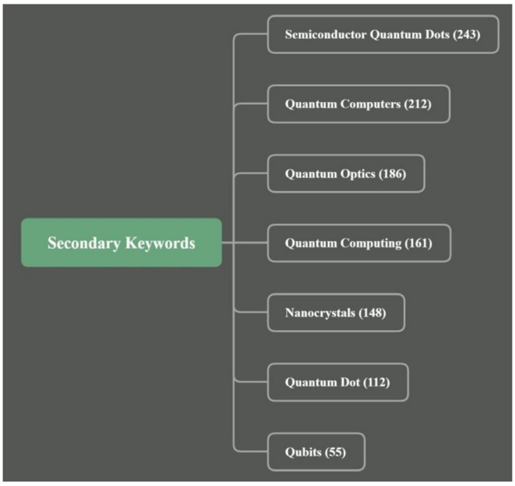

Figure 3

Chart shows the secondary keywords of quantum dots. Data fetch from Scopus and research database. (Access on 8th July 2021)

3. Results and Findings

One thousand two hundred thirty-one papers were analyzed categories by field of quantum dots. Field normalized time and indicators are used to analyze the impact of citations. We concentrated on the contribution of published papers belonging to 15% of most commonly cited papers in the corresponding document type, subject area, and publication year. The used procedure is explained in (Wigger et. al.,2021, p.2000128) to ensure that the exact top 10% of published papers in relevant subject areas are selected or finalized for further meta-analysis. The citation window is set from 1986 to mid-2022 for specific field searches using the primary and secondary keywords. The publication count, citation count, text mining techniques, and scientific activity are used to lighten the scientometric and bibliometric studies in the quantum dot. The search considers primary and secondary keywords to recognize and highlight/popular research areas and disclose their evolution over time. Findings motivate and help field experts know the impact of the revolution in the quantum dot to find the research gaps. The quantum dot is vital in various subject fields to forward the speed of discoveries. The opportunities are open while finding the top score agencies working in the same domain of quantum dots. This Section 3 explores the quantum dot field's findings, advancement, opportunities, and research gaps.

The paper covers several research questions:

i. What is the top working area in Quantum Dots?

ii. What are the top contributing countries in the field of Quantum dots since 1986, along with highlighting the active institutes?

iii. How are the funding agencies and countries correlated?

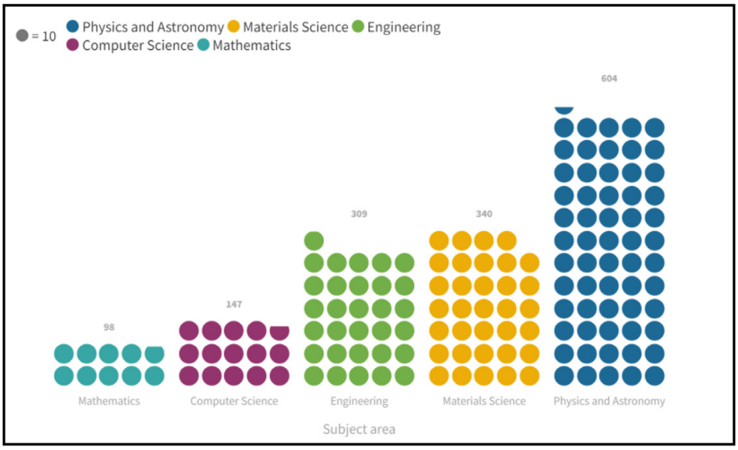

Figure 4

The pie chart shows trending Quantum dots in quantum computing working areas. Data fetch from Scopus research database. (Access on 5th Jan, 2021)

The Pie chart (See Figure 4) indicates work on Quantum dots in quantum computing world as per data from Scopus research database. Figure 4 shows that 40% is the maximum amount of work which is done in the field of Physics and Astronomy. The least amount that is 6% work takes place in Mathematics. Material Science and Engineering field have contribution of 23% and 21% respectively with 10% work contributed by Computer Science.

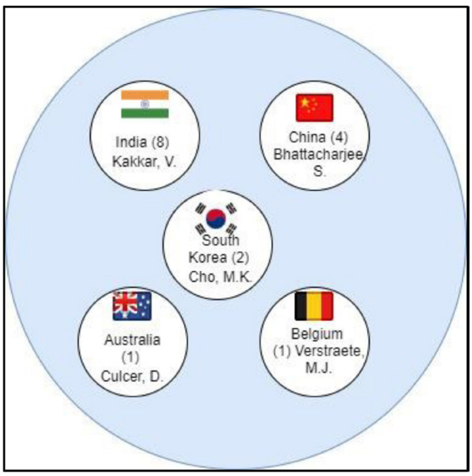

Figure5

Shows top countries along with publication count and active authors working in Computer Science field using quantum dots in quantum computing. Data fetch from Scopus research database. (Access on 5th Jan, 2021)

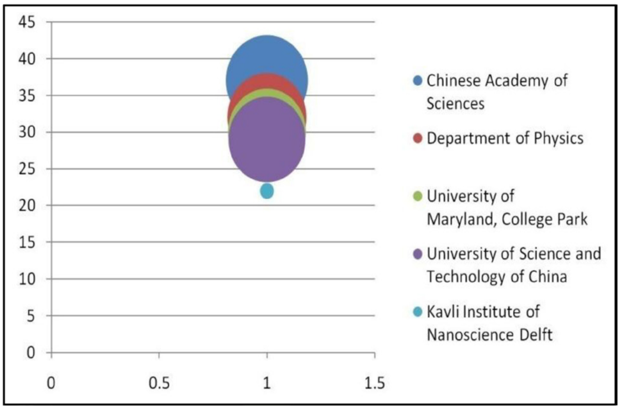

Figure 6

Active institutes working on quantum dots in quantum computing from 2018-2021. Data fetch from Scopus research database. (Access on 8th Jan, 2021)

The Figure 5 shows the relation between active authors, country and number of publications for data fetched from Scopus research database. The focus on the work happening in the field of Computer Science reflects that India has maximum number of publications for quantum dots with 8 counts. Kakkar V is one of the Indian author, actively working in this field. China has the best count of 4 publications. Bhattacharjee S is active author for Quantum dot from China.Belgium and Australia have 1 count each for publication with Cucler and Verstraete being active authors respectively.

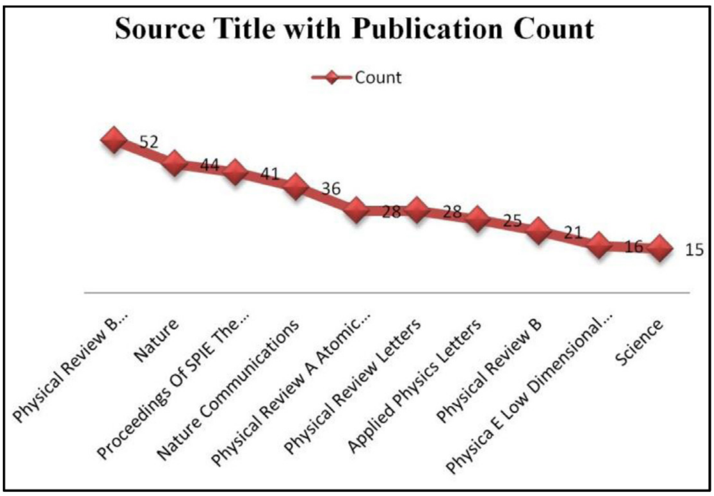

Figure 7

Line chart shows the active sources in the field of quantum dots in quantum computing. Data fetch from Scopus research database. (Access on 5th July, 2021)

Figure 6 shows the top notch institutes working on Quantum dots. Kavli Institute of Nanoscience Delft has 21 numbers of publications. Their work comprises of making use of small atomic qubits. The University of Science and Technology in China has 29 numbers of publications on Quantum dots. The University of Maryland has 32 numbers of Publications. Their predominant work is on Entanglement at specified distance. The Department of Physics has total 33 publications. Chinese Academy of Sciences has the greatest number of Publication and their publication count is 37.

The Figure 7 shows the Physical *Review B Condensed Matter and Materials Physics has maximum number of publications count with 52. Science has least number of* Publications *count with 15, almost 1/3 of maximum count. Nature publication has 44 publication counts. Whereas, Nature communications has 36 counts, Physical review letters and Applied Physics letters have 28 and 25* Count respectively. Last but not the least, Physical *Physical Review B source has 21 publications.*

The Figure 8 shows active institutions with research publication who are working in the quantum dot. The year-wise publication count presents the interdisciplinary growth in the domain of quantum dot. The Institutions covered the multiple domains to encompass large number of application. The UNSW Sydney and University of Melbourne has 4 and 5 publication in the interdisciplinary domain respectively. The Delft University of Technology has 6 publications in quantum dot hardware research. Chinese Academy of Sciences and University of Cambridge has publication in area of how the different materials are used to obtain quantum dots emitting in specific spectral ranges.

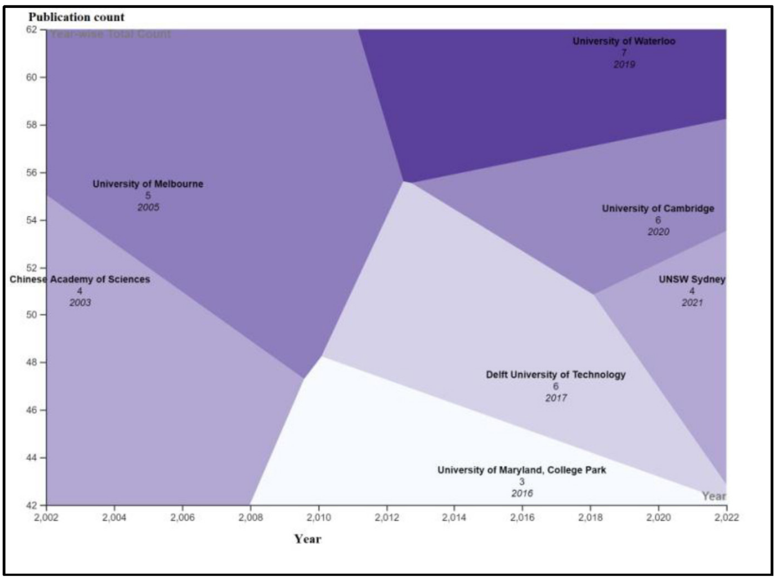

Figure 8

Voronoi diagram shows the year-wise publication count and top active institutions in the respective year

National Research Foundation of Korea is a funding agency located in South Korea which has funded Kumoh National Institute of Technology (See Table 1). Kumoh National Institute of Technology has total 4 publication counts with authors like Jeon J.c, Erniyazov. S & Safoev, N. Kumoh National Institute of Technology is also affiliated to the Ministry of Science, ICT and Future Planning. They have worked together on 4 publications mainly worked by Author Jeon, J.C.Kumoh National Institute of Technology has total 8 publications with 2 different funding agencies.Northeast Petroleum University, City University of Hong Kong, Beijing University of Posts and Telecommunications, Inner Mongolia University of Science and Technology are funded by National Natural Science Foundation of China based in China. They (See Table 1) have around 4 publication counts.

AgenciaEstatal de Investigación from Belgium is affiliated to European Theoretical Spectroscopy Facility ETSF who has 2 publication counts.Riken, Keio University, Tokyo Institute of Technology is funded by Ministry of Education, Culture, Sports, Science and Technology. They are based in Japan and have 2 publication counts.

Nowadays, quantum technology comes with the superior advantages in various applications (See Table 2). But the exact powers of the quantum computer are unidentified because of the lack of tool to design suitable quantum circuits. The author (Jiang et. al., 2021, p.1) initiates with quantum flow to contribute to the exploiting quantum power.

Table 1

Top Funding agencies with publication count, top affiliation along with country and authors in respective funding agencies.

Funding Agencies	Publication count	Affiliation Name (S)	Country	Author(s) Name
Ministry of Science, ICT and Future Planning	4	Kumoh National Institute of Technology	South Korea	Jeon, J.C.
National Natural Science Foundation of China	4	Northeast Petroleum University, City University of Hong Kong, Beijing University of Posts and Telecommunications, Inner Mongolia University of Science and Technology	China	Cao, C., Chen, T., Duan, Y.W., Fan, L., Han, Y.H., Han, Y.H.
National Research Foundation of Korea	4	Kumoh National Institute of Technology	South Korea	Jeon, J.C., Erniyazov, S., Safoev, N.
Ministry of Education, Culture, Sports, Science and Technology	2	Riken, Keio University, Tokyo Institute of Technology	Japan	Devitt, S.J., Kodera, T., Van Meter, R.
Agencia Estatal de Investigación	2	European Theoretical Spectroscopy Facility ETSF	Belgium	Verstraete, M.J.

Table 2

Details of recent research work related to quantum dots and its application

Sr No.	Paper Title	Publication Year	Author(s)	Journal Name	Details
1	"Probabilistic teleportation of a quantum dot spin qubit" (Kojima et. al., 2021, p.68)	2021	Kojima, Y.	npj Quantum Information	Create and detect maximally entangled states using the triple quantum dots.
2	"Adiabatic quantum state transfer in a semiconductor quantum-dot spin chain" (Kandel et. al., 2021,p.1)	2021	Kandel, Y.P.	Nature Communications	Presents Adiabatic quantum state transfer via quantum dot spins.
3	"A co-design framework of neural networks and quantum circuits towards quantum advantage" (Jiang et. al., 2021,p.1)	2021	Jiang, W.	Nature Communications	Introduced QuantumFlow to prove quantum advantage
4	"Technique for two-dimensional nearest neighbour realisation of quantum circuits using weighted look-ahead" (Chhangte & Chakrabarty, 2020,p. 281)	2020	Chhangte, L.	IET Computers and Digital Techniques	Introduced global qubit ordering technique
5	"Efficient Implementation of Nearest Neighbor Quantum Circuits Using Clustering with Genetic Algorithm" (Bhattacharjee et. al., 2020,p.40)	2020	Bhattacha-rjee, A.	Proceedings of The International Symposium on Multiple-Valued Logic	Proposed improved design approach for quantum circuits. K-means clusterign scheme and genetic algorithm used to order the qubits
6	"High-performance resistive switching memory with embedded molybdenum disulfide quantum dots" (Yu et. al., 2021,p. 172104)	2020	Yu, X.	Applied Physics Letters	Discussed approach resistive switching properties and emerging ways of data storage.
7	"High-Dimensional Similarity Search with Quantum-Assisted Variational" (Mo et. al., 2017,p.1600221)	2020	Gao, N.	International Conference on Knowledge Discovery and Data Mining	Describes adiabatics and gate model schemes with the quantum assisted variational autoencoder approach.

The unitary matrixes explore quantum advantage with the help of encoding and input data into 2k qubits (here k is the qubits) with random variables. Using the MNIST dataset author shows the quantum flow accuracy and reduced cost complexity. The paper discussed about quantum Teleportation, using the bell measurement. The triple quantum dots are used to create and detect the entangled states for teleportation. Paper highlights an improvement in single-triplet mixing with the help of optimizing the device parameters (Kojima et. al., 2021, p.68).

Author (Kandel et. al., 2021, p.1) presents the proof of adiabatic quantum state transfer via quantum dots pins the process shows single and two spin states in approximately 127 nano seconds. The introduced method gives long spin chain in spin state transfer. The discussed future Scope opens all the opportunities to achieve universal adiabatic quantum computing in quantum dot spin.

As author explains (Chhangte & Chakrabarty, 2020,p. 281) the quantum computers are based on quantum dots and superconducting physical constraint, that requires moving qubits to be adjacent. “The initial placement of qubits and the swap gate insertion techniques affect the circuit cost (Chhangte & Chakrabarty, 2020,p. 281)”. The author presents Global Qubit Ordering Technique to reduce the cost of circuit. The technique was the permutation of the interaction between qubits.

As discussed in the section 1.1 the superconducting qubits accomplish the height to implement quantum computing devices. The evidence for accomplishment is discussed in (Bhattacharjee et. al., 2020, p.40) the paper, which proposed an improved designed approach for transforming quantum circuits for the nearest neighbor based model using genetic algorithms. The initial stage k-means scheme is used to divide qubits into discrete phase and then the genetic algorithm is performed to order qubits in the separate cluster.

The tremendous amount of data flowing in this digital era and traditional memory technologies are facing various types of challenges. To overcome such type of Problematic challenges, challenges the Resistive Random Access Memory (RRAM) is introduced with an immense potential. The uses of molybdenum disulfide quantum dots in resistive switching devices are counted in one of the emerging memory technologies. The work(Yu et. al., 2021, p. 172104) discussed the approach for the development of the resistive switching properties and improving the data storage.

he structure of the environment affects the evolution speed of quantum system. Via engineering multiple environments author (Mo et. al., 2017, p.1600221) found the new degree of freedom to speed up the evolution in quantum system. To test the proposed concept the author uses quan- tum dots in planar photonic crystal under current technologies. The recent progress (Madsen et. al.,2022; Law, 2021; Thapliyal, 2010) in the quantum hardware has the potential of efficiently handling high dimensional data. To demonstrate the advantage of quantum system and technology, authors (Gao et. al., 2020, p. 956) describes both adiabatic and gate model schemes,which are directly related to the quantum dots. The discussed

Table 3

Co-relation between Quantum Dots and clustering algorithm

Author Name	Funding Agencies	Funded Areas	Top Countries	Top sources
Afonso, P.	Army Research Laboratory	Computer Science	United States	IEEE International Conference on Emerging Technologies and Factory Automation ETFA
Benet, G.	Association of Research Libraries	Computer Science	China	2005 IEEE Computational Systems Bioinformatics Conference Workshops and Poster Abstracts
Blanes, F.	Chinese Academy of Sciences	Physics and Astronomy	Germany	2009 International Conference on Emerging Technologies ICET 2009
Chang, J.Y.	Ministry of Science and Technology of the People's Republic of China	Physics and Astronomy	Finland	Chemphyschem
Chen, J.K.	National Basic Research Program of China	Physics and Astronomy	Netherlands	Chinese Physics B
Chung, P.W.	National Institute on Drug Abuse	Biochemistry, Genetics and Molecular Biology	Pakistan	IEEE International Symposium on Spread Spectrum Techniques and Applications

Quantum Assisted Variational Auto Encoder (QVAE) approach has the capability of achieving enhancement of the discrete variational autoencoder. The experiment result shows the relation between Euclidean distance and hamming distance on the Moderate Resolution Imaging Spectroradiometer (MODIS) dataset. After the appearance of the complex feature rich data, advanced analysis techniques can be used. Some authors present a good match of quantum dots to show extremely helpful results in rich datasets (Thapliyal, 2009; Eriksson et. al., 2004; Ardavan et. al., 2003; Claessens et. al., 2008; Córcoles, et. al., 2015; Ohno, et. al., 1999; Hsieh, et. al., 2009; Zhang, et. al., 2008). Quantum dots include various pioneered approaches to automated clustering algorithms in n dimensions. To highlight the upcoming research area to researchers following details will be helpful. The Table 4 shows the list of active authors working on the advancement of the quantum dot in the clustering problems. The Table 3 also gives the boom to the advanced technology with their respective subject areas. The top countries and sources show the opportunities.

Authors' research on the impact of quantum dot material is listed (See Table 3). The energies are constrained by man-made artificial quantum dots, and the quantum theory then enters the perspective to excite higher energy states. Along with China and Germany, the United States is at the forefront of research into quantum dot hardware. The fields of computer science and physics are the ones with the most developments using quantum dots. The research on quantum dots and computer science is being headed by the author Afonso. Table 3 above covered active authors, funding agencies, top regions, top nations, and pertinent sources.

4. Discussion and Conclusion

The Quantum revolution promises to enhance the classical computers into machines equipped with operations to break the most robust encryption or model the physics of molecules. Billions of qubits are required for quantum operation while performing complex modelling.

The qubits exchange spin depends on the quantum dots to improve computation speed; for this reason, advancement in the quantum operation needs to be focused on the process of a quantum dot. The paper presents the top authors and their work in the quantum dot field. The correlation between the institutes and authors explores the path to reach the collaborators. Technology advancement and providing an environment with the future technology the agencies give funds to grab the opportunity Section 3 discusses the top funding agencies and their top-funded subject areas. The discoveries break the knowledge limits, and the papers explain some of the relevant papers in a quantum dot to touch on the details of the recent work in the quantum dot research area. A quicker progression in quantum computing research is required to emphasize the field of quantum dots.

uantum Dots exhibits the exclusive electronic properties intermediate between bulk semiconductors and discrete molecules. The dots have the uncommon height surface to volume ratio of particles and quantum confinement due to limited number of atoms and special shape of quantum dots. The properties of quantum dots are not only decided by the size but also by the shape composition and structure, for instance, solid or hollow. The unique size and composition tunable electronic properties of the Nano structures make them interesting for a variety of application and new technologies such as electronics like single electron transistor, optical application like TV displays, solar cell information stor- age, imaging medicine and sensing. Quantum dots are playing significant role in the medi- cal application, including potential cancer treatment (Zhang, et. al.,2008, p. 83). Quantum dots can be designed in such a way that they can be accumulated in particular parts of the body and the dots deliver entire anti-cancer drugs bound to them (Zhang, et. al.,2008, p. 83). The extensive advantage is that they can be aimed at single organs organs more precisely than the traditional drugs reducing the horrid side effects caused due to the untargeted conventional chemotherapy (Li et. al., 2019,p.2011).

Future scope and future directions for researchers working on quantum hardware technology:

- The improvement and advancement in spin encoding and spin measurement will enable the quantum power to handle the massive data.

- The convergence property of Quantum Machine Learning model depends on the quantum circuits. Those quantum circuits can be improved using properties of the quantum dots.
- The challenges associated with high dimensional quantum circuit need to be overcome in the near future to use the accessible quantum power.
- The additional resources of Quantum dots, quantum computers can be used to implement a data driven quantum circuit training algorithm on large size datasets.

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