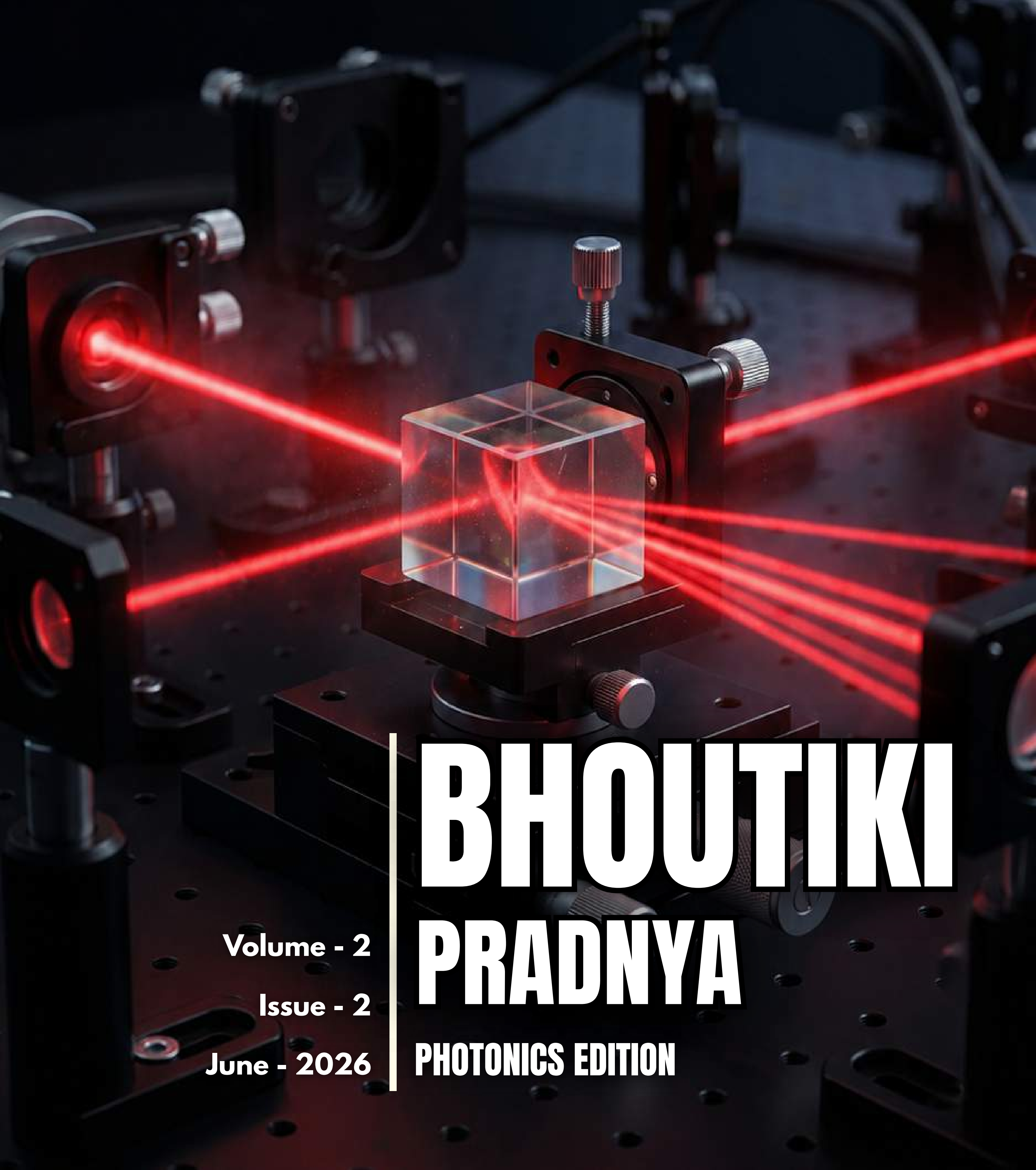
FOR THE SPREAD OF LIGHT

भौतिकी

The Physics Club



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CONTACT DETAILS:

Head, Department of Physics, MES's Nowrosjee Wadia College, Prin. V. K. Joag Path, Pune - 411 001
bhoutiki_physics@nowrosjeewadiacollege.edu.in
020-26162944 (Ext - 230)

PREFACE

We take great pride in presenting this special edition of BHOUTIKI Pradnya, devoted to the captivating realm of Photonics the science and technology of light. From unraveling the mysteries of the universe to enabling everyday innovations, photonics has profoundly transformed how humanity understands, communicates, and explores the world. It bridges fundamental physics with cutting-edge applications, illuminating pathways that continue to shape modern life.

This edition offers a diverse collection of articles that reflect the breadth and depth of photonics research. This edition include the articles on, Raman Spectroscopy of Two-Dimensional Materials, Realities Created Through Light extending vision beyond human perception, Thin Film & Nanostructure Strategies for UV Photodetectors, Doppler Cooling, Entanglement of Three Quantum Memories, Photonics Behind LIGO etc.

We are privileged to honor Dr. D. D. Bhawalkar, whose visionary leadership laid the foundation for India's photonics research ecosystem. His pioneering contributions at the Raja Ramanna Centre for Advanced Technology (RRCAT), Indore continue to inspire generations of scientists and students.

The BHOUTIKI Physics Club also proudly celebrates the recognition of Dr. K. Rajalakshmi Menon, Distinguished Scientist and Director General of Aeronautical Systems, DRDO, an esteemed alumna of our parent institute, batch of 1986. Her remarkable achievements exemplify the heights of excellence that our academic community aspires to.

Adding a lighter dimension, this edition features memes on photonics, blending humor with science, and highlights the accomplishments of our students in PHYSIQUEST, a testament to their curiosity, creativity, and dedication.

Through this special issue, we aim to spark curiosity, foster interdisciplinary exploration, and underscore the transformative power of light in science and society. May this edition serve not only as a repository of knowledge but also as a source of inspiration for all readers.

ABOUT COLLEGE

Welcome to Nowrosjee Wadia College – A Beacon of Excellence Since 1932

Established on July 21, 1932, just months after the founding of the Modern Education Society, Nowrosjee Wadia College has stood as a pillar of academic brilliance and cultural vibrancy in Pune. Guided by its inspiring motto "For the Spread of Light," the college has been instrumental in opening doors to higher education for generations of students, especially in the eastern region of the city.

Affiliated with Savitribai Phule Pune University and proudly holding autonomous status, Nowrosjee Wadia College has earned numerous accolades, including the prestigious First Best College Award from SPPU and an A+ grade from NAAC in 2017. The college continues to shine as a consecutive Divisional Winner of JALLOSH, the university's celebrated cultural fest.

Offering a rich blend of undergraduate and postgraduate (NEP 2.0) programs in both Science and Arts disciplines, the college attracts bright minds from across India and abroad. With world-class infrastructure, vibrant student life, and a legacy of excellence, Nowrosjee Wadia College remains the first choice for holistic education and personal growth.

ABOUT DEPARTMENT

Department of Physics – Advancing Research and Innovation

The Department of Physics at Nowrosjee Wadia College, Pune, is a recognized postgraduate teaching and research center under Savitribai Phule Pune University (SPPU). It currently offers comprehensive academic programs leading to B.Sc., M.Sc., and Ph.D. degrees, fostering a strong foundation in both theoretical and applied physics.

A hallmark of the department is the Electro-Acoustics Research Laboratory (EARL), an SPPU-recognized center for doctoral research. Building on its legacy of excellence, the department has expanded into Materials Science, with the Advanced Functional Materials Laboratory (AFML) offering cutting-edge research opportunities in nanomaterials and functional thin films. These studies focus on conductive and transient properties crucial to thin-film device technologies.

The department has successfully guided numerous Ph.D. and M.Phil. scholars and continues to mentor several active research candidates. Its commitment to innovation is supported by grants from prestigious bodies including the American Physical Society (APS), University Grants Commission (UGC), Indian Space Research Organization (ISRO), Department of Science and Technology (DST) and Board of College and University Development (BCUD-UoP).

ABOUT BHOUTIKI

The term 'BHOUTIKI' in the Physics Club logo likely signifies 'Physics' in Sanskrit, encapsulating the foundational principles of the natural sciences. It beautifully reflects the essence of exploring the physical universe, spanning phenomena from the microscopic to the cosmic scale.

Through 'BHOUTIKI,' we aim to honour the legacy of scientific excellence and inspire a new generation of physicists to delve into the mysteries of the universe.

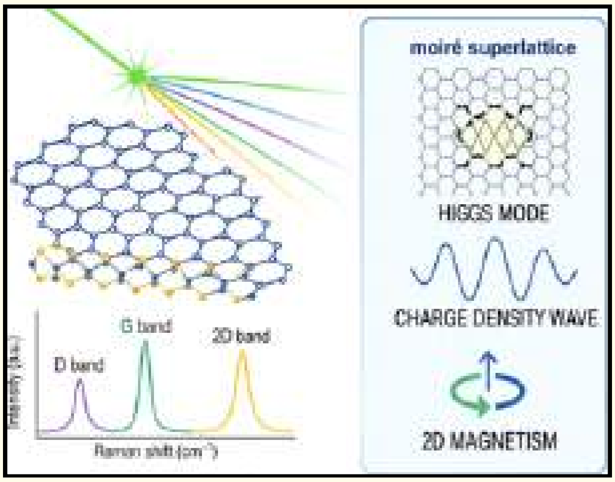
Throughout the year, the club will host a wide variety of activities, each thoughtfully designed to spark curiosity and deepen participants' understanding of the intricate beauty of physics. These activities include: Guest Lectures and Seminars, Workshops and Skill Sessions, Experimental Demonstrations, Science Outreach Programs, Debates and Panel Discussions, Physics Quiz Competitions, Project Showcases, Movie Screenings and Discussions, Publication of Quarterly Digest, Experiment Design Competitions, Peer Teaching and Learning, Problem-Solving Sessions, Celebration of Physics Days, Collaborations and Competitions, Educational Visits, PHYSIQUEST: The department's flagship annual event.

With this diverse range of initiatives, the Physics Students Club aims to foster a vibrant community that celebrates the pursuit of knowledge and the joy of discovery in the realm of physics.

CONTENTS

Raman Spectroscopy of Two-Dimensional Materials: Past, Present, and Future

Dr. Amit Pawbake
tamitpawbake@gmail.com
European High MagneticField Lab (LNCMI) CNRS Grenoble - France



Abstract

Two-dimensional (2D) materials have transformed condensed matter physics and nanoscience since the isolation of graphene in 2004. Their reduced dimensionality gives rise to unique electronic, optical, magnetic, and topological properties that require advanced characterization tools capable of probing matter at the atomic scale. Raman spectroscopy has emerged as one of the most powerful and versatile techniques for investigating these systems. Initially employed for layer-number identification and structural characterization of graphene, Raman spectroscopy has evolved into a sophisticated probe of electron-phonon coupling, charge density waves, magnetism, phase transitions, and collective excitations such as Higgs modes. This review discusses the historical development of both Raman spectroscopy and 2D materials, examines the current state-of-the-art applications in quantum materials research, and highlights future opportunities involving moiré systems, ultrafast spectroscopy, nanoscale imaging, and quantum sensing.

1. Introduction: Two Scientific Revolutions Converge

The story of Raman spectroscopy in 2D materials represents the convergence of two major scientific developments. The first began in1928 with the discovery of the Raman effect by Sir C. V. Raman, providing a fundamentally new method for probing vibrational and electronic excitations in matter. The second emerged nearly eight decades later with the isolation of graphene by Andre Geim and Konstantin Novoselov in 2004, launching the modern era of 2D materials.

The rapid growth of 2D materials research immediately created a demand for characterization techniques capable of probing atomically thin crystals without causing damage. Raman spectroscopy naturally emerged as the ideal solution because phonons, crystal symmetry, and electronic interactions become strongly modified when a material is confined to 2D limit.

Over the past two decades, Raman spectroscopy has evolved from a simple fingerprinting technique into a sensitive probe of many-body interactions and emergent quantum phenomena. The history of Raman studies in 2D materials can therefore be divided into three eras:

Past (2004–2012): During this period, graphene research focused on its fundamental characterization, including the identification of graphene layers and the analysis of defects and strain. Significant advances were made in understanding its vibrational properties, leading to the discovery of dimensionality-dependent phonon behavior, which provided deeper insights into the unique physical properties of graphene and other 2D materials.

Present (2012–2026): Research has expanded beyond basic graphene characterization to explore a wide range of emergent quantum phenomena in 2D materials. Key areas of focus include exciton–phonon coupling, charge density waves, and magnetic excitations, which reveal the complex interactions between electronic, lattice, and spin degrees of freedom. Investigations of quantum phase transitions have provided insights into the evolution of novel electronic states under external stimuli, while the emergence of moiré physics in stacked van der Waals heterostructures has opened new avenues for studying strongly correlated and tunable quantum systems.

Future (2026 and beyond): Future research is expected to leverage Raman spectroscopy as a powerful tool for exploring and controlling quantum phenomena in low-dimensional materials. Emerging directions include quantum sensing applications with enhanced sensitivity and precision, ultrafast Raman spectroscopy for tracking nonequilibrium dynamics on femtosecond timescales, and nanoscale Raman imaging that enables spatially resolved investigations beyond the diffraction limit. These advances will facilitate the detection and characterization of novel collective modes and emergent quantum states, providing deeper insights into complex many-body interactions and next-generation quantum materials.

2. Historical Evolution of Raman Spectroscopy and 2D Materials

2.1. Early Development of Raman Spectroscopy

Raman spectroscopy is based on the inelastic scattering of photons by matter. When incident light interacts with a material, most photons are elastically scattered (Rayleigh scattering), while a small fraction exchanges energy with elementary excitations, producing Raman-shifted photons. The effect was discovered in 1928 by sir C. V. Raman and quickly became an important spectroscopic technique. However, practical applications remained limited until the invention of lasers in the 1960s dramatically increased signal intensity.

The Raman intensity can be expressed as

$$\mathbf{I \propto |ei \cdot R \cdot es|^2}$$

where ei and es are the polarization vectors of incident and scattered light, respectively, and R is the Raman tensor.

The resulting Raman spectrum provides information about phonon energies, Crystal symmetry, Electron-phonon coupling, Magnetic excitations, Structural disorder and Phase transitions.

The non-destructive nature of Raman spectroscopy, combined with sub-micrometer spatial resolution and compatibility with cryogenic, magnetic, strain and high-pressure environments, makes it particularly attractive for studying 2D materials.

2.2 Emergence of Graphene and the Birth of Modern 2D Materials

The isolation of graphene overturned long-standing assumptions regarding the stability of atomically thin crystals. Graphene exhibited remarkable carrier mobility, thermal conductivity, and mechanical strength. A pivotal breakthrough occurred when researchers discovered that Raman spectra changed dramatically with graphene thickness.

The 2D band exhibited characteristic evolution from monolayer to multilayer structures, providing a simple and non-destructive method for identifying graphene layers. This success established Raman spectroscopy as the "workhorse" characterization technique for 2D materials.

3. The Past Era: Raman as a Structural Fingerprinting Tool

3.1 Layer Identification

The first decade of graphene research heavily relied on Raman spectroscopy for determining thickness and quality.

Three prominent peaks became standard metrics:
G mode (~1580 cm^{-1}) ; D mode (~1350 cm^{-1}) ; 2D mode (~2700 cm^{1})

The shape, intensity, and linewidth of the 2D peak enabled precise determination of layer number.

Soon afterward, similar approaches were developed for: MoS_2, WS_2, $MoSe_2$, WSe_2, Black phosphorus

The evolution of Raman frequencies with thickness became one of the earliest that dimensionality fundamentally alters lattice dynamics.

3.2 Defects, Strain and Doping

Researchers quickly realized that Raman spectra were extremely sensitive to local perturbations. Shifts in phonon frequencies provided quantitative measurements of: Mechanical strain, Carrier concentration, Grain boundaries Crystal defects

This capability transformed Raman spectroscopy into a powerful metrology tool for device fabrication.

4. The Present Era: Raman as a Probe of Quantum Many-Body Physics

A major transition occurred around 2012–2015. Raman spectroscopy moved beyond structural characterization and became a probe of emergent quantum phenomena.

4.1 Electron–Phonon Interactions

Electron-phonon coupling governs many physical properties of quantum materials, including superconductivity and charge transport. In 2D systems, reduced screening enhances these interactions. Raman spectroscopy reveals electron-phonon coupling through: Phonon renormalization, Frequency shifts, Linewidth broadening, Fano resonances

These signatures have been extensively observed in graphene, $NbSe_2$, $MoTe_2$, and correlated moiré materials.

4.2 Charge Density Waves

Charge density waves (CDWs) are among the most important collective states found in layered quantum materials. In compounds such as: 1T-TaS_2, 2H-$NbSe_2$ and $TaSe_2$ Raman spectroscopy detects: Soft phonons, Zone-folded modes, Amplitude modes, Symmetry breaking

Because Raman directly probes lattice distortions associated with CDW formation, it has become one of the most effective methods for tracking CDW phase transitions in reduced dimensions.

4.3 Raman Signatures of Magnetism

The discovery of intrinsic 2D magnets such as CrI_3 and $CrGeTe_3$ opened a completely new research frontier of collective spin excitations (spin wave/ magnon). Unlike conventional transport measurements, Raman spectroscopy can directly probe spin-related excitations. Observable features include: One-magnon scattering, Two-magnon scattering, Spin-phonon coupling, Magnetic symmetry breaking which has energy in THz.

The sensitivity of Raman scattering to spin ordering makes it particularly valuable for atomically thin magnetic materials where traditional magnetic characterization becomes difficult.

4.4 Higgs Modes and Collective Excitations

Perhaps the most exciting modern application of Raman spectroscopy is the detection of collective amplitude modes. When continuous symmetry is spontaneously broken, two types of excitations emerge: Goldstone modes. Higgs (amplitude) modes.

Raman spectroscopy is especially sensitive to Higgs excitations because of symmetry-selective scattering channels. In CDW materials such as: $NbSe_2$, TaS_2 Raman measurements revealed amplitude oscillations of the order parameter, providing condensed matter analogues of the Higgs boson.

Future studies in atomically thin CDW systems may provide unprecedented opportunities to investigate Higgs physics under strong quantum confinement.

5. Raman Spectroscopy Across Phase Transitions

One of Raman spectroscopy's greatest strengths is its ability to monitor phase transitions in real time. Examples include:

Structural transitions
$MoTe_2$ and WTe_2 exhibit Raman signatures that distinguish semiconducting and topological phases.

Magnetic transitions
$FePS_3$ and CrI_3 show dramatic changes in phonon spectra at magnetic ordering temperatures.

CDW transitions
Soft modes emerge as systems approach the transition temperature.

Superconducting transitions
Electron-phonon coupling and collective excitations produce measurable spectral changes.

These capabilities make Raman spectroscopy a universal probe of competing orders in quantum materials.

6. Future Directions: Raman Spectroscopy in the Quantum Era

The next decade is likely to witness another transformation.

6.1 Moiré Quantum Materials

Twisted bilayer graphene and twisted transition metal dichalcogenides (TMDs) have emerged as versatile platforms for engineering strongly correlated electronic phase through moiré superlattices. Their exceptional tunability has enabled the observation of a wide range of quantum phenomena, making them ideal systems for investigating many-body interactions. In the future, Raman spectroscopy is expected to play a crucial role in probing these complex states, potentially providing direct signatures of correlated insulating phases, superconducting fluctuations, and symmetry-breaking electronic orders. Furthermore, advances in Raman techniques may enable the detection and characterization of collective excitations in flat-band systems, offering valuable insights into the microscopic mechanisms underlying emergent quantum phenomena in moiré materials.

6.2 Ultrafast Raman Spectroscopy

Time-resolved Raman techniques enable direct observation of ultrafast dynamical processes in quantum materials, including non-equilibrium phonons, ultrafast phase transitions, photoinduced charge density wave (CDW) melting, and coherent Higgs mode oscillations. By tracking these transient responses in real time, this approach provides a powerful window into the evolution of collective excitations under nonequilibrium conditions. As experimental capabilities continue to advance, time-resolved Raman spectroscopy is expected to become increasingly important for probing and understanding transient quantum states in complex materials systems.

6.3 Nanoscale Raman Imaging

Tip-enhanced Raman spectroscopy (TERS) achieves spatial resolution below 10 nm, enabling unprecedented nanoscale optical access to quantum materials. This capability will allow direct visualization of moiré domains, localized defect states, magnetic textures, and domain walls with exceptional spatial precision. By bridging spectroscopy with atomic-scale imaging, TERS opens a pathway to studying structural and electronic heterogeneity at length scales previously inaccessible to conventional Raman techniques.

6.4 Quantum Magnetism and Spin Liquids

Future Raman experiments may enable the detection of exotic quasiparticle excitations, including fractionalized spinons, Majorana quasiparticles, and topological magnons. By probing their unique spectral signatures, these measurements could provide compelling evidence for long-sought quantum spin-liquid states and other strongly correlated quantum phases. Such advances would significantly deepen our understanding of emergent excitations in frustrated magnetic systems and topological quantum matter.

6.5 Artificial Intelligence-Assisted Raman Analysis

Machine learning methods are increasingly being used to extracthidden structure and correlations from large and complex spectral datasets. Key applications include automated phase identification, real-time device monitoring, accelerated materials discovery, and quantum state classification. By enabling rapid, data-driven interpretation of Raman and related spectroscopic signals, these approaches are transforming how experimental data is analyzed and significantly expanding the scope of information that can be retrieved from modern spectroscopy experiments

Conclusions and Outlook

The role of Raman spectroscopy in 2D materials has evolved substantially over the course of graphene research. In its early stages, it primarily functioned as a structural fingerprinting tool for identifying graphene and assessing basic material quality. It now serves as a versatile probe of many-body physics, capable of accessing a broad range of emergent phenomena including phonons, magnons, charge density waves, quantum phase transitions, and collective excitations such as Higgs modes. Looking ahead, continued progress in ultrafast spectroscopy, nanoscale imaging, quantum optics, and machine learning is poised to further expand its capabilities, transforming Raman spectroscopy into a central platform for investigating emergent quantum states in low-dimensional systems. As research increasingly focuses on moiré quantum matter, 2D magnetism, and topological phases, Raman spectroscopy is expected to remain a key technique for discovery, solidifying its transition from a diagnostic method into a fundamental probe of quantum materials.

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Light Trapped on a Chip for Millions of Times Longer

Scientists developed a new photonic device that traps light on a chip for an exceptionally long time using advanced van der Waals materials. This greatly strengthens light–matter interactions and could enable more efficient **quantum light sources, optical sensors,** and **photonic circuits**.

Realities Created Through Light: Seeing Beyond Human Vision

Garimella Satya Sahithi
sahithi12005@gmail.com
Department of Zoology, MES's Nowrosjee Wadia College, Pune 411 001

Light falls, reflects, and reveals the world exactly as it is, or so we assume. Right from the glow of our phone screens, modern life runs on our ability to generate, control, and manipulate light. We believe that what we see is simply colour, simply surface, simply there. But what if some of that colour isn't really there at all, and is just bending of light instead of pigments? And what if I say that what we, humans, see is not all that there is?

We trust light and colour without thinking about it. Sunlight wakes us up in the morning, guides us through crowded streets, and lets us read, recognise faces, and make sense of the world.

Over time, we have learned to control light — focusing it through lenses, splitting it into colours, sending it across oceans as signals. We gave this control a name: photonics — the science of generating and manipulating light. It sounds like something modern. Engineered. Human. But the truth is quieter, and far older.

Long before we understood and started to control it for our needs, Mother Earth was already using it — not just to illuminate, but to communicate, deceive, attract, mainly to survive. Evolution didn't wait for human equations and worked directly with light itself, shaping structures that could reflect it, filter it, and create effects we are still trying to replicate. In that sense, photonics is not an invention. It is a rediscovery.

Among the most striking examples of this are insects — delicate creatures that, at first glance, seem defined by beauty alone. For example, insect wings shimmer, their colours appear vivid and almost unreal, and the patterns seem to be painted with artistic precision. The vivid blue of a Morpho butterfly's wings, specifically Morpho peleides, arises from structural colouration and the shape of the

seem defined by beauty alone. For example, insect wings shimmer, their colours appear vivid and almost unreal, and the patterns seem to be painted with artistic precision. The vivid blue of a Morpho butterfly's wings, specifically *Morpho peleides,* arises from structural colouration and the shape of the

Figure 1: The Peleides Blue Morpho *(Morpho peleides)*

Insects like butterflies, dragonflies, and honeybees do not simply display light. They are also shaped to perceive and respond to it. Their eyes detect wavelengths beyond human vision, revealing patterns on flowers invisible to us. Their behaviours, like feeding, navigation, and even mate selection, are guided by signals encoded in light itself. In this way, they exist within a visual world far richer than the one we experience. Light, for them, is not just illumination. It is information essential for survival.

Seeing Beyond Human Vision

Not all organisms perceive the world and their surroundings in the same way humans do.

What is ordinary, colourful, or even invisible to us may carry entirely different meanings to another species. Surfaces, movements, and colours that humans barely notice can serve as sources of information in the visual world of insects.

The difference lies not in the environment, but in the eyes observing it.

Among the organisms shaped by such a visual reality is the Lime Swallowtail Butterfly *(Papilio demoleus).* (Fig.2) Common and often overlooked, it carries within its wings, vision, and behaviour a sophisticated interplay of biology and photonics — one that reveals how deeply light is woven into life itself.

Figure 2: The Lime Swallowtail Butterfly *(Papilio demoleus)* (Photo by me!!)

Though familiar and commonly seen, the butterfly experiences light in ways fundamentally different from humans. Its perception is built through specialised compound eyes capable of detecting wavelengths that allow it to interact with a world layered with optical signals invisible to us.

The eyes of the Lime Swallowtail Butterfly are compound eyes (Fig. 3), made up of thousands of microscopic visual units known as ommatidia. Unlike human eyes, which rely on a single lens to form an image, compound eyes gather information from many directions simultaneously, creating a mosaic-like perception of the environment. But the true difference lies not only in the structure, but in the range of light these eyes can detect as well.

Human vision itself is limited to only a narrow region of the electromagnetic spectrum — the visible range extending roughly from violet to red. As a result, much of the optical information present in nature remains beyond human perception. In technical terms, this visible range spans approximately 380 – 750 nanometres. [2]

The lime swallowtail is believed to perceive wavelengths extending into the ultraviolet region

Figure 3: The Compound Eyes of the Swallowtail Butterfly (Photo by John Kimbler)

(~300 – 400 nm), which lies outside the visible range, similar to other swallowtail butterflies of the *genus Papilio*.

While humans are trichromatic, swallowtails in the *Papilio* genus often have **tetrachromatic vision**, meaning they use four distinct types of receptors: Ultraviolet (UV), Blue, Green, and Red.

To the butterfly, flowers are not simply coloured objects. A flower that appears plain yellow to humans may contain ultraviolet markings invisible to us, acting as nectar guides that direct pollinators toward food sources. In this way, light becomes a biological language. The butterfly does not merely observe this language. It evolved within it.

Evolution Through Light

Vision is not accidental. The visual systems of butterflies did not develop merely to create beauty, but to aid in survival. Over millions of years, butterflies and flowering plants evolved alongside one another in a close mutualistic relationship shaped by light, colour, and perception. (Mutualism is a symbiotic relationship, where both the living beings involved benefit from the relationship.)

As flowering plants evolved increasingly distinct optical patterns to attract pollinators, butterflies gradually evolved visual systems capable of detecting them more efficiently. In response, flowers developed colours and ultraviolet markings that stood out more clearly to insect eyes.

In this way, evolution began working directly through light. At the centre of this interaction lies physics. Different surfaces absorb, reflect, and scatter light at different wavelengths. Petals reflecting ultraviolet wavelengths, for example, create contrast patterns detectable to butterflies and appearing to them almost like a structured map of signals and guides. (Fig. 4)

Figure 4: Human Vision vs. Insect Vision (The dark patterns act as a map for pollinators, guiding them to the nectar and pollen at the center of the flower)

Natural selection gradually favoured butterflies capable of interpreting these optical cues more effectively. Better perception meant locating nectar faster, avoiding predators more efficiently, and identifying suitable mates more accurately. Over generations, vision itself became increasingly specialised for survival within a world shaped by light.

Lessons from Light

The interaction between butterflies and light has not only shaped their evolution and survival, but has also begun influencing modern science and technology.

Researchers studying butterfly vision and wing microstructures have discovered that many optical principles used in photonics already exist within nature. How butterflies manipulate, detect, and respond to light has inspired developments in imaging systems, optical materials, and wavelength-sensitive technologies.

Butterfly vision has particularly contributed to advances in optical imaging. The compound eyes of butterflies and other insects are capable of detecting rapid motion and interpreting visual information from multiple directions simultaneously. Inspired by such systems, scientists have explored compound-eye-based cameras and wide-angle imaging devices capable of enhanced motion detection and panoramic vision. [3]

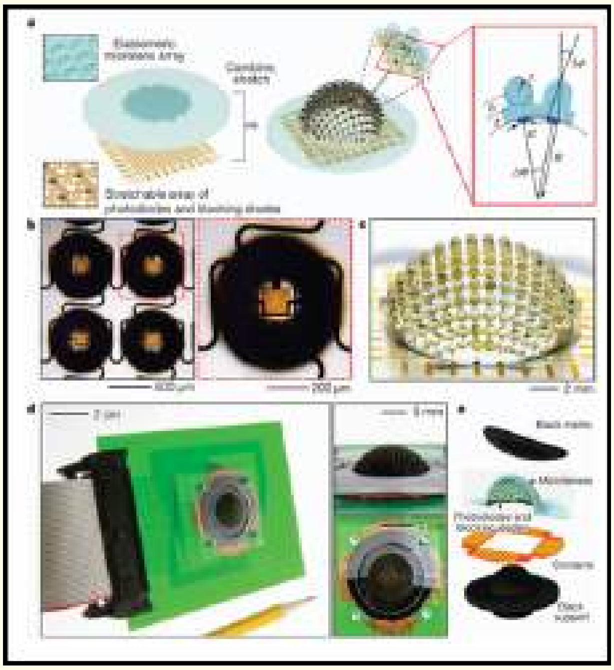

Figure 5: Schematic illustrations and images of components and integration schemes for a digital camera that takes the form of a hemispherical, apposition compound eye. [3]

In addition, the ultraviolet sensitivity observed in butterflies has influenced the development of UV imaging technologies used in environmental monitoring, medical imaging, and agriculture. By studying how butterflies detect optical signals invisible to humans, researchers continue to improve technologies designed to interpret hidden information carried through light.

Another important area of research involves structural colouration — colours produced not by pigments, but by microscopic physical structures that interact with light itself. Studies on butterfly wings, particularly in species such as Morpho butterflies, have shown that nanoscale arrangements on the wing surface selectively reflect specific wavelengths while scattering others, creating vivid iridescent colours [4]

These naturally evolved photonic structures have inspired research into anti-reflective coatings, optical sensors, security technologies, and energy-efficient colour displays. Unlike artificial pigments that may fade over time, structural colours emerge directly from the interaction between light and microscopic architecture.

These developments reveal an important idea: nature did not merely inspire photonics aesthetically. It mastered many of its principles long before humans understood them scientifically.

The butterfly, therefore, represents more than a beautiful biological organism. It represents an evolved optical system — one that continues to influence how humans study, manipulate, and understand light itself.

Conclusion

The Lime Swallowtail Butterfly is often noticed only for its delicate beauty, yet beneath its patterned wings lies a remarkable interaction between biology, physics, evolution, and light. Through specialised compound eyes capable of perceiving wavelengths beyond human vision, the butterfly experiences a world layered with information invisible to us.

Its relationship with flowering plants reveals how evolution shaped perception itself through mutualism, while its visual system demonstrates principles that continue to inspire modern photonics and optical technologies. What appears to humans as simple colour or surface may, to the butterfly, become guidance, communication, or survival.

In studying the lime swallowtail, we are therefore not merely studying an insect. We are exploring how light can shape perception, behaviour, and reality itself.

Perhaps the most remarkable discovery is not that butterflies see more than humans, but that every organism may exist within its own unique visual world — realities continuously created through light.

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Honouring Professor Jainendra Jain's Historic Achievement

Professor Jainendra Jain has become the first Indian to receive the prestigious **Wolf Prize in Physics** for his pioneering contributions to the **Quantum Hall Effect**. His achievement is a powerful reminder of the extraordinary scientific talent India possesses when given the right opportunities.

It is equally inspiring to see Prof. Jain continue giving back to the country as a part of the newly established **Lodha Theoretical Physics Institute**.

Thin Film & Nanostructure Strategies for UV Photodetectors

Dr. Shashikant Shinde
sdshinde@nowrosjeewadiacollege.edu.in
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

Ultraviolet (UV) radiation lies between visible light and X-rays in the electromagnetic spectrum. Although invisible to the human eye, it exerts a profound influence on biological systems, the environment, and modern technology. UV radiation is commonly divided into four regions:

- UVA (315–400 nm): Not absorbed by the ozone layer, UVA penetrates deeply into the skin and is primarily responsible for photoaging.
- UVB (280–315 nm): Partially absorbed by the ozone layer, UVB causes sunburn, DNA damage, and is strongly linked to skin cancer.
- UVC (100–280 nm): Completely absorbed by the ozone layer, UVC is harnessed for sterilization and disinfection.
- Extreme UV (10–100 nm): Fully absorbed by the atmosphere, this range is exploited in semiconductor technology, particularly UV photolithography.

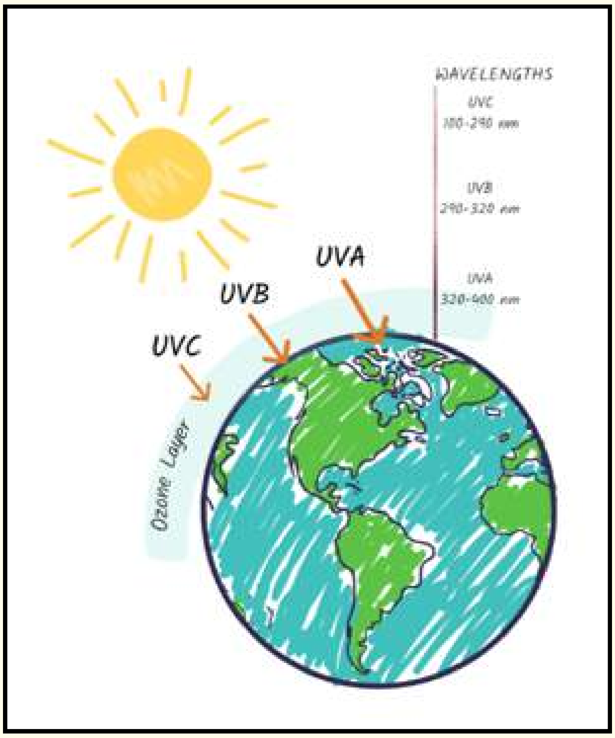

Fig. UV light absorption in the atmosphere (https://noontidesunwear.com)

Most solar UV radiation is filtered by the ozone layer. Only wavelengths longer than 280 nm reach Earth's surface. Detectors highly sensitive to UV-C and far-UV, while rejecting longer wavelengths, are termed solar-blind. Similarly, detectors sensitive to UV radiation but rejecting visible light (>400 nm) are called visible-blind.

UV detection enables diverse applications, including chemical and biological monitoring, flame detection, astronomy, and optical communications. High-performance detectors must meet the 5S criteria: sensitivity, signal-to-noise ratio, spectral selectivity, speed, and stability.

Advances in UV Photodetectors

Traditional UV-enhanced silicon detectors face limitations due to Si's bandgap (1.1 eV), requiring costly filters and suffering from thermal degradation. Wide-bandgap semiconductors such as GaN, diamond, and SiC offer superior performance without filters, enabling high-temperature operation. For example, InGaN-based MIS Schottky photodiodes with CaF_2 insulation have demonstrated stability up to 523 K.

One-dimensional (1D) nanostructures further enhance sensitivity due to their large surface-to-volume ratio. Materials such as ZnO nanowires, Ga_2O_3 nanobelts, and GaN nanowires show remarkable photo-response, though high-temperature stability remains a challenge.

ZnO-Based Nanostructured Photodetectors:

Nanostructured ZnO has emerged as a leading candidate for UV detection due to its wide bandgap (3.34 eV), large exciton binding energy (60 meV), and transparency to visible light. Its wurtzite structure imparts strong piezoelectric properties, making ZnO useful in both photonic and mechanical sensing.

ZnO nanostructures exhibit diverse morphologies nanowires, nanobelts, nanotubes, nanosheets, and more each with distinct optical and electrical properties. Since the first demonstration of ZnO nanowire photodetectors in 2002, significant progress has been made:

- Surface functionalization with polymers enhances photoresponse by several orders of magnitude.
- Annealing effects improve stoichiometry and responsivity, with oxygen annealing yielding superior performance.
- Ag/ZnO heterostructures exploit Schottky contacts for enhanced detection efficiency.

These strategies demonstrate that ZnO nanostructures can deliver highly sensitive, visible-blind UV detection across a broad wavelength range.

Multilayer structures in UV photodetectors such as ZnO/Ga_2O_3 heterostructures or stacked wide-bandgap semiconductors offer several distinct benefits compared to single-layer devices. These advantages arise from band engineering, interface effects, and dimensionality control.

- By combining materials with different bandgaps (e.g., ZnO ~3.3 eV and Ga_2O_3 ~4.9 eV), multilayers can selectively detect UVA, UVB, or solar-blind UVC ranges with higher precision.
- Interfaces between layers act as carrier confinement regions, reducing recombination and boosting photoresponse.
- Heterojunctions suppress leakage pathways, leading to lower noise and higher signal-to-noise ratios.
- Ga_2O_3 layers block longer wavelengths, enabling detectors to respond only to UVC/extreme UV while rejecting visible and near-UV light.
- Wide-bandgap multilayers withstand high-temperature environments (engines, aerospace, semiconductor lithography) better than Si-based detectors.
- Layer thickness and dimensionality engineering (e.g., ZnO nanowire/Ga_2O_3 thin film stacks) allow tuning of rise/decay times for fast switching or sustained monitoring.
- Multilayers can be fabricated on diverse substrates, enabling flexible, transparent, or high-power device designs.

In summary, multilayer UV photodetectors leverage the high sensitivity of ZnO nanostructures together with the thermal stability and solar-blind selectivity of Ga_2O_3. This synergy yields devices that are more efficient, spectrally selective, and durable than single-layer counterparts.

Looking ahead, research should focus on integrating the complementary strengths of thin films and nanostructures, advancing epitaxial growth techniques, and designing robust architectures capable of operating under high-temperature and high-irradiance conditions. Wide-bandgap semiconductors particularly ZnO and Ga_2O_3 are poised to play a pivotal role in shaping the next generation of UV photodetectors.

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Doppler Cooling

Diganta Hazarika
diganta h@hotmail.com
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

Context

Cooling something with any form of light sounds counterintuitive. In general, we observe that when light shines on some material, the material gets heated. However, over the years, scientists have come up with a few different ways to cool down a material with laser to the cryogenic temperature range. Laser cooling techniques that exploit photon absorption and emission can be broadly categorised into the following:

- **Doppler cooling:** It is the foundational laser cooling technique and is used extensively in quantum photonics. The cooling is done by hitting atoms in motion with red-detuned lasers from the opposite direction, utilising the Doppler effect. We will discuss this technique in a little more detail in this article. The minimum achievable temperature with this technique is called the Doppler cooling limit.

- **Sub-Doppler cooling:** These techniques utilise a polarisation gradient created using multiple lasers and keep pushing the atoms to lower energy sub-levels. With this method, the temperature can be brought below the Doppler cooling limit. Sisyphus cooling is one such example.

- **Sub-recoil cooling:** These techniques cool atoms to temperatures where their thermal energy is less than the recoil energy of a single scattered photon. Velocity-Selective Coherent Population Trapping (VSCPT) and Raman cooling are examples of this category.

- **Solid-state cooling:** With this type, some solids can be directly cooled with a laser. The method is also called anti-Stokes cooling. A laser with energy slightly lower than the mean emission energy of the material makes it emit photons of higher energy. The additional energy is extracted from the vibrational energy of the material, due to which the temperature of the solid lattice goes down

Overview of Doppler cooling

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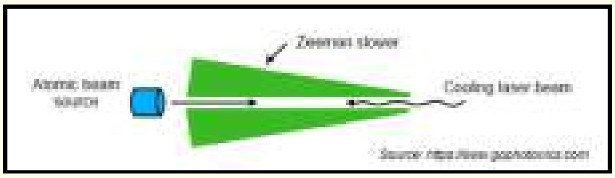
A little history

Doppler cooling is based on the same fundamental light-matter interactions (photon absorption and emission) that photonics is based on. Doppler cooling was originally proposed in 1975 independently by two teams: a) Theodor W. Hänsch and Arthur L. Schawlow and b) David J. Wineland and Hans Georg Dehmelt. In a very significant experimental achievement in 1987, scientists were able to confine and cool a large number of atoms to sub-millikelvin temperatures with the help of Zeeman slower and magneto-optical-trap (MOT).

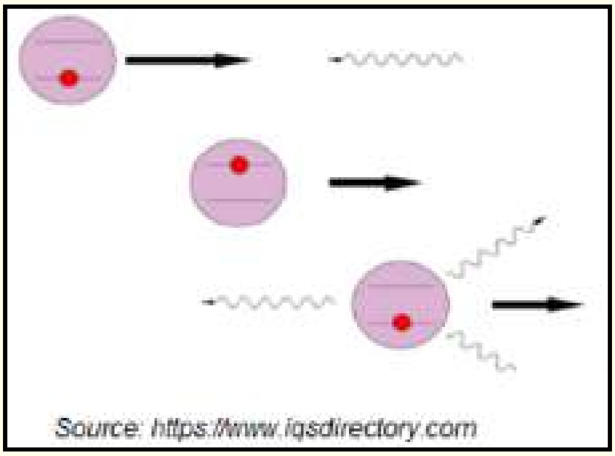
Brief process description

A solid sample of the material (such as Rubidium, Cesium, or Sodium) is heated to a high temperature inside a specialised effusive oven. The material melts and vaporises into a dense gas of energetic atoms. The gas escapes through a collimator, forming a beam and enters an ultra-high vacuum chamber to ensure that the beam does not collide with air molecules, maintaining its alignment. The beam then passes through a skimmer to remove any stray atoms drifting off the axis. This results in a perfectly collimated, highly focused atomic beam that enters the laser cooling area.

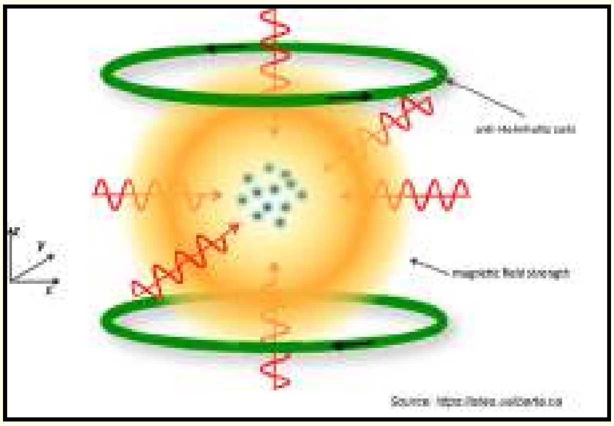
In the cooling area, a red-detuned (having a slightly lower frequency than that of the resonant frequency of the material in the beam) laser targets the beam from the opposite direction. However, due to the Doppler effect, an atom in the beam perceives the



to have the resonant frequency and undergoes the collision. Please note that had the frequency been non-resonant, the atom would have behaved as transparent, and the laser would have passed through it without the collision. As the collision happens, the atom absorbs the photon and moves from its ground state to the excited state. Because of the impact of the collision, the atom loses its momentum and slows down. The atom soon moves back to the ground state, emitting a photon. However, as the emission happens in random directions, the net impact of several such emissions on the atom's momentum is zero. Hence, the whole process makes the atoms lose their momentum and thereby kinetic energy. And as we know, the loss of kinetic energy indirectly means that the temperature of the atoms goes down.



Now, let's talk about the role of the Zeeman slower. As the atoms lose momentum, the laser red-detuned with respect to the initial velocity of the atom would stop interacting with the atom as the Doppler effect wouldn't be able to shift the laser frequency to the atom's resonant frequency. However, the Zeeman slower, with its tapered magnetic field along the cooling area, shifts the atom's energy levels (Zeeman effect), and the laser continues to interact with the slower atoms as well. Sometimes after a collision, an atom could undergo an unwanted quantum jump, which moves it to a dark state. The atom in the dark state becomes invisible to the laser. However, because of the magnetic field in the Zeeman slower, the atom wobbles (Larmor precession) around the magnetic field axis. This brings the atom out of the dark state, and it can interact with the laser again for further cooling.



After the atoms are cooled, they need to be kept confined and cool. A magneto-optical-trap (MOT) is used in this step. The MOT consists of three pairs of lasers from opposite directions covering all three dimensions (x, y and z) of space, and a pair of anti-Helmholtz coils (generally kept in the z direction). Without the anti-Helmholtz coils, the setup of the lasers is called optical molasses with its primary job of providing continuous Doppler cooling in all three dimensions. The anti-Helmholtz coils take care of the confinement. They create a tapered magnetic field in all dimensions, with its field strength being zero at the centre. As an atom moves away from the centre, its energy levels shift, and the lasers start to interact with it and push it back to the centre.

Relevant materials for Doppler cooling

Doppler cooling can be used to cool alkali metals (Rubidium, Cesium, Sodium, Lithium etc.) and alkaline earth metals (Calcium, Magnesium, Stronium etc.). It is so, primarily for the following reasons:

- These elements behave like a simple two-level system (a ground state and an excited state), making optical manipulation easier.
- Their energy transitions are possible with available continuous wave lasers.
- They do not move to dark states easily, even after thousands of transitions.

Doppler cooling and photonics interdependency

Although both photonics and Doppler cooling are based on the same basic principles, they are distinct fields of study and yet are closely linked. Traditionally, a Doppler cooling setup required a room filled with bulk mirrors, beam-splitters, large gas lasers etc. With photonics, the whole setup can be miniaturised in a chip with the help of waveguides. The laser can be directed to target atoms with sub-micron precision.

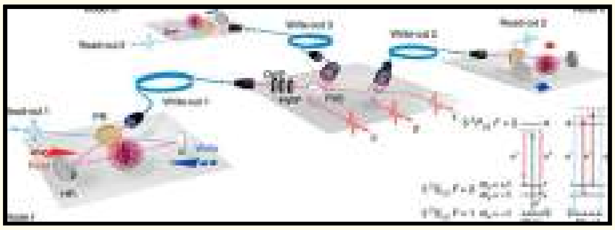
The MOT can be set up by splitting a single laser into multiple lasers with the help of a few special parts in the chip. Photonics also help tune the laser frequencies with better precision. On the other hand, Photonic quantum networks require storing quantum information (photons) inside an atomic vapour and retrieving it later without distortion. Doppler cooling removes thermal velocity, preventing the atoms from moving around and scrambling the stored photonic states. This ensures the integrity and accuracy of the store information.

Entanglement of three quantum memories via interference of three single photons

Lekha Kadekar

lekha.kadekar.9@gmail.com

Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001



Quantum memory networks as an intermediate stage in the development of a quantum internet will enable a number of significant applications To connect and entangle remote quantum memories, it is best to use photons. In experiments entanglement of two memory nodes has been achieved via photon interference. Going beyond the state of the art by entangling many quantum nodes at a distance is highly sought after. Here, we report the entanglement of three remote quantum memories via three-photon interference. We employ laser-cooled atomic ensembles and make use of a ring cavity to enhance the overall efficiency of our memory–photon entanglement. By interfering three single photons from three separate set-ups, we create entanglement of three memories and three photons. Then, by measuring the photons and applying feed-forward, we achieve heralded entanglement between the three memories.

A photon entanglement system is disclosed which includes a plurality of remote nodes (Nodes A, and Node B,) each without a quantum memory; and a central entangling node (Node C) in both quantum and classical communication with the remote Nodes configured to provide photon entanglement there between, and includes a first and second broadband photon generators each adapted to generate sets of photon pairs at: i) random times within time-bins, and ii) random frequency bins, wherein one photon of each pair set is transmitted to an associated remote node over quantum channels, and a multiplexed Bell-state analyser configured to receive another photon of the pair, wherein if the received photons arrive at about same time, then the received photons are marked as being entangled by the controller which communicates the associated time-bin to the associated remote nodes and thereby entangling their associated photons.

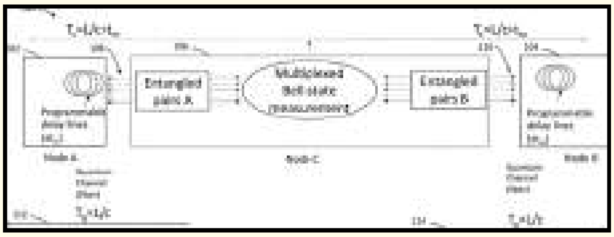


FIG. 1 is a schematic of a physical layer for quantum entanglement, according to the present disclosure is provided.

The present disclosure generally relates to the field of quantum optics, and in particular, to a system and method and system for use in

quantum-based communication. This section introduces aspects that may help facilitate a better understanding of the disclosure. Accordingly, these statements are to be read in this light and are not to be understood as admissions about what is or is not prior art.

Quantum mechanics is the study of particles whereby Newtonian laws of physics applicable to larger objects change drastically. Photons are such particles where quantum mechanics dictate a different relationship than Newtonian physics. For example, a phenomenon called photon entanglement occurs when two photons are paired in a superposition, whereby if the photons are separated their relationship with one another is maintained. For example, while prior to measurement, photons with certain entanglement properties do not have a defined polarization, if determined that one photon's electric field's oscillation direction (also known as polarization) is along the horizontal (vertical) direction the otheris horizontal (vertical) as well. If direction of photon's electric field is ascertained, the direction of field of its twin would be immediately knowable to the observer. term suffers from the degradation of the quantum optical information transmitted over long distances. The typical classical repeaters, however, add excessive noise to the already noise-sensitive quantum information making the traditional repeaters unusable. To remedy this limitation, quantum repeaters are needed. Quantum repeaters have been proposed that rely on quantum memories or multiparticle entanglement to extend the communication distance beyond what is allowed by direct connection of optical fibers. The probabilistic nature of typical quantum photon sources based on spontaneous parametric down conversion or four-wave mixing in nonlinear materials makes it difficult to create synchronous entanglement between neighbouring nodes. To synchronize multiple quantum sources that generate entangled pairs of photons at random times, quantum memories were proposed to store quantum information (entanglement) as created by sources while waiting for all nodes to receive entangled 20 photons. The protocol can extend the quantum communication distance via the quantum repeater architecture where Use of quantum mechanics has already provided such properties for encryption and other secure applications. This is because it would be essentially impossible to cause intrusion into a communication scheme that is dependent on such properties. However, given the infancy of this field, effective physical layers for communication based on entanglement has not been developed. The need for a quantum optical communication network has been highlighted by recent demonstrations and blueprints by, for example, Chinese Satellite Communication effort, U.S. Department of Energy Blueprint on Quantum Internet, Europe's Quantum Internet Alliance, Canada's Quantum Encryption and Science Satellite, just to name a few. Efficient and deterministic distribution of quantum entanglement is key to developing future quantum networks. A network of this kind has applications in networked sensing for global parameter estimation, secure communication and distributed quantum computing. To make the optical communication scheme fundamentally secure, photon entanglement between optical nodes is proposed. In general, an optical based communication system suffers from the degradation of the quantum optical information transmitted over long distances. The typical classical repeaters, however, add excessive noise to the already noise-sensitive quantum information making the traditional repeaters unusable. To remedy this limitation, quantum repeaters are needed.

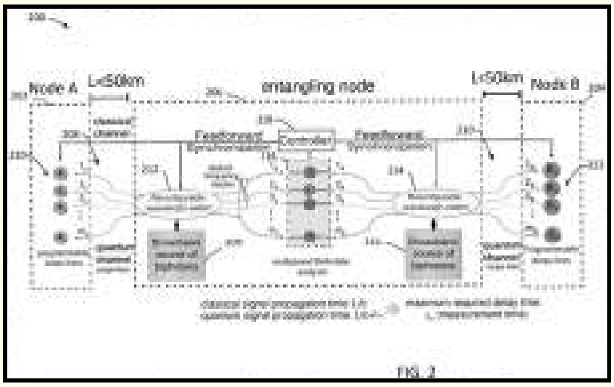


FIG. 2 is another schematic for a multi-node quantum entangled architecture, according to the present disclosure.

Quantum repeaters have been proposed that rely on quantum memories or multiparticle entanglement to extend the communication distancebeyond what is allowed by direct connection of optical Fibers. The probabilistic nature of typical quantum photon sources based on spontaneous parametric down conversion or four-wave mixing in nonlinear materials makes it difficult to create synchronous entanglement between neighbouring nodes. To synchronize multiple quantum sources that generate entangled pairs of photons at random times, quantum memories were proposed to store quantum information (entanglement) as created by sources while waiting for all nodes to receive entangled photons. The protocol can extend the quantum communication distance via the quantum repeater architecture where quantum memories act as a long-lived and low loss tuneable delay line to synchronize quantum events. Quantum memories in such architectures must store optical information, coherently, for at least L/c, where L is the distance between the two nodes in a network and c is speed of light. Moreover, quantum memoires should also possess near unity quantum efficiency and add low to no noise to the optical signal carrying quantum information. High bandwidth (on the order of 10 s GHz) and telecommunication wavelength operation of quantum memories are other requirements for practical applications of quantum networks. To date, there is no quantum memory or deterministic source of entangled photons that even partially satisfy requirements of a quantum repeater and thus building a quantum-enabled secure network cannot be envisioned in the near future based on existing protocols.

Therefore, while faithful encoding, transmission, and detection of quantum information carried by electromagnetic field promises fundamentally secure communication, long-distance quantum communication utilizing entanglement and memory-based repeater shave not been realized. Therefore, there is an unmet need for a novel method, protocol, and system that can be used for practical and near-term quantum communication to address the lossy nature of optical systems and particularly low susceptibility to noise in quantum entangled systems while utilizing existing technology.

An arrangement for a distributed quantum-based communication system using entangled photons is disclosed. The system includes a plurality of remote nodes (Nodes A, and Nodes B,) each without a quantum memory. The system further includes a central entangling node (Node C) disposed between each of Nodes A, and Nodes B,, wherein Nodes A, and B, are in both quantum communication and classical communication with Node C and in photon entanglement therebetween. The central node includes a controller. The central node further includes a first and second pair of broadband photon generators each adapted to generate photon pair sets at: i) random times within time-bins assigned by the controller, and ii) random frequency bins, wherein one photon of each entangled photon pair set is transmitted to an associated remote node (Node A,) and another photon of the photon pair set is transmitted to another remote node (Node B,) over the associated quantum channels.

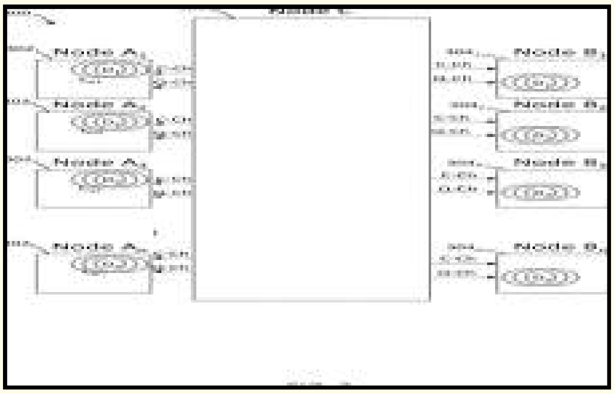


FIG. 3 is yet another embodiment of a physical layer, according to the present disclosure.

The central node further includes a multiplexed Bell-state analyser configured to receive another photon of the pair sets of photons and adapted to perform Bell-state measurements between the received photons. If the received photons arrive at about same time having about same frequency, then the received photons are marked as being entangled and thus identified as belonging to an associated time-bin. The controller is configured to communicate the associated time-bins to the associated remote nodes (Node A, and Node B,) over the associated classical channels, thereby entangling their associated photons. Each Node A, and the corresponding Node B, include a tuneable delay configured to delay arriving photons at each of said Node A, and B, by at least a delay time t constituting difference in arrival time between photons over the quantum channel and data over the classical channel. A time-bin is a predetermined duration of time periodically repeated by the controller to synchronize photon generation and detection and each quantum channel dedicated to a frequency bin probabilistically contains a photon during each time-bin. A method for distributed quantum-based communication system using entangled photons is also disclosed. The method includes providing a plurality of remote nodes (Nodes A, and Nodes B,) each without a quantum memory, providing a central entangling node (Node C) disposed between each of Nodes A, and Nodes B,, wherein Nodes A, and B, are in both quantum communication and classical communication with Node C and in photon entanglement therebetween, generating a plurality of broadband photon pairs by a broadband photon generator at: i) random times within time-bins assigned by the controller, and ii) random frequency bins; communicating one photon of each entangled photon pair set to an associated remote node (Node A,) and another entangled photon pair set to another remote node (Node B,) over the associated quantum channels, communicating another photon of the pair sets of photons to a multiplexed Bell-state analyser disposed in 40 Node C, and performing Bell-state measurements between the received photons. If the received photons arrive at about same time having about same frequency, then the received photons are marked as being entangled and thus identified as belonging to an associated time-bin. The method further includes communicating the associated time-bins to the associated remote nodes (Node A, and Node B,) over the associated classical channels, thereby entangling their associated photon, and delaying photons in each Node A, and the corresponding Node B, each by a corresponding tuneable delay by at least a delay time t, constituting difference in arrival time between photons over the quantum channel and data over the classical channel. A time-bin is a predetermined duration of time periodically repeated by the controller to synchronize photon generation and detection and each quantum channel dedicated to a frequency bin probabilistically containsa photon duringeach time-bin.

For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to the embodiments illustrated in the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of this disclosure is thereby intended. In the present disclosure, thereby intended. In the present disclosure,

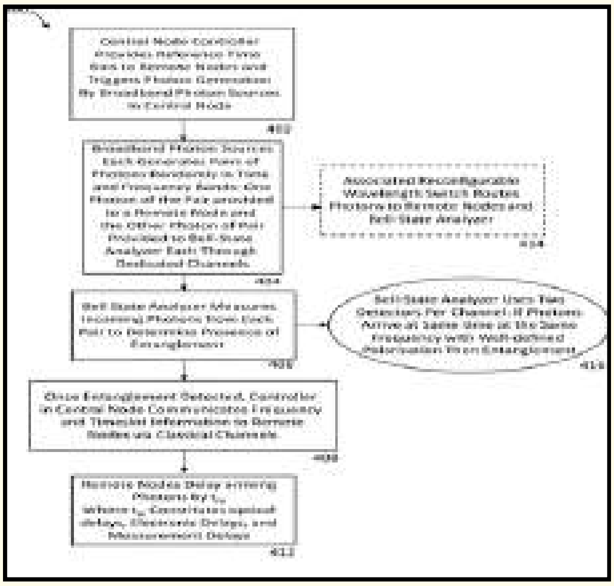


FIG. 4 is a block diagram of a method for distributed photon entangled quantum-based communication, according to the presentdisclosure.

For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to the embodiments illustrated in the drawings, and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of this disclosure is thereby intended. In the present disclosure, the term "about" can allow for a degree of variability in a value or range, for example, within 10%, within 5%, or within 1% of a stated value or of a stated limit of a range. In the present disclosure, the term "substantially" can allow for a degree of variability in a value or range, for example, within 90%, within 95%, or within 99% of a stated value or of a stated limit of a range.

A novel method and system are disclosed that can be used for communication to address the lossy nature of optical systems and particularly low susceptibility to noise in quantum entangled systems. Towards this end, a practical approach to securely connect at least two nodes, Node A and Node B, sharing entangled photons over long distances is presented. The entanglement shared between the two nodes can be used to securely communicate secret massages, teleport quantum information or map entanglement to qubits within quantum processors to performdistributed quantum computing.

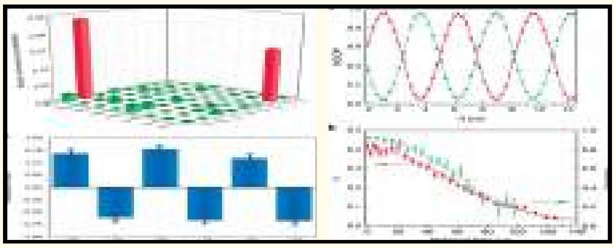


Fig. 5 Characterization of a single entangled atom–photon pair a, Normalized coincidence probabilities (NCOP) as a function of Raman pulse delay δt relative to the

write pulse, with the atomic state measured in the basis of $|\uparrow\rangle \pm |\downarrow\rangle$

1. Tuneable delay line at remote nodes: AGILTRON®: FIBER COIL VARIABLE TIME DELAY LINE and ULTRAFAST SYSTEMS: OPTICAL DELAY LINE;

2. Multiplexed Bell-state measurement device: IDQ: ID281 SUPERCONDUCTING NANOWIRE and IDQ: ID900 TIME CONTROLLER SERIES:

3. Broadband photon source: OZOPTICS: Polarization Entangled Photon Sources;

4. Quantum Channels: EITC: DARK FIBER NETWORKS:

5. Controller in Node C: NI: MULTIFUNCTION I/O and NI: DIGITAL I/O: and

6. Reconfigurable wavelength switch: IPG PHOTONICS®: FEMTOSHAPE-SR. Those having ordinary skill in the art will recognize that numerous modifications can be made to the specific implementations described above. The implementations should not be limited to the particular limitations described. Other implementations may be possible.

Conclusion

An arrangement for a distributed quantum-based communication system using entangled photons, comprising: a plurality of remote nodes (Nodes A, and Nodes B,) each without a quantum memory; and a central entangling node (Node C) disposed between each of Nodes A, and Nodes B,, wherein Nodes A, and B, are in both quantum communication and classical communication with Node C and in photon entanglement therebetween, the central node comprising: a controller; a first and second pair of broadband photon generators each adapted to generate photon pair sets at: i) random times within time-bins assigned by the controller, and ii) random frequency bins, wherein one photon of each entangled photon pair set is transmitted to an associated remote node (Node A,) and another photon of the photon pair set is transmitted to another remote node (Node B,) over the associated quantum channels; and a multiplexed Bell-state analyser configured to receive another photon of the pair sets of photons an adapted to perform Bell-state measurements between the received photons, wherein if the received photons arrive at about same time having about same frequency, then the received photons are marked as being entangled and thus identified as belonging to an associated time-bin, wherein the controller is configured to communicated the associated time bins to the associated remote nodes (Node A, and Node B,) over the associated classical channels. thereby entangling their associated photons.

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- Figures - available from:Nature Photonics

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The Photonics Behind LIGO: Using Light to Detect Gravitational Waves

Yash Bundile

yashbundile20@gmail.com

Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

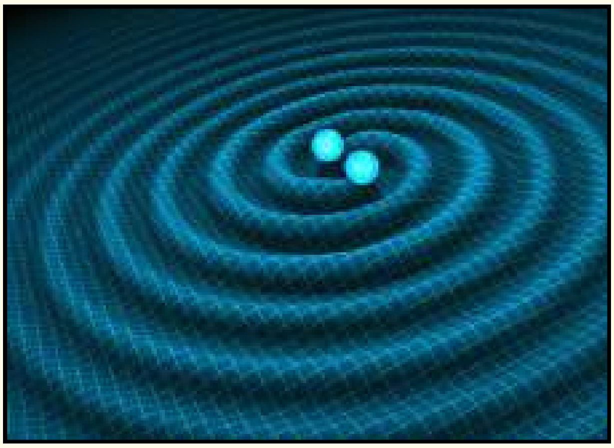
Introduction

When the first detection of gravitational waves was announced in 2015, it was celebrated as one of the most important scientific discoveries of the century. The detection confirmed a prediction that Albert Einstein had made almost a hundred years ago, and opened up a whole new way to study the Universe. Most of the discussion around this discovery has been about black holes, neutron stars, and Einstein's theory of General Relativity. However, there is another fascinating aspect of this achievement that often receives less attention which is **"PHOTONICS."**

LIGO, or Laser Interferometer Gravitational-Wave Observatory, is one of the most sensitive scientific instruments ever built. It can measure distance changes smaller than the diameter of a proton. Such exceptional precision is achieved by the advanced optical technologies. LIGO is a great example of how photonics can be used to solve some of the biggest scientific problems.

What Are Gravitational Waves?

Gravitational waves are nothing but the ripples in spacetime produced by accelerating massive binary objects. Events such as the collision of black holes or neutron stars generate these waves, which then travel across the Universe at the speed of light.

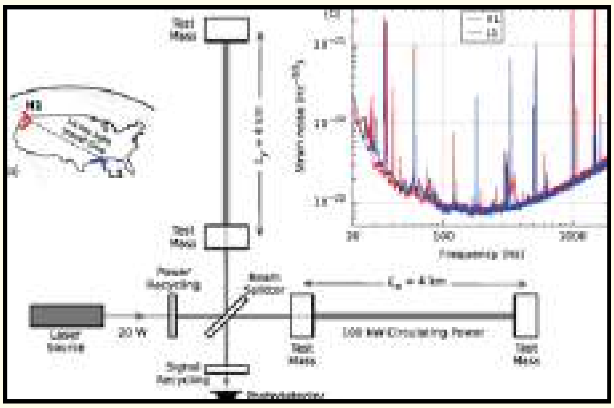


across the Universe at the speed of light.

When a gravitational wave passes through Earth, it slightly stretches space in one direction while compressing it in another. These changes are very small. This gravitational wave causes the length of LIGO's 4-kilometre-long arms to vary by thousands of times smaller than the diameter of a proton.

Such small changes might be impossible to detect. But the solution comes from one of the most precise measurement tools available which are laser light.

The Basic Idea Behind LIGO



Simplified diagram of an Advanced LIGO detector (not to scale).

LIGO instrument is based on a device called a **Michelson interferometer.** This instrument has two long arms, which are at right angles to each other. A powerful laser beam is directed towards a beam splitter, which divides the light into two separate beams.

Each beam travels down one arm of the interferometer, reflects from a mirror at the end, and returns to the beam splitter. The beams are then recombined and directed towards a photodetector.

If the two arms have exactly the same length, the returning light waves interfere destructively, so almost no light reaches the detector. But if a gravitational wave changes the arm lengths even slightly, the interference pattern changes. So, there's a little bit of light getting through to the detector, and that means there's a gravitational wave.

The entire detection process relies on measuring tiny changes in the properties of light, making photonics the backbone of the experiment.

Why Does LIGO Use Lasers?

Ordinary light sources such as bulbs or LEDs are not suitable for LIGO because they emit light which has different wavelengths and random phases. In case of LIGO, it requires a highly coherent and stable source of light.

For this reason, LIGO uses a Nd laser which operates at a wavelength of 1064 nm, which falls in the near-infrared region of the electromagnetic spectrum. This laser produces light with a very narrow range of wavelengths and excellent beam quality.

Apart from this one of the biggest challenges is to maintain the stability of the laser. Even tiny change in frequency or intensity could produce signals larger than the gravitational waves. Therefore, the feedback systems continuously monitor and stabilize the laser output. demonstrates one of the most precise applications of modern laser technology.

Fabry-Pérot Cavities and Mirrors

Although each arm of LIGO is physically 4 km long, the light travels a much greater distance. This is achieved by using optical resonators known as **Fabry-Pérot cavities.**
The mirrors at both ends of each arm are designed to reflect light several times before it passes the cavity. Instead of making a single trip down the arm, the laser beam bounces back and forth repeatedly.
As a result, the effective path length becomes hundreds of kilometers using this technique. This increases the interaction time between the light and any passing gravitational wave, which make it easy to detect the signal. The use of such optical cavities helps in enhancing the measurement sensitivity without a need of a very large instrument.

The mirrors used in LIGO are one of the most precise optical components ever manufactured. Each mirror is polished to get a smooth surface and it is coated with multiple thin dielectric layers to achieve a reflectivity of more than 99.999%.

Such high reflectivity ensures that the laser light remains inside the interferometer for as long as possible, increasing the sensitivity of the detector. Even tiny defects in the mirrors could affect the measurement.

Quantum Photonics and Squeezed Light

As LIGO became more sensitive, quantum physics came into the picture and it effects in light started to limit its performance. The random arrival of photons at the detector creates fluctuations known as shot noise, which can overshadow the weak gravitational-wave signals under the noise.

To reduce this noise, LIGO uses a quantum-optical technique called squeezed light. In squeezed states, quantum uncertainty is redistributed so that the quantity being measured can be determined more precisely. This innovative application of quantum photonics allows LIGO to detect event the fainter signals and observe events occurring farther away in the Universe. Which makes the instrument more precise and sensitive.

Conclusion

The discovery of gravitational waves is often described as a breakthrough in theoretical physics and astronomy. But photonics also played a very important role. From highly stable lasers and precision interferometry to advanced optical coatings and quantum light sources, nearly every part of LIGO depends on the photonics.

What makes LIGO particularly fascinating is that it transforms light into a tool capable of measuring distortions in spacetime itself. By combining concepts from optics, photonics, and quantum physics, scientists have engineered an instrument sensitive enough to detect some of the most important events in the Universe.

LIGO is a prime example of demonstrating the powerful role of photonics in expanding our understanding of the Universe.

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India Shines with Five Gold Medals at the International Physics Olympiad

India scripted history at the **56th International Physics Olympiad (IPhO) 2026** held in **Bucaramanga, Colombia**, with an unprecedented performance as **all five members of the Indian team won Gold medals**. The gold medallists are **Kanishk Jain**, **Riddhesh Bendale**, **Rishit Garg**, **Swarit Joshi**, and **Shresth Suraiya**—led India to a **joint World Rank #1**, alongside **China**, **Kazakhstan**, **Russia**, **South Korea**, and **Taiwan**, among **381 students representing 87 countries**. This remarkable achievement marks India's finest-ever performance at the prestigious global competition and reflects the exceptional talent, dedication, and scientific excellence of the country's young physicists.

The historic success is a proud milestone for the nation and a testament to the rigorous training, mentorship, and commitment of India's Olympiad programme. By achieving a clean sweep of five Gold medals, the Indian team has demonstrated the country's growing strength in science education and research, inspiring countless young minds to pursue physics and scientific innovation while further cementing India's reputation on the global stage.

Dr. D. D. Bhawalkar: The Pioneer of Laser Science in India

BHOUTIKI Physics Club
bhoutiki_physics@nowrosjeewadiacollege.edu.in
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

Dr. D. D. Bhawalkar

India's scientific progress in the field of optics and photonics owes much to the dedication and vision of a few pioneering scientists. Among them, **Dr. Dilip Devidas Bhawalkar** holds a special place. Widely regarded as one of the founding figures of laser science in India, Dr. Bhawalkar played a crucial role in establishing advanced laser research and accelerator technology in the India. Through his scientific achievements, institution-building efforts, and leadership, he helped India to emerge as a significant contributor in modern photonics and high-technology research.

Early Life and Education

Dr. D. D. Bhawalkar was born on **16 October 1940** in Sagar, Madhya Pradesh. From an early age, he showed exceptional academic ability and interest in science. He pursued his undergraduate and postgraduate studies in Physics at Sagar University (now Dr. Harisingh Gour University), where he graduated with distinction and secured top ranks in the university examinations.

Recognizing his potential, Dr. Bhawalkar continued his higher studies at the **University of Southampton, United Kingdom**, one of the leading institutions in electronics and laser research. There, he earned a Master's degree in Electronics followed by a Ph.D. in Laser Physics. At a time when lasers had only recently been invented and the field was still in its infancy, Dr. Bhawalkar chose to specialize in this emerging discipline, demonstrating remarkable foresight and scientific curiosity.

Returning to India

After completing his doctoral studies, Dr. Bhawalkar served as a lecturer at the University of Southampton. Despite promising opportunities abroad, he made a significant decision to return to India in 1967. He joined the **Bhabha Atomic Research Centre (BARC)** as a Scientific Officer, motivated by a desire to contribute to India's scientific and technological development.

During the 1960s and 1970s, laser science was still an emerging field worldwide. In India, research facilities and expertise in this area were limited. Dr. Bhawalkar took up the challenge of establishing indigenous capabilities in laser research. Through his efforts, BARC developed one of the country's most comprehensive laser research programmes, covering both fundamental studies and practical applications.

Contributions to Laser Science

Dr. Bhawalkar is widely recognized as one of the pioneers of laser research in India. His scientific work covers several areas, including high-power lasers, laser instrumentation, laser-produced plasmas, and photothermal spectroscopy.

One of his major contributions was the development of **high-power neodymium-glass laser systems**, capable of generating intense laser pulses. These systems proved essential for studies involving laser-produced plasmas, which have important applications in nuclear fusion research, materials science, and high-energy density physics.

His work significantly advanced India's capabilities in laser technology and laid the foundation for future developments in industrial, medical, and scientific applications of lasers. Dr. Bhawalkar also introduced new methods for measuring weak optical effects in gases using Gaussian laser beams, contributing to the advancement of photothermal spectroscopy.

Founding the Centre for Advanced Technology

Raja Ramanna Centre for Advanced Technology (RRCAT)

Dr. Bhawalkar's most significant contribution was his role as the **founder Director** of the **Centre for Advanced Technology (CAT)** in Indore, established by the Department of Atomic Energy in 1987. The institution, later renamed the **Raja Ramanna Centre for Advanced Technology (RRCAT)**, has become one of India's premier research centres in lasers, particle accelerators, synchrotron radiation, and advanced photonics.

Building a world-class scientific institution from the scratch is never an easy task. Dr. Bhawalkar not only oversaw the creation of state-of-the-art laboratories and research facilities but also developed a vibrant scientific culture that encouraged innovation, collaboration, and excellence.

Under his leadership, CAT made remarkable progress in developing advanced laser systems and accelerator technologies. The research centre eventually became a key participant in international scientific collaborations, including projects related to the **Large Hadron Collider (LHC)** and the **International Linear Collider (ILC).**

The success of RRCAT stands as a testimony to Dr. Bhawalkar's visionary leadership and institution-building abilities.

Awards and Recognition

Dr. D. D. Bhawalkar's pioneering contributions have earned him several prestigious honours and recognitions.

Some of the major awards received by him include:

- **Shanti Swarup Bhatnagar Prize for Science and Technology (1984)**, India's highest science award.
- **Padma Shri (2000)**, India's fourth-highest civilian honour.
- **Goyal Prize in Physics.**
- **H. K. Firodia Award.**
- **Homi Bhabha Award.**

He has also been elected as a Fellow of several prestigious scientific academies, including the **Indian Academy of Sciences (IASc)**, the **Indian National Science Academy (INSA)**, and the **National Academy of Sciences, India (NASI)**. Additionally, he became a Fellow of the **Optical Society of America**, reflecting international recognition of his contributions.

Legacy

Dr. D. D. Bhawalkar's life shows how visionary scientists can significantly influence a nation's scientific progress. Recognizing the immense potential of laser technology at an early stage, he played a pivotal role in establishing India as a leader in laser and photonics research. His pioneering contributions continue to inspire young researchers, and his legacy remains a guiding force in India's ongoing advancements in photonics, accelerator science, and emerging technologies.

"Scientific institutions are built not merely with bricks and machines, but with vision, perseverance, and people."

Dr. D. D. Bhawalkar exemplified all three.

Illuminating India's Skies: The Journey of Dr. K. Rajalakshmi Menon

BHOUTIKI Physics Club

bhoutiki_physics@nowrosjeewadiacollege.edu.in

Department of Zoology, MES's Nowrosjee Wadia College, Pune 411 001

Introduction

In the annals of Indian defence science, few names shine as brightly as Dr. K. Rajalakshmi Menon, Distinguished Scientist and Director General (Aeronautical Systems) at the Defence Research and Development Organisation (DRDO). Her career exemplifies the fusion of scientific brilliance, visionary leadership, and unwavering dedication to national self-reliance. From her early academic pursuits to her stewardship of India's most complex airborne surveillance systems, Dr. Menon has carved a legacy that continues to inspire generations of scientists and engineers.

Academic Foundations

Dr. Menon's journey began with a strong academic grounding. She earned her B.Sc. in Physics in 1986 from MES's Nowrosjee Wadia College, Pune and her M.Sc. in Computer Science from the University of Poona. Her pursuit of excellence led her to the Indian Institute of Science (IISc), Bengaluru, where she completed her Ph.D. in Target Recognition under the Department of Aerospace Engineering. This rigorous training equipped her with the analytical and technical skills that would later define her contributions to India's defence ecosystem.

Entry into DRDO

In 1988, Dr. Menon joined DRDO as Scientist B at the Centre for Airborne Systems (CABS), then known as ASWAC. From the outset, she was entrusted with responsibilities that demanded both technical acumen and strategic foresight. Her early work laid the foundation for her lifelong association with airborne surveillance and control systems a domain where India sought indigenous capability to reduce dependence on foreign technologies.

Pioneering the AEW&C Program

One of Dr. Menon's most celebrated achievements is her leadership in the Airborne Early Warning & Control (AEW&C) program. This ambitious project aimed to develop a sophisticated airborne surveillance system capable of detecting, tracking, and managing aerial threats. As Deputy Project Director and later Project Director, she oversaw the design, integration, and testing of the AEW&C system. She spearheaded the development of Command and Control (C2) functions, including Threat Evaluation, Weapon Assignment, and Battle Management implemented indigenously for the first time in India. Between 2013 and 2017, she led extensive flight test campaigns, ensuring the system's operational readiness. In February 2017, under her stewardship, AEW&C was formally inducted into the Indian Air Force (IAF), making India the fifth nation worldwide to achieve this milestone. This achievement not only strengthened India's defence preparedness but also showcased the nation's ability to innovate in highly complex technological domains.

Expanding Horizons: Radar and Imaging Systems

Following her success with AEW&C, Dr. Menon contributed significantly to radar and imaging technologies during her tenure at the Electronics & Radar Development Establishment (LRDE). She advanced the design of Synthetic Aperture Radars (SAR) for UAVs, fighters, satellites, and manned platforms. Her work introduced novel technologies for high-resolution imaging radars, enhancing India's surveillance and reconnaissance capabilities. These innovations reinforced India's position as a leader in radar technology within the global defence community.

Expertise and Leadership

Dr. Menon's expertise spans a wide spectrum of defence technologies:

- System Engineering of complex systems
- C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance)
- Battle Management and guidance systems
- Airborne Radars and electronic warfare sensors
- Image Intelligence and target recognition

Her leadership style blends technical rigor with strategic vision, enabling her teams to deliver results in projects of national importance.

Recognition and Legacy

Dr. Menon has been honoured as a Distinguished Scientist within DRDO and is a Fellow of the National Academy of Engineering (FNAE). Beyond accolades, her true legacy lies in the systems she has helped build and the scientists she has mentored.

As an alumna of Nowrosjee Wadia College (Batch of 1986), her journey from student to national leader stands as a beacon of inspiration. She embodies the values of perseverance, innovation, and service to the nation.

Conclusion

Dr. K. Rajalakshmi Menon's career is a testament to the transformative power of science when guided by vision and dedication. Her pioneering work in airborne surveillance and radar systems has fortified India's defence capabilities and elevated its standing on the global stage. As she continues to lead DRDO's aeronautical systems, her vision of self-reliance and innovation will undoubtedly shape the future of Indian defence technology.

Her story reminds us that the pursuit of knowledge, when coupled with national service, can illuminate not just the skies but the destiny of a nation.

Image Courtesy: DRDO and Respected Owner

https://www.youtube.com/watch?v=JM5RPTUwg0k

Raja Ramanna Centre for Advanced Technology (RRCAT)

Vidhi Baldota

vidhibaldota15@gmail.com

Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

The Raja Ramanna Centre for Advanced Technology (RRCAT) is a premier research facility located on a sprawling, picturesque 760-hectare campus on the outskirts of Indore, India. Founded as a specialized unit of the Department of Atomic Energy, the centre was established to expand upon the pioneering work of the Bhabha Atomic Research Centre in two highly sophisticated, non-nuclear domains: particle accelerators and laser technologies. The historical journey of the institute began on February 19, 1984, when the foundation stone was laid by Gyani Zail Singh, the President of India. By June 1986, the first delegation of scientists relocated from Mumbai to Indore, transforming the newly constructed campus into a bustling hub of active scientific research and community living, complete with state-of-the-art laboratories, housing, schools, and sports complexes

In the domain of particle accelerators, RRCAT has earned global recognition by indigenously designing and commissioning Indus-1 and Indus-2, India's premier synchrotron radiation sources. Indus-1 is a 450 MeV electron storage ring producing radiation from mid-infrared to soft X-rays, while Indus-2 is a massive 2.5 GeV ring designed specifically for high-intensity X-ray production. Spanning a circumference of 172.5 meters, Indus-2 stands as the largest and highest-energy particle accelerator in the country, serving as a vital national facility. Beyond these flagship machines, the accelerator division actively develops specialized proton accelerators, industrial electron beams for food preservation, free-electron lasers, and critical supporting technologies like superconducting radio-frequency cavities, high-power generators, and extreme cryogenics.

Equally prominent is the laser division, which focuses on the complete lifecycle of laser technology,from growing custom optical crystals to building diverse laser systems like high-power carbon dioxide, semiconductor, and excimer lasers. These systems are actively applied across heavy industries for precision cutting, drilling, and additive manufacturing, as well as in the medical sector for surgical tools and diagnostic imaging.

At the fundamental level, RRCAT scientists utilize these advanced lasers to conduct ground-breaking experiments in laser-plasma interactions, the cooling and trapping of individual atoms, nonlinear optics, and biological tissue spectroscopy, consistently pushing the boundaries of modern physics

Raja Ramanna Centre for Advanced Technology (RRCAT) Logo

Alongside these primary divisions, RRCAT places a strong emphasis on fostering academic growth and collaborative research through national programs and dedicated student training initiatives. The center acts as a crucial bridge between fundamental academic physics and large-scale industrial engineering, offering unique opportunities for young researchers and university students to work directly with state-of-the-art facilities like the Indus synchrotrons. By organizing national conventions, hosting technical workshops, and running competitive research fellowships, RRCAT actively grooms the next generation of experimental physicists and engineers. This continuous influx of young talent ensures that India remains self-reliant and highly competitive on the global stage of advanced beam physics and quantum technologies.

Escape Room

BHOUTIKI Physics Club
bhoutiki_physics@nowrosjeewadiacollege.edu.in
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

Probir Roy, Peter Littlewood & François Englert

Anurag Mehta
anuragvaishali15@gmail.com
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

Probir Roy

Probir Roy (4 October 1942 - 30 May 2026) was an Indian particle physicist and a former professor at Tata Institute of Fundamental Research.

Probir Roy graduated in physics with honours from Presidency College under Calcutta University in 1962 before moving to Cambridge University to obtain an MA (Cantab) from King's College, Cambridge in 1965. Subsequently, he joined Stanford University for his doctoral studies and secured a PhD, mentored by S. M. Berman, for his thesis in Kaon physics, in 1968. During this period, Roy worked at Stanford Linear Accelerator Center as a research assistant (1966–1968) and as a temporary research associate (1968). He remained in the US for three more years for his post-doctoral work at Cornell University where he worked at the laboratories of Kenneth G. Wilson, who would go on to receive the Nobel Prize in Physics in 1982, and Toichiro Kinoshita, an APS fellow, simultaneously serving the university as an instructor. Before returning to India in 1972, he had a one-year spell at CERN during 1971–72 as a visiting scientist.

During his college days at King's College, Cambridge, Roy received three honours from the institution; Powel Prize for the best student in natural sciences (1964), senior scholarship (1964) and honorary scholarship (1965). The Council of Scientific and Industrial Research awarded him the Shanti Swarup Bhatnagar Prize, one of the highest Indian science awards in 1987. The Indian Academy of Sciences elected him as a fellow in 1989 and he became a fellow of the Indian National Science Academy in 1992. Two years later, INSA selected him for the exchange fellowship between the academy of the Royal Society and the American Physical Society elected him as a fellow in 1995. He delivered the Meghnad Saha award oration of the Indian Association for the Cultivation of Science in 1997 and received the elected fellowship of the National Academy of Sciences, India in 2001.

Dr Roy has made significant contribution in theoretical high energy physics, especially the phenomenology of deep inelastic lepton-hadron-photon processes, ultralight neutrinos in supersymmetric grand unified theories and of Higgs meson signals and mass limits in supergravity theories. His sum rule on two photon processes is important.

Peter Littlewood

Peter Brent Littlewood (18 May 1955 – 15 June 2026) was a British physicist and Professor of Physics at the University of Chicago.

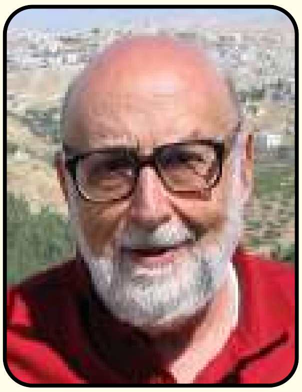
He gained a first-class degree in Natural Sciences at the University of Cambridge in 1976, and was then awarded a Kennedy Scholarship to work at the Massachusetts Institute of Technology for two years. He returned to Cambridge in 1977 to complete his PhD.

Beginning in 1980, he worked at Bell Labs, finishing his time there as head of the theoretical physics research after assuming the position in 1992. He continued to be a member of technical staff until 2001.

He then headed the Cavendish Laboratory as well as the Theory of Condensed Matter group. He was the 12th Director of Argonne National Laboratory.

Littlewood served as the founding chair of the board of trustees of the Faraday Institution from 2018 to 2024.

Littlewood held six patents, published more than 200 articles in scientific journals and gave more than 200 invited talks at international conferences, universities and laboratories.



François Englert

François Englert (6 November 1932 – 18 June 2026) was a Belgian theoretical physicist and 2013 Nobel Prize laureate.

Englert graduated as an electromechanical engineer in 1955 from the Free University of Brussels (ULB) where he received his PhD in physical sciences in 1959. From 1959 until 1961, he worked at Cornell University, first as a research associate of Robert Brout and then as assistant professor. He then returned to the ULB, where he became a university professor and was joined there by Brout who, in 1980, with Englert coheaded the theoretical physics group. In 1998 Englert became professor emeritus. In 1984 Englert was first appointed a Sackler Professor by Special Appointment in the School of Physics and Astronomy at Tel-Aviv University. Englert joined Chapman University's Institute for Quantum Studies in 2011, where he served as a distinguished visiting professor.

He was awarded the 2010 J. J. Sakurai Prize for Theoretical Particle Physics (with Gerry Guralnik, C. R. Hagen, Tom Kibble, Peter Higgs, and Robert Brout), the Wolf Prize in Physics in 2004 (with Brout and Higgs) and the High Energy and Particle Prize of the European Physical Society (with Brout and Higgs) in 1997 for the mechanism which unifies short and long range interactions by generating massive gauge vector bosons.

Englert made contributions in statistical physics, quantum field theory, cosmology, string theory, and supergravity. He was the recipient of the 2013 Prince of Asturias Award in technical and scientific research, together with Peter Higgs and CERN.

Englert was awarded the 2013 Nobel Prize in Physics, together with Peter Higgs for the discovery of the Brout–Englert–Higgs mechanism. This was a theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider.

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Physics Memes

Shubham Jadhav
sj307721@gmail.com
Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001

Photon has ZERO rest mass because it can never be at rest.

Optical Fibers transmit photons(light) using total internal reflection(TIR).

LASER light is very focused.

Photodetectors can convert optical signals into readable electrical signals.

A photon has a spin of 1.

Ultrafast Lasers Shrunk onto a Tiny Photonic Chip

Researchers achieved a major milestone by integrating **ultrafast femtosecond lasers onto a photonic chip**—something long considered a "holy grail" in integrated photonics. These chip-scale lasers could make medical imaging devices, atomic clocks, environmental sensors, and quantum technologies much smaller, cheaper, and more portable.

Why it matters: Future laboratory-grade laser systems may one day fit inside handheld devices.

PHYSIQUEST 2K26

BHOUTIKI Physics Club

bhoutiki_physics@nowrosjeewadiacollege.edu.in

Department of Physics, MES's Nowrosjee Wadia College, Pune 411 001





PHYSIQUEST-2K26 was the annual departmental fest organized by the **Department of Physics** under **NOWROS-2026**, bringing together students to celebrate physics through creativity, innovation, and healthy competition. This edition marked a significant milestone in the fest's history as, for the first time ever, **PHYSIQUEST was conducted over two full days**, allowing participants to engage in a wider range of activities and making the celebration bigger than ever before. The two-day format created a vibrant atmosphere across the department, with enthusiastic participation from students of various colleges and a perfect blend of learning, teamwork, and fun.

The fest featured a variety of exciting events, including the **Escape Room, Talent Show, Poster & Exhibition Competition**, the release of the latest edition of B**HOUTIKI Pradnya – Astronomy & Astrophysics**, and the **Valedictory Ceremony**. Among all the events, the **Escape Room** emerged as the biggest attraction, receiving an overwhelming response from participants. Students enthusiastically solved puzzles and challenges, making it one of the most talked-about highlights of the fest. The **Poster & Exhibition Competition** showcased scientific creativity and innovation, while the **Talent Show** provided a platform for students to display their artistic abilities beyond academics. With excellent participation, enthusiastic volunteers, and a memorable two-day experience, **PHYSIQUEST-2K26** successfully upheld the department's tradition of promoting scientific curiosity, collaboration, and excellence.

PHYSIQUEST - 2K26 Winners

Poster Competition

Medal	UG	PG
Gold	Arham Pinjari	Zoya Shaikh
Silver	Chanchal Agarwal Kiran Choudhary	Komal Pareek
Bronze		Lekha Kadekar Manisha Chauhan

Escape Room

Rank	Team Members
1	Prerna Rao Shreyashree Demanna Manisha Chauhan Bushra Sayyad

Exhibition Competition

Medal	UG	PG	Diploma
Gold	Yashvardhan Shukla Kiran Choudhary	Divya Bhagat	Aditi Shirke Aadesh Babar
Silver	Rucha Joshi Soham Waghmare	Faraaz Shaikh	Dnyandeep Gotamwad Shivam Bikkad Atharva Padale
Bronze	Shrushti Dandi Mandira Koirala		

Talent Show

Medal	Winners
Gold	Yash Menon & Rucha Joshi and Mandira Koirala
Silver	Isha Vala & Diganta Hazarika
Bronze	Lekha Kadekar & Shrushti Dandi

Academic Toppers

Year	Toppers
SY Sem-3	Rucha Joshi
TY Sem-5	Vidhi Baldota

Year	Toppers
M.Sc.1 Sem-1	Diganta Hazarika
M.Sc.2 Sem-3	Namrata Jangam

Special Prizes

Recipients	Acheivements
Vidhi Baldota	3rd Rank at Avishkar State Level Competition 2nd Rank at Anveshan Zonal Level Competiton
Anurag Mehta	3rd Rank at Avishkar State Level Competition 2nd Rank at Anveshan Zonal Level Competiton
Sanskruti Uttekar	Represented College at Jallosh-2025 Skit - South-West Zone at Karnataka State Drama - 2nd Prize at Rajyanatya
Atharva Randive	Represented Maharashtra Directorate in All India Gaurd of Honor
Avdhoot Sable	Represented Maharashtra Directorate in PM Rally
Vedant Shinde	Represented Maharashtra Directorate in All India Yachting Regatta Camp 2026

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