QUANTUM VIBES

Bi-monthly newsletter on Indian Quantum Technology Activities

2023
MAY
ISSUE 2

Cabinet approves National Quantum Mission

Inside the Minds

Prof. Anil Prabhakar, IIT-M

Quantum Key Distribution

Beyond the repeaterless loss-rate – A Glimpse on Current Trends

Dr. R. Srikanth, PPISR

Editor's Note

"In this edition, we align with the Celebration of World Telecom Day and the recent announcement of the National Quantum Mission by the Government of India."

I am delighted to present the second edition of the 'Quantum Vibes' newsletter with great pleasure. As you may recall, the inaugural issue of this newsletter was inaugurated by Prof. Tarun Souradeep, Director of RRI, in the presence of distinguished quantum technology researchers from across the nation who had gathered at Mysore to attend the Quantum Techade event organized by CDAC.

We are glad to announce the establishment of the Advisory Board for Quantum Vibes in this edition. It is with immense pleasure that I extend a warm welcome to our esteemed board members : Prof. Apoorva Patel, IISc and Dr. Chandrashekar, IMSc & IISc, who bring an abundance of knowledge and experience in the field of Quantum Technology.

Further, our team would like to extend an invitation to experts working in the field of Quantum Technology to join our Advisory Board. We firmly believe that your expertise and insights will further enrich our discussions and help us remain at the forefront of advancements in this rapidly evolving field.

In this edition, the newsletter focuses on Quantum Communications, aligning with the celebration of World Telecom Day in the month of May each year. We are privileged to feature insightful interview of Prof. Anil Prabhakar from IITM, who has made significant contributions to the field of Quantum Communications.

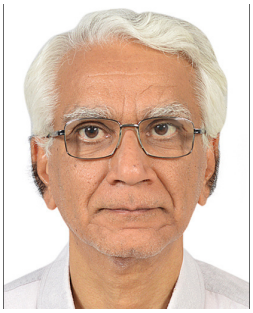
Dr. Srikanth from PPISR has presented a comprehensive survey on recent trends in utilizing weak coherent pulses to overcome the QKD rate loss limit without the need for repeaters, which is a very worthy read.

This issue also covers important events conducted during this period, as well as the latest publications on quantum technologies.

Of particular significance, the current edition coincides with the announcement of the National Quantum Mission by the Government of India, aimed at strengthening quantum technology research and development nationwide. With this crucial initiative, I am confident that India will gain the necessary momentum to establish a prominent global position among countries at the forefront of advancing quantum technologies.

DR. S.D SUDARSAN
Editor

MEET THE ADVISORY BOARD



Prof. Apoorva D. Patel

Prof. Apoorva D. Patel is a professor at the Centre for High Energy Physics, Indian Institute of Science, Bangalore. He is notable for his work on quantum algorithms, and the application of information theory concepts to understand the structure of genetic languages. His major field of work has been the theory of quantum chromodynamics, where he has used lattice gauge theory techniques to investigate spectral properties, phase transitions, and matrix elements.

His research interests are Lattice gauge theories, Renormalisation group, Light-front QCD, Quark-gluon plasma, Quantum computation, Languages of genes and proteins and Black hole thermodynamics.

Dr. Chandrashekar C.M

Dr. Chandrashekar's research group at IMSc works on some of the theoretical aspects of quantum information, quantum simulation and quantum computation and research group at IISc works on some of the experimental aspects of photon based quantum information processing and quantum optics.

His research interests are broadly in the area of quantum information processing and quantum computation. On the theoretical side, his group works on developing quantum algorithms and protocols for quantum simulation on near term quantum hardware, quantum communication protocols, quantum network and probing the dynamics of quantum information. On the experimental side, his group works on engineering single and entangled states of photon engineering for various quantum information processing applications.

Join the Advisory Board of Quantum Vibes

We also extend a warm invitation to other experts actively involved in the field of Quantum Technology to join our Advisory Board. Your valuable insights and expertise will greatly contribute to the growth and development of Quantum Vibes.

Quantum key distribution

Beyond the repeaterless loss-rate – A glimpse on current trends - Dr. R. Srikanth

Quantum communication enables quantum key distribution (QKD), a revolutionary advance in information security, allowing two distant parties to share a verifiably secret and secure cryptographic key (Bennett & Brassard 2014). Decades of research on fiber-optic cable technology has now brought QKD to a point where long-distance real-world quantum communication is practical (Dynes et al. 2019). In these systems, quantum signals are subject to loss such that their achievable key rates fall linearly with the transmittance (η) of the channel (Pirandola et al 2017), a seminal result in practical quantum cryptography. This linear rate-loss scaling entails a too low rate for long haul networks, whose links correspond to or are strategically important for metropolitan cities.

In theory, the use of quantum repeaters, installed across N nodes between which players implement entanglement distillation, can ameliorate the rate-loss scaling to $\eta^{1/(N+1)}$, allowing secure, long haul quantum communication over arbitrarily long distances (Duan et al. 2001). However, quantum repeaters require technologies that are rather far from practical.

The twin-field (TF) QKD protocol (Lucamarini et al. 2018), which can be described as a marriage of measurement-device-independence (MDI) (Lo, Curty & Qi, 2012) and single-photon interference (Rao and Srikanth, 2023), is a clever way to go beyond the repeaterless rate-loss for practical quantum communication.

The essential idea is as follows. TF-QKD, like MDI, employs an intermediate measurement node midway between the two endpoints. Players at both ends transmit a weak coherent state pulse each, both of which are interfered at the intermediate node by a possibly untrusted player. On account of the weakness of the signals, the interference is of first-order (single-particle) rather than two-photon (second-order). The protocol is designed so that the interference pattern reveals the relative value of the senders' input values, without revealing anything about their absolute values, which can be inferred by the legitimate senders, and used to generate a secret, shared key between the two senders.

This halves the transmission distance for either user, and correspondingly the signal transmission loss. This yields an advantageous rate-loss that scales as $\sqrt{\eta}$, a quadratic improvement over the standard repeaterless case.

An important variant of the TF-QKD scheme is the sending-not-sending (SNS) protocol (Wang, Yu and Hu, 2018). The original scheme requires phase slice reconciliation, which not only reduces the efficiency but also requires careful phase alignment between the two senders. By contrast, the SNS protocol involves the secret key bit being generated in cases where precisely one of the two parties sends a pulse and the other doesn't, and thereby lowers misalignment errors.

Twin-Field Quantum Key Distribution (QKD) is a protocol for secure communication based on quantum principles. It is a variant of QKD that combines concepts from measurement-device-independence (MDI) and single-photon interference.

Twin-field quantum key distribution (TF-QKD) can overcome the fundamental rate-loss limit in the point-to-point QKD without a quantum repeater and achieve high key rates over long distances. However, TF-QKD protocol and its variants commonly use weak coherent pulses (WCPs) as light sources.

Security against general attacks on TF-QKD has been studied by various authors, eg., Curty, Azuma & Lo, (2019) and Currás-Lorenzo, G. et al (2021). TF-QKD provides such a breakthrough in practically enhancing secure range, that a number of recent experiments have implemented variants of it, most recently over a distance of 830 km (Wang et al. 2022).

The most important challenge remains the stringent need for phase stability of the lasers used, because of which all existing experimental setups have adopted a closed interferometer configuration. Such a setup turns out to be a gigantic Mach-Zehnder interferometer, where an intermediary prepares the pulses from a single source, and shares it to the senders in the protocol. Such a configuration is inflexible and also resource-inefficient on account of the need for additional service fibers to accommodate the two-way communication and also the need for hardware to implement optical frequency locking. Thus, one way to enhance the range of QKD is to explore ways to realize TF-QKD in a more resource-efficient, open interferometer configuration (Zhou et al. 2023).

QKD will indubitably be part of the future quantum technological landscape. The main challenge is to develop innovative protocols in cryptography or computation that can accommodate the horizons of technological feasibility. TF-QKD or its variants indeed constitute such protocols.

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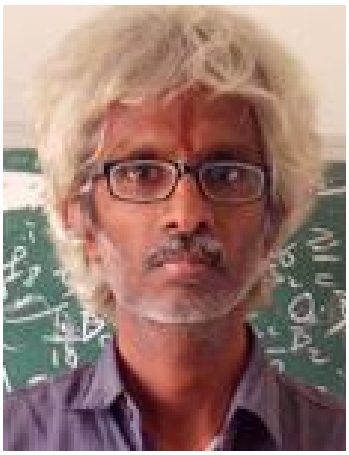


Dr. R. Srikanth

Dr R. Srikanth is Associate Professor in the Theoretical Sciences Department of Poornaprajna Institute of Scientific Research, Bengaluru, who obtained his PhD from the Astrophysics Dept., IISc, Bengaluru. He has over 100 publications in international peer-reviewed journals, and serves as a reviewer for several journals. He is on the editorial board of the international journal Quanta. His main areas of research interest are: Foundations of quantum mechanics, Quantum information theory, Quantum cryptography and Solar physics (supergranulation, etc.). He is the founding coordinator of the Center for Foundational Study within PPISR, which aims to explore ways to bridge science and philosophy.

https://ppisr.res.in/r-srikanth/

INSIDE THE MINDS

An interview with Prof. Anil Prabhakar, IIT-Madras

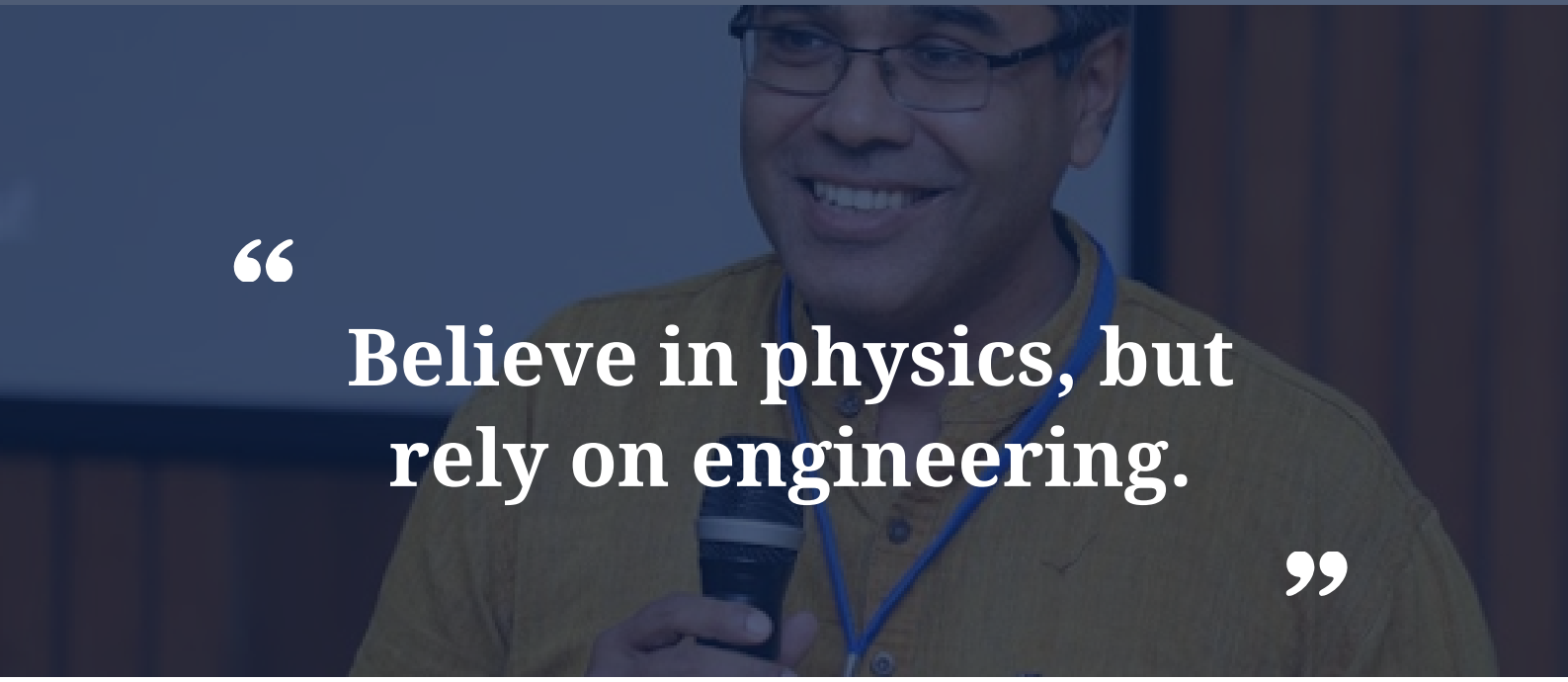
PROF. ANIL PRABHAKAR

Prof. Anil Prabhakar received his PhD in 1997 from Carnegie Mellon University, with a dissertation on the Nonlinear Spin-wave Optical Interactions. He has been with the faculty at the Dept. of Electrical Engineering, IIT-Madras since 2002, and is engaged across multiple laboratories that work on quantum technologies, fibre lasers and opto-fluidics.

His current research interests in the areas of quantum technologies, have applications in metrology, quantum communication and quantum computing. As a Founder of QuNu Labs and of Quanfluence, both incubated by IIT Madras, he focused on quantum communications and photonic quantum computing, respectively.

An earlier startup, Unilumen Photonics that focused on fibre lasers was acquired by Jiva Sciences. He is currently the Director of Yali Mobility and Enability Foundation, companies that focus on rehabilitation engineering.

He has over 50 research publications, has co-authored a book on Spin Waves, a few book chapters, and has 18 patents on a wide range of devices in areas of photonics, magnonics and assistive devices.



Believe in physics, but rely on engineering.

Can you discuss any exciting ongoing research projects or breakthroughs in quantum communication that you and your team are working on?

We are extending our current work in three directions.

- Measurement device independent QKD
- Entangled photon distribution
- Photonic integrated circuits for quantum key distribution

We have proposed the Quantum Internet with Local Access (QuiLA), linking Chennai, Bengaluru, Hyderabad, Indore and Delhi. From a metro area quantum access network (MAQAN) to QuiLA is a natural progression as we aim to strengthen our defensive capabilities through the use of quantum communications.

What are some of the most pressing challenges facing quantum communication today, and how do you anticipate these will be addressed in the near future?

Quantum repeaters are critical devices for long distance quantum communication, but are still in their infancy. Being able to demonstrate this technology at TRL>4 would allow us to being building quantum networks without relying on secure nodes. India needs an aggressive program to build quantum repeaters, and compete with the likes of Amazon.

Did you know?

The Metro Area Quantum Access Network (MAQAN) can serve as a platform for testing quantum communications and showcasing various protocols employed in quantum communication.

How does your involvement in the MAQAN project with C-DAC and SETS contribute to advancing this field with potential for future breakthroughs?

I like to think of MAQAN as a collaboration, bigger than just a project. MAQAN has set the benchmark of collaborative projects on quantum technologies. By bringing together organizations with complementary skills, we have been able to do better than what each organization could do individually. Now, we have newer partners like ERNET and BEL joining the collaboration.

What advice would you give to students and young professionals who are interested in pursuing a career in quantum communication and related fields?

Believe in physics, but rely on engineering. Making quantum technology work to scale, and with stability and robustness, requires that we develop precision engineering. We must also be willing to take risks and leapfrog ahead, always having faith that the underlying quantum physics will work if we do our engineering correctly.

What is your perspective on the development and commercialization of quantum communication technologies, and how do you envision India's role in this effort?

These are still early days for quantum technologies, in communication, computing and sensing. This is also the time for entrepreneurs to step up and lead the way. Quantum 2.0 is all about translating what has worked in our research laboratories into practical applications. Our demographics allow us to build in India, for India. But good engineering is appreciated worldwide and we should leverage the National Quantum Mission to build technologies for the world.

AN OVERVIEW OF CURRENT ADVANCEMENTS

Quantum Communication in India

A Spotlight on India

> **The entire telecom sector has transformed over the past 8 years and today Quantum is the new frontier of telecom technology.**
>
> *Shri. Ashwini Vaishnaw*
> *Union IT Minister*

First International Quantum Communication Conclave held in New Delhi

March 28, 2023: The First International Quantum Communication Conclave, a two-day event organized by the Department of Telecom in collaboration with CDOT, TSDSI, and IEEE Communications Society - Delhi Chapter, at Vigyan Bhawan in New Delhi. The conclave served as a significant platform for industry experts, academics, research and development centers, and government representatives to deliberate on the potential applications of quantum technologies in establishing a secure communication infrastructure.

The event was inaugurated on March 27th by Shri Ashwini Vaishnaw, the Minister of Communications, Electronics & Information Technology and Railways, along with Shri Devusinh Chauhan, the Minister of State for Communications. During the conclave, the Ministers unveiled the standards for the 'Test Guide of Quantum Key Distribution (QKD) System' and 'Quantum-Safe and Classical Cryptography System', highlighting the importance of these advancements. Additionally, Shri Ashwini Vaishnaw made an exciting announcement about the Quantum Hackathon 2023, aimed at identifying vulnerabilities in QKD and PQC solutions and reinforcing the Quantum Ecosystem in India. The event also featured the prestigious Pandit Deendayal Upadhyaya Telecom Skill Excellence Awards - 2022, honoring deserving recipients for their outstanding contributions in the field.

Source: PIB

A quantum outreach program was held at Kannur University to celebrate World Quantum Day.

On **April 26, 2023**, the Department of Information Technology at Kannur University, in collaboration with CDAC-Bengaluru and IEEE India, hosted the Quantum Outreach Program to commemorate World Quantum Day.

During the event, various aspects of quantum computing were explored. Dr. C M Chandrashekar from IISc delivered a presentation on the construction of quantum computers and the boundless possibilities they offer. Shri. Srikanth Chandrashekaran, Senior Director of IEEE, shed light on the involvement of IEEE in quantum computing, while Dr. Asvija, Joint Director of C-DAC Bangalore, shared insights on quantum networks. Mr. Henry Sukumar, Joint Director of C-DAC Bangalore, provided an overview of the Quantum Computing Simulator and QSim.

The event witnessed the participation of 100 attendees from diverse engineering colleges in Kannur, including students and faculty members from Kannur University.

World Quantum Day

World Quantum Day is an international, community-driven event on April 14 to spark interest and generate enthusiasm for quantum mechanics. April 14th — or "4.14" — marks the rounded first three digits of Planck's constant (in eV), a value which sets the quantum scale.

Raman Research Institute and ISRO achieve a breakthrough in securing quantum communication via satellites

April 2023: In a noteworthy advancement, scientists at the Quantum Information and Computing Lab of the Raman Research Institute in Bengaluru have achieved a breakthrough in their efforts toward using satellites for secure quantum communication. In partnership with ISRO's UR Rao Satellite Centre, the team successfully demonstrated secure communication between a stationary device and a moving receiver using Quantum Key Distribution and a Pointing, Acquisition, and Tracking system. This accomplishment is a significant milestone in the QUEST initiative (Quantum experiments using satellite technology). Previously, in 2021, the Raman Research Institute had demonstrated the transmission of quantum keys between two stationary points.

Source: Indian Express

MYTHS VS FACTS

Myth: Quantum communication is immune to hacking and eavesdropping.

Fact: Quantum communication provides a high level of security against certain types of attacks, especially in the context of quantum key distribution. However, it is not immune to all forms of hacking and eavesdropping. Quantum communication protocols can still be vulnerable to side-channel attacks, implementation flaws, and advanced computational attacks. Ongoing research focuses on developing robust quantum communication protocols and addressing potential security loopholes.

RRI and Indian Navy to develop secure maritime communications using Quantum Technology

April 2023: The Raman Research Institute's (RRI) Quantum Information and Computing (QuIC) lab has signed a Memorandum of Understanding (MoU) with the Indian Navy's R&D establishment, the Weapons and Electronics Systems Engineering Establishment (WESEE), to develop secure maritime communications using Quantum Technology. As part of the five-year agreement, RRI will lead the research to develop quantum key distribution techniques to enhance free space communication security for the Indian Navy.

Professor Souradeep emphasized the integration of fundamental and applied sciences as well as science and technology in this project to yield national advantages.

Urbasi Sinha, Group Head of QuIC Lab, emphasized the potential benefits that India can derive from its scientific discoveries and technological advancements.

Source: PIB

> **India has been making remarkable progress in the field of quantum communication. With dedicated research institutes and a strong focus on developing indigenous quantum technologies, we are witnessing significant growth in this domain.**
>
> *Dr. Ashutosh Sharma*
> *Secretary, Department of Science and Technology, Government of India.*

RS.6003.65CR | 2023-24 TO 2030-31

NQM

NATIONAL QUANTUM MISSION

RS. 6003.65 CR

The Union Cabinet has given its approval for the National Quantum Mission, allocating a budget of Rs. 6003.65 Crore for the period of 2023-24 to 2030-31. This mission aims to bolster research and development in the field of Quantum Technology in India.

50-1000 QUBITS

To help develop intermediate-scale quantum computers with 50-1000 physical qubits in 8 years in various platforms like superconducting and photonic technology.

2000 KM RANGE

Targets satellite-based secure quantum communications between ground stations over a range of 2000 kms within India, long-distance secure quantum communications with other countries, inter-city quantum key distribution over 2000 km, as well as multi-node Quantum network with quantum memories.

4 T-HUBS

Four Thematic Hubs (T-Hubs) will be set up in top academic and National R&D institutes to promote R&D in areas that are mandated to them

Source
PIB

NQM

Union Minister of State for Science and Technology and Earth Sciences Dr. Jitendra Singh and Union Minister for Information and Broadcasting Shri. Anurag Thakur address the media after a cabinet meeting in New Delhi.

19th April 2023

The National Quantum Mission was approved by the Union Cabinet on Wednesday, with a budget of Rs 6,003 crore for eight years.

Under the ambit of the National Quantum Mission, the establishment of four thematic hubs in various institutions across India has been announced. These hubs aim to enhance research and development in the field of quantum technology. The Department of Science & Technology will spearhead the mission, with a designated mission director overseeing its implementation.

Announcing the decision, Science & Technology Minister Dr. Jitendra Singh said,

"The decision is going to give India a quantum jump in the field."

The mission will have defined milestones that are expected to be achieved over the course of eight years (2023-24 to 2030-31).

A mission secretariat will be established by the government, consisting of a governing body led by eminent scientists in the field of quantum technology. This governing body will provide direction and guidance for the mission's work. Additionally, a Mission Technology Research Council will serve as a scientific advisory body to support the governing body in making informed decisions.

"**As technology is evolving, understanding is evolving and so are the applications. In the area of therapeutics, healthcare, and security the use is being realized,**" the minister added.

HIGHLIGHTS OF

Quantum Techade

Theme:
Co-creation & Collaboration

10-12 March 2023
Mysore

50+
Participants

The event provided a platform for experts to share their knowledge and experiences, identify gaps in the Indian quantum technology domain, and discuss the challenges and opportunities in the field. The panel discussions and round table sessions provided valuable insights into the current state of quantum technology and the way forward.

The Quantum Techade: Co-creation and Collaboration Summit 2023, organized by C-DAC, was a three-day event focused on co-creation and collaboration among experts from various fields in the pursuit of quantum technology advancements.

50+ participants from various organizations, including MeitY, SAC, ISRO, DRDO, SAMEER, TIFR, CMET,BEL, BIS, IISc., RRI, and IIT, SETS, DIAT, PRL, and Amrita University.

"**Quantum Vibes**" - a bi-monthly newletter focussing on Quantum activities in India was launched during the event.

PUBLICATIONS

List of selected publications in Quantum Communication during Jan to May 2023.

Quantum contextuality provides communication complexity advantage *Feb 2023*	Physical Review Letters, 130(8), 080802 *Gupta, S., Saha, D., Xu, Z. P., Cabello, A., & Majumdar, A. S.*
Combating errors in quantum communication: an integrated approach. *Feb 2023*	Scientific Reports, 13(1), 2979. *Bala, R., Asthana, S., & Ravishankar, V.*
Improvement in quantum communication using quantum switch *March 2023*	Physica Scripta, 98(4), 045101 *Mitra, A., Badhani, H., & Ghosh, S*
Twin-field quantum key distribution without optical frequency dissemination *Feb 2023*	Nature Communications, 14(1), 1-8. *Zhou, L., Lin, J., Jing, Y., & Yuan*
Suppressing quantum errors by scaling a surface code logical qubit *Feb 2023*	Nature 614, 676–681 *Google Quantum AI*

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