



## Efficient second-harmonic and terahertz generation from single BiB<sub>3</sub>O<sub>6</sub> crystal using nanosecond and femtosecond lasers

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The paper reports the efficient UV and terahertz generation from a 1.29 mm thick and Type I,  $\theta = 28.9^\circ$  cut BiB<sub>3</sub>O<sub>6</sub> (bismuth triborate, BIBO) crystal using femtosecond and nanosecond laser pulses. We have employed 800 nm wavelength pulses of 50 and 140 fs obtained from a Ti:sapphire laser amplifier and oscillators at 1 kHz and 80 MHz repetition rates, respectively. The conversion efficiency of second-harmonic generation (SHG) was  $\sim 50\%$  while that obtained for terahertz (THz) generations was of the order of  $1.85 \times 10^{-5}\%$ . In addition, LDS-698 dye laser radiation tunable between 650–700 nm was also used as a source for SHG between the 325–350 nm range. The dye laser was pumped by SHG (532 nm) radiation from an electro-optically Q-switched Nd:YAG laser having a pulse repetition rate of 10 Hz and a pulse width of 10 ns. A conversion efficiency of 4.01% was obtained for generation of UV at 343.5 nm. Finally, we have measured the transmission, refractive index, absorbance, and conductivity properties of BIBO crystal in the THz domain. We also ascertained the coherence length, relative permittivity and reflectivity of the crystal. © 2021 Optical Society of America

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### 1. INTRODUCTION

There is a continuous need for growing new nonlinear optical materials with improvised linear and nonlinear optical properties which can cover a wide range of transmission between the deep-UV to far-infrared range. It is possible to generate efficient deep-UV to mid-IR radiation by employing different types of nonlinear frequency conversion processes such as second-harmonic generation (SHG), sum-frequency mixing and difference-frequency mixing (DFM), etc. Some of the well-known nonlinear crystals such as KH<sub>2</sub>PO<sub>4</sub> (KDP), KD\*P,  $\beta$ -BaB<sub>2</sub>O<sub>4</sub> ( $\beta$ -BBO), LiB<sub>3</sub>O<sub>5</sub> (LBO), LAP, KTiOPO<sub>4</sub> (KTP), BNA, DAST, etc., are widely used for making efficient nonlinear devices. In addition, some of the selected inorganic and organic crystals such as BBO, KTP, DAST, BNA, etc., can also be used for the generation of powerful terahertz (THz) radiation using DFM, plasma generated from filamentation of femtosecond laser, and optical rectification techniques [1–6]. Among all the BBOs is the first very promising borate group crystal which has found potential applications in the generation of deep-UV to terahertz radiation due to its excellent optical and nonlinear properties. Bhar *et al.* have reported the best use of the phase-matching condition for efficient deep-UV-vis

radiation using frequency mixing techniques. They have used Q-switched nanosecond pulse in their study and employed sum frequency generation (SFG) and SHG techniques [7–9]. There are many more groups who have used femtosecond pulse for powerful UV generation from BBO crystal using the 800 nm wavelength [10,11]. The same femtosecond laser is also used for THz generation and measurement of refractive indices in the THz domain [12,13].

The BiB<sub>3</sub>O<sub>6</sub> (bismuth triborate, BIBO) crystal was introduced by Hellwig *et al.* in 1998 [14–17]. It is a highly promising negative biaxial nonlinear optical crystal that belongs to monoclinic group C<sub>2</sub> and apart from having a large nonlinear optical coefficient and laser high damage threshold, it is nonhygroscopic as well. It offers an optical transparency between the 160 nm to 2.7  $\mu$ m region. The UV transmission cutoff of BIBO is at much deeper wavelength than BBO and it offers large effective nonlinearity ( $d_{\text{eff}} = 3.2$  pm/V). Its nonlinear coefficient is 3.5–4 times higher than that of LBO and 1.5–2 times higher than that of BBO. These attractive properties have recently been explored to demonstrate the potential of BIBO for efficient SHG using continuous wave [18,19], long pulse, nanosecond, picosecond [20,21], and femtosecond pulsed lasers [22–26]. For example, conversion efficiencies of SHG at 532 nm in the





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Full Length Article

## Tunable and low-threshold random lasing emission in waveguide aided Rhodamine-6G dye incorporated silica embedded thin films

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## ARTICLE INFO

## Keywords:

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Tunable visible light emission

## ABSTRACT

A simple and low-cost approach for producing tunable and low threshold RL emission in the visible region is reported by using a fluorescent laser dye as gain medium and light scattering is achieved in silica nanospheres (SNS) under the pump light of 532 nm, obtained by second harmonic generation of a Q-switched Nd: YAG laser fundamental radiation of 1064 nm wavelength. Depending upon the size ( $a$ ) of the scatterer particles in comparison to the wavelength ( $\lambda$ ) of the pump light, the scattering mechanism can be classified into different categories. However, to demonstrate various RL parameters for scatterer particles residing in Rayleigh scattering ( $a < \lambda$ ) and Geometrical optics regime ( $a > \lambda$ ) in Rh6G dye doped PVA film, we have deliberately synthesized two different sized SNS (notably, 400 nm and 1000 nm). Also, to demonstrate the tuning in the RL emission by enhancement in pump photon density the gain medium has been enclosed within two glass slides. The performances of developed three RL systems, one made with bare film (S1), one cover with one glass slide (S2) and another one in which the gain medium is enclosed between two glass slides (S3) have been compared. It has been demonstrated experimentally that in the developed RL system with 400 nm SNS particles, RL emission in the incoherent regime is obtained. On the other hand, in the case of 1000 nm SNS particles, RL emission in the coherent regime is demonstrated. The tunable random lasing emission covering 585–592 nm wavelength regions with the lowest emission line-width of 4.2 nm and the lowest RL threshold of 1.59 mJ/cm<sup>2</sup> is obtained from the developed RL systems. The demonstrated low cost and simple strategy for the development of tunable RL devices provided here will find novel applications in laser-based imaging, RL based sensing, and other optoelectronic devices.

### 1. Introduction

Thanks to the recent progress in the industrial applications of CW and pulsed laser sources. Although conventional laser sources are proved to be very effective for their various applications in fundamental and applied research fields, but still there exist a lot of challenges [1–6]. Therefore, there is a recent surge in the development of laser sources and particularly a lot of impetus has been given in the development of random lasers (RLs) by employing various luminescent materials as gain media [1–4]. However, unlike conventional laser sources, which include (i) a pump source, (ii) a gain medium, and (iii) optical resonators, RLs use a different approach for its operation. Random scattering of light provided by jumbled nano/microstructures present inside a gain medium offers a substitution of optical cavity to achieve lasing [2–6]. The generation of light in RLs mainly relies on several factors, like

geometrical configurations, optical properties of gain/scattering media, structural distinctions of the scattering particles etc. However, enclosing the whole random medium into a waveguide feedback configuration gives additional degrees of freedom to simultaneously tune the emission regimes along with decreasing the lasing threshold through various approaches, such as through pump volume amplification techniques, increasing the pump photon density via wave guiding, changing the cavity length ( $l_c$ ), or by changing scattering strength [3–8]. Further, the optical feedback mainly depends on the scattering mean free path ( $l_{sc}$ ) and transport mean free path ( $l_t$ ) of a randomized system. Any change in  $l_{sc}$  may also cause the transition of RL emission from incoherent to coherent regime and vice versa [5–9]. However, three distinct scattering regimes can be defined [7], as given below, depending upon the size of the nanoparticles/microparticles used as scatterer particles in RL systems.

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# Emission peak shifted incoherent random laser through the combined effects of coupling of surface plasmons in a triangular shaped silver nanostructure, microbubbles, and the waveguiding mechanism

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The random laser (RL) is now becoming an essential tool for various photonics applications, and a plethora of research advancements in RL coupled with developments in the field of techniques of syntheses of various nanostructured materials is taking place. But the realization of tuning the peak emission wavelength of RL is still very challenging. However, in this report we have demonstrated an emission peak shifted tunable low threshold incoherent RL in the visible region in a gain medium of a commercially available dye laser material and by employing the rarely used scatterer materials of triangular silver nanoparticles (TSN), microbubbles, and the waveguiding mechanism. The scattering properties of trapped microbubbles, along with the localized surface plasmon resonance property of TSN of appropriate concentration within waveguided thin films composed of glass substrates, have been methodically investigated to demonstrate the reduction in lasing threshold and tunability in the peak emission wavelength. A two-fold reduction in RL threshold by addition of TSN in the disordered system, along with a considerable narrowing down of the emission spectra to a few nanometers, are obtained. Furthermore, the peak emission wavelength shift of 6 nm is reported by suitably changing the system configuration by the addition of an optimum concentration of TSN along with trapped microbubbles. The as-developed system shows high-quality laser performance with the maximum value of  $\eta = 0.64$ , a quantity describing the ratio of the number of stimulated radiative photons within RL and the total number of emissive photons. We propose that the total internal reflections from the microbubble surface, along with plasmonic enhancement and scattering from the TSN, mediate the waveguided RL to achieve the low threshold. Therefore, this report is an early step towards demonstrating efficient RL in a ternary scattering system. Many more avenues for investigating this developing research issue may be helpful for the future development of affordable and robust optoelectronic devices. © 2023 Optica Publishing Group

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## 1. INTRODUCTION

The fascinating realm of random lasers (RLs), also designated as “mirror-less lasers,” has inspired remarkable curiosity in the scientific community, leading to deep dives into the novel territory of the interaction of light with matter having randomness [1,2]. Since the first theoretical prediction given by Letokhov [3], random lasing action has been investigated in varieties of physical arrangements, gain media, and scatterer particles. Lasing action in a random medium is generally achieved by significantly expanding the trajectory of the light inside a volume, and amplification occurs due to multiple scattering, raising

the gain length  $l_g$  ( $l_g$  is defined as the length over which the intensity of light is amplified by a factor  $e$ ), owing to which the gain surpasses the overall loss in the system [4]. In contrary to conventional lasers, in RLs, strong light scattering by random scatterers present within the gain medium could improve the confinement of light that may result in the development of closed optical loops within the gain medium that are inherent to coherent RLs [5]. On the other hand, while light gets scattered multiple times by the scatterers placed within the gain medium, some selected modes may obtain a higher dwell time within the medium. Consequently, they can sustain over longer scattering

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## Research Article

# Employment of nonlinear optical properties of GO/Ag nanocomposite scatterer materials for achieving random lasing in the visible region in the gain medium of a commercially available dye

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## ABSTRACT

Graphene oxide (GO) and silver nanoparticles (AgNPs) are recently been widely employed in various sectors including in photonics applications due to their fascinating properties. On the other hand, huge interests are shown by the researchers for development of scatterer materials for achieving random laser (RL) with improved performances. In this work, the GO/Ag nanocomposite material comprising of GO nanosheets and AgNPs have been prepared and its remarkable nonlinear optical (NLO) properties are employed for the first time to demonstrate RL in the visible region by the introduction of disorder and multiple scattering within the amplifying medium of Rhodamine-B dye. Interestingly by changing the cuvette path lengths, here we have shown that the gain volume within the amplifying media can be varied effectively, which directly influence the lasing threshold. The larger value of NLO coefficients in GO/Ag scatterer induced greater refractive index contrast ( $\Delta n$ ) between the scatterer and surrounding medium and thus enhances the light-matter interactions in the GO/Ag nanocomposite and consequently the lasing threshold for RL generation is reduced significantly by 50 % than that of bare GO as scattering center. This report opens an exciting prospect of using NLO properties of GO/Ag nanocomposite for achieving enhanced scattering in different gain media for demonstration of low threshold RL, which may revolutionize the future development of RLs.

## 1. Introduction

In recent decades, the field of photonics has witnessed a remarkable advancement, with a growing emphasis on the development of novel light sources and laser technologies. Among these developments, the phenomenon of random lasing has emerged as a captivating and promising area of research [1]. In random lasers (RLs), amplification of light is provided from multiple scattering events within the disordered configuration of dye and scattering medium [2]. Since, the theoretical prediction by Letokhov in 1967 [3], RLs have gained considerable attention in the scientific community. After the first experimental demonstration of coherent RL in ZnO [4], rigorous theoretical and experimental investigations on RLs have been carried out in different gain media [5–9]. The intrinsic properties of RL, such as low threshold, robustness against external perturbations, and potential for compact and versatile designs for chip-scale optoelectronic devices, have picked up the interest of researchers of inter-disciplines. Most importantly, the

efficacy of RL depends on various nanostructures present within the disordered media. In this regard, scattering centers present within an active media is significant in determining its RL characteristics such as the lasing threshold, modal characteristics etc. Particularly, the size, geometrical shape, concentration of scatterers within the gain medium greatly impacts its emission characteristics. In recent years, there has been a growing demand of employing discrete categories of nano/micro-structures in gain media. Particularly, these scattering media including metal [10], semiconductor [11], metal organic framework [12], biological structures [13,14], liquid crystals [15], external feedbacks [16,17], micro-bubbles [18] etc., which have been extensively employed for generation of coherent [19] or white [20] RL emission, however with some drawbacks. Interestingly, the intrinsic nonlinearity in two-dimensional (2D) materials enables the manipulation of gain and absorption profiles, which plays a pivotal role in controlling the threshold for RLs. These 2D materials can be tailored to exhibit tunable and highly efficient nonlinear responses, affecting the

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**MEMORANDUM OF UNDERSTANDING**

This Memorandum of Understanding is made on this the .....<sup>17<sup>th</sup></sup> day of .....<sup>March</sup>..... 2011 between **Oil and Natural Gas Corporation Limited (ONGC)**, a company registered under the Companies Act 1956, having its registered office at Jeevan Bharti Building, Tower-II, 124 Indira Chowk, New Delhi-110001 and one of its offices at Dehradun (herein after referred to as ONGC which expression shall unless repugnant to the context include its representatives, successors and permitted assignees) of the **FIRST PART** and

Burdwan University Burdwan established under / registered under West Bengal, 1959 Act, having its office at Burdwan, West Bengal (hereinafter referred to as Burdwan University which expression shall unless repugnant to the context include its representatives and successors and permitted assignees) of the **SECOND PART**.

**Whereas** the Burdwan University has been established for the purposes, among others, for imparting education in Science, Arts, and the learned professions and of furthering advancement of learning and original research.

**And Whereas** ONGC is engaged in the business of hydrocarbons exploration and exploitation and has decided to institute ONGC Scholarships in Burdwan University.

**Now Therefore** in consideration of the mutual covenants set out in this MoU, the parties hereby agree on the terms and conditions details hereunder:

**1. OBJECTIVE:**

To strengthen industry-academia linkage by instituting ONGC Scholarships in Burdwan University for rewarding, encouraging and assisting meritorious students for higher studies in the petroleum upstream related education.

**2. RESPONSIBILITIES AND COMMITMENTS:**

In the spirit and context of the purpose of this MOU the parties agree to assist each other, to be committed to professional excellence, to communicate on a regular basis and to encourage open dialogue and cooperation between ONGC and Burdwan University.

**3. SCHOLARSHIP**

i) There will be two scholarships in Burdwan University.

ii) These scholarships will be called "ONGC Scholarships" and the scholarship holders will be called as "ONGC Scholars".



iii) The department / course and degree for which ONGC Scholarships will be instituted are presented in following table:

Sl. No.	Department / Course	Degree
1	Chemistry	M.Sc
2	Physics	M.Sc.

iv) The criteria for selection of student for award of ONGC Scholarship, the scholarship amount and scholarship duration will be as follows:

Sl. No.	Degree	Year in which scholarship will be given	Qualifying criteria	Scholarship Amount (Rs per month)	Scholarship Duration
1	M.Sc.	Second Year	First rank in M.Sc. First Year	5000	1Year

#### **4. OBLIGATION OF BURDWAN UNIVERSITY BURDWAN:**

- i) The Burdwan University will select the student for award of ONGC Scholarship as per the criteria detailed in 3.iv) above.
- ii) The Burdwan University after the selection of student for ONGC Scholarship will intimate Head ONGC Academy, Kaulagarh Road, Dehradun through a written report giving detail of the student selected. Biodata and photograph of the selected student will also be enclosed with the report.
- iii) The Burdwan University will send a written demand note to Head, ONGC Academy, Kaulagarh Road, Dehradun for release of the fund for two ONGC Scholarships in an academic year for disbursement to the ONGC Scholars.
- iv) The Burdwan University will receive the fund for ONGC Scholarships from ONGC and will disburse the same to the ONGC Scholars regularly.
- v) The Burdwan University will submit the ONGC Scholarship fund utilization report in respect of an academic year to Head, ONGC Academy, 9, Kaulagarh Road, Dehradun confirming that the ONGC Scholar has received the entire ONGC Scholarship amount due to him, before requesting for release of fund for the next academic year.



## **5. OBLIGATION OF ONGC:**

- i). ONGC will award two ONGC Scholarships in the Burdwan University as detailed below:

Sl. No.	Department / Course	Degree
1	Chemistry	M.Sc
2	Physics	M.Sc.

- ii) ONGC will release the total fund for two ONGC Scholarships (scholarship at a rate of Rs. 5000 per month) in respect of an academic year after receiving the ONGC Scholar selection report and a written demand note from the Registrar of Burdwan University to Head, ONGC Academy, 9, Kaulagarh Road, Dehradun for release of the total fund for ONGC Scholarships.

## **6. VALIDITY OF MOU:**

This MOU is effective from the academic year 2011-12. The ONGC reserves the right to terminate this MOU at any point of time.

## **7. DISPUTE RESOLUTION:**

In the event of any dispute or difference between the parties hereto, such dispute or difference shall be resolved amicably by mutual consultation or through the good offices of Head ONGC Academy. In case such resolution is not possible, then the unresolved dispute or difference shall be referred to a committee consisting of two members each from ONGC and the Burdwan University with Director (HR) of ONGC as its head, the decision of the committee shall be binding upon both the parties. Provided, however, any party aggrieved by such decision may make a further reference for setting aside or revision of the decision to the CMD of ONGC whose decision shall bind the parties finally and conclusively.

## **8. APPLICABLE LAW AND JURISDICTION:**

All question disputes or differences arising under out of or in connection with the MOU shall be governed by Indian Laws, both procedural and substantive and shall be subject to exclusive jurisdiction of Courts at Dehradun.

## **9. AMENDMENT:**

This MOU may be amended in writing with the mutual consent of both parties.



# 10. OPERATION, CONDUCT AND IMPLEMENTATION:

Burdwan University and ONGC agree to nominate specific personnel for operational, conduct and implementation of this MOU.

- a. Head ONGC Academy, ONGC shall be the sole operator on behalf of ONGC.

Address :Head ONGC Academy,  
KDMIPE Campus, 9, Kaulagarh Road, Dehradun-248195  
Phone No. : 0135-2754283  
Fax No. : 0135-2758832

- b. Registrar, Burdwan University shall be the sole operator on behalf of the Burdwan University.

Address :Registrar,  
Burdwan University, Burdwan, West Bengal  
Phone No. :  
Fax No. :

The document signed by both the parties constitutes the entire understanding between ONGC and the Burdwan University, Burdwan.

In witness whereof, the parties to this MOU through their authorized representatives have affixed their signatures on this MOU on the day and year first hereinabove mentioned.

Signed: [Signature]

On behalf of Burdwan University Burdwan

Name: SHOROSIMOHAN DAN

Registrar Burdwan University Burdwan  
REGISTRAR (Addl. Charge)  
UNIVERSITY OF BURDWAN  
BURDWAN-713104

Date: 17.3.2011

Place: Burdwan

Witness: Souvanshu Mukhopadhyay  
17.03.2011

Signed: [Signature] 17/03/2011

On behalf of ONGC

Name: DR. TARUN CHAKRABORTI

Head ONGC Academy, Dehradun

Date: 17.03.2011

Place: BURDWAN

Witness: [Signature] 17-3-2011.

( PROF. MANAS BANERJEE )

[9434252709]



Head of  
The Department of Physics  
UNIVERSITY OF BURDWAN

[Signature]  
(PABITRA CHATTOPADHYAY)  
HOD, Chemistry  
The University of Burdwan





SL NO. 03



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MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE

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फाइलसंख्या / File No.: BSI- 295/1 (Misc.)/2025-Tech. /1209

Date: 25<sup>th</sup> June, 2025

### TO WHOM IT MAY CONCERN

This is to certify that Botanical Survey of India, Ministry of Environment, Forest and Climate Change, Govt. of India, is having a Memorandum of Understanding (MoU) with the Department of Botany, The University of Burdwan, since 2014 toward scientific and Academic collaboration. As per the term and condition of the MoU, currently both the Organizations are in the process of renewing the MoU with renewed objectives. It is also to certify that, during the period of 2019 to till date, both BSI and The Department of Botany pursued activities which establishes strong linkages and collaboration between the two institutes

1. Scientists of BSI registered their research students for Ph. D in Botany under the University of Burdwan.
2. Conducted several collaborative research works and produced Ph.Ds
3. Shared research facilities for research.
4. Shared Herbarium facilities.
5. Faculty of University of Burdwan worked as expert member for recruitment of research personnel.
6. Organized jointly Botanical Science Congress in March 2024.

The faculty members from the University of Burdwan who have made a strong linkages and collaboration with BSI are Prof. Soumen Bhattacharjee (Coordinator, UGC Center for Advanced Study), Dr. Asok Ghosh etc.

The Scientists of BSI, who have made a strong linkages and collaboration with the Department of Botany, The university of Burdwan are Dr S.S. Dash (Scientist F & Additional Director, BSI), Dr. Tapan Sil (Scientist E), Late Dr. B. K. Sinha (Scientist F), Dr Avishek Bhattacharjee (Scientist E) etc.

Hope in future we will carry forward our close association for academic and research.

  
25/6/2025

(एस. एस. दाश / S. S. Dash)

वैज्ञानिक एफ / Scientist 'F'

(प्रभारी, तकनीकी अनुभाग / In-charge, Tech. Section)



**MEMORANDUM OF UNDERSTANDING (MOU) BETWEEN  
THE UNIVERSITY OF BURDWAN, WEST BENGAL AND  
BOTANICAL SURVEY OF INDIA (BSI) [A NATIONAL BODY  
SETUP IN 1890 TO SURVEY THE COUNTRY FOR ITS  
BOTANICAL RESOURCES WITH HEADQUARTER AT CGO  
COMPLEX, 3<sup>RD</sup> MSO BUILDING, BLOCK-F, SECTOR-I,  
SALT LAKE CITY, KOLKATA-64]**

Botanical Survey of India, the nodal research organization supported by Ministry of Environment and Forests, always plays a significant role in fulfilling nation's commitment to various International conventions like Convention on Biological Diversity (CBD), Convention on International trade in International Endangered species of wild Flora and Fauna (CITES), etc. It has ample expertise in exploring, identifying, creating inventories and documenting the rich diversity of plant resources of the country with particular reference to protected areas and fragile ecosystems. Its activities also include identification of endemic, endangered and threatened species, conservation of threatened taxa, collection and identification of ethnobotanically important plant resources, etc.

The University of Burdwan sincerely sought the collaboration of BSI so that both the organizations can enter into an understanding in protecting the fragile microcosm of unique biodiversity glorifying the Golapbag campus of the University and adding value to the existing knowledge base, teaching and research activities involving the Department of Botany in the process.

The Department of Botany of the University of Burdwan, established in 1964 under the leadership of the eminent teacher and



scientist, Prof. P. N. Bhaduri, Ph. D (London), is one of the pioneer institutes of Plant Science with apt reputation in both teaching and research. Since then the department has successfully completed DSA phase I, II, III and COSIST. In fact, it is the first Department of this University which was considered as a Centre for Advanced Study (CAS) by the UGC in the year 2007 and presently department is in the second year of phase II of CAS scheme. As a mark of record of excellent research, members of the faculty of this Department have published more than 1600 research papers in various peer reviewed journals of national and international repute. More than 200 research students have been admitted to PhD degree under the guidance of faculty members of this department. Apart from teaching, the department is trying to strengthen R & D linkage with different Scientific Institutions with the objective to enhance collaborative research work and develop knowledge base with non commercial application.

So, for fulfilling the objective as stated the authorities of both the organizations decided to collaborate in the following issues for mutual benevolence in matters of phytodiversity conservation and development of research and academic activities based thereupon.

1. Acharya Jagadish Chandra Bose Indian Botanic Garden, BSI will help in preparing a proposal by the Botany Department, University of Burdwan for inclusion of the Golapbag campus of the University as 'Protected Site' by the state government for conservation of its plant diversity in the



greater interest of the society since this area together with Ramnabagan Wildlife Sanctuary which constitutes a green patch in the periurban area to sustain a wide diversity of fauna and abate pollution to optimize the environment of Bardhaman city has been experiencing threats of biodiversity impoverishment especially of the rare species. Moreover aesthetic attributes of the campus emanating from variation in microhabitats (terrestrial, semiaquatic and aquatic), occupancy by both indigenous and exotic species of trees, herbs, shrubs and vines, ornamentals and the faunal diversity especially of birds (migratory waterfowls sustained by the wide variety of aquatic plants) is highly praiseworthy deserving periodic surveillance for protection.

2. BSI will help the Department of Botany, University of Burdwan to develop its existing herbarium and enrich with digital images of plant specimens especially from Type section of Central National Herbarium (CAL), and provide other related infrastructural facilities. For developing the existing departmental Herbarium, its integration with the activities of BSI is deemed essential.
3. BSI will help the Department of Botany, University of Burdwan for developing a Botanic garden in Golapbag campus of the University, where BSI will take active role in sharing its expertise to develop the garden.
4. BSI shall train the technical staff and research scholars of the University for Taxonomic Documentation.



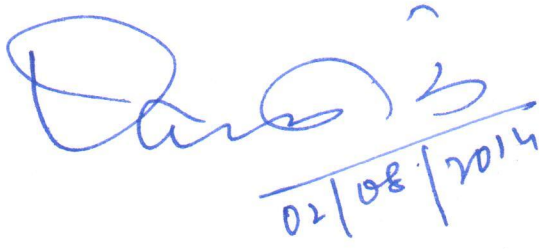
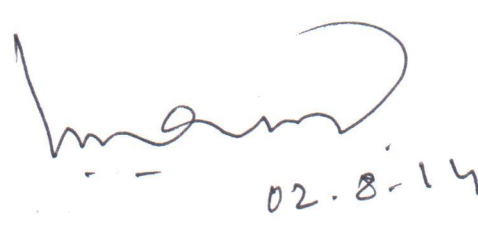
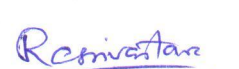
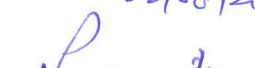




5. BSI will organize trainings, workshops on collection, processing of specimens, their preservation etc.
6. Both BSI and the Department of Botany, University of Burdwan, West Bengal can exchange plant specimens, especially of the Flora of West Bengal.
7. Both the BSI and Department of Botany, University of Burdwan, West Bengal can be involved in faculty exchange programme.
8. BSI will facilitate and sponsor research in some common thrust areas where faculties and scientists from both the Institutes can work in collaborative projects.

In its turn, the University of Burdwan will contribute through its Botany Department in the following issues:

1. University will recognize the BSI scientist as research guide and will recognize BSI as a research organization for Ph. D. programme as per the existing statutory norms of the University of Burdwan.
2. Department of Botany will collect medicinal plants from the district and the adjoining areas where the local healers use them for therapeutic purpose and share the same along with the data-base of ethnomedicinal plants (which are not the part of any codified, classical traditional Indian medicinal system) with BSI.
3. Department will also submit the proposals to DST, Govt. of West Bengal and other Central agencies for getting appropriate funding in order to carry out the assigned responsibilities to be undertaken by the organization.
4. Department shall donate the duplicate herbarium specimens for preservation in CAL and other herbaria of BSI.
5. Department will assist in carrying out advanced biochemical and molecular characterization of plant specimens.



6. University will give priority access to BSI scientists for availing University Science Instrumentation Centre (USIC) facilities
7. University and Department in particular shall simultaneously identify its own Taxonomists and the Taxonomists of its affiliated Colleges for identifying plants and submitting authenticated samples.
8. Any other academic responsibility which may be assigned to the Department based on its expertise, available resources and feasibility for mutual benefit shall be discharged as far as practicable.

 02/08/2014	 02.8.14.
<b>DIRECTOR BOTANICAL SURVEY OF INDIA</b>	<b>VICE-CHANCELLOR UNIVERSITY OF BURDWAN</b>
<b>Witness:</b>  02/08/2014  02/08/14  2/8/2014	<b>Witness:</b>  02.08.14  02.08.14.  2/8/14



**SI. NO. 04**

**Memorandum of Understanding**

**For**

**IRNSS Navigation Receiver Field Trial and Data Collection**

**Between**

**Space Applications Centre  
Indian Space Research Organization  
Department of Space, Government of India  
Ahmedabad - 380015**

**And**

**THE UNIVERSITY OF BURDWAN  
RAJBATI, BURDWAN, WEST BENGAL, 713104**







This MOU is entered into on 7<sup>th</sup> day of December, 2015

BETWEEN

Space Applications Centre, Jodhpur Tekra, Ambawadi Vistar P.O., Ahmedabad, 380015, a centre of Indian Space Research Organization, Department of Space, Government Of India (hereinafter called "SAC" which expression shall where the context so admits include its successors and permitted assignees) of the one part,

AND

THE UNIVERSITY OF BURDWAN, RAJBATI, BURDWAN, WEST BENGAL, 713104

### 1.0 Preamble:

Whereas, Space Applications Centre (hereinafter referred to as "SAC" which expression shall where the context so admits include its successors and permitted assignees) of the one part and "THE UNIVERSITY OF BURDWAN" (hereinafter referred to as "BU" which expression shall where the context so admits include its successors and permitted assignees) of the one part BU, both are parties to this MoU;

Whereas, SAC is involved in design and development of space-borne instruments for ISRO missions and development and operationalization of applications of space technology for national development. The applications cover communication, broadcasting, navigation, disaster monitoring, meteorology, oceanography, environment monitoring and natural resources survey. SAC designs and develops all the transponders for the INSAT and GSAT series of communication satellites and the optical and microwave sensors for IRS series of remote sensing satellites, Navigation payloads for IRNSS and GAGAN programme. Further, SAC develops the ground transmit/receive systems (earth stations/ ground terminals) and data/image processing systems;

Whereas, The University of Burdwan is a leading University in West Bengal engaged in teaching and research in different fields of knowledge and learning. One of the fields of training and research of the University is use of space based technologies and satellite based navigation systems (GNSS, hereinafter). The University has a GNSS laboratory used for training and research purposes and is willing to extend the activities using IRNSS and GAGAN.







**2.0 Effective Date and Duration of MoU:** This MoU is effective from the date of its signing and is valid for a duration 2 (Two) years from the date of signing. It may be extended further in writing based on mutual consent.

### **3.0 Scope of MoU:**

Scope of the MoU involves Site identification, site preparation, and Installation of the IRNSS receiver. IRNSS Navigation Data collection and analysis to be carried out on regular basis for verification and for other mutually agreed topics of research for both parties. Depending upon the requirement certain scientific experiments can be planned and executed within overall MoU umbrella. With mutual consent, both the Parties can extend the period of data collection and observation locations (sites).

### **4.0 Methodology:**

4.1 Suitable Site Selection

4.2 Installation and commissioning of IRNSS Receiver

4.3 Continuous IRNSS and GPS data logging, analysis of the data

4.4 Transmission of IRNSS and GPS data to SAC as and when demanded by SAC  
Data transmission mechanism can be mutually worked out.

### **5.0 Deliverables:**

5.1 SAC deliverables { i, ii & iii through ACCORD Software & Systems Pvt. Ltd }

- i. IRNSS receiver and data processing systems as detailed in Annexure-1.  
(Delivery @ site)
- ii. Number of receiver units allocated as per SAC receiver Allocation committee's recommendation in view of your response to EOI for IRNSS Receiver deployment
- iii. User and operations manual (Delivery @ site)
- iv. Format for Quarterly (Every Three months) status report

5.2 BU deliverables

- i. All necessary logistics so that IRNSS Receiver shall be established to collect positional data in raw and RINEX format received from IRNSS, GPS constellation with 1 sec update rate
- ii. Send a Quarterly status Report on usage/performance of receiver to SAC in a prescribed format.
- iii. Send the Receiver data to SAC as and when asked for



## **6.0 Guidelines on Receiver / Data Usage:**

The data is to be used strictly for internal research purpose only. The Receiver is for experimentation and field trial only and should not be used for any operational purpose. IRNSS constellation is evolving and has not been declared operational for Position Navigation and Time. So the results/performance of IRNSS should be viewed in that context.

## **7.0 Responsibility of Each Party:**

SAC and BU shall jointly work towards IRNSS system verification using data collected from IRNSS receivers. In addition, following are the specific responsibilities.

### **7.1 BU:**

- 7.1.1 All the logistics support, site identification, site preparation, required for setting up of IRNSS Receiver will be provided by BU.
- 7.1.2 Installation of the IRNSS Receiver at the site will be carried out by ACCORD SYSTEMS
- 7.1.3 Utmost care to be taken in handling the IRNSS Receiver.
- 7.1.4 Send the Receiver Data to SAC when asked for
- 7.1.5 Safety and security of the IRNSS Receiver
- 7.1.6 IRNSS data reception, processing, archival to be done by BU.

### **7.2 SAC:**

- 7.2.1 SAC will provide IRNSS Receiver Unit(s) and Receiver operation manual(s) on returnable basis (As detailed in Annexure-1)
- 7.2.2 SAC will provide technical assistance to BU in working out modalities of
  - Data collection, data sharing, etc.
- 7.2.3 SAC will provide technical assistance to BU in proper operation and maintenance of IRNSS Receiver
- 7.2.4 SAC will provide technical assistance to BU in identifying appropriate research areas considering capabilities of this Receiver

## **8.0 Project schedule:**

- 8.1 Selection of Suitable Site(s) within 10 days from the date of signing MoU by BU
- 8.2 Installation and Commissioning of IRNSS Receiver by M/S ACCORD.

8.3 Regular data collection and analysis will be carried out for the duration of the MoU from the date of Installation and Commissioning of IRNSS Receiver

### 9.0 Training:

M/S ACCORD will provide necessary training and guidelines for site identification, receiver operations. SAC will provide guidelines for data collection, processing and data transfer

### 10.0 Project Monitoring:

- 10.1 SAC and BU shall identify focal person(s) who shall be responsible for organizational matters and interfacing for day to day operation, such as functioning of IRNSS Receiver, security etc. Each party shall pursue its independent research using data from these IRNSS Receiver, with mutual consultation.
- 10.2 A periodic Quarterly status report should be generated by BU regarding Receiver operations. A User meet to share results, experience will be held at SAC every six months.

### 11.0 Functionaries

1. Dr Anindya BOSE, Scientific Officer (Selection Grade), (BU Focal Persons)  
Department of Physics, The University of Burdwan, Golapbag, Burdwan 713 104
2. Dr Joydeep Chakravorty, Scientific Officer (Sr Scale)  
Department of Physics, The University of Burdwan, Golapbag, Burdwan 713 104
1. ATUL P. SHUKLA, Group Head, DCTG/SNAA, (SAC Focal persons)
2. YAGNESH R. PATEL, Sci/Engr-SF, SNTD/DCTG

### 12.0 Confidentiality:

- 12.1 During the tenure of MoU and thereafter both parties undertake on their behalf and on behalf of their employees/representatives to maintain strict confidentiality and prevent disclosure thereof of all the information and data exchanged/generated pertaining to this agreement. However, the data may be published and shared jointly for scientific publication after mutual consent in writing.
- 12.2 BU will not disclose any research result and Foreground information, generated out of or involving the data, its derivative or information thereof from the IRNSS



Receiver established (at given site) as per terms of this MoU to any third party without seeking prior written permission.

### **13.0 Intellectual Property Rights :**

All the research results and foreground information as well as foreground Intellectual Property Rights, generated out of or involving the data, its derivative or information thereof, from IRNSS Receiver and sites established as per terms of this MoU whether or not legally protected, shall be owned by SAC. BU will be free to use such data for their internal R&D purposes with intimation to SAC.

Notwithstanding any provisions mentioned above or any future licensing agreements, SAC shall be deemed to have all rights including non-exclusive, irrecoverable and royalty-free license for the unlimited development and use of any and all Foreground information and Foreground Intellectual Property Rights, generated out of or involving the data, its derivative or information thereof, from the IRNSS Receiver established (at given site) as per terms of this MoU, whether or not legally protected, for the purposes of its own applications.

### **14.0 Change In Scope of Work:**

Any change in scope of work would be with mutual consent of both the parties in writing.

### **15.0 Modifications to MoU:**

- 15.1 Any amendment or modifications of this MOU shall be in writing by both parties.
- 15.2 The modifications/changes shall be effective from the date on which they are made/ executed, unless otherwise agreed to.

### **16.0 Force Majeure:**

Neither party shall be held responsible for non-fulfillment of their respective obligation under this MoU due to circumstances beyond their control but not limited to war, flood, cyclones, riots, strikes etc. If such condition continues beyond six months, the parties shall then mutually decide about the future course of action. Either party shall intimate each other of any such event.

### **17.0 Indemnity:**

BU shall exercise reasonable skill, care and diligence in the performance of this MoU activity and indemnify and keep indemnified SAC in respect of any loss, damage or claim howsoever arising out of related to breach of MoU, statutory duty or negligence by BU or

its employees, agents or subcontractors in relation to the performance or otherwise of the services to be provided under this MoU.

## 18.0 Termination of MoU:

18.1 During the validity of the MoU, if it is found that if the IRNSS system is not in use, misuse or due care is not taken, SAC has right to dismantle/uninstall the IRNSS Receiver established as per terms of this MoU with intimation to BU.

18.2 Similarly if BU considers it necessary to dismantle the IRNSS Receiver established as per terms of this MoU for unavoidable reason at a given site, BU will try to provide an alternate site for the IRNSS observations and facilitate SAC to relocate IRNSS Receiver. If however, BU fails in providing such alternate, SAC will be free to dismantle/uninstall and remove the IRNSS Receiver established as per terms of this MoU along with accessories.

## 19.0 Arbitration:

In the event of any dispute or difference between the parties hereto, such disputes or differences shall be resolved amicably jointly by Director, SAC and Registrar, BU

## 20.0 Jurisdiction: Ahmedabad shall be the jurisdiction.

In witness whereof, the parties hereto have signed this MOU on the

Tapan H. Misra  
7/12/15

(Shri TAPAN MISRA)

Director,

Space Applications Centre (SAC),

Ahmedabad

तपन मिश्रा / TAPAN MISRA

निदेशक / Director

अंतरिक्ष उपयोग केंद्र (इसरो)

Space Applications Centre (ISRO)

भारत सरकार / Government of India

अहमदाबाद / Ahmedabad-380 016.

(Dr D K Panja)

Registrar,

The University of Burdwan

Burdwan

REGISTRAR

THE UNIVERSITY OF BURDWAN

BURDWAN-713104



APC

Anindya Bose  
(DR ANINDYA BOSE)

APC



## Annexure-1

### List of deliverables for (1 set of) IRNSS/GPS/SBAS Receiver

Sl. No.	Item Description	Qty
1.	IRNSS/GPS/SBAS Receiver	1
2.	AC-DC Adapter	1
3.	DC-DC Adapter	1
4.	Antenna	1
5.	Antenna base plate	1
6.	Antenna mounting rod	1
7.	Battery	1
8.	Charger for battery	1
9.	TNC (M) to TNC (M), 15 m low-loss RF cable	1
10.	TNC (M) to TNC (M), 2 m low-loss RF cable	1
11.	SMA (M) to SMA (M), 2 m RF cable	2
12.	Cat5E Ethernet cable	1
13.	RS232-USB converter cable	1
14.	DC-DC adapter input cable	1
15.	DC-DC adapter output cable	1
16.	Battery to receiver power cable	1
17.	Car Cigarette connector to receiver power cable	1
18.	3 Pin AC power cable for charger	1
19.	User Guide	1
20.	CD containing GUI & other drivers	1
21.	M4 Allen key	1
22.	Adjustable Spanner	1
23.	M4 Allen screws with nuts for receiver	4
24.	M4 Allen screws with nuts for DC-DC adapter	4
25.	M4 Allen screws with nuts for antenna	4
26.	Carry Case	1



भा.कृ.अनु.प.-केन्द्रीय आलू अनुसंधान संस्थान  
शिमला-171001 (हि.प्र.)  
ICAR - CENTRAL POTATO RESEARCH INSTITUTE  
Shimla-171 001, HP (India)



No.F.ST/18-1/2015

Dated: 22<sup>nd</sup> February, 2016

To

Spud Post

Dr. Jai Prakash Keshri,  
Professor & Incharge, CRSFM,  
Coordinator, DBT, HRD Programme,  
Centre of Advanced Studies in Botany,  
The University of Burdwan,  
Burdwan 713 104 (WB)

**SL.NO.-05**

FAX: 91-0342-2556260/64452, e-mail keshrijp@gmail.com, keshri\_jp@yahoo.com

Subject: Allotment of breeder seed- regarding.

Sir,

This has reference to your letter dated 01 February, 2016 addressed to Director, ICAR-CPRI Shimla. In this regard please find enclosed herewith Xerox copy of MoU for your record. It is to inform you that the Director, CPRI, Shimla has allotted 15 qtls of breeder seed of Kufri Jyoti from CPRS, Jalandhar. You may contact Head, CPRS, Jalandhar (Mob no.- 9465820837) for further necessary information.

Yours faithfully,

(Sanjeev Sharma)

Acting Head, Division of Seed Technology

Encl.: As above.

Copy to: The Head, CPRS, Post Bag No.1, Model Town, Jalandhar, (Punjab) (Mob no.- 9465820837) for information please.

Telephones: EPABX: 2624830, 2625182, 2625074, 2625073, 2621480, 2625181, 2624575, 2624501; Fax: 0177-2624460; e-mail: [headseedcpri@gmail.com](mailto:headseedcpri@gmail.com) Website: <http://cpri.ernet.in>





पश्चिमबङ्ग पश्चिम बंगाल WEST BENGAL

U 455344

*Jai Prakash Keshri*  
In-Charge  
CRSP SEEDS & AND SEED  
MULTIPLICATION FARM  
KODWAR UNIVERSITY  
TALABAG 11 BUDWAN

MEMORANDUM OF AGREEMENT  
BETWEEN  
THE INDIAN COUNCIL OF AGRICULTURAL RESEARCH  
AND  
PRIVATE SEED PRODUCERS  
FOR  
ENHANCEMENT OF SEED PRODUCTION CHAIN OF POTATO IN THE COUNTRY

1. This MOU signed on 24/9/2015 2015 between the Indian Council of Agricultural Research (ICAR), Krishi Bhawan, New Delhi, a society registered under the Societies Registration Act, 1860 and to be implement at Central Potato Research Institute, Shimla (through its Director) hereinafter referred to as 'CPRI' which is an institute of ICAR in the first instance and M/s Crop Research & seed Multiplication Farm here in after referred as CRSMF a firm engaged in potato seed production.

2. Whereas the ICAR is charged with the responsibility to undertake, aid, promote and coordinate Agricultural and Animal Husbandry education and research and its application in practice, and to do things as it may consider necessary incidental and conducive to the attainment of these objectives while the CPRI, Shimla is an apex level national institution charged with the responsibility to undertake research and development in all aspects of potato cultivation including production of nucleus and breeder seed of potato through conventional and high-tech system at five various regional stations/centres situated in different states in India.
3. And whereas M/s (CRSMF, The University of Burdwan, PO-Rajbati, Burdwan-713104, West Bengal) owns minimum of 15 acre land and is engaged in production of potato seed for the past three years and maintains farms in good condition with all necessary infrastructure where large scale multiplication of breeder seed in subsequent two/three stages i.e. Foundation Seed-I (FS-I), Foundation Seed-II (FS-II) and Certified Seed (CS) is to be undertaken.
4. And whereas in the case of cooperatives (societies), it should have a minimum core strength of 25 members. In case of NGOs it should be a registered NGO, having clear cut mandated activities related to Agriculture Sector. Besides it should own a minimum of 15 acre land for undertaking seed production in three clonal cycles.
5. And whereas the CPRI and Private Seed Organization/Progressive Potato Growers/NGOs/Cooperative Society inspired by their common objectives of promoting alternate seed production chain for potato to maximize the availability of certified/quality seed in the country have decided to enter into this agreement.
6. And whereas M/s CRSMF is desirous of collaborating with CPRI in potato seed multiplication in three clonal cycles viz. foundation seed-I (FS-I), foundation seed-II (FS-II) and certified seed (CS) with a view to enhance availability of potato quality seed to the potato cultivators of the country.
7. And whereas M/s CRSMF will undertake all activities/steps that are required for production of FS-1, FS-2 and certified seed as per seed certification standard CPRI will not be responsible for any lapse on their part leading to rejection by the seed certification agency.
8. And whereas M/s CRSMF will ascertain quality of the seed at CPRI premises at the time of its lifting. Any complaints regarding seed quality, thereafter will not be entertained at all.
9. And whereas M/s CRSMF is bound to multiply the breeder seed supplied by CPRI in three clonal generations (FS-1, FS-2 and certified seed). He will dispose-off only the certified seed and not of earlier clonal generation viz. FS-1 and FS-2.
10. And whereas M/s CRSMF will keep record of seed production at each stage i.e. FS-1, FS-2 and certified. The seed inspection report/certificate from the seed certifying agency will be submitted to CPRI that will include area certified and seed produced annually.
11. And whereas M/s CRSMF will be solely responsible for dispose-off the certified seed and CPRI in no way will be held responsible in case of non-disposal of the seed stocks.
12. ~~the national seed production programme of CPRI~~
13. And whereas the interested parties/firms/farmers/NGO will apply for allotment of breeder seed to CPRI by furnishing the details about their establishment viz. land holding, farm infrastructure, investment capacity, technical knowhow in the area of



Information  
CROP RESEARCH AND SEED  
MULTIPLICATION FARM  
BURDWAN UNIVERSITY  
TARABAG II, BURDWAN

potato seed production (with supporting document). The NGOs and cooperatives will submit details of their establishment as above including Registration No. & certificate, validity and number of farmer members.

14. And whereas the CPRI will select the growers/firms/NGO/Society based on merit and subject to availability of seed stocks.
15. A maximum of 40 quintal breeder seed will be allotted to each allottee subject to availability of seed stocks and capacity of the organization/firm.
16. And Whereas the CPRI is willing to provide the necessary technical knowhow, advice and training on usual payment basis if required by them.
17. Activities undertaken under the MOU shall be in accordance with the rules and norms governing consultancies, contract research, contract service and transfer intellectual property involving Institutes of the ICAR. The parties of this agreement may, by mutual consent, add, modify, amend or delete any work, phrases, or article of the agreement.
18. The agreement shall be effective for a minimum period of three years. The MOU can be terminated by either party by serving notice to the other party by giving 3 months notice.
19. In the event of non-compliance of any of the articles enshrined in the MoU, CPRI reserves the right to terminate the MoU and black list the firm for future.
20. In case of any dispute between the two parties arising out of or in connection with this agreement, the same shall be referred to the sole arbitrator appointed by the Secretary, Department of Agricultural Research and Education (DARE) & Director General, ICAR and the decision of Arbitrator would be final.

IN WHEREAS WHEREOF, the parties hereunto have signed this on 24/9/2015 date of September 2015 at Shimla.

For first party

For second Party

(Dr. B. Pal Singh)

Director, CPRI, Shimla or

Indian Council of Agricultural Research

M/s Owner/proprietor of the Agency  
**Jai Prakash Keshri** In-charge  
(Dr. Jai Prakash Keshri) CROP RESEARCH AND SEED  
In charge, CRSMF MULTIPLICATION FARM  
Professor BURDWAN UNIVERSITY  
Centre of Advanced Studies in Botany TARABAG II, BURDWAN  
The University of Burdwan  
Burdwan 713104  
West Bengal, India

Witness:

Witness:

1. (Dr. K.K. Pandey)

1. (Dr. Sabyasachi Patra)

Division of Seed Technology  
CPRI, Shimla

CRSMF, The University of Burdwan

2. Head of Station

2. (Dr. Dipendra Nath De)

Estate Officer,  
The University of Burdwan.



## Deoxyelephantopin—a novel PPAR $\gamma$ agonist regresses pressure overload-induced cardiac fibrosis via IL-6/STAT-3 pathway in crosstalk with PKC $\delta$

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<sup>a</sup> Department of Zoology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata, 700019, India

<sup>b</sup> Kusuma School of Biological Sciences, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, 110016, India

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### ARTICLE INFO

#### Keywords:

Deoxyelephantopin  
PPAR $\gamma$  agonist  
Cardiac hypertrophy  
Fibrosis

### ABSTRACT

Pathological cardiac hypertrophy is associated with ventricular fibrosis leading to heart failure. The use of thiazolidinediones as Peroxisome Proliferator-Activated Receptor- $\gamma$  (PPAR $\gamma$ )-modulating anti-hypertrophic therapeutics has been restricted due to major side-effects. The present study aims to evaluate the anti-fibrotic potential of a novel PPAR $\gamma$  agonist, deoxyelephantopin (DEP) in cardiac hypertrophy. AngiotensinII treatment *in vitro* and renal artery ligation *in vivo* were performed to mimic pressure overload-induced cardiac hypertrophy. Myocardial fibrosis was evaluated by Masson's trichrome staining and hydroxyproline assay. Our results showed that DEP treatment significantly improves the echocardiographic parameters by ameliorating ventricular fibrosis without any bystander damage to other major organs. Following molecular docking, all-atomistic molecular dynamics simulation, reverse transcription-polymerase chain reaction and immunoblot analyses, we established DEP as a PPAR $\gamma$  agonist stably interacting with the ligand-binding domain of PPAR $\gamma$ . DEP specifically down-regulated the Signal Transducer and Activator of Transcription (STAT)-3-mediated collagen gene expression in a PPAR $\gamma$ -dependent manner, as confirmed by PPAR $\gamma$  silencing and site-directed mutagenesis of DEP-interacting PPAR $\gamma$  residues. Although DEP impaired STAT-3 activation, it did not have any effect on the upstream Interleukin (IL)-6 level implying possible crosstalk of the IL-6/STAT-3 axis with other signaling mediators. Mechanistically, DEP increased the binding of PPAR $\gamma$  with Protein Kinase C- $\delta$  (PKC $\delta$ ) which impeded the membrane translocation and activation of PKC $\delta$ , downregulating STAT-3 phosphorylation and resultant fibrosis. This study, therefore, for the first time demonstrates DEP as a novel cardioprotective PPAR $\gamma$  agonist. The therapeutic potential of DEP as an anti-fibrotic remedy can be exploited against hypertrophic heart failure in the future.

### 1. Introduction

In the last few decades, pressure overload-induced pathological cardiac hypertrophy leading to heart failure has become a major health concern. There has been substantial progress in understanding the molecular drivers of hypertrophic pathogenesis. The outcome of such studies has primarily been the identification of potential therapeutic targets to manage clinical manifestations such as ventricular fibrosis. One such class of anti-hypertrophic therapeutics is the thiazolidinedione (TZD) group of Peroxisome Proliferator-Activated Receptor- $\gamma$  (PPAR $\gamma$ ) ligands (Yamamoto *et al.*, 2001; Asakawa *et al.*, 2002) the use

of which has often been restricted due to numerous off-target effects (Chigurupati *et al.*, 2015). Therefore, there is an unmet need for alternative PPAR $\gamma$ -modulating cardioprotective remedies. The present study was intended to explore the therapeutic potential of deoxyelephantopin (DEP) as a novel PPAR $\gamma$  agonist that can act as an anti-fibrotic agent against hypertrophic heart failure.

PPAR $\gamma$ , a member of the nuclear receptor superfamily, is transcriptionally upregulated in hypertrophied hearts where it mediates downstream pro-hypertrophic signals, notably in the absence of exogenous agonists (Krishnan *et al.*, 2009; Banerjee *et al.*, 2020). Interestingly, agonist binding to PPAR $\gamma$  acts as a functional switch regulating the

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opposing effects of liganded vs. unliganded PPAR $\gamma$  in renal inflammation (Wen *et al.*, 2010). Nonetheless, whether or not the effects of augmenting cardiac PPAR $\gamma$  during hypertrophy are dependent upon agonist binding remains largely unknown. Although the PPAR $\gamma$ -independent role of DEP has been studied in cancer cells (Zou *et al.*, 2008), the PPAR $\gamma$ -dependent function of DEP and its implication in pathological cardiac hypertrophy have not been explored till now.

Earlier studies have documented the increased membrane translocation and activation of Protein Kinase C- $\delta$  (PKC $\delta$ ) in the pathologically hypertrophied heart (Naskar *et al.*, 2014; Chatterjee *et al.*, 2019). Agonist-dependent induction of PPAR $\gamma$  reduces membrane translocation of PKC $\delta$  due to increased association between PPAR $\gamma$  and PKC $\delta$  (Von Emetben *et al.*, 2007); however, whether similar interaction between the induced PPAR $\gamma$  and PKC $\delta$  modulates cardiac pathophysiology is still unknown. On the other hand, PKC $\delta$  is known to interact with Signal Transducer and Activator of Transcription (STAT)-3 upon stress and phosphorylate it to induce its transcriptional activity (Novotny-Diermayr *et al.*, 2002; Gartsbein *et al.*, 2006). Induction of IL-6/STAT-3 axis is already well-reported to augment myocardial fibrosis during pressure overload hypertrophy (Mir *et al.*, 2012). Taking cues from all these reports, we hypothesized that the anti-fibrotic potential of DEP in the hypertrophied heart might be dependent upon a possible PPAR $\gamma$ /PKC $\delta$ /STAT-3-mediated pathway. Taken together, the present study is the first which explores the cardioprotective efficacy and the mechanism of action of DEP as a PPAR $\gamma$  agonist. This is also the first report that determines the relative effects of PPAR $\gamma$  augmentation in the ligand-bound vs. unbound conformation as a possible therapeutic approach against cardiac fibrosis.

of Health (NIH Publication No. 85-23, revised 1996) and approved by the Institutional Animal Ethics Committee, University of Calcutta (Registration No. 885/GO/RE/S/05/CPCSEA), registered under "Committee for Control and Supervision of Experiments on Animals" (CCSEA), Ministry of Environment, Forest and Climate Change, Government of India.

### 2.3. Isolation and maintenance of adult cardiac fibroblast

Adult cardiac fibroblasts were harvested from heart tissues of 24 weeks old male rats by collagenase dispersion method (Mir *et al.*, 2012). Briefly, the animals were euthanized in a pre-filled carbon dioxide (CO $_2$ ) chamber with 100% concentration of CO $_2$ . The harvested heart tissue was thoroughly minced and digested with collagenase type 2 (80 units/mL DMEM). The digested cell suspension was centrifuged and the obtained cell pellet was resuspended in freshly prepared complete media supplemented with 10% fetal bovine serum (FBS). Isolated fibroblasts were confirmed by staining with anti-vimentin antibody (Cell Signaling Technology, Cat. No. 5741) (Fu *et al.*, 2020). The cells were maintained at 37 °C and 5% CO $_2$  in cell culture flasks and subsequently passaged.

### 2.4. Generation of hypertrophy *in vitro*

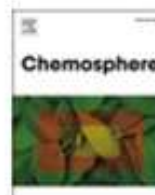
75–80% confluent serum-starved adult cardiac fibroblasts were treated with 10<sup>-8</sup> mol/L (Sar1) angiotensinII (AngII). The AngII was replenished to the cells at every 6 h for the 24 h of total incubation period (Mir *et al.*, 2012).





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# The role of arsenic resistant *Bacillus aryabhattai* MCC3374 in promotion of rice seedlings growth and alleviation of arsenic phytotoxicity

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## HIGHLIGHTS

- As resistant *Bacillus aryabhattai* AS6 strain isolated from contaminated rhizosphere.
- AS6 strain could tolerate As (v) and As (III) upto 100 mM and 20 mM respectively.
- It exhibited IAA and siderophore production, P-solubilization and ACCD activity.
- High As removal and bioaccumulation of AS6 confirmed from various *in vitro* studies.
- It improved rice seedling growth under As(V)-spiked soil by reducing phytotoxicity.

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## ABSTRACT

The biological agents have been utilized as an affordable alternative to conventional costly metal remediation technologies for last few years. The present investigation introduces arsenic (As) resistant plant growth promoting rhizobacteria (PGPR) isolated from the As-contaminated agricultural field of West Bengal, India that alleviates arsenic-induced toxicity and exhibited many plant growth promoting traits (PGP). The isolated strain designated as AS6 has identified as *Bacillus aryabhattai* based on phenotypic characteristics, physio-biochemical tests, MALDI-TOFMS bio-typing, FAME analysis and 16S rDNA sequence homology. The strain found to exhibit five times more resistance to arsenate than arsenite with minimum inhibitory concentrations (MIC) being 100 mM and 20 mM respectively. The result showed that accumulation of As was evidenced by SEM-EDAX, TEM-EDAX studies. The intracellular accumulation of arsenic was also confirmed as in bacterial biomass by AAS, FTIR, XRD and XRF analyses. The increased rate of As (V) reduction by this strain found to be exploited for the remediation of arsenic in the contaminated agricultural field. The strain also found to exhibit important PGP traits viz., ACC deaminase activity (2022 nmol  $\alpha$ -ketobutyrate/mg protein/h), IAA production (166  $\mu$ g/ml), N<sub>2</sub> fixation (0.32  $\mu$ gN fixed/h/mg proteins) and siderophore production (72%) etc. Positive influenced of AS6 strain on rice seedlings growth promotion under As stress was observed considering the several morphological, biochemical parameters including antioxidants activities as compared with an uninoculated set. Thus this strain might be exploited for stress amelioration and plant growth enhancement of rice cultivar under arsenic spiked agricultural soil.

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## 1. Introduction

Arsenic is a toxic metalloid caused serious health problems were described as "the greatest mass poisoning in human history" by World Health Organization (WHO, 2001) and recognized as "Class-1 human carcinogen" by the USEPA (United States Environmental Protection Agency) as a global concern (Ng et al., 2003). In the periodic table, Arsenic (As) belongs to a group 15, period 4, P block

Abbreviations: MALDI-TOFMS, Matrix assisted laser desorption ionization-time of flight mass spectrometry; FAME, Fatty acid methyl ester; SEM, Scanning electron microscopy; TEM, Transmission electron microscopy; EDAX, Energy dispersive X-ray spectroscopy; FTIR, Fourier transform infrared spectroscopy; XRF, X-ray fluorescence.

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## Chapter 3

# Role of ACC Deaminase as a Stress Ameliorating Enzyme of Plant Growth-Promoting Rhizobacteria Useful in Stress Agriculture: A Review



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**Abstract** The crop production is inhibited by a large number of both biotic and abiotic stresses. These stresses include presence of toxic heavy metals, high salt, flood, drought, temperature, wounding, various pathogens, etc. The agricultural production was intensified by management of these stresses with increased use of chemicals, and it needs more attention for incoming population explosion. These chemical inputs caused several harmful effects on the environment and sustainable agriculture. It is necessary to decrease dependence of chemical input for sustainable agriculture with a holistic approach and also essential for environmental protection. One such possible approach is the use of 1-aminocyclopropane-1-carboxylate (ACC) deaminase-producing plant growth-promoting rhizobacteria (PGPR) to protect the crop plants from the harmful effects of both biotic and abiotic stresses. The enzyme ACC deaminase (EC 4.1.99.4) regulates stress ethylene production by catalysing ACC into  $\alpha$ -ketobutyrate and ammonia. Various research works have documented the application of ACC deaminase-producing PGPR under both normal and stressed conditions responsible for the increased growth, health and productivity of crop plant. These beneficial rhizobacteria may decrease the dependence on agrochemicals (fertilizer and pesticides) to stabilize the agroecosystems and maintained sustainable agriculture. Different biochemical and biophysical properties of this enzyme and its regulation have been briefly described. This review also describes the role of ACC deaminase enzyme in plant growth and production by ameliorating different stress conditions including heavy metal, salinity, drought, flood, temperature, etc. Finally, the latest paradigms for useful application of ACC deaminase-containing plant growth-promoting rhizobacteria in different agroecosystems have been discussed comprehensively under stress conditions to highlight the recent scenario with the aim to develop future insights.

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