

Physics Academy of North East (PANE) Newsletter



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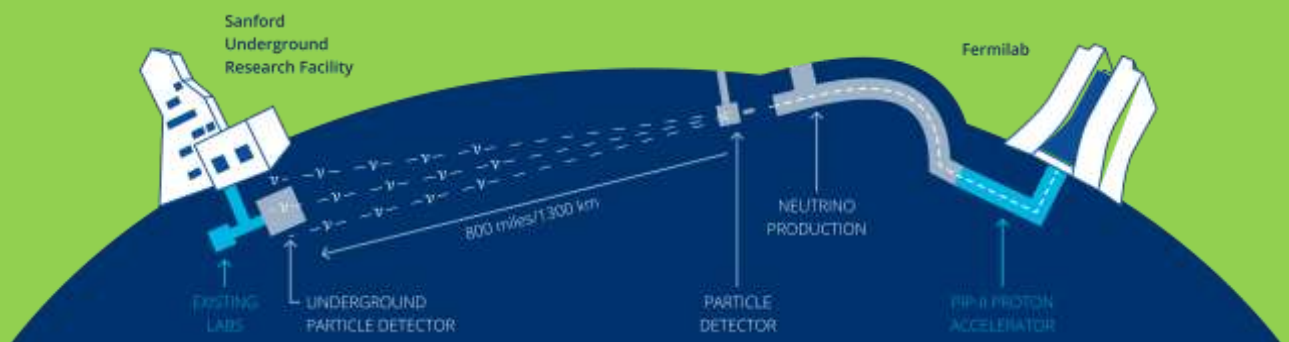


Figure Credit: <https://lbnf-dune.fnal.gov/how-it-works/introduction/>



Figure Credit: Coordinated Movements Prevent Jamming in an Emperor Penguin Huddle, PLoS One. 2011; 6(6): e20260

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EDITORIAL

This issue of PANE Newsletter is coming after a long wait of three years and is being inaugurated at the Silver Jubilee of PANE and this is, thus, a distinct one. As per a decision taken in the PANE General Body Meeting a few months ago in November 2022 (which I, unfortunately, could not attend), the editorship of PANE Newsletter was entrusted upon me. In this short span of time, I tried to do this job in the most sincere manner. However, as was also observed by the previous editor (Dr. Subhaditya Bhattacharya) that “PANE Newsletter is suffering from lack of manpower,” collection of articles and editing them becomes an issue (I hope the newsletter will have a full editorial board soon and we can also obtain an ISSN).

Nevertheless, I must admit that I was lucky to receive a large number of articles from different fields. I take this opportunity to thank all the authors. While, as the editor I do not give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made, the selected articles are certainly very informative and interesting. At this juncture, I apologise to those whose articles could not be accepted and wish them all the best in their future endeavour.

The articles published in this issue can be categorised into four categories. These are purely research articles, pedagogical articles, popular (informative) articles and articles related to PANE events and activities.

This issue is, certainly, a very unique one for another reason. It is stretched over a wide extent of space and time. The selected articles are from across the world, from institutes of Northeast India to Fermilab, USA. Again, as far as the time scale is concerned, the authors of this issue include one of the pioneers of theoretical physics research in this part of the country, Prof. Krori, who is in his mid-nineties (a direct student of Prof. S. N. Bose and Prof. M. N. Saha), as well as, very young researchers working with state-of-the-art facilities.

Samrat Dey

ABOUT PHYSICS

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At the outset I confess that this small write-up is intended for the first learners of physics at the higher secondary level. At that stage a number of science subjects, namely, physics, chemistry, botany, zoology and anthropology confront them. Initially, most of them think alike about all these subjects but they disillusioned after some time when they discover that physics is absolutely different from other science subjects. But how is it different? To get the answer, let me narrate some stories hereunder.

Isaac Newton was the father of physics. The study of physics starts with laws known as Newton's laws of motion. He also gave the law of gravitation and the particle theory of light. But what was he? He was a professor of mathematics at Cambridge University since the age of 26. He also developed calculus – differential and integral. It is a very important tool of mathematics.

James Clerk Maxwell developed the kinetic theory of gases and made contributions to thermodynamics. His greatest work is the theory of electro-magnetism which is at the root of telecommunication, etc., etc. And what was he? He was a mathematician from Cambridge. The nineteenth century physics meant just mechanics (also called Newtonian mechanics) plus Maxwell's theory of electromagnetism. Other developments in physics came later.

Abdus Salam was an M.A. in mathematics from Lahore University (in undivided India). He was in the Arts stream. He went from to study higher mathematics at Cambridge University. Physics was a part of the course there. He came to like physics and switched over to higher physics. He passed out in first class in Physics. He did his Ph.D. at Cambridge University and later received Nobel Prize in physics.

P. A. M. Dirac had an engineering degree. But he was interested in physics. So he took a course in advanced mathematics and did research in physics. Later he received Nobel Prize in physics.

Rogen Penrose, professor of mathematics in Oxford University, won Nobel Prize in physics in 2020.

Prof. S. N. Bose and Prof. M. N. Saha, both men of mathematics, taught us physics in the M.Sc. class at Calcutta University. Prof. Bose was the father of quantum statistics (1923) and Prof. Saha developed the theory of ionisation in stars (1920).

And so on.

From the above stories, one finds that mathematicians happen to be great physicists. What does this mean?

Physics is based on mathematics and, further, on mathematics-like reasoning, to be specific, on geometry-like reasoning. In geometry, one will have to use preceding theorems to grasp the succeeding theorems. Similarly, one can understand ideas making use of preceding physical laws/ ideas.

I conclude this small write-up with best wishes for the young first learners of physics!

IMPORTANCE OF RESEARCH IN BASIC SCIENCES FOR SUSTAINABLE DEVELOPMENT

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We study history to know how the present situation came about, in order to understand it better. History is the story of how a possibility became the reality. The history of politics tells us how time rejected countless possibilities and allowed just one to become a firm reality. Chance has therefore played an important role in the history of politics. In the history of science, on the other hand, time has gradually caused truth to prevail. Necessity has been more influential than chance in the history of science. This is precisely where the growth of an exact science differs from that of politics.

We study science to understand nature and to question why our world is the way it is. Studying the development of science may help to improve our understanding of nature and its new philosophical traditions. Professor Abdus Salam, celebrated Pakistani Nobel laureate in Physics once remarked “Scientific thoughts and its creation is the common and shared heritage of mankind”, which simply reflects the universal nature of scientific knowledge but with no permanent dominance in science by a single nation. Though the overall conceptual part of scientific research is global in nature, its practical implementation needs a region specific science policy framework. Here lies the famous quotation “Think globally and act locally”.

In the history of science, it is practically impossible to find a piece of technology that cannot be traced back to the work of scientists motivated purely by a desire to understand the world. It emphasizes the need for the study of basic sciences for meaningful participation in the cutting-edge research activities at the global platform. New audacity of the Imagination and creative thinking are two crucial ingredients for great advances in science. It also embodies the scientific culture which characterizes originality, independence of thought and dissent, and therefore a challenge to established cultural values. The safeguards for independence are free inquiry, free thought, free speech, tolerance and the willingness to arbitrate disputes on the basis of evidence. Individual researchers and research institutions have the responsibility for developing a scientific culture in modern society.

James Clerk Maxwell, the famous English scientist had developed in 1865 the mathematical theory of electricity and magnetism, popularly known as ‘electromagnetic theory’ which is the first unified theory, without any concern about the practical utility of the work. In fact, the knowledge was never targeted to a specific application. In course of time, it finally leads to many useful applications such as radio, television, mobile phones, internet etc. The work of Albert Einstein on his theory of relativity was based on his curiosity to understand the

dynamics of space and time, and this leads to many applications including mass-energy relation which helps in understanding the energy release in atomic bomb based on nuclear fission and hydrogen bomb based on nuclear fusion. The birth of quantum mechanics which explains the subatomic world, has the same story. Modern innovative technology is the direct product of quantum physics. In fact, at present the Quantum optics and quantum computer are seeds for new emerging technologies of tomorrow.

In the present global scenario of science policy, it is generally considered that the developing world and poorer nations are expected to focus only on applied problems that can prove direct results to the nation's economy. For developing countries and poorer nations to work on pure and basic science, is often viewed from outside as indulgent and wasteful. Therefore, many government-funded projects are largely based on applied sciences to boost economy. This is more in developing countries as research in basic science is not encouraged because of its less economic value.

However, the bias on basic sciences in the name of less economic value is not a very good concept. In applied sciences the goal is merely to use research as a tool, but research in basic sciences is to become a valuable and self-sustaining pursuit in its own right. Research in basic sciences will generate a completely new knowledge which can lead the heart of modern economy. It may not give us an instant result but it will give us a deeper understanding about the world that changes all the time. In fact, new focus on basic research will produce a lasting change in science of the region. It is a paradigm shift in scientific revolution. The formulation of General Theory of Gravity by Albert Einstein in 1915 as a new theory of gravity, is itself an example.

Research in basic sciences also offers an opportunity for scientists of poorer nations to stand on their own feet without the need for international supports to assess the scientific questions of their own nation and to contribute to the universal quest for knowledge. It encourages the freedom of scientific pursuits. The researchers themselves are encouraged to set the agenda for innovation and discovery to boost its research quality and innovation, in the process to strengthen the scientific foundation of the nation. It therefore not only inspires young minds to study science but also provides a study stream of qualified people for business and industry where the high-tech, intellectual experience allows them to make a positive impact. The balance between encouraging basic research and demanding technological output must be guarded closely.

The United Nations Agenda 2030 which will last for 15 years, was officially enforced from 1 June, 2016. It emphasizes the support of the governments in Science, Technology, Engineering and Mathematics (STEM) education and research in basic sciences. The scientific community urged Agenda 2030 to consider a minimum GDP percentage devoted by every nation to STEM education and basic research. The UNESCO G8 forum on Education, Research and Innovation, emphasizes the interconnection between Higher Education, Scientific Research and Innovation. Such new partnership which is generally christened as 'Triangle of Knowledge' is the key to sustainable development of a nation. In short, sustainable development of a nation can only be achieved through proper implementation of

triangle of knowledge – a synergy between education, research and innovation. Higher education is described as the driving force of human progress and there is a need for an innovative society in order to prepare its people to embrace global changes in the era of 21st century. With the emergence of globalization, there has been a growing demand of quality higher education and research all over the world. Globalization also carries a philosophical paradox. In fact, globalization has brought both opportunities and threats to the existing higher educational institutes and traditional universities as they require some immediate measures such as international collaboration and cooperation among the institutes, networking and partnerships, faculty exchange program and academic mobility at all levels, effective implementation of ICT in higher education and research sectors to meet the global competencies.

In the context on the discussion of the problems and prospects on higher education in North East part of India, the following relevant observations are highlighted. In this region there is a huge regional disparity resulted from the increasing technological gap and digital divides with the rest of the country. Such disparities are major obstacles for imparting quality education and basic research in this region. This region requires at least some dedicated research institutes of national importance to tackle local specific research and development (R&D). For meaningful participation in the cutting-edge research activities at the global level from the soil of this region, the establishment of dedicated research institutes in basic science and technology in this region is very much necessary. This will definitely fill up the gap in the process of globalization of higher education and basic research in this region.

There should be a very strong appeal from the people of this region to the policy makers of the Government of India, for the establishment of institutes of national importance such as IISER in this North East region in the near future for effective participation at the national and international level. The region qualifies for such initiatives for nurturing her rich human resources and these new initiatives will definitely neutralize geographical barrier and other regional disadvantages. This will bring true meaning of the theme of National Science Day 2023 “Global Science for Global wellbeing.”

PHYSICS DIALOGUE USING CHATGPT

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ChatGPT is an artificial-intelligence chatbot developed by OpenAI (a research company from San Francisco, California, USA) and launched in November 2022. It is built on top of OpenAI's GPT-3 family of Large Language Models (LLM) and has been fine-tuned (an approach to transfer learning) using both supervised and reinforcement learning techniques. ChatGPT is fine-tuned from GPT-3.5, a language model trained to produce text. ChatGPT was optimized for dialogue by using Reinforcement Learning with Human Feedback (RLHF) – a method that uses human demonstrations and preference comparisons to guide the model toward desired behavior. These models use cutting-edge deep-learning techniques and were trained on vast amounts of data to fit 175 billion parameters to 400 billion words from the internet written by humans, including conversations, so the responses it provides may sound human-like. It is important to keep in mind that this is a direct result of the system's design (i.e. maximizing the similarity between outputs and the dataset the models were trained on) and that such outputs may be inaccurate, untruthful, and otherwise misleading at times. ChatGPT is being made available as a research preview so the team behind can learn about its strengths and weaknesses.

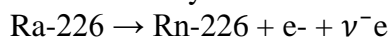
ChatGPT was launched as a prototype on November 30, 2022, and quickly garnered attention for its detailed responses and articulate answers across many domains of knowledge. However its uneven factual accuracy has been identified as a significant drawback. Also it has limited knowledge of the world and events after 2021 and may also occasionally produce harmful instructions or biased content. Following the release of ChatGPT, OpenAI's valuation was estimated at US\$ 29 billion in 2023. OpenAI's investors include Microsoft, Reid Hoffman's charitable foundation, and Khosla Ventures.

Now-a-days, ChatGPT's capabilities can be explored from the site <https://chat.openai.com>. I thought of testing its capabilities using a few questions from Physics and a few logical questions as well. I am trying to share the result of this exploration here; the results are of a mixed variety as we will shortly see.

Question No 1. What happens when Radium undergoes beta decay?

ChatGPT Answer: When radium undergoes beta decay, one of its neutrons is converted into a proton, and an electron (beta particle) and an antineutrino are emitted. The resulting nucleus has one more proton and one less neutron than the original nucleus, and therefore a different atomic number.

The beta decay of radium can be represented by the following equation:



In this equation, Ra-226 represents the radium nucleus, Rn-226 represents the radon nucleus formed after beta decay, e^- represents the emitted electron (beta particle), and $\bar{\nu}_e$ represents the emitted antineutrino.

The half-life of radium-226, the most common isotope of radium, is approximately 1,600 years. During beta decay, the emission of beta particles can produce ionizing radiation that can be harmful to living organisms. Therefore, radium and its decay products should be handled with caution and proper protective measures should be taken to prevent exposure.

Comment: This is the correct answer.

Question No 2: Iron floats in Mercury. Is Iron heavier than Mercury?

ChatGPT Answer: No, iron is not heavier than mercury. In fact, iron is much denser than mercury and has a much greater mass per unit volume. The reason that iron can float on mercury is that mercury is an exceptionally dense liquid, and it is one of the few elements that is denser than iron.

Mercury has a density of approximately 13.5 grams per cubic centimeter, while the density of iron is around 7.9 grams per cubic centimeter. This means that if you have a piece of iron and a volume of mercury of the same size, the iron will have a much greater mass than the mercury.

The reason that iron can float on mercury is due to the phenomenon of buoyancy. When an object is placed in a liquid, the liquid exerts an upward force on the object called the buoyant force. If the buoyant force is greater than the weight of the object, the object will float. In the case of iron and mercury, the buoyant force exerted by the mercury on the iron is greater than the weight of the iron, so the iron floats on the surface of the mercury.

Comment: This is a wrong and confused answer (although the conversational style is perfect).

Question No 3: A is heavier than B and C is heavier than A. Is B heavier than C?

ChatGPT Answer: Not necessarily.

We cannot conclude whether B is heavier than C based solely on the given information.

For example, it is possible that A is slightly heavier than B, and C is significantly heavier than both A and B. In this case, B would be the lightest of the three and therefore not heavier than C.

On the other hand, it is also possible that A is much heavier than B, and C is only slightly heavier than A. In this case, B would be the lightest of the three and therefore definitely lighter than C.

Therefore, we cannot make a definite conclusion about the relative weights of B and C based only on the given information.

Comment: This is a confused answer to a clear-cut question.

Question No 4: Tell me if it is true: Galileo was unhappy with Newton's theory of gravitation.

ChatGPT Answer: It is not true that Galileo was unhappy with Newton's theory of gravitation, as Galileo died more than 30 years before Newton published his theory of gravitation in 1687.

In fact, Galileo's work on the laws of motion and his observations of the heavens were important predecessors to Newton's work. Newton himself acknowledged his debt to Galileo, and the two scientists are often mentioned together in discussions of the history of physics.

It is possible, however, that some later scientists or commentators may have expressed dissatisfaction with Newton's theory of gravitation, perhaps in comparison to later developments in physics or in the context of philosophical debates about the nature of scientific knowledge. However, this would not have been a view held by Galileo, who did not have the opportunity to comment on Newton's work.

Comment: This is the correct answer.

Question No 5: Without an elastic medium, can mechanical simple harmonic motion be possible?

ChatGPT Answer: No, mechanical simple harmonic motion cannot be possible without an elastic medium.

Mechanical simple harmonic motion is a type of periodic motion that occurs when a system is displaced from its equilibrium position and then experiences a restoring force that is proportional to the displacement, and acts towards the equilibrium position.

In order for such motion to occur, the system must have a restoring force that is proportional to the displacement, and this restoring force is typically provided by the elasticity of the medium. For example, a mass attached to a spring can exhibit simple harmonic motion because the spring exerts a restoring force that is proportional to the displacement of the mass from its equilibrium position.

Without an elastic medium to provide the restoring force, mechanical simple harmonic motion is not possible. While there may be other types of periodic motion that can occur in the absence of an elastic medium, they would not be considered simple harmonic motion according to the usual definition.

Comment: This is the correct answer.

Question: Martha is Alec's mother. Jacob is Alec's maternal uncle. How are Martha and Jacob related?

ChatGPT Answer: Martha is Alec's mother, and Jacob is Alec's maternal uncle. This means that Jacob is Martha's brother. So, Martha and Jacob are siblings, specifically they are brother and sister.

Comment: This is the correct answer.

Question: A and B are C's parents. Is it possible that C witnessed A and B's marriage?

ChatGPT Answer: No, it is not possible for C to have witnessed A and B's marriage if A and B are C's parents. In order for A and B to be C's parents, they must have become a couple and had a child together. This means that they would have been married or became common-law partners prior to or after the birth of C. If C witnessed their marriage, it would imply that C was born before A and B got married, which is not possible if A and B are C's biological parents. Therefore, if A and B are C's parents, it is not possible for C to have witnessed their marriage.

Comment: This is the correct answer.

Thus we have seen that although people are talking a lot about the almost human-like conversational style of ChatGPT, it seems to be overestimated at times and still has miles to go as regards the truth of its answers. We have tried to check only in limited domains of human knowledge (Physics and Logic). But similar shortcomings must be available in other domains as well. It is not surprising considering the stupendous proportion of the job. It will definitely get better in the days to come.

FIREFLY LIGHT AT HIGH TEMPERATURE

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“What should we make of fireflies, their quick flare
 of promise and disappointment, their throwaway style?”

Frank Ormsby, "Fireflies" from *Goat's Milk*

Summer evening light shows of fireflies are a delight for humans. These light shows are performed by flying male fireflies. They flash patterns of light to females. The females, which lie on grass or bushes, flash in response to these signals. When a male recognises the ‘consenting’ signal from a particular female, he continues to flash and moves closer. Eventually, through a series of flashes, they find each other and mate. Different species of firefly send out different mating signals.

Along with poets, the light of the firefly has been attracting the attention of scientists for over a century. This light is the outcome of a very efficient *chemiluminescent reaction*, and that is where most of the interest lies. In this reaction, light is induced inside the firefly abdomen where the enzyme luciferase catalyses the photo-emitter luciferin in presence of oxygen, ATP and Mg^{2+} ion, generating the excited-state oxyluciferin, which subsequently decays to the ground state.

There are two categories of fireflies, based of their time of appearance after sunset. One type of firefly begins flashing within half an hour, and the other one appears after half an hour from the sunset. The first type is classified Early Starting or Dusk Active, and the second type Late Starting or Dark Active. In an experiment, 23 of the 32 specimens of dark-active species studied were found to emit green light (wavelength peak $\lambda_{\max} \leq 558$ nm), while 21 of the 23 specimens of dark-active species emitted yellow light ($\lambda_{\max} \geq 560$ nm) [1].

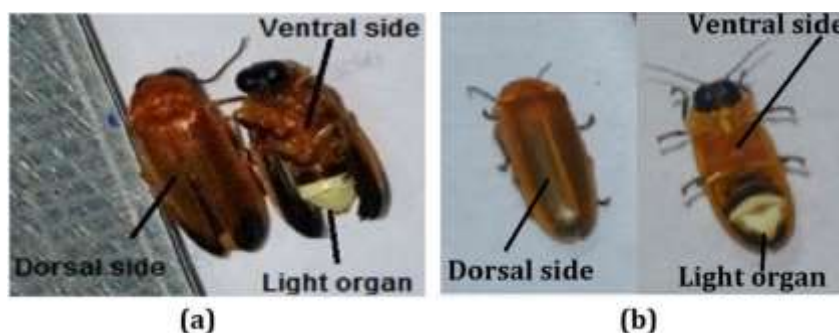


Figure 1: The two firefly-species investigated. (a) The widely available *Luciola praeusta*. (b) The rare *Sclerotia substriata*.

The firefly species easily found in the north east India is *Luciola praeusta* (Figure 1 (a)). It appears just after sunset, and therefore should come under the Early Starting category. A rare species was found in the campus of Gauhati University a couple of years ago; it was identified as *Sclerotia substriata* by the well known expert on Asian fireflies Dr. Lezley Ballantyne of Australia (Figure 1(b)). It begins flashing later than 30 minutes after sunset, hence should qualify as a Late Starting species.

For finding the reason behind this, steady-state and pulsed emissions from male specimens of *Luciola praeusta* and *Sclerotia substriata* were investigated at temperatures considerably higher than the ones at which they normally flash. When the temperature was raised to 42 °C for *L. praeusta*, the wavelength peak shifted towards the side of the higher wavelength [2]. For the species *S. substriata*, the redshift occurred at 34 °C [3]. These are shown in Figure 2. It was known that different species of fireflies emitted in slightly different spectral regions due to slight differences in their enzyme structures [4]. Therefore, the redshift of the peak pointed towards a change in the structure of the enzyme luciferase catalysing the light-producing reaction.

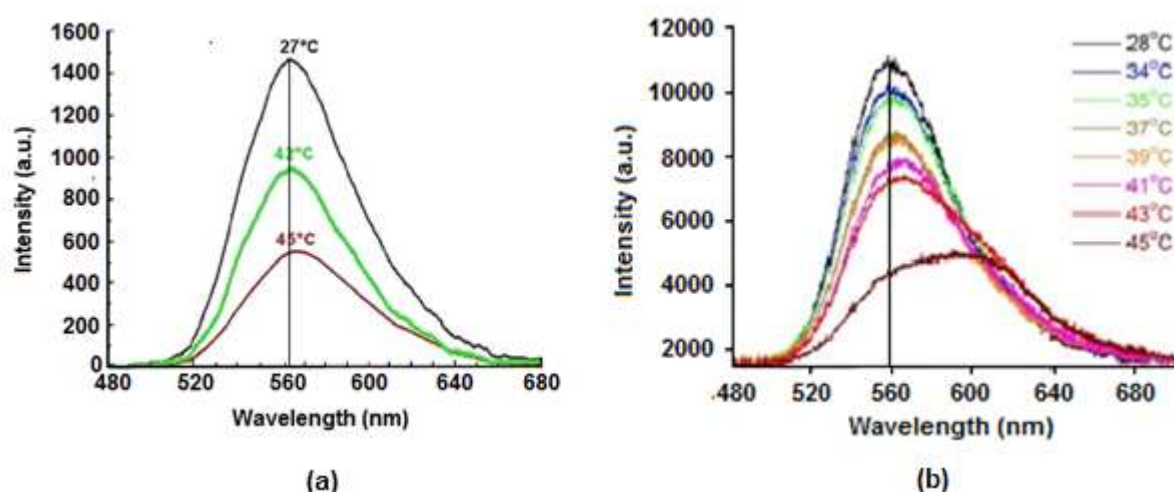


Figure 2: Emission spectra of male fireflies at normal and considerably higher flashing temperatures. (a) For the species *Luciola praeusta*, the peak got shifted just after 42 °C. A vertical line is drawn to make the shifting clear. (b) For *S. substriata*, the peak-shifting occurred just after 34 °C. The drawn vertical line, again, makes the shifting clear.

Widths of the flashes emitted by both the species of firefly decreased with increase in temperature, became minima at 42 °C for *L. praeusta* and 34 °C for *S. substriata*, and increased considerably thereafter with large fluctuation for slight increase in temperature (Figure 3). These happenings were irreversible: if the temperature was lowered to the usual flashing ones, the normal values or characteristics of the spectra and pulses were not observed. So 42 °C for *L. praeusta* and 34 °C for *S. substriata* were the temperatures at which thermal denaturation of the enzyme catalyst luciferases of the two fireflies probably took place.

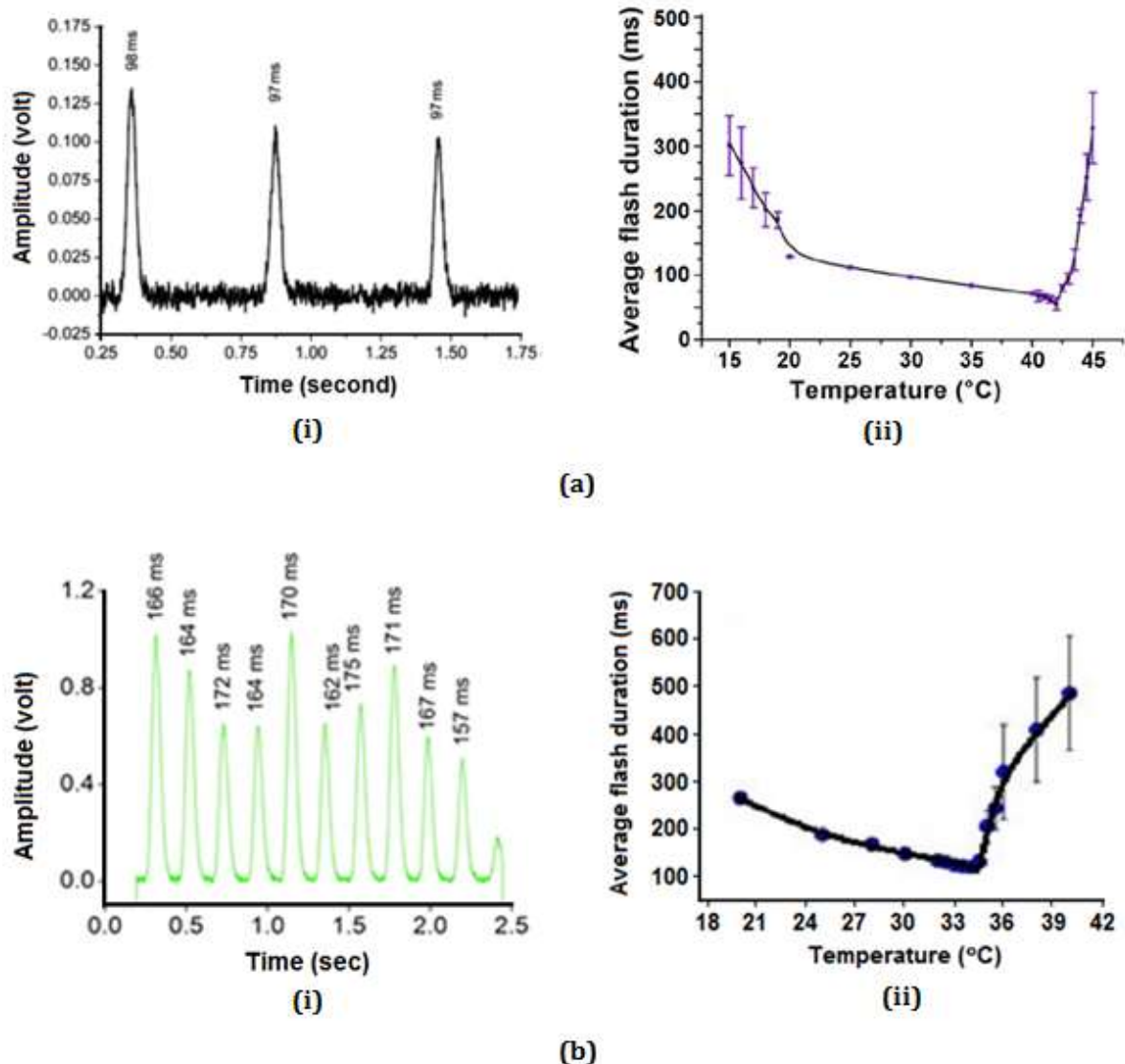


Figure 3: **(a)** Flashes and flash duration-change with temperature of a male *L. praeusta* firefly. (i) Typical flashes at 30 °C; (ii) Pulse width at different temperatures. **(b)** Flashes and temperature variation of the flash duration of a male *S. substriata* firefly. (i) Typical flashes at 28 °C; (ii) Pulse width at different temperatures.

These hot-effects most probably indicated their temperature tolerance, and could be the reason for the species *L. praeusta* being early-starting or dusk-active, and for the species *S. substriata* late-starting or dark-active in the summer. In this part of the globe, the maximum temperature in the hottest days in the summer usually becomes 36 - 37 °C, cooling down to about 34 - 35 °C at the time of sunset. This is sufficiently below the optimum temperature of 42 °C for *L. praeusta*, and so these fireflies could easily come out just after sunset. But the same cannot be said of the other species *S. substriata*. The temperature at the time of sunset in a hot summer day is around its peak-shifting temperature, which makes it impossible for these fireflies to come out at that time. This insect has to wait for some time for the

temperature to cool down to about 30 °C. This is the probable region why it chooses to dwell in big trees in the bank of a big pond. Shades from branches and leaves of the trees help to keep the temperature within the temperature optimum of this firefly. In the hot days, these fireflies are observed to start flashing 2 – 3 hours, sometimes more than 3 hours, after sunset, sitting on leaves or branches of trees.

However, it is noticed that in the few cloudy or rainy summer days when the temperature at the time of sunset becomes 30 °C or less, one or two specimens of *S. substriata* come out just about half an hour after sunset. It, thus, becomes almost dusk-active, and there is little difference in the appearance times between this species and the dusk-active *L. praeusta* inhabiting the same locality. Generally, though, the majority of *L. praeusta* fireflies come out in advance of half an hour after sunset on *any* day, while the majority of the *S. substriata* fireflies comes out roughly 45 min after sunset in *those* days. Hence, the conclusion that the peak-wavelength, though generally determining a firefly's active time, does not determine its time of coming out — the temperature indicating denaturation of the luciferase is the chief deciding factor.

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DESICCATION CRACK AND ABSORBABILITY

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1. Introduction:

The absorbability of the soil is governed by the granular and particle size of the soil[1][2]. The study of soil desiccation can provide information on the mechanism of drying. Many variables such as temperature, moisture, pressure, weathering, etc., regulate the desiccation of the soil. Nevertheless, water evaporation and water diffusion are the principal causes.

There are three stages of water evaporation from soil[3]. These are-

i) Stage I: Initial-evaporation: At this point, there is a very high potential for evaporation rate, which is determined by atmospheric conditions rather than soil hydraulic conductivity. When there is a water level, the first stages of evaporation can be observed.

ii) Stage II: Intermediate-evaporation: Evaporation rates are lower than in stage I. At this point, the soil's hydraulic conductivity begins to govern the evaporation rate.

iii) Stage III: Final-evaporation: This stage has very low evaporation rates, and the hydraulic conductivity of the soil governs the evaporation rate. For long periods of time, it lasts.

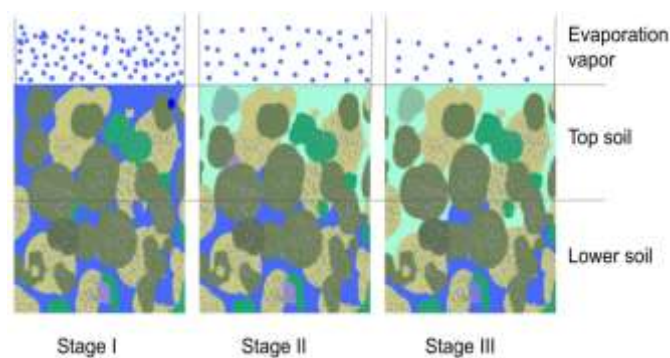


Figure 1: Water evaporation from the soil.

1.1. Cracks and Their Analysis:

There are two types of cracks found on the surface: (i) cracks caused by desiccation-desiccation cracks, and (ii) cracks caused by shrinkage of sediment-syneresis cracks. Desiccation crack patterns are classified as: (i) three-armed star, (ii) starburst, (iii) spiral crack, (iv) en passant cracks, (v) en echelon array (vi) bricklayer, (vii) hexagonal tiling, (viii) wavy crack, and (ix) wing crack [4].

The fractal dimension theory and the euler number can be used to analyse the desiccation crack image over time, with theory-

(a) Euler number: Growth in nature is never discrete and discontinuous. The Euler number is a mathematical formula for understanding and studying growth. It is defined as:

$$\chi = N - H$$

where, N is the number of isolated cracks and H is the number of solid blocks bounded by cracks. As the single ped is a whole sample when there is no crack, N = 0 and H = 1 [5].

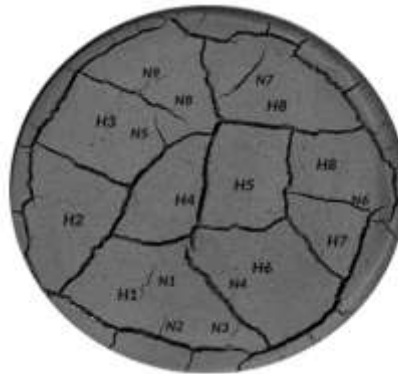


Figure 2: Identification of Isolated crack (N) and Ped(H) from the sample.

(b) Fractal dimension: The Fractal dimension is used here to study the structural shape of the desiccation cracks in relation to temperature and desiccation, and how the coordinates of the soil change. It is defined as -

$$D = - \left[\frac{\log N}{\log \epsilon} \right]$$

Here, D is the fractal dimension, N the number of self-similar shapes (unit length), and ϵ the magnification factor (reduction of unit length).

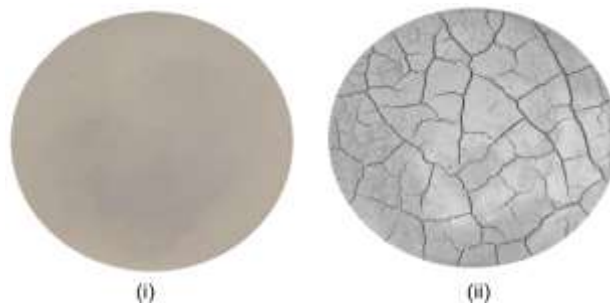


Figure 3: (i) Initials' Image = 0 hour, Fractal dimension (D) = 0 (ii) Final Image = 90 hours, Fractal dimension(D)=1.421

2. Experimental Methods:

The experiment was carried out in a hot air oven at a temperature of $50 \pm 2^\circ\text{C}$. Crack Images were collected every two hours, and analyzed using the fractal and the euler theory. For the

fractal dimension study we utilized the Fiji(ImageJ) software, and the results were observed by plotting. Experiments were conducted as shown in Figure 4.



Figure 4: The experiment's experimental procedures.

2.1. Image Analysis in Fiji/ImageJ:

Fiji (ImageJ) was used for image analysis. Calculating the fractal dimension requires converting the image into a binary image. The results were plotted in Origin and studied for further details as shown in Figure 5.

3. Results:

In this study, we found that the same soil, for a given thickness, generates the same fractal dimension above the soil's maximum absorbability, even when we added more water to the soil; however, when we changed the thickness of the soil sample above the soil's maximum absorbability, we obtained different crack patterns depending on the thickness of the sample[5]. Figure 5 shows the calculated fractal dimensions of the water percentages, based on crack images over time. As a result of the plotted graph analysis (Figure 5), the result can be concluded that the added water does not affect the fractal dimension because they showed the same result for different water contents. Here, A soil with a maximum absorbency of 41% was used for the experiment. In other words, even if we vary the amount of water added to the soil, the desiccation cracks did not change when the added water to the soil crossed 41%.

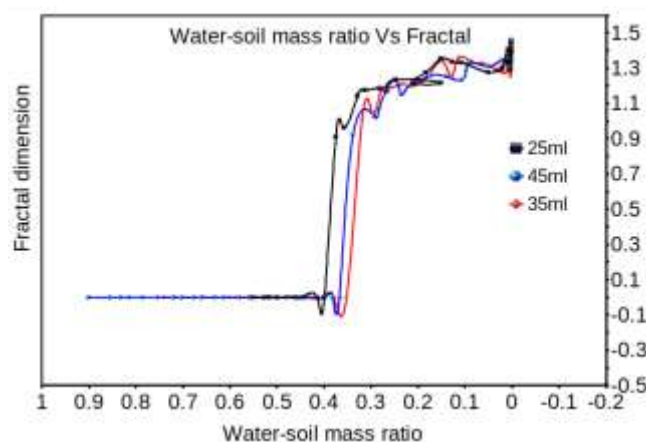


Figure 5: Fractal dimensions of the same thickness but different water percentages. In 50 gm of soil, we added 25ml, 35 ml, and 45 ml; The soil has 41% maximum absorbability.

Our result for the thickness effect above the soils' maximal absorbability is shown in Figure 6. Figures (i), (ii), and (iii) of Figure 6 show different crack patterns, each of which has a different thickness, but a similar percentage of water. In each soil sample, the amount of water is above the maximum amount that can be absorbed. The following crack images have different fractal values such as 1.331, 1.428, and 1.522, respectively. Even above the soil's maximal absorbability, the results indicate differences in fractal dimensions.

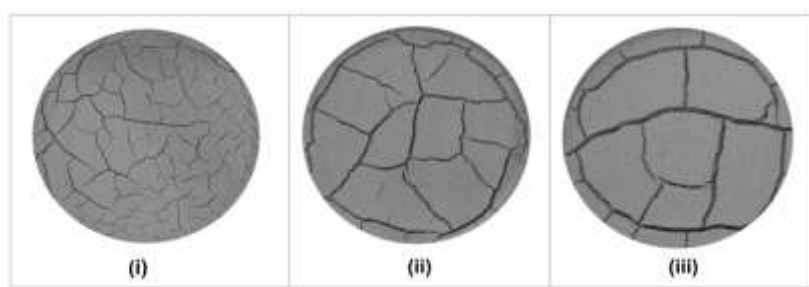


Figure 6: If D is the fractal dimension, then crack images with varying thickness of 100 gm, 200 gm, and 300 gm have $D = 1.331$, 1.428 , and 1.522 , respectively.

4. Conclusion:

According to the study, when we reach a material's maximum absorbability, the added water percentage does not regulate the desiccation cracks of the soil; rather, the soil's thickness does, even over the material's maximum absorbability. This investigation taught us how the desiccation phenomenon affects the material and causes a desiccation-related cracks.

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- [1] University of Hawai'i, "Soil Water." College of Tropical Agriculture and Human Resources' (CTAHR), copyright © -2023 University of Hawai'i 2007. [Online]. Available: <https://www.ctahr.hawaii.edu/MauiSoil/default.aspx>
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- [4] L. Goehring, Ed., *Desiccation cracks and their patterns: formation and modelling in science and nature*. Weinheim: Wiley-VCH, 2015.
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DISCOVERY CLASS PARTICLE ACCELERATOR FOR NORTH EAST: A PROPOSAL BY CUPAC - NE COLLABORATION

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1. Objectives:

- **Create a World Class Particle Accelerator Facility:** A 5 MV Van De Graff accelerator with an ECR ion source at the high voltage terminal and a PIMS (Positive Ion Mass Spectrometry Facility) with a Microgan ECR Source. Both are first of its kind in the nation. The facility will have commensurate experimental facilities: a supersonic windowless gas jet system coupled to a recoil separator, 5 kW pulsed neutron source and ion beam processing facility with extreme fluence. Detailed technical description of the project can be found in reference [1].
- **Human Resource Development:** Train young accelerator physicists/technologists from MSc/PhD students of the NE region & Improve quality of College Education by training graduate students in latest scientific techniques.
- **Cutting Edge Scientific Research:** Nano Science and Engineering using Swift Heavy Ions at extreme fluence, Archaeological investigation of modern and ancient samples with unprecedented accuracy and precision, Earth and Geological Science related to Climate Research, Nuclear Astrophysics investigations in AGB stars and Accelerator Driven Boron Neutron Capture Therapy. The facility will make national research effort globally competitive in each of these domains.
- **Improve Economical Situation:** Improve scientific understanding of perennial flood problems by rivers of the region.
- **Understanding Heritage and History:** Through latest scientific technique PIMS.

2. Brief Outline of the Project:

- Particle Accelerators are tools of discovery. Due to sophisticated technologies involved in accelerator construction and operation, accelerator technology is considered as a key tool in nation building and training younger generation in these high-tech fields is extremely important. Realizing this, India also has undertaken accelerator development programme in a big way. Several accelerator facilities were created in Delhi, Mumbai, Kolkata, Chennai etc. And our country is also investing heavily in several international accelerator projects in Switzerland, Germany and France etc. Indian students and researchers are sponsored by Government to work in these accelerator facilities and learn latest technologies and perform innovative research in various fields.
- It is a general perception of the North East people that although having plenty of human and natural resources, the region is lacking behind the nation in all measurable scientific indexes. It is due to lack of modern scientific infrastructures and experimental facilities for students and researchers. This is preventing our children from realizing their God given potential and competes with the rest of the nation and the world. If we succeed in constructing this state of the art accelerator facility, it will go a long way elevating the research quality not only of the North Eastern researchers but of the nation as a whole as well.

3. Key Accomplishments of the CUPAC-NE Collaboration:

- **Formation of the Collaboration and endorsements:** Cotton University Particle Accelerator Centre and North East Collaboration (CUPAC-NE Collaboration) was formed with Universities/Institutes/Colleges from North Eastern States as member Institutes to address this issue. We also started strong collaboration with scientists from: BARC, IUAC, VECC, INO etc. in furtherance of our goals. Major R & D program has started in domains closely related to the proposed accelerator facility. Geographical map of our collaboration is shown in Figure 1. A total of 23 institutes/Universities of the region endorsed the project (refer table 1).
- **Outreach:** As the vision of CUPAC-NE collaboration is to provide hands on training to the students and researchers of North East region so that they can attain their true potential, the collaboration has taken several concrete steps in this direction. Six seminars were organised so far in Nagaland (FAC, Mukokchang), Manipur (RIST, Imphal) and Assam (AU Silchar; ASTU, Guwahati; CPP, Guwahati). We also held several technical discussions with colleagues from Arunachal (NERIST and RGU), Meghalaya (NEHU, Lady Irwin College), Nagaland (FAC), Bodoland University etc. Two advanced courses in Neutrino Science and Nuclear Astrophysics were organized in which national experts delivered lectures to the students from all NE States.
- **Research proposals from North Eastern community:** As a result of our outreach, we were able to receive 14 Letters of Intent to perform research with the proposed facility as well as develop beam lines. These LOIs were from diverse fields: Archaeology

(Cotton University), PIMS (NERIST, Itanagar), Swift Heavy Ion In materials using Nuclear Techniques (Rangiya College, Manipur University, NERIST, Tezpur University, CPP), Accelerator Driven Boron Neutron Cancer treatment research (Neutron production Target: Bodoland University & FAC, Nagaland, High power proton beam line: NEHU, Neutron moderator: BBCI & GU, Phantom: GMCH & GU, Boron Drug: Cotton University, Nuclear Forensic: Forensic Science Laboratory, Assam, Quaternary Geology to study Brahmaputra River Flood Problem using PIMS: GU).




Figure 1: *CUPAC-NE (Cotton University Particle Accelerator Centre and North East) Collaboration map.

Table 1: List of Letters of Endorsement from VC/Head of Institutes of Collaborating Universities/Institutes of NE region:

Serial No	Name of state Name of University/Institution of NE region
1	Rajib Gandhi University, Itanagar, Arunachal Pradesh
2	NERIST, Nirjuli, Arunachal Pradesh
3	Assam University, Silchar & Diphu Campus
4	B. Borooah Cancer Institute, Guwahati
5	Bhattadev University, Bajali
6	Bodoland University, Kokrajhar
7	Cotton University, Guwahati
8	Dibrugarh University, Dibrugarh
9	Jorhat Central College, Jorhat
10	Sibsagar College, Sibsaagar
11	B.H. College, Barpeta
12	Dimoria College, Kamrup (Metro)
13	Dispur College, Guwahati
14	Mayang College, Morigoan
15	Pandu College, Guwahati
16	Pragjyotish College, Guwahati

17	Pub Kamrup College, Kamrup
18	Manipur University, Imphal
19	North Eastern Hill University, Shillong
20	Mizoram University, Aizwal
21	Fazl Ali College, Mokokchung, Nagaland
22	Nagaland University, Kohima
23	Tripura University, Agartala, Tripura

- Regional and National Workshop:
- To get all our collaborators together, a regional conference was organised on 29th July 2020 which was attended by faculties from Arunachal, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura.



COTTON UNIVERSITY
Research & Development
 Panbazar, Guwahati- 781001, Assam, India
 Website: www.cottonuniversity.ac.in

Discussion on the **"Proposal for installation and operation of
 accelerator technology in NE Region"**
 (Collaboration of NE Universities for CUPAC)
 29th July, Wednesday 11.30 am -1.00 pm
 Link: <https://meet.google.com/qys-ixqb-bdf?hs=122&authuser=0>

Agenda:

1. Meeting will be chaired by Prof N Nimai Singh, Manipur University
2. 11.30-11.35: Welcome address by Prof. G. C. Wary
3. 11.35-11.45: "Vision for the "State of the Art Accelerator Facility for NE Region": Prof. Kalyanee Boruah, GU
4. 11.45-12.05: "Science and technology of the proposed accelerator facility" : Dr. J. J. Das
5. 12.05-12.45: Discussion
6. 12.45-12.55: Comments from Chairperson
7. 12.55-13.00: Vote of thanks: Dr. M Patgiri

Prof. G. C. Wary
 Deem, R&D
 Cotton University

- We also organized a one-day National Workshop on 24th January 2021. In this workshop, leading experts of the nation publicly reviewed our project and LOIs. Important suggestions were also made to improve upon, which are incorporated in the proposal. Official transcripts of both the workshops are included along with this submission.



COTTON UNIVERSITY
Research & Development
 Jalandhar, Guwahati-781004, Assam, India
 Website: www.cottonuniversity.ac.in

Ref: CU/R&D/Conf/WS/Meet@LI Date: 24/01/2021

Pre-submission Review of CUPAC-NE Accelerator Facility
 One Day National Workshop
 On 24 January, Sunday 2021
 Mode of Workshop: Video Conferencing
 Link: <https://meet.google.com/tzi-idts-rnw>

Anchor person: Dr. Mritula Bara, Cotton University

9:15-11:50 Inaugural Session: Chair: Prof. N. Nizam Singh, Manipal University

Introduction of Dignitaries: Dr. M. Patgiri, Cotton University (15)
 Welcome address: Prof. B. C. Goswami, Hon'ble Vice-Chancellor, Cotton University (10)
 Inaugural address by Guest of Honor: Dr. Himanta Biswa Sarma, Hon'ble Minister of Education, Finance, Health etc., Assam (15) (Invited)
 Address by Chief Guest: Shri Sarbananda Sonowal, Hon'ble Chief Minister of Assam (15) (Invited)
 Keynote address: **Sustenance of Accelerators in Indian Universities:** Prof. A. C. Pandey, Director, IUAC, New Delhi (15)
 Address by Distinguished Guest: Shri B. Kalyan Chakravarthy, IAS, Principal Secretary, Education, Assam (10)
Concept for an Accelerator Facility for North East India: Prof. K. Boruah, Gauhati University (10)
The CUPAC-NE Facility - the Road Ahead: Prof. B. M. Jyawa, NEHU, Meghalaya (10)
CUPAC-NE Collaboration - Vision and Mission: Prof. G. C. Wary, Dean R&D, Cotton University (10)
Glimpse of the proposed CUPAC-NE Accelerator Project: Prof. J. Das, Cotton University (10)
 Summary of Expert Review of proposed CUPAC-NE facility and LOIs:
Accelerator Technology & Fundamental and Applied Sciences: Dr. S. Randeria, BARC (10)
Letter of Intent: Dr. B. K. Nayak, BARC (15)
 Session Chair's Comment (5)

12:00-1:05 Technical Session-I: Chair: Dr. Th. Gomti Devi, NERIST, Arunachal Pradesh

Theme: Current status of accelerator Science in India and possible role for CUPAC-NE Facility
Pelletron Accelerator & AMS in India: Dr. Sundeeep Chopra, IUAC (15)
Fundamental Science with accelerators in India: Dr. V. M. Datar, TIFR/BARC (15)
Status of Neutron Science in India: Dr. P. C. Rout, BARC (15)
Experimental Nuclear Astrophysics programs with low energy accelerators: Dr. M. Saita Sarkar, SINP (15)
 Session Chair's Comment (5)

— Break —

2:00-3:15 Technical Session-II: Chair: Dr. Anshad Hussain, Tripura University

Theme: Research Interest of NE Users Community: LOI received (6x11)

- **Construction of Beam Lines:** Prof. B. M. Jyawa (NEHU), Dr. Th. Gomti Devi (NERIST), Dr. M. Bhargava/Dr. K. Kalita (Rangiya College/GU)
- **Neutron Source & AD-BRCT:** Dr. B. Brahma (Bodoland University), Dr. A. Borah (Nagaland), Dr. A. Kanaki (BCCI), Prof. K. Baruah (GU)
- **PIMS:** Dr. M. Hazarika (CUJ), Prof. P. Phukan (GU)
- **SINP:** Prof. B. M. Singh (MUS), Dr. M. Kalati (CPRI-IPR, Guwahati), Dr. D. Mahanta (TIU)

Session Chair's comment (5)

3:11-4:16 Concluding Session: Chair: Prof. P. K. Kalita, RGU, Arunachal Pradesh
 Open Discussion: Comments from CUPAC-NE Collaborators (25)
 Observer: Mr. Abul Basumatary, Director, MDA/NER, New Delhi (10)
 Summary: Dr. B. K. Nayak, BARC (25)
 Session Chair's comment (5)

Vote of Thanks: Dr. A. Barthakur, Cotton University (10)

• Realizing our Educational Goal:

- To materialize our vision of developing next generation accelerator physicists from the NE region, we are taking following steps in implementation plan of our project: 100⁺ PhD projects were identified in the accelerator construction, development of beam lines & research facilities and operation. These will be undertaken by JRFs registered in NE Universities. We plan to construct the beam lines (8) for delivering beam to distinct research experiments e.g. Swift Heavy Ion in Materials (3), Neutron Source (2), Life Sciences (1), Nuclear Physics & Astrophysics (2), one each in the name of a NE State. The collaborators from that State will take full responsibility for its design, construction and eventual

operation and maintenance. We have received tremendous positive response in this regard.

- **Selected examples of technical progress made by our students:**

- Conceptual design of the accelerator is shown in Figure2 which could provide beams of species satisfying ion optical qualities for investigation of key reactions in AGB stars at Gamow peak for nuclear astrophysics. The accelerator will also provide 5 kW pulsed neutron source. To our knowledge this configuration is first of its kind in the world.
- Differentially pumped windowless gas target: Gas flow dynamics calculation and 3D CAD model is completed. Fabrication process has started at IUAC. Nation's first such cell. See Figure3 [2].
- Neutron Beam shaping assembly for AD-BNCT: Please refer to Figure 4. First order Physics design and 3D-CAD model is completed. Detailed validation with GEANT 4 is progress [3]
- Brahmaputra laboratory for training BSc/MSc students of Cotton and NE universities. [Ref.: Mridul Deka, private communication 2022]. The lab will have all modern infrastructures to assemble, test and offline commissioning of different R&D projects of the collaboration. Refer Figure 5 for details.
- Training of students in advanced ion optical codes for simulation of beam lines and spectrometers have also been started. Please refer to orientation program booklet.

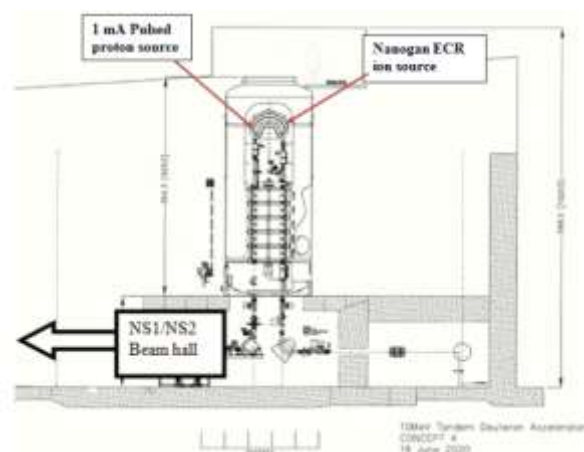


Figure 2: A unique configuration for the proposed for CUPAC-NE accelerator with 2 ion sources at the terminal of a tandem accelerator by replacing the bending magnet. One will be a pulsed proton source and the other a Nanogan ECR source. This modification will enable to

get high quality pulsed neutron beam. This will allow retaining optics of the ECR injector to obtain Gamow peak energy and also obtain high intensity pulsed proton beam.

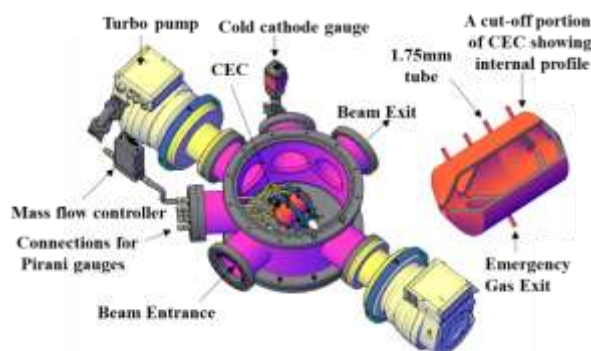


Figure 3: 3D Auto CAD design of the Vacuum chamber, pumping system of differentially pumped windowless gas cell. The cell is shown on right top. The cell is being readied for fabrication at IUAC, New Delhi.

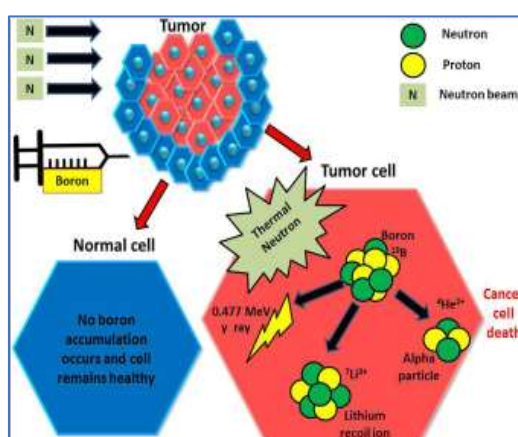


Figure 4a: Destruction of Cancer cell in BNCT (Boron Neutron Capture Therapy).

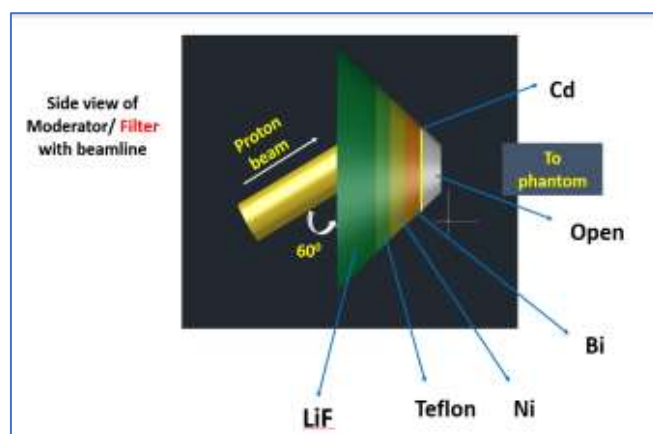


Figure 4b: The 3D AUTOCAD model of the neutron BSA developed at Cotton University.

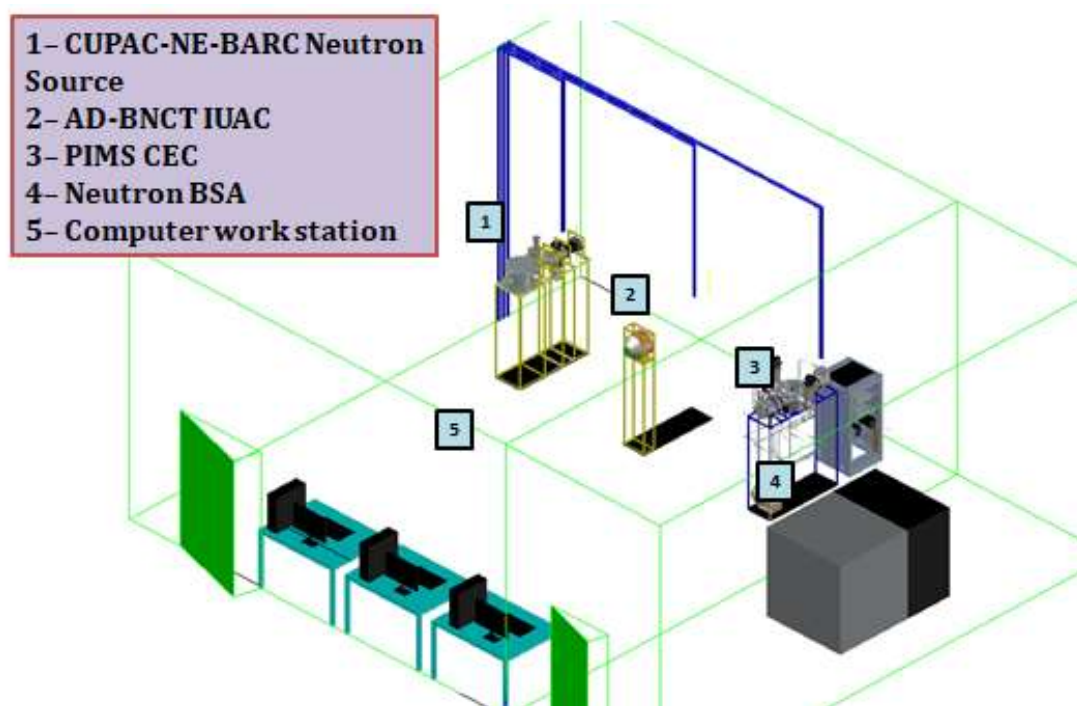


Figure 5: Layout of Brahmaputra lab designed for installation and testing of hardware to be developed under CUPAC-NE R&D projects. This laboratory will be used by BSc/MSc students of Cotton and NE universities to assemble test and offline commission of the hardware at Cotton.

4. Working Out Implementation Strategy and Budget:

- Our plan is to simultaneously start technical construction of **PIMS (Phase-1)**, civil construction of the Pelletron facility and design of beam lines (Phase-II) and design of research equipment (Phase-III) immediately. PIMS will be ready for operation in 3 years while full Pelletron facility, beam line and research facilities will be completed in about 8 years. Commissioning and operation schedule of the full accelerator facility is 2028 and 2030 respectively. Estimated cost for operation and construction is **Rs. 301 Cr.**
- **Five year blocks:** We are dividing the project into three 5-yr blocks:
 - In First 5 year, PIMS will be operational, civil construction and infrastructure development of Pelletron accelerator and prototyping of beam lines and research facilities will be completed. Testing of the prototypes will be done at national laboratories.

- In the 2nd 5 year block, installation and commissioning of Pelletron Accelerator, beam lines and research facilities will be completed. In the 3rd block, starting 2031, the whole facility will be made operational.
- In each of these 5 year blocks, 40 JRFs will be appointed who will carry out the primary scientific design. To supervise them, 10 senior Technologists/Fellows will be appointed with 5 year tenure. The targeted candidates for filling these positions are recently retired accelerator technologists from National Accelerator Laboratories in variety of fields like: Mechanical Engineering, Electrical & control system, Power supply and magnet engineering, accelerator operation and maintenance, beam line and research instrumentations. These professionals will be matched to their last salary drawn and free accommodation will be provided.
- This scheme will be continued for 3 cycles after which we will start appointing our outstanding graduates (9 in total) as permanent scientists of the Centre who will carry forward our mission and vision. Cotton University administration is favourable to this proposal.

5. Establishing Management Structure of the Facility:

Administrative setup: Since the CUPAC-NE Collaboration facility is planned to be set up as primarily a collaborative project of NE region under the direct leadership of Cotton University, Guwahati in its premise, so Cotton University Authorities (AC/EC/Court) shall govern the Centre as per rules & regulations of the University till further notification in this context. Pending setting up of the administrative structure and the rules & regulations of the Centre, a Core Committee (of 15 members) for implementation of the project under the direct supervision of Vice-Chancellor shall be constituted.

The constitution of the Core Committee:

1. Chairperson: Vice Chancellor, CU
2. Member Secretary: Prof G C Wary
3. PI of the project (Member Secretary in absentia): Prof Jiban Jyoti Das, Physics, CU

Members (Proposed):

4. Dean, R&D, CU
5. Registrar, CU
6. Academic Registrar, CU
7. HoD Physics Department, CU
8. Dr Abhijit Barthakur, Physics, CU (Co-PI)
9. Prof Debojit Sarma, Physics, CU (Co-PI)
10. Prof. Mahadev Patgiri, Physics, CU (Co-PI)

Members from participating Universities of North East:

- 11-15. Five External Members
- 16-17. Two Co-opted members of Interdisciplinary Departments of CU

Endorsements to the Project: We are pleased to announce that **23** letters of endorsement were received from VCs/Heads of **NE Universities/Institutions**. These are enclosed as part of this submission

Land: Cotton University has provided **5** acres of land in Bongara Campus for the facility

Collaborating Institutes: Participants of **CUPAC - North East Collaboration** are included in the proposal.

6. Conclusion:

- **“Timely Completion of PIMS Construction”:** As it stands today, we would be first of its kind facility in India and only second in the World. Successful completion of the project will boost status of North Eastern region immediately to one of the top R&D hub of the Nation and also the World.
- The Development of Infrastructure & Civil construction and prototyping are time consuming and prone to delays. So this is planned in the 1st 5 yr block. We would request you kindly to allocate **Rs. 57 Cr during FY21-FY26 so that we can maintain the proposed time schedule.**

7. References:

- [1] Wary, G.C. et. al., ‘Proposed accelerator facility for fundamental and applied sciences by CUPAC – North East’, Proceedings of the Dae Symp. on Nucl. Phys. 65 (2021), pp. 5-6.
- [2] N. Pandit, G.C. Wary et al: Design status of the differentially pumped gas cell for Positive Ion Mass Spectrometry (PIMS) submitted to 66th DAE Annual Symposium on nuclear Physics, Dec 1-5, 2022 Cotton University, Guwahati.
- [3] D. Saikia, M. Baro et. Design of Beam Shaping Assembly (BSA) for Accelerator Driven Boron Neutron Capture Therapy (AD- BNCT) submitted to 66th DAE Annual Symposium on nuclear Physics, Dec 1-5, 2022 Cotton University, Guwahati.

STUDIES ON FUSION ENHANCEMENT AND HINDRANCE INDUCED BY DEFORMED IONS

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Introduction:

Heavy ions induced reactions by stable, neutron rich medium heavy projectiles on specific deformed, spherical targets are getting significant interest in recent years. There are many projectiles including the radioactive ones are engaged with low energy to LINAC boosted energies where most of the recent experiments are carried out either in nationwide facilities (IUAC, New Delhi and BARC-TIFR, Mumbai) or in abroad. The systems used for such measurement by us are $^{16}\text{O} + ^{116}\text{Sn}$, $^{61,62}\text{Ni}$ and $^{16}\text{O} + ^{176}\text{Yb}$; quite a few to be mentioned.

Results and Discussion:

In the present experiment, a pulsed ^{18}O beam with 4 microsec pulse separation was allowed to bombard upon the isotropically (99.6%) enriched ^{116}Sn target of thickness approx 150 microg/cm², prepared on a 30 microg/cm² thick C backing, inside the HIRA target chamber [1,2]. The targets were mounted with carbon facing the beam. Measurements were done at $E(\text{lab})$ ranging from 52 - 86 MeV in steps of 1 MeV below the barrier and 2 - 2.5 MeV above the barrier, covering the energy range $0.89V(\text{CB})$ - $1.47V(\text{CB})$. To monitor the beam and for absolute normalization of Evaporation Residue (ER) cross-sections, two solid state silicon detectors were mounted at $\theta(\text{lab}) = 15.5$ degree in the horizontal plane. A C-foil was kept 10 cm downstream of the target for re-equilibration of the charge state of ERs.

A position-sensitive multi-wire proportional counter (MWPC), with an active area of $150 \times 50 \text{ mm}^2$ was mounted at the HIRA focal plane for detection of ERs. Time of flight (mTOF) of ERs over the distance from the target to the detector was measured, which helped in distinguishing the ERs from scattered beam-like particles at $E(\text{c.m.}) = 74.3, 49.9$ and 44.6 MeV. The background spectrum was obtained by taking a run of 1 hour with a blank target frame in which no event had been recorded within the ER gate. Such good separation of ERs helped in measuring fusion cross-section down to $E(\text{lab}) = 52$ MeV. List mode data were collected and analysed offline using the program candle.

When the two phonon excitations of 2^{+} vibrational state of ^{18}O , given the high degree of collectivity of this low-lying state, is invoked by coupling it mutually with the single phonon coupling of 2^{+} and 3^{-} states of ^{116}Sn , the fusion excitation functions seem to

reproduce the experimental data fairly well in the whole energy range. The result, obtained by this coupling scheme, shown in Figure1, almost overlaps with that of the cross-section obtained. The present system has a positive Q-value of 4.081 MeV for 2n stripping channel. All the other transfer channels have negative Q-values. For the present system, the neutron transfer coupling has been included in the CCFULL code through transfer coupling strength parameter (F) for two neutron transfer which is varied in the range from 0.2 to 0.5 fm to obtain an appropriate fit to experimental fusion cross-section. With $F = 0.3$ fm, the CCFULL result gives best fit to the data. The effect of neutron transfer, here, appears to be a small reduction of the fusion cross section at most energies. But overall fusion cross sections is observed to be enhanced as compared to multi channels BPM as seen in Figure 2.

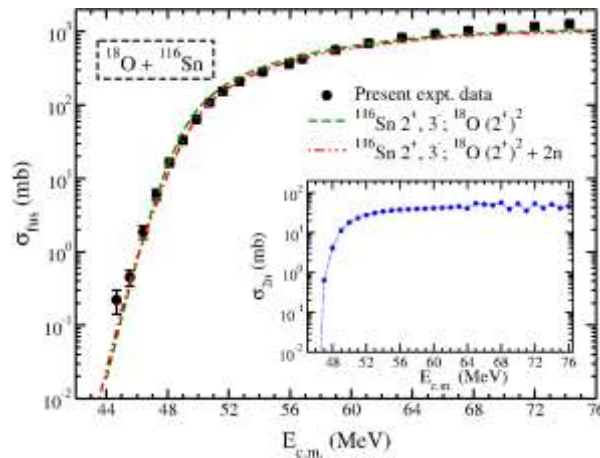


Figure 1: Fusion excitation function measurement on $^{18}\text{O}+^{116}\text{Sn}$ system. The inset is the contribution of 2n transfer channel which contribute to fusion hindrance, but overall enhancement is observed.

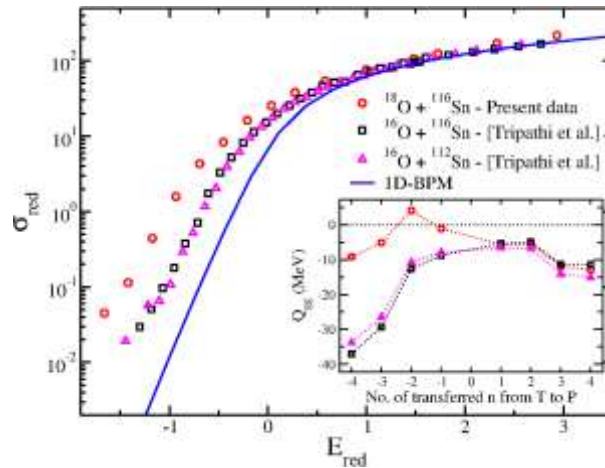


Figure 2: A comparative studies among the three systems as depicted. The ^{18}O induced system is seen to be more enhanced in fusion excitation function measurement. The inset is the various positive Q-valued transfer channels.

Similarly, fusion excitation functions have been measured for $^{16}\text{O} + ^{61}\text{Ni}$ and $^{18}\text{O} + ^{62}\text{Ni}$ systems around the Coulomb barrier ($\approx 0.8V_B - 1.3V_B$) using the recoil mass spectrometer called Heavy Ion Reaction Analyzer (HIRA)-one of the third facility worldwide. The ground state Q - value for 2 neutron stripping is positive for the system with ^{18}O as projectile. Strong enhancement of the experimental fusion cross sections were observed below the barrier for all the systems compared to that of the predictions of the simple barrier penetration model. To understand such enhancement, coupled channels formalism has been used. The sub-barrier enhancement for $^{16}\text{O} + ^{61}\text{Ni}$ is found out mainly due to the strong octupole vibration in ^{61}Ni as shown in Figure 3. A comparative study of these systems indicated that the coupling of 2 neutron transfer channel with the collective excitations is the reason behind the sub-barrier fusion enhancement for ^{18}O induced reaction is studied as shown in Figure 4. Here, the inelastic coupling and 2n neutron transfer is found to be the dominant channels for the enhancement of fusion cross section. After all the comparison of these systems with other systems of different Ni isotopes, we have noticed that the signature of the role of coupling to neutron transfer channels due to ground state positive Q-value for neutron transfer is not unambiguous.

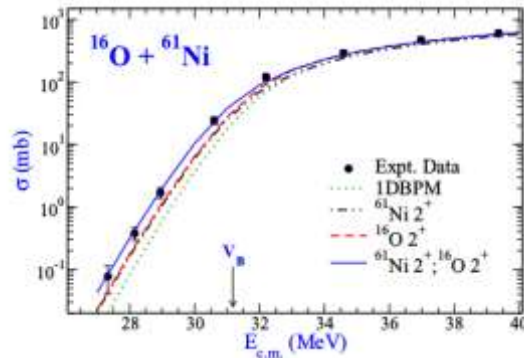


Figure 3: Experimental fusion excitation function for the $^{16}\text{O} + ^{61}\text{Ni}$ system along with results of the calculation involving different modes of coupling between interacting partners using the CCFULL code.

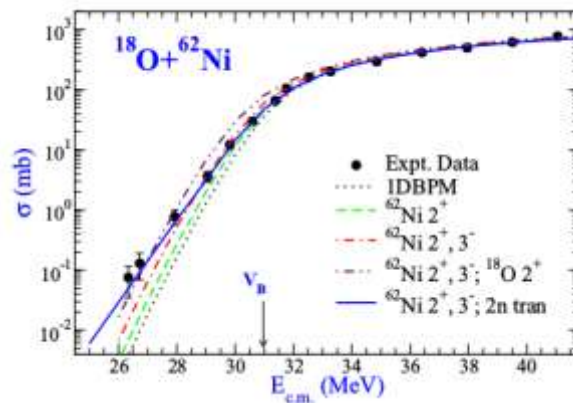


Figure 4: Same as Figure 3 but for $^{18}\text{O} + ^{62}\text{Ni}$ system.

Conclusions:

Fusion enhancement is observed for $^{16,18}\text{O}$ induced reactions with ^{116}Sn , 61 , ^{62}Ni targets. $^{18}\text{O}+^{116}\text{Sn}$ is observed to influence by both 2n-extra nucleon projectile than that of ^{16}O . $^{16}\text{O}+^{61}\text{Ni}$ is seen to behave normally in terms of fusion enhancement. However, $^{18}\text{O}+^{62}\text{Ni}$ is seems to be enhanced by the 2n-stripping transfer reaction having positive Q-value. More experimental investigation is waited in order to draw a proper conclusion both in terms of systematic theory development and experimental confirmation. Our recent attempt is to find the precise value of β_4 from the back angled quasi-elastic measurement at TIFR, Mumbai pelletron facility is communicated for publication[3].

Acknowledgement:

Research scholars of GU, HIRA groups of IUAC, NPD groups of both BARC and TIFR, Pelletron crews, target lab persons related to this work are greatly acknowledged.

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DEVELOPMENT OF AN IRRADIATION AND TESTING FACILITIES AT RANGIA COLLEGE

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Introduction:

Ion beam irradiation on some specific samples of next generation plasma reactors have become important in last decade in view of the International Thermonuclear Experimental Reactor (ITER). In this regards the collaborative work with plasma focus device is the only way for doing internationally reputed work worldwide. The second part of this work is the characterization facility inhouse which can be benifitted by individual and students at large. With this aim a characterization facility is developed by procuring a Optical microscope (OM) and etching technique in research laboratory in Physics Department of Rangia college. In figure.1, we have shown the photograph of the laboratory, where we installed an OM along with a display unit, so that any kind of samples exposed with radiation can be revealed through it. The experimental setup is partitioned with Aluminium panel which gives us a clean and dust free room. As a testing purpose, we also exposed alpha particles from ^{241}Am source (borrowing from Gauhati University) on LR-115 samples, and checked the track formation as shown in Fig. 2 and 3 respectively after preliminary analysis. After preparing the sample, those samples were exposed by the cosmic radiation but counts were very small.



Figure 1: Photograph of the Physics Research Laboatory at Rangia College.

Irradiation Facility at CPP-IPR:

The schematic diagram of the experimental setup used as neon source is shown in Fig.1. It is basically a 2.2 kJ Mather geometry PF device having powered by $7.1\mu\text{F}$, 25 kV fast

discharging capacitor. A homebuilt power supply is used to charge the capacitor having an inbuilt low inductance pressurized spark gap switch. The coaxial electrode system shown in Fig.1 is housed inside a stainless steel chamber of 6 litre volume. The detail descriptions of the mechanical and electrical parameters of our PF were reported on Ref. [1,2]. The production of neon ion beam by filling the chamber with neon gas with the help of self generated $\mathbf{J} \times \mathbf{B}$ force was explained by Bhuyan et al. [1]. The experimental setup is established in Centre of plasma physics- Institute for Plasma Research, Sonapur.

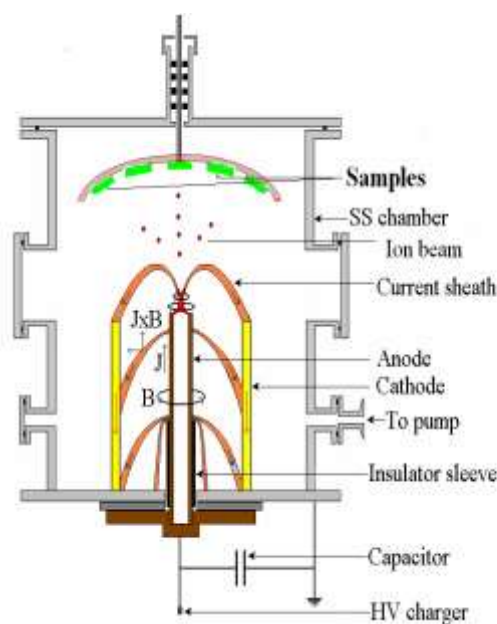


Figure 2: Schematic diagram of plasma focus device with graphite samples in CPP-IPR.

Solid State Nuclear Track Detector (SSNTD), Tungsten and graphite samples of square sizes of $5 \times 5 \text{ mm}^2$ and $10 \times 10 \text{ mm}^2$ were prepared [4]. The samples were then introduced inside the PF chamber and mounted axially as well as at different angles with the help of a movable sample holder. First of all the proton and alpha ions are characterized with the passive detector SSNTD. After characterizing those ions, the tungsten and graphite samples were exposed inside the PF chamber with proton as well as alpha ions.

In-House Etching facility:

The procurement of the etching facility and the solutions (NaOH and distilled water etc) is carried out. Therefore, the Physics laboratory of Rangia College is ready for studying the formation of tracks and reveals them with facility developed under the minor research project.

The exposed and reference tungsten and graphite samples were characterized with the help of FEINTECHNIK make optical microscope (OM) along with a display unit which is installed in our college laboratory. From the optical micrograph we have observed the track formation by proton and alpha particle which are shown in the figure 4.

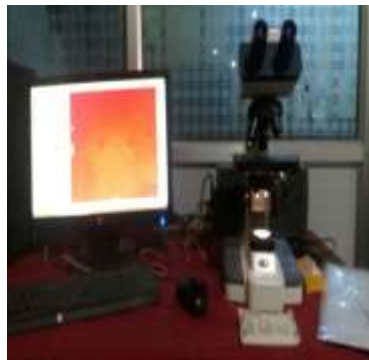


Figure 3: Optical Microscope with the display unit showing image of the sample.

Results and Discussions:

(i) After the etching the LLR-39 detectors is revealed in our microscope and tracks are observed evidently.

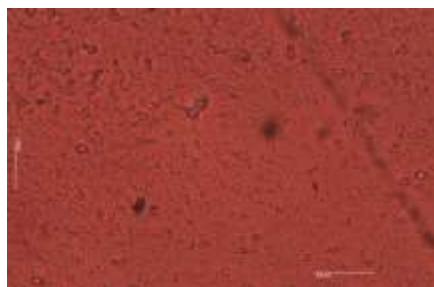


Figure 4: Alpha track formation on LR-115 sample as seen in OM.

(ii) The irradiated samples (alpha ions) of tungsten, graphite and CR-39 is seen to create tracks and seen in the fig.5.

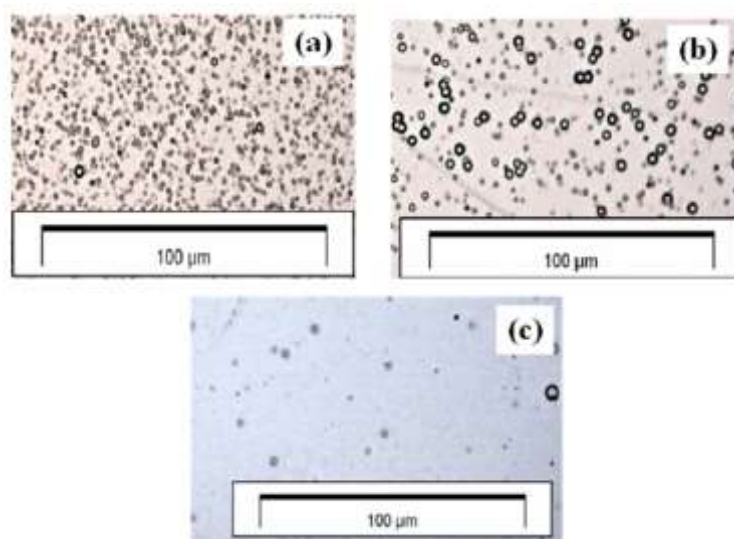


Figure 5: Visualise tracks after processing the etching using our microscope .

(iii) The human bone from geapraphy department of rangia College is seen by our microscope an th to see the nuclear force.

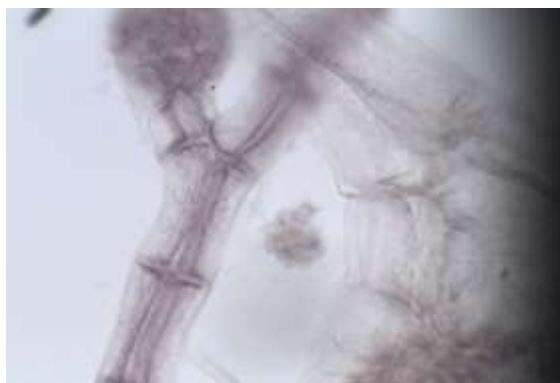


Figure 6: A human bone is scanned in our Laboratory.

Summary:

Ion beam irradiated samples are characterized in our recently developed laboratory. The samples are irradiated in CPP-IPR and Gauhati University and the etching methodology is carried out in our lab and tracks are visualized with an optical microscope. This attempt has been done to teach the B. Sc students and research scholars of Rangia College at large. More such facilities are yet to come in near future.

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NEUTRINO OSCILLATION AND THE FUTURE OF PARTICLE PHYSICS

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Consider voting in an election for your preferred candidate who belongs to a particular political party. However, you may find that, in some cases, the candidates switch their political parties after winning the election. You might argue that this is a widespread phenomenon in Indian politics nowadays based on various human behaviour's and other factors.

Surprisingly nature also exhibits a very similar phenomenon. Neutrino is a fundamental particle of nature like an electron. Neutrino oscillation is a phenomenon that occurs when neutrinos change their type or flavour as they travel through space. Although it may seem weird, this is one of the most exciting discoveries in particle physics in recent years. My goal is to try to provide a glimpse of this phenomenon in this article.

To understand neutrino oscillation, we first need to know that electron neutrino, muon neutrino, and tau neutrino are the three different flavours of neutrinos. The electron, muon, and tau particles are the charged particles that correspond to each of these flavours of neutrinos. Physicists once thought that neutrinos had no mass, but experiments conducted in the late 1990s revealed that neutrinos do have small masses. This discovery prompted the recognition that as neutrinos travel through space, they can alter their flavours. Neutrino oscillation is caused by a microscopic quantum mechanical phenomenon called neutrino flavour mixing. The mixing is similar to how different colours of light can combine to create new colours. For example, red and blue light can mix to create purple light. Besides the three flavours of neutrinos, as described earlier, there are also three different mass neutrinos referred to as mass 1, mass 2, and mass 3. Our life would be easy if each flavour neutrino matched up with a single mass. It turns out that the mass and the flavour neutrinos do not exactly overlap, which makes neutrinos very evasive. Therefore, each neutrino with a certain flavour is made up of a variety of neutrinos with various masses. Now, quantum mechanics tells us the probability with which each neutrino of a specific mass can act as a particular flavour. For example, a mass 1 neutrino is very likely to behave as an electron neutrino. Suppose a neutrino is created in some nuclear reaction as an electron neutrino. Then, since it is a combination of three different mass neutrinos, it can oscillate among all three different flavours of neutrinos as it travels through space. The neutrino can no longer be described as a pure electron neutrino. The mixing process continues as the neutrino travels, changing the ratios of the three different types of neutrinos. Thus, the neutrino could change from an electron neutrino to a muon or tau neutrino and vice versa.

The oscillation probability of a neutrino, say from electron neutrino to muon neutrino, depends on the differences between the masses of each mass neutrino. An interesting fact is that physicists are still unsure of whether mass 3 is the heaviest or the lightest among all mass neutrinos. Neutrino physicists frequently discuss two possible outcomes for the distribution of neutrino mass. This ordering of neutrino masses is known as the neutrino mass hierarchy problem. There are two groups of potential answers based on the experimental data on neutrino oscillations. The mass 1 is considered to be the lightest neutrino, followed by the mass 2 and the mass 3 neutrino in the normal mass ordering. This is referred to as normal since it reflects the masses of the corresponding charged particles linked to neutrinos as described earlier. It makes sense that the mass neutrino that typically manifests as an electron neutrino will be lighter than the other mass neutrinos given that the electron is significantly lighter than the muon and tau particles. In other words, the mass 1 neutrino, which is the lightest of the mass neutrinos, makes up the majority of the electron neutrino. In the inverted mass ordering, mass 3 neutrino is considered the lightest instead of mass 1 neutrino. In this paradigm, the electron neutrino is mostly made of the heavier mass neutrino. Experiments with better precision can determine whether neutrinos have a normal or inverted mass ordering.

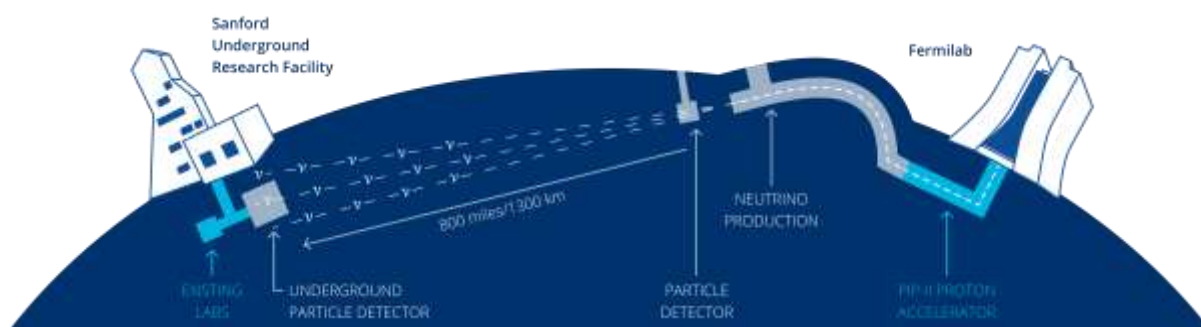


Figure Credit: <https://lbnf-dune.fnal.gov/how-it-works/introduction/>

An international effort in the quest to understand neutrinos is the Deep Underground Neutrino Experiment (DUNE). This experiment is currently under construction. The host laboratory for DUNE is the Fermi National Accelerator Laboratory, also known as Fermilab, of the U.S. Department of Energy, which collaborates with other organizations and more than a thousand scientists from around the world. Massive neutrino detectors are the core of DUNE, and they are located at Fermilab in Illinois and Sanford Underground Research Facility in South Dakota. The infrastructure and the world's most intense neutrino beam are produced by Long-Baseline Neutrino Facility. The neutrino beam is propelled by Fermilab's PIP-II particle accelerator. The neutrino beam passes through a detector on the Fermilab site, then travels a distance of 1,300 kilometers through the earth's crust, and then the detector which is placed underground in South Dakota. The long-distance between the near and far detector provides optimal sensitivity to the neutrino properties that physicists want to measure.

So why is neutrino oscillation so exciting? Well, for one thing, it's a completely unexpected

Phenomenon that has forced physicists to rethink their understanding of the fundamental particles that make up the universe. But more than that, it plays an important role in our understanding of the universe as a whole. Neutrino oscillation is a complex and fascinating phenomenon, and physicists are still trying to fully understand it. But it has opened up a whole new world of possibilities for particle physics research and our understanding of the universe.

X-RAY CRYSTALLOGRAPHY AND ITS IMPLICATION IN DRUG DESIGN

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Crystallography is the branch of science that straddles various disciplines including physics, chemistry, mathematics, biology, material science, geology, etc to study crystals. As X-ray radiation is primarily used to study crystals, the field is often called X-ray crystallography. X-ray crystallography is essentially the study of crystals by the diffraction or ordered scattering of X-rays. The diffraction or scattering phenomenon gave us information about the interaction between X-rays and matter and how atoms are arranged in three-dimensional space. It helps us to understand the relationship between the atomic structure of matter and its properties. Crystallographers study diverse substances from living cells to materials and protein molecules to ceramics. X-ray crystallography is regarded as one of the greatest discoveries of the twentieth century. Why the water boils at 100 °C or the ethanol boil at 78 °C whereas propane has a boiling point of -42 °C? Why the blood is red but the grass green? Or how the proteins control the movement of ions into or out of a cell or do various works in our body or how antibody binds to specific foreign particles such as virus or bacteria to protect us- the answer to all varieties of the problem might come from the structural analysis of the respective entity by the help of X-ray crystallography.

Modern crystallography prospered after the discovery of X-ray by Rontgen in 1895 for which he has conferred the first Nobel Prize in Physics 1901. Soon after, Max Von Laue was awarded Nobel Prize in Physics in 1914 to show that crystals can diffract X-ray. The idea of using X-ray diffraction to study the structures of crystals was first proposed by William Henry Bragg and his son William Lawrence Bragg in 1912. They used X-rays to study the structure of table salt and showed that the arrangement of atoms in the crystal could be determined from the pattern of diffraction of X-rays. This technique, known as X-ray crystallography, has since become one of the most powerful tools in the field of structural biology. Both William Henry Bragg and his son William Lawrence Bragg was conferred with Nobel Prize in Physics in 1913 and considered one of the best Nobel Prize in the area of Physics. The work started by Bragg's has not stopped, and X-ray crystallography remained the foremost technique to determine the atomic structure of almost every molecule from physics, chemistry, and biology to material science. There are at least 33 Nobel Prizes including 55 Laureates is awarded to date for their work associated with crystallography or in the field of crystallography. Ironically, there exists a healthy fraction of women Nobel Laureates in crystallography in comparison to others fields.

Proteins play a vital role in the cellular metabolism of all living organisms. They perform most of the work in cells including catalyzing various chemical reactions; transmitting signals

between different tissues, cells, and organs, transporting or storing ions and small molecules within the cell or throughout the body, etc. Proteins are built from the assembly of small molecules called amino acids through peptide chains in a specific sequence that dictates their shapes and functions. The three-dimensional structure of the protein will determine its function. Therefore, the knowledge of the crystal structure of the protein is of utmost importance not only to understand how protein works but also to use that information for different purposes such as controlling or modifying of protein's function, predicting and visualizing various bio-molecular interactions (proteins, nucleic acids, small molecules, etc), understanding protein folding problem and designing effective drugs, etc. However, the size of the protein molecules is difficult to see under the naked eye or visible microscope. The X-ray diffraction technique is used not only to 'see' the three-dimensional structures of proteins, in atomic detail but also to look at their shapes and sizes that provide the structural information invaluable for understanding the structure-function relationship. The crystal is the basic requirement for crystal structure determination. The other steps involved in the structure determination of protein included protein expression and purification, growth of the suitable diffracting crystal, data collection, structure determination, and validation.

A drug may be considered a substance that is used to treat, prevent, or diagnose a disease or medical condition. Many good drug targets are proteins. The knowledge of the structure of proteins or bio-molecules has enabled the rational design of drugs that specifically target these proteins and their associated diseases. Hence, structure plays a vital role in healthcare.

One of the key applications of X-ray crystallography in drug discovery is in the field of structure-based drug design (SBDD) and fragment-based drug discovery (FBDD). In SBDD, the three-dimensional structure of a target molecule is used to design drugs that bind to specific regions of the molecule and modulate its activity. X-ray crystallography is used to determine the structure of the target molecule, as well as the structure of the drug bound to the target, which can be used to optimize the drug's binding properties. On the other hand, fragment-based drug discovery (FBDD), a relatively new approach that aims to identify small molecules that can bind to specific protein targets with high affinity and selectivity. The method involves screening a library of low molecular weight compounds, or fragments, for binding to the target protein. Once a fragment has been identified, it can be optimized to improve its binding affinity and selectivity, ultimately leading to the development of a drug. The determination of the 3D structure of the protein target and its complex with the small molecule provides insight into the binding mechanism which is critical for the development of drugs with high affinity and specificity.

There are many drugs on the market that were developed using SBDD. Here are some examples include Tamiflu which is used to treat influenza; Relenza, used to treat influenza; Xarelto, used to prevent blood clots; Humira, used to treat autoimmune diseases; Gleevec, used to treat certain types of cancer; Januvia, used to treat type 2 diabetes; Triumeq, used to treat HIV, etc. On the other hand, several successful drugs have been also discovered using the FBDD approach. For example, Venetoclax, a drug used to treat chronic lymphocytic leukemia, was developed using FBDD and X-ray crystallography. The drug binds to the B-cell lymphoma 2 (BCL-2) protein, preventing it from blocking apoptosis (programmed cell

death) and leading to cancer cell death. Another example is the development of Rucaparib, a drug used to treat ovarian cancer. The drug was developed using FBDD and X-ray crystallography to target poly (ADP-ribose) polymerase (PARP), an enzyme involved in DNA repair. The drug binds to PARP and prevents it from repairing damaged DNA, leading to cancer cell death. Other drugs that have been developed using FBDD include Tazemetostat, an EZH2 inhibitor used to treat follicular lymphoma, Entrectinib, a TRK inhibitor used to treat solid tumors, Lenvatinib, a VEGFR inhibitor used to treat thyroid cancer, Rigosertib, a RAS inhibitor used to treat myelodysplastic syndromes, etc.

Drug design is a complex, time-consuming process that requires a multidisciplinary approach to bringing out the final product as a “drug” in the market. X-ray crystallography has had a significant impact on both structure-based drug design and fragment-based drug design. Both techniques have led to the discovery of several successful drugs. The gaining popularity of both SBDD and FBDD methods in the field of drug discovery that is assisted by X-ray crystallography will continue to play a critical role in the development of safe and affordable drugs to treat several diseases in the future.

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COLLECTIVE BEHAVIOUR IN NATURE: A DIVE INTO ACTIVE MATTER

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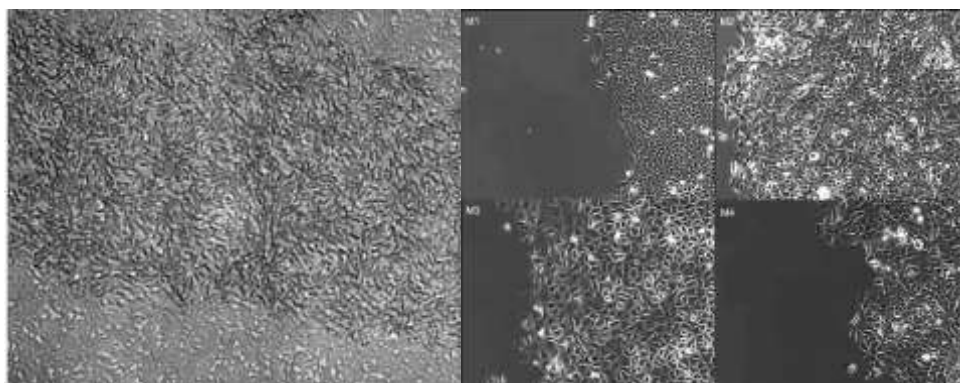


Figure 1: (Left) A swarm of bacteria under a microscope with X40 magnification (*Source: Swarming bacteria undergo localized dynamic phase transition to form stress-induced biofilms, eLife, <https://t.ly/x4wR0>*); (right) collective sheet migration of breast cancer cells (*Source: Carole Parent lab at the University of Michigan Life Sciences Institute*).

Nature is beautiful and mesmerising in its own distinctive ways. In the vast expanse of the natural world, there is an intricate dance of collective behaviour that unfolds every day. This fascinating collective behaviour is a phenomenon that can be observed across a wide range of scales in the natural world starting from tiny bacteria at the microscale, to colonies of ants at mesoscales, and to even ecosystems at the largest scale. A bacterium in itself is a tiny organism, but it becomes mighty when it comes to collective behaviour, which is usually termed as bacterial swarming. The various events in their collective behaviour through elaborate self-assembly represents a different world altogether. Under favourable conditions, enormous number of bacteria can congregate to form complex colonies. In these cohesive colonies, known as the swarms, they exhibit stark pulsing and shifting in intricate patterns which are actually the result of the thousands of individual bacteria's movement in unison. It is unmissable for a curious eye that the motion of the swarms appears as the movement of a living mesoscopic organism in life, and their collective behaviour leads to a phenomenon which is much bigger in scale as compared to their individual counterparts. Various studies indicate that this collective behaviour is manifestation of a combination of chemical signalling and physical interactions between the individual bacteria. Is this not a reminder that even the smallest and seemingly simplest organisms have the power to work together in incredible and awe-inspiring ways? Collective behaviour is observed in various multi-cellular organisms. Powerful microscopic investigations reveal that cells in multi-cellular organisms

are able to move together in a coordinated manner, and as a result they can migrate to different parts the multi-cellular body. It is a verified fact that during embryonic development, cells move together to form the various organs and tissues of the body. Further, cells can come together to form complex tissues and organs, which in turn play crucial and specific roles. It is noteworthy that in these processes each individual cell has a very specific role to play in the overall function of the tissue. For example, in the human heart itself, individual heart muscle cells come together to form the cardiac tissue that is responsible for pumping blood throughout the body. These cells work together in a coordinated manner to create the rhythmic contractions that make up the heart-beat.



Figure 2: A group of ants forming a live bridge with their bodies (*Source: Ants building moving bridges from their live bodies, University of Sydney, <https://t.ly/Pvmj>*)

At an intermediate scale, colony of insects, ants and bees exhibit complex and coordinated behaviour that is both fascinating and efficient. Various ecological studies show that each individual plays a specific role in these colonies, and the collective behaviour of the group allows for the efficient gathering of resources and more importantly protection from predators. Especially, ant colonies are a classic example in this respect. These fascinating organisms have the specialized strategy of task allocation, foraging, defence and thus survival through collective efforts. This division of labour is achieved through a combination of chemical communication and behavioural demonstration. The Figure 2 above shows one of the most amazing aspects of collective behaviour in an ant colony. In some ant species, when faced with an obstacle such as a gap or a crevice, ants will work together to build a bridge made of their own bodies, allowing other ants to cross over safely. At a similar level, animal herds and bird flocks demonstrate the power of collective behaviour. In these groups, there is well-organized partition of specified tasks, and the individuals work together to coordinate movement, share information, and protect themselves from danger.

It is hard to believe that any of us has never been mesmerised while looking at the clear sky on a summer evening and witnessing the different flocks of birds. The mere sight of a flock of birds moving in unison across the sky is a breath-taking display of collective behaviour. For a surprised eye, the flock appears to have been choreographed by some unseen force, and their synchronized movements as a cohesive group is a marvel to behold. The members of the group soar and dip in perfect harmony which gives the impression of it being a single object moving. However it displays the property of a soft fluid as it can change its shape. As the

flock disappears over the horizon, we are left with a sense of wonder and awe, and a deep appreciation for the mysteries of the natural world. One of the key features of flocking behaviour is the ability of birds to move in a coordinated way, even though they are not directly communicating with each other. This coordination is achieved through a combination of visual clues, such as the position and movement of nearby birds, and individual responses to these signs. The schooling behaviour in fish is another mesmerizing display of collective behaviour in the animal kingdom. Similar to flocking in birds, the fishes swim in tight formations to twist, turn, swoop and swirl in perfect harmony to achieve certain objectives. In a fish school, their objectives range from efficient foraging to increased opportunities for reproduction to collective protection from predators. These collective behaviours in bird flocks and fish schools show the effectiveness of community work and strength of interconnectedness.



Figure 3: (Left) Starling murmuration- huge groups of starlings showing collective behaviour through spectacular display of twist, turn, swoop and swirl across the sky (*Source: Wikimedia commons*); (right) a large school of fish exhibiting coordinated swimming in tight formations (*Source: Wikimedia commons*).

The huddle formation of Emperor penguins is undoubtedly another stunning display of collective behaviour. Being inhabitants in the harshest environment on earth, these creatures form a tightly-packed group to survive the freezing Antarctic winter. In this extraordinary show of collective behaviour, the Emperor penguins stand shoulder-to-shoulder in an extremely tight packed fashion. While huddling is key to their survival ensuring conservation of heat, the leaning of every individual against its neighbour achieves another crucial factor-protecting themselves from the unforgiving relentless wind. Another astoundingly interesting observation is that the penguins take turns to stand on the outer edge of the huddle, braving the elements to give their companions a chance to rest in the warmth of the centre. It needs to be noted that although the individual movement of each penguin is nearly impossible, the motion of the huddle as a unit is not jammed, which one usually observes in case of jamming transition in a highly compact dense solid. The penguins continually shuffle, thus allowing the structure to reorganize, but simultaneously maintaining the huddle packed.



Figure 49: A view of a colony of Emperor Penguins in Antarctica showing formation of huddle (Source: Coordinated Movements Prevent Jamming in an Emperor Penguin Huddle, PLoS One. 2011; 6(6): e20260.)

At the largest scale, ecosystems themselves can exhibit collective behaviour, where different species interact and influence each other's behaviour to create complex patterns of interactions and feedback loops. Various studies have shown that trees in a forest work together, through complex root systems and chemical signalling to share resources and thus enable protection of each other from pests and diseases. The foundational principle of collective behaviour in every ecosystem is survival and thriving of all the inhabitants. Thus, it can be inferred that starting from the smallest grains of sand to the largest herds of animals' collective behaviour in nature is abundant and this is achieved via coordination and sharing of resources or motion. In this fascinating phenomenon, each entity plays its specific role while maintaining a delicate balance, thus giving rise to breath-taking and awe-inspiring events. The most important factor in any of the naturally occurring collective behaviour is that there is no external driving agent to forward the phenomenon. The individual units or agents of the systems interact with each other which leads to a synchronisation in their movement or behaviour. These phenomena of flocking in birds, schooling in fish, swarming in insects, and herding in mammals are termed as emergent properties. These properties are termed emergent as they are not present in the individual units of the system. They emerge as a result of the interaction among the agents leading to spontaneous organization and coordination of individuals in a group, and thus they can not be predicted just by looking at the individual properties of each agent. Nevertheless, the interactions between the individuals can be influenced by a variety of factors such as physical forces, environmental causes, or social factors. One of the most significant points to note is that collective behaviour or the phenomenon of self-assembly manifests itself over large length and timescales compared to that of the individual constituents.

One of the foremost questions that naturally arises in our mind is: what might be the underlying reasons for this kind of emergent collective behaviour? Are the objects or the organisms (referred to as the active agents) following a certain kind of dynamics (aggregation, orientation) for no specific reason? Another interesting question is, whether it is possible to gain some understanding of these phenomena based on the properties of matter?

Undoubtedly, this understanding will have far-reaching important implications. In this context, studies regarding physics of active matter plays a prime role. This is due to the reason that active matter systems illustrate the emergence of collective behaviour of physical systems by taking into account the interaction between the individual units, and employing simple rules of alignment. Thus, collective behaviour is closely related to the concept of active matter. The system comprises of self-propelled individual agents such as particles or organisms, and thus active matter, essentially, can be living or non-living. When these agents interact with each other, they can exhibit a range of emergent collective behaviours, such as flocking, swarming (in case of organisms), clustering, and aggregation or segregation (in case of particles), and multitude of various other phenomena. It is important to note the active agents can be living organisms such as bacteria or cells, or synthetic particles such as self-propelled micro- or nanorobots. Furthermore, one needs to keep in mind that the concept of active matter is rooted in the field of statistical physics, which seeks to understand the behaviour of large systems of particles. Importantly, active matter differs from traditional matter (or materials), because the individual units in active matter have the ability to move on their own autonomously, as opposed to traditional matter where the constituent units simply respond to the external forces. Active matter systems are typically driven by internal energy sources, such as the metabolic processes of cells (in case of living biological systems) or the external energy input provided to synthetic micro-units (in case of traditional matter). These energy sources allow the individual components of the system to move and interact with each other, giving rise to complex collective behaviour and associated emergent phenomena.

The field of research in active matter has become one of the prime areas of focus for scientists from a broad range of discipline including Physics, Biology, Chemistry, and Computer Science etc. It is rapidly growing and interdisciplinary in nature. It focusses on understanding the principles governing the collective dynamics from various approaches and the emergence of non-equilibrium behaviour, emergent pattern formation, role of external factors etc. With the advent of technological development in the recent years especially in the field of microscopy and computational resources, it has undergone a revolution in the study of active matter and a great deal of understanding has been achieved especially at the intersection of Biology and Physics. Broadly, the research of active matter typically involves a combination of theoretical modelling and experimental techniques.

One of the prominent experimental approaches of studying active matter is through investigations of active Janus systems. These special particles known as active Janus particles are synthetically prepared and they have two distinct sides with different physical or chemical properties. Notably, the origin of the term "Janus" dates back to the Roman god Janus, who is depicted as having two faces looking in opposite directions. A synthetic Janus particle has two sides that face in different directions, and hence it carries that name. These particles can be made active via introducing self-propulsion using special techniques depending on their design and the external environment. For example, platinum-coated silica spheres are made to self-propel via the process of self-phoresis. On the other hand, some research groups have designed Janus particles having different electrical or magnetic properties on each side, allowing them to move in response to external electric or magnetic fields. There are optical Janus particles which undergo light-induced motion, due to their different optical properties

on each side, such as difference in absorption or reflection of light. Sophisticated optical microscopy, such as bright-field and fluorescence microscopy, can be used to visualize the motion and interactions of active Janus particles in real-time. There are studies with confocal microscopy where three-dimensional information about the particles' position and orientation can be obtained. Another exciting area in studies of Janus particles involves the method of particle tracking and it has gained wide usage as the motion and interactions of self-propelled particles can be monitored with high accuracy. In this technique, the position and trajectory of individual particles are tracked over time using bright-field microscopy, fluorescence microscopy, confocal microscopy, or digital holographic microscopy. The trajectory of the individual active agents allows researchers to quantify the statistical properties of particle motion, such as the mean squared displacement and velocity correlations etc. It is important to note that the techniques described above are widely used in studies of living biological systems such as bacteria colony. Another very important approach of investigating active matter is rheology. The field of rheology is the study of the deformation and flow of materials under the influence of applied stress or strain. Basically, it deals with the mechanical behaviour of materials. In complex systems like biological and synthetic active matter, the self-propulsion of the particles can generate complex flows and mechanical stresses. As a result of these complex processes the rheological properties of the surrounding fluid is impacted through induced flows. Thus, by investigating the rheological characteristics of active matter a comprehensive understanding of active dynamics and elastic properties can be obtained. It is noteworthy that rheological studies can be performed at two contrasting scales. In addition to bulk rheological measurements, the sophisticated technique of micro-rheology techniques brings forth the complex local mechanical properties of the active particles themselves. The studies concerning rheological properties of active matter is important for a wide range of applications, including drug delivery, tissue engineering, and microfluidic devices. It can also provide insights into the fundamental principles of self-organization and collective behaviour in living and synthetic systems.

Theoretical studies and computational modelling concerning the complex active and living biological matter has made significant progress in the recent years. Especially, the rapid progress of available computational resources has unveiled a plethora of fascinating phenomena along with their understanding in the field of active matter research. Analytical studies based on approaches of statistical mechanics provides a theoretical framework for understanding the collective behaviour of active systems. Field theoretic and particles-based analyses have been successfully used to understand many complex emergent phenomena in active systems. Computational modelling is a powerful tool in active matter research that allows researchers to simulate and study the behaviour of self-propelled particles in complex systems. It involves developing mathematical models and algorithms that can be used to simulate the dynamics of the particles in a computer. In one approach known as the agent-based modelling the behaviour of individual active units and their interaction with each other and the environment can be simulated. Using models of self-propelled agents these studies have been able to mimic the emergence of collective behaviour in large populations. In the continuum model, which is the other extreme opposed to the agent-based models, the behaviour of the active systems are depicted as continuous fluid or field. This method is especially useful for investigating dynamics of the systems at large length-scales under

different physical conditions. Two more computational approaches which are popular and widely used are the methods of molecular dynamics simulation and Brownian dynamics simulation. Molecular dynamics simulations, commonly known as MD, exploit the knowledge of classical mechanics to simulate the motion of individual particles in a system. To implement the effect of activity some simple physical rules are imposed upon the system. The trajectory of the individual constituents can be used to analyse various aspects concerning the interactions between particles and their environment, as well as the effects of external forces on the particles. Brownian dynamics simulation studies are very similar to molecular dynamics studies, with the addition that the effects of thermal fluctuations and stochasticity on the motion of the particles are also incorporated. In the past decade, the computational modelling method has positioned itself as an indispensable ingredient of active matter research allowing researchers to explore and test different hypotheses about the behaviour of self-propelled particles in active matter systems, and to make predictions about the behaviour of these systems under different conditions.

Essentially, the field of active matter research is immensely “active”. It is dynamic and interdisciplinary that explores the fundamental principles of self-assembly and collective behaviour in complex systems. The study of active matter has a broad range of applications such as understanding the behaviour of biological systems and their associated complex phenomena, drug delivery, developing novel materials and micro-robots etc. By employing a range of theoretical, experimental and computational techniques that includes particle tracking, rheology, statistical mechanics, and field theoretic approaches, as well as computer simulation and modelling; the complex interactions between particles and their environment and the emergence of collective behaviour have been studied. Although there has been significant progress in research of active matter, many important questions still remain unresolved. Thus, the study of active matter is a rapidly growing exciting area and many aspects of it still remain unexplored. It bears the potential to revolutionize our understanding of self-organization and collective behaviour in complex systems, and to lead to the development of new and innovative technologies.

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RECENT ACTIVITIES OF PHYSICS ACADEMY OF NORTH EAST (PANE)

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After assuming the charge of the general Secretary of Physics Academy of North East (PANE), I invited DAE-UGC consortium to start an awareness program on “Utilization of in-house and large scale DAE facilities” and organised it accordingly by UGC-Department of Atomic Energy (DAE)-Consortium for Scientific Research (CSR) on 6th August 2021 for the whole N.E. states. The inauguration programme was patroned by the director of CSR, Indore centre Prof. Amlan J. Pal and co-ordinated by director of CSR, Kolkata centre Dr. Abhijit Saha. The programme is co-hosted online by K. Kalita, General Secretary (GU) and Joint Secretary S. Arshad Hussain (TU) of PANE.



XII PANE Conference (2021) at Tripura University

After that we held a three days biennial national conference in Tripura University, during 15-17 December 2021 with the convenorship of Prof. S. Arshad Hussain. The keynote speech was delivered by Dr. Sabu Thomas, Vice Chancellor, Mahatma Gandhi University, Priyadarshini Hills, Kerala, India -686 560 on “new opportunities in sustainable nano materials from agrowaste”. The conference was a grand success. The conference papers were published in Materials Today: conference proceedings and IJERT. One of the new initiative was that PANE felicitated eight distinguished persons from the eight NE states. Five best oral and poster presenters (each) were awarded during the conference. The sponsorship of keynote address expense and the awards were given by Bipin Pal Das Memorial Oration, Guwahati by Dr. Alakananda Das.



Foundation Day Lecture (2022) at Gauhati University

After that, the 23rd foundation day of PANE is celebrated in its head office the department of Physics of Gauhati University on 6th April 2022 as a part of the 75 years of existence of Gauhati University. The eminent nuclear physicist from Tata Institute of Fundamental Research, Mumbai Prof. Indranil Majumdar was delivered the foundation day talk on “Studies in nuclear structure and Nucleosynthesis using proton beam”.



XIII PANE Conference (2022) at Manipur University

The 13th biennial national conference of PANE were held in Manipur University during 8-10, November 2022 with Dr. Th. Gomti Devi as the Convener. The keynote address was delivered by Prof. Biswarup Mukhyapadyhaya, Professor, FNASc, Shanti Sarup Bhatnagar Awardee, IISER, Kolkata on “The spirit of progress in fundamental physics: where every answer raises questions”. It was held in physical mode. This time two distinguished physicists of NE were felicitated and the three best Oral and poster (each) presenters were awarded. The publication of contributed papers (Oral) is in progress in Materials Today: Conference proceedings and another one as a book chapters. There were one significant development of PANE is that one of the books, “The Conceptual Development of Physics” edited by N. Nimai Singh and K. Kalita is also published by PANE. The annual conference of PANE is chosen to be held in Sikkim Alpine University during December 2023 and another thematical conference is recommended by EC to be held in USTM, Meghalaya during March

2024 or so. The 14th biennial conference of PANE is recommended by GB to be held in Tezpur University, Assam in the year 2024.

Finally, the 24th foundation day celebration would be held in Pragjyotish College, Guwahati during 6th April 2023 and the FD lecture will be delivered by Professor and Director of IISER, Kolkata, Prasanta K. Panigrahi on “Indian contributions to science and technology: A brief walk down the memory line”. Also, during the ceremony we are going to felicitate Prof. Jayanta Kumar Sharma, Tezpur University who translated the book of Sir Isaac Newton “the Philosophiæ naturalis Principia mathematica” into the Assamese language “Prinicipia: Prakritik darkhanar Ganitik Neeti” and the Newsletter (2022-23) of PANE will be also released with the Editorship of Dr. Samrat Dey. Another important development is that PANE has started to publish an e-journal, namely PANE- a Journal of Physics” with the Chief Editorship of Prof. N. Nimai Singh and its Co-editorial board very soon. The work done by PANE is a team work of all office bearers and we look forward to do more in the near future. For more, one can visit our permanent website: www.pane.co.in.

A BRIEF REPORT OF XIII BIENNIAL NATIONAL CONFERENCE OF PHYSICS ACADEMY OF NORTH EAST (PANE-2022) DURING 8-10 NOVEMBER 2022 ORGANIZED BY THE DEPARTMENT OF PHYSICS, MANIPUR UNIVERSITY

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The Department of Physics has organized 03 (three) days XIII Biennial National Conference of Physics Academy of North East (PANE-2022) during 8-10 November, 2022 under the Convenorship of Dr.Th.Gomti Devi, Associate Professor, Department of Physics, Manipur University in hybrid mode (Offline and online mode). Dr.N. Chandrachani Devi and Dr. M. Shubhakanta Singh are the joint convenors. The objectives for organizing the Conference are given below:

- To create a platform where physicists working in various fields in different parts of the country can share their knowledge, experiences, innovations and inventions to larger audiences, which will benefit the young researchers most.
- To create awareness among the academics, scientists and young scientists about the various advanced physics research areas from the lectures delivered by eminent scientists and Academics from different parts of the country and motivate them to take up research and teaching in the rapidly growing areas.
- To create a professional network of collaborative research with the researchers of the North-Eastern region to other parts of the country.



The Conference is sponsored by SERB, New Delhi for providing TA/DA of the Young and Senior Scientists and for pre-conference printing, respectively. Twenty eight (28) speakers including one Keynote speaker, five plenary speakers and 22 invited speakers from Institutions and Universities such as IISER Kolkata; S.N. Bose National Centre for Basic

Sciences, Kolkata; Jamia Milia Islamia; IIT Delhi; CQuERE, Kolkata; Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, China; Tezpur University; Delhi University; IIT Guwahati; Assam University; Indian Institute of Astrophysics, Bangalore; IISC Bangalore; Gauhati University; Tripura University; Banaras Hindu University; Cotton University; Mizoram University; Hyderabad University, Dibrugarh University, IIT Kanpur; Rajiv Gandhi University, NIT Manipur and Manipur University have delivered their lectures in these three days programme. Furthermore, participants from other North East Institutions and different parts of the country participated in offline and online modes.



On 08/11/2022 (Tuesday), the Conference was inaugurated by Prof. C. Amuba Singh, Former Vice-Chancellor, Manipur University as the Chief Guest; Prof. N.Nimai Singh, President PANE; Prof. Kushal Kalita, Secretary PANE; Prof. A. Surjalal Sharma, Director RIST and Professor of University of Maryland; Prof. K. Yugindro Singh, Dean (Schools of Mathematical and Physical Sciences) as the Guest of Honours and Prof. H. Basantakumar Sharma, President organizing Committee at 9.30 AM at Court Hall, Manipur University using offline and Webex online mode. Participants who couldn't participate physically attended online mode. One Physics book "Conceptual Developments in Physics" was released in the inauguration function.

In the inaugural function, the following eminent physicists have been felicitated for their contribution towards the development of Physics.

1. Prof. R.K. Gartia
Retired Professor, Emeritus Professor, Department of Physics, Manipur University, Manipur
2. Prof. Barin Kumar Sarma,
Retired Professor, Department of Physics, Gauhati University, Assam

After the inauguration function, Keynote address is delivered by **Prof. Biswarup Mukhopadhyaya, Professor, FNASc, Shanti Swarup Bhatnagar Awardee for Science and Technology, IISER Kolkata on the topic "The spirit of progress in fundamental Physics :Where every answer raises questions"**. After the keynote address, there are three (03) technical sessions (1A, 1B and 1C sessions) in the morning from 11.00 AM-1.00 PM (i) Condensed Matter Physics & Material Science (CMPMS) session (ii) Astrophysics,

Cosmology and Nuclear Physics (ACN) session (iii) Interdisciplinary Research and Atmospheric Physics session. Each technical session has a plenary talk followed by invited talks.



In the CMPMS session, **Prof. Tanushri Saha Dasgupta**, Director, S. N. Bose National Centre for Basic Sciences, FNA, FNASc, FSc, Fellow of American Physical Society delivered a plenary talk on the topic “**Quantum Materials by Computation: Challenges & Opportunities**”, followed by invited talks of Prof. Shyama Rath (Delhi University), Prof. Pabitra Nath (Tezpur University), Prof. Sh. Dorendrajit Singh (Manipur University) and Prof. Perumal Alagarsamy (IIT Guwahati). The technical session is chaired by Prof. Neeraj Khare, IIT Delhi.

In ACN technical session, **Prof. Md. Sami**, Jamia Milia Islamia (Former Professor), Professor, SGT University Gurugram delivered a Plenary talk on the topic “**Recipe for quintessential inflation**”, followed by invited talks of Prof. Buddhadeb Bhattacharjee (Gauhati University), Prof.J.J. Das(Cotton University), Prof. Ashoke K.Sen(Assam University), Prof. Ch. Pravabati (IIA, Bangalore) and Dr.N. Madhavan, (IUAC, Delhi). The technical session is chaired by Prof. K. Yugindro Singh, Manipur University.

In Interdisciplinary Research and Atmospheric Physics technical (1C) session, **Prof. Dongfeng Xue**, Professor, Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, delivered a Plenary talk on the topic “**Multiscale origin of materials crystallization**”, followed by invited talks of Prof. Kalyan Bhuyan (Dibrugarh University), Prof. R.C. Tiwari (Mizoram University), Prof. Anrup Gohain Barua (Gauhati University) and Dr. Ranjan Changmai (DHSC College). Prof. Syed A. Hussain, Tripura University, chaired the technical session.

In the afternoon technical sessions (2A, 2B and 2C) from 2.00 PM-4.30 PM, there are oral presentations: 12 presenters for CMPMS, 12 for Astrophysics and Cosmology and 11 presenters for Interdisciplinary research and Atmospheric Physics in offline and online mode. There was poster session from (11.30 AM-4.30 PM) on the first day of the Conference. There was a Cultural Program (Cultural Program + Conference Dinner) from 6-9 PM at the Centenary Hall, Manipur University.

On the second day (Day-02) of the Conference, date 09/11/2022, Wednesday, there are three technical sessions 3A, 3B and 3C from (9.00-10.30) AM (i) Condensed Matter Physics & Material Science (CMPMS) (ii) Atomic, Molecular Physics and Spectroscopy (iii) High energy Physics. At CMPMS technical session (3A session), Prof. Neeraj Khare delivered a Plenary talk on the topic “**Designing Multifunctional Nanocomposites for Clean Energy Generation and Environment Remediation**”. The Plenary talk is followed by invited talks of Prof. Syed Arsad Hussain (Tripura University), Dr. Bibhu Prasad Swain (NIT Manipur) and Prof. Subroto Mukherjee (IISc, Bangalore). The technical session was chaired by Prof. Sh. Dorendrajit Singh, Manipur University.

In 3B technical session, **Prof. Bhanu Pratap Das**, Professor, Director, CQuERE, Visiting Professor-Germany, California, Japan, Hungary, USA, UK delivered a Plenary talk on the topic “**Quantum Computing: Applications to Atoms and Molecules**”, followed by invited talks of Prof. Ranjan Kumar Singh (BHU), Prof. Ashwini Kumar Singh (IIT Guwahati) and Dr. S. Ranjita Chanu (IIT Kanpur). Prof. Anrup Gohain Barua, Gauhati University, chaired the technical session.

In 3C technical session, there are invited talks delivered by Prof. MK Das (Tezpur University), Prof. Bipul Bhuyan (IIT Guwahati) and Prof. Rukmani Mohanta (Hyderabad University). Prof. B. Mukhopadhyaya chaired the technical session.

After these sessions, there are three parallel technical sessions, i.e. 3A, 3B and 3C, from 10.30 AM -1.00 PM. Prof. Sumitra Phanjoubam chaired the parallel technical session 3A and twelve (12) participants gave the oral presentation for this session.

For parallel technical session 3B, there were 12 oral presenters and Prof. Dilip Angom chaired the session. For parallel technical session 3C, Prof. MK Das chaired the session and there are 12 oral presenters. After the lunch break, there is a program for sight-seeing at Loktak Lake.

On day-03 (10/11/2022, Thursday), there are two parallel sessions (4A and 4B sessions):

- (i) Communication and Instrumentation & CMPMS (4A)
- (ii) Astrophysics, Cosmology and Nuclear Physics & High energy Physics (4B).

There are 13 oral presentations (7 for Communication and Instrumentation and 6 for CMPMS) for 4A session and chaired by Prof. H. Basantakumar Sharma (Manipur University). In the 4B parallel technical session, there are 11 oral presentations; 6 for ACN and 5 for High Energy Physics and chaired by Dr. Subrata Hazarika and Dr. Abhijit Das, Assam University.

After the lunch break, there is a valedictory session from 3.30 PM-4.30 PM. At the valedictory session, two “PANE Young Researcher Award” for POSTER presentations and two “PANE Young Researcher Award” for ORAL presentations are awarded to the following participants:

ORAL PRESENTATION

1. Mr. Anshuman Baruah, Department of Physics, Assam University
Title: Wormhole solutions in modified gravity with a Kalb-Ramond Background
2. Ms.L.C.Sonia, Department of Physics, Manipur University
Title: Optical, Magnetic and Spin resonance studies of MFe_2O_4 (M-Mn, Co, Zn) Ferrites

POSTER PRESENTATION

1. **Mr. Shailendra Kumar Mishra, Department of Physics, NIT, Patna**
Title: Study of Structural and optical characterization of sputtered ZrO_2 , ZrO_2 -Pt and ZrO_2 -Pt-Ag doped nanoparticles and their applications in photoluminance and photocatalytic activity
2. **Mr. Partha Kumar Paul, Department of Physics, Tezpur University**
Title: Explaining Dark Matter and Neutrino mass in a $A_4 \otimes Z_8$ flavour symmetry based ν_2 HDM

It has been announced at the valedictory function that papers presented in the Conference can submit their full paper to (1) Materials Today: Proceedings (Elsevier) (2) Book Chapter Publication.

Thus the Conference ended successfully and I thanked the Vice-Chancellor, Manipur University, organizing Committee, keynote speaker, plenary and invited speakers and participants for their support, encouragement and participation in successfully completing the Conference.

Lastly, the organizing team would like to thank all the participants who attended the Conference offline and online in PANE-2022, without whom the Conference won't be successful.

Lastly, we would like to thank the Science and Engineering Research Board (SERB), DST, India, for the sponsorship and support in organizing the Conference.

Physics Academy of North East (PANE) Newsletter



XIII PANE Conference (2022) at Manipur University



Foundation Day Lecture (2022) at Gauhati University



XII PANE Conference (2021) at Tripura University