<u>Brief report on BRNS funded PROJECT</u>

(This part should be uploaded as a word file. Please delete the fileds which are not applicable)

Sanction Number: 2012/34/61/BRNS dated 1st March, 2013

Mode of Execution: RP

Date of Start: 1st April, 2013

Date of Completion: 31st March, 2017

Total Amount Sanctioned (in Lakhs): Rs. 25,70,901/- (including additional amount for salary arrears)

Amount Received (in Lakhs with date): Rs. 25,43,398/- dated 01.03.2013, 01.12.2014, 30.11.2015 and 05.10.2016

Category: Conceptual

Title: Study of the role of collisions and their effect on instabilities in high density laser-plasma interactions as well as low-density plasma transport

Name of PI & Affiliation: Dr. Nilakshi Das, Professor, Department of Physics, Tezpur University, Napaam, Tezpur, Assam-784028

Name of CI & Affiliation: Dr. G. A. Ahmed, Associate Professor, Department of Physics, Tezpur University, Napaam, Tezpur, Assam-784028

Name of PC & Affiliation: Dr. Kartik Patel, L&PTD, BARC, Trombay, Mumbai-400085

Name of major Equipments procured and their cost:

1. One High End Workstation (Model No. HP Z820)	Rs. 7,77,000.00/-
2. One 3 KVA On-Line UPS System	Rs. 1,20,225.00/-
3. One Laptop Computer with Core- i7 Processor (Probook 4440 s)	Rs. 69,000.00/-

Present working status of the Equipment: Good

Number of Journal Publications with impact factor (attach list as Annex- I): 5 (five)

Number of symposia presentations: 3 (three)

Number of staff trained under this project: 1 (one)

List of Objectives as mentioned in original proposal

(List accomplishments/ short falls against each of the objectives)

The objectives can be categorized as follows –

1. A self sufficient computational facility will be developed in the PI's institute for the execution of the project.
2. Investigation of the generation, growth and saturation of large magnetic fields through

the Weibel instability arising in laser-plasma interaction. including the effect of collisions among plasma particles on the Weibel instability.

3. Study of the effect of the self-generated magnetic field on the hot electrons created due to laser-plasma interaction.
4. To study the motion of a streaming low-density plasma and the effect of collisions in it motion.

Accomplishments of the projects in 3 to 4 bullets:

1. We have investigated the role of the angle of incidence of a short pulse laser on magnetic field generation in overdense plasmas with the help of 3D-PIC simulations using the code Picpsi-3D. We have observed the formation of periodic density ripple-like structures are formed due to emission of energetic electron jets from the plasma surface, which may be due to vacuum heating. These ripples carry forward and return currents that are responsible for the formation of periodic magnetic field structures on the plasma surface.
2. We have investigated the role of target thickness in proton acceleration from near-critical mass limited plasma targets by an intense short pulsed circularly polarized laser with the help of three dimensional (3D) particle-in-cell (PIC) simulations using the code Picpsi-3D. We have observed that the radiation pressure accelerated protons are highly energetic and hence travel much faster through the target and reach the target rear side as the target thickness is decreased. Thus, radiation pressure dominates the acceleration process on decreasing target thickness which leads to an increase in maximum proton energy and beam collimation.
3. We have investigated the acceleration of protons from an overdense plasma target in the presence of an axial magnetic field with the help of 3D-PIC simulations using the code Picpsi-3D. We have observed that an axial magnetic field favours target normal sheath acceleration mechanism in the case of right circularly polarized laser, whereas protons are accelerated more effectively by the radiation pressure in case of left circularly polarized laser.
4. We have done an analytical study of relativistic second-harmonic generation in the reflected component by an obliquely incident s-polarized laser from a cold underdense plasma in the presence of a magnetic field. We have observed that the presence of magnetic field enhances the value of the modified relativistic factor γ, which results in the reduction of the second-harmonic conversion efficiency.

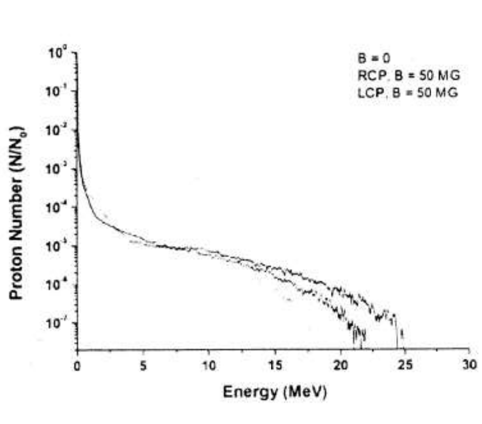
Summary in about 300 words (which is understandable by general scientific fraternity) bringing out the novelty of the work:

With the advances in high power lasers, the interaction of plasma with high intensity laser fields has become possible. Harmonic generation from lasers serve as an excellent tool for laser plasma diagnostics, especially to diagnose warm and hot dense matter. We have done an analytical investigation on relativistic second-harmonic generation in the reflected component by an obliquely incident s-polarized laser from a cold underdense plasma in the presence of magnetic field. We have found that the second harmonic conversion efficiency increases with the increase in angle of incidence as well as the laser electric field amplitude.

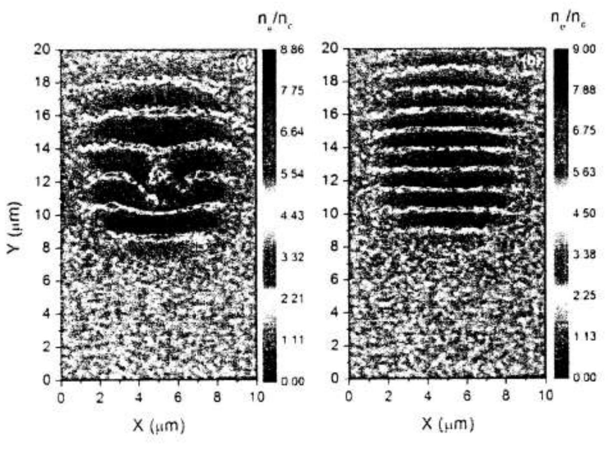
The interaction of intense ultra short laser pulses with plasma also results in the generation of high amplitude magnetic fields. We have investigated the role of angle of incidence of a short pulse laser on magnetic field generation in overdense plasmas with the help of three dimensional (3D) particle-in-cell (PIC) simulations using the code Picpsi-3D. We have observed the formation of periodic magnetic field structures on the plasma front surface when the laser is incident obliquely on the surface.

The generation of energetic protons has been an interesting area of research in the field of laser plasma interactions due to its wide range of applications in fast ignition scenarios, proton radiography, nuclear physics, cancer therapy and many more. We have investigated the role of target thickness in proton acceleration from near-critical mass limited plasmas by an intense short pulsed circularly polarized laser with the help of 3D-PIC simulations. Huge magnetic fields generated during intense laser plasma interactions can have a considerable effect on the high energy electron flow and thus can significantly influence ion acceleration. We have investigated the acceleration of protons from an overdense plasma target in presence of an axial magnetic field with the help of 3D-PIC simulations and have observed that a left circularly polarized laser produces higher energetic protons.

Insert two photographs representing outcome of the project:



Proton energy spectrum (Kuri et al., Phys. Plasmas 24, 013112, (2017))



Formation of periodic magnetic field structures (Kuri et al. Laser. Part. Beams. First View (2017))

Whether any of the staff has submitted/ been awarded research degree on the basis of work carried out on the project. If so, degree and title of thereon and year of submission/ award.

The project staff, Mr. Deep Kumar Kuri, has registered for Ph. D. on August, 2014 in Dept. of Physics, Tezpur University, Assam and is continuing his research under the supervision of Prof. Nilakshi Das.

Detailed technical report of the entire work done on the project.

<u>Work done during financial year 2013-2014:</u>

1. Fund received on 1st March 2013.
2. Junior Research Fellow (JRF) appointed on 26^{th} July, 2013.
3. High End Workstation, Laptop, UPS and other equipments were purchased and installed during November and December, 2013.
4. The Linux based Fedora operating system and the PIC simulation code Picpsi-3D has been installed during January, 2014.
5. ***Study of electron-ion collisional effect on Weibel instability in a Kappa distributed unmagnetized plasma***

When intense ultrashort laser pulse interacts with a solid target, it is found that large magnetic field of the order of 10^8 G is generated [1]. It is a challenging task to understand the origin and evolution of large scale magnetic field in astrophysical environment and fast ignition scenarios. Weibel [2] in his classic work (1959) showed that velocity anisotropy of electron may lead to spontaneous excitation of transverse electromagnetic wave. Achterberg [3] suggested that filamentation and temperature anisotropy driven Weibel instability are responsible for generation of magnetic field in the early stage of universe, ultra-relativistic shocks associated with Gamma Ray Bursts, etc. In recent years, Weibel instability has been widely studied in laser-produced plasmas. Sandhu et al. [4] have reported about their observation of generation of ultra-short (6ps) multi-Megagauss (27 MG) magnetic pulse during interaction of intense laser pulse ($10^{16}Wcm^{-2}$, 100 fs) with a solid target. In Fast Ignition (FI) scheme, the electron beam may have significant temperature anisotropy, which leads to the Weibel instability. Non-Maxwellian plasma is widely found in space with suprathermal tails in electron or ion distribution. Energetic electrons may be generated in laser-plasma during beamtarget interaction. Such energetic electrons are well fitted by the Kappa distribution. Kappa distribution has been used to explain different waves and instabilities, and the results are found in good quantitative agreement with observations, which indicate that Kappa distribution may be a more appropriate substitute of Maxwellian distribution in some circumstances.

We have done an analytical investigation on Weibel instability using non-relativistic Kappa distribution taking into account the effect of electron-ion collision. The conclusions drawn are as follows:

1. Weibel mode exhibits growth for low values of collision frequency. Growth rate is higher for Maxwellian plasma particles.
2. The electron-ion collision frequency is affected by the spectral index j. Suprathermal electrons experience less collision than the Maxwellian ones where the other parameters remain unchanged.
3. In presence of collisions, Weibel mode shows damping. The damping is high for a plasma with Maxwellian distribution function. For the same set of plasma parameters, Weibel instability persists to a greater extent for suprathermal electrons.
4. With decrease in temperature anisotropy, the point of intersection of the growth rate curves for different spectral indices shifts towards lower values of k.
5. As the temperature anisotropy parameter b increases, the normalized value of k corresponding to maximum growth rate shifts towards higher values.

References:

1. M. Tatarakis, I. Watts, F. N. Beg, E. L. Clark, A. E. Dangor, A. Gopal, M. G. Haines, P. A. Norreys, U. Wagner, M.-S. Wei, M. Zepf, and K. Krushelnick, Nature 415, 280 (2002).
2. E. S. Weibel, Phys. Rev. Lett. 2, 83 (1959).
3. A. Achterberg and J. Wiersma, Astron. Astrophys. 475, 1 (2007).
4. A. S. Sandhu, A. K. Dharmadhikari, P. P. Rajeev, G. R. Kumar, S. Sengupta, A. Das, and P. K. Kaw, Phys. Rev. Lett. 89, 225002 (2002).

Work done during financial year 2014-2015:

To study the second harmonic generation by an obliquely incident s-polarized laser from a magnetized plasma.

With the recent advances in high-power lasers, the interaction of plasma with high-intensity laser fields has become possible. Harmonics generated due to the interaction of intense short-pulse lasers with plasmas has been an active area of research in recent years [1]. Second-harmonic generation is one of the most widely discussed areas in laser–plasma interactions as it has many applications such as the study of material properties, biological samples etc. It can be used as a diagnostic tool for overdense plasmas since at second harmonic frequency laser can penetrate into such plasmas and may provide us information regarding various phenomena occurring therein. Generation of second harmonics by a linearly polarized laser beam propagating through an underdense plasma embedded in a transverse magnetic field has been analyzed [2]. Verma and Sharma [3] have investigated second harmonic generation by a laser produced plasma having a density ripple in the presence of an azimuthal magnetic field. Interaction of ultrahigh-intensity lasers with plasmas induces transverse currents due to quiver motion of the electrons. Laser intensities upto 10^{20} W/cm^2 has been achieved, which while propagating through the plasma makes the electrons move with relativistic velocities and the electron motion becomes nonlinear and thus leads to the generation of harmonics.

We have done an analytical study of relativistic second-harmonic generation in the reflected component by an obliquely incident s-polarized laser from a cold underdense plasma in the presence of a magnetic field. The conclusions drawn are as follows:

1. The efficiency is found to increase with the angle of incidence upto the critical angle.
2. Second-harmonic conversion efficiency increases with a_0 which is also revealed in the literature [4]. However, in the presence of magnetic field, the conversion efficiency starts decreasing as the magnetic field is increased.
3. The presence of magnetic field enhances the value of the modified relativistic factor γ, which results in the reduction of the second-harmonic conversion efficiency.

References:

1. P, Gibbon, IEEE J. Quantum Electron. 33, 1915 (1997).
2. P. Jha, R.K. Mishra, G. Raj, and A.K. Upadhyay, Phys. Plasmas 14, 053107 (2007).
3. U. Verma and A.K. Sharma, Laser Part. Beams 27, 719 (2009).
4. K.P. Singh, D.N. Gupta, S. Yadav, and V.K. Tripathi, Phys. Plasmas 12, 013101 (2005).

Work done during financial year 2015-2016:

To investigate the role of target thickness in proton acceleration from near-critical mass-limited plasmas.

The generation of high energetic protons have been an interesting area of research in the field of laser-plasma interactions due to its wide range of applications in fast ignition scenarios [1], proton radiography [2], proton imaging techniques [3], nuclear physics [4], cancer therapy [5,6] as well as in astrophysics [7]. Multi-MeV protons havebeen generated experimentally [8–10] which can be well explained by the popular target normal sheath acceleration mechanism (TNSA) [11]. In this mechanism, a high intensity laser ionizes the front side of the target and generates hot electrons which travel towards the target rear side and form a negatively charged electron sheath. The strong longitudinal electric field of this highly charged electron sheath accelerates the protons from the rear side of the target. At ultrahigh intensities about 10^{20} W/cm2, the radiation pressure of the laser starts dominating the acceleration process and the ions get accelerated effectively from the target front side up to relativistically high energies via. radiation pressure acceleration (RPA) [12,13] mechanism.

We have investigated the role of target thickness in proton acceleration from near-critical mass limited plasma targets by an intense short pulsed circularly polarized laser with the help of three dimensional (3D) particle-in-cell (PIC) simulation using the code Picpsi-3D [14]. The simulations have been done by using targets of thicknesses 8, 3, 2 and 1 μm. The conclusions drawn are as follows:

1. Protons get accelerated more effectively from the target front surface due to the radiation pressure of a circularly polarized laser. The front surface accelerated protons are more energetic and collimated than the ones which are accelerated by the TNSA mechanism from the target rear side.
2. The radiation pressure accelerated protons are highly energetic and hence travel much faster through the target and reach the target rear side as the target thickness is decreased. Thus, RPA dominates the acceleration process on decreasing target thickness which leads to an increase in maximum proton energy and beam collimation.
3. The use of a circularly polarized laser reduces volumic heating and also prevents the effect of transverse hot electron recirculations to a considerable extent which improves the energetic proton beam collimation.
4. The maximum proton energy as well as the number of accelerated protons increases on decreasing target thickness. However, the monoenergetic character is not observed in the energy spectrum as the monoenergetic nature of RPA is diluted due to multidimensional effects.
5. For same values of laser intensity and target thickness, TNSA mechanism dominates over RPA for a p-polarized laser, while the reverse happens for a circularly polarized laser.
6. The proton energy obtained is found to be maximum for the target of an optimum thickness of 0.5 μm.

References:

1. M. Roth, T.E. Cowan, M.H. Key, S.P. Hatchett, C. Brown, W. Fountain, J. Johnson, D.M. Pennington, R.A. Snavely, S.C. Wilks, K. Yasuike, H. Ruhl, F. Pegoraro, S.V. Bulanov, E.M. Campbell, M.D. Perry, H. Powell, Phys. Rev. Lett. 86, 436 (2001).
2. N.S.P. King et al., Nucl. Instrum. Methods Phys. Res. Sect. A 424, 84 (1999).
3. M. Borghesi, A. Schiavi, D.H. Campbell, M.G. Haines, O. Willi, A.J. Mackinnon, P. Patel, M. Galimberti, L.A. Gizzi, Rev. Sci. Instrum. 74, 1688 (2003).
4. V.Y. Bichenkov, V.T. Tikhonchuk, S.V. Tolonnikov, JETP 88, 1137 (1999).
5. V.S. Khoroshkov, E.I. Minakova, Eur. J. Phys. 19, 523 (1998).
6. S.V. Bulanov, T.Z. Esirkepov, V.S. Khoroshkov, A.V. Kuznetsov, F. Pegoraro, Phys. Lett. A 299, 240 (2002).
7. B.A. Remington, R.P. Drake, H. Takabe, Phys. Plasmas 7, 1641 (2000).
8. E.L. Clark, K. Krushelnick, J.R. Davies, M. Zepf, M. Tatarakis, F.N. Beg, A. Machacek, P.A. Norreys, M.I.K. Santala, I. Watts, A.E. Dangor, Phys. Rev. Lett. 84, 670 (2000).
9. A. Maksimchuk, S. Gu, K. Flippo, D. Umstadter, V.Y. Bychenkov, Phys. Rev. Lett. 84, 4108 (2000).

10. R.A. Snavely, M.H. Key, S.P. Hatchett, T.E. Cowan, M. Roth, T.W. Phillips, M.A. Stoyer, E.A. Henry, T.C. Sangster, M.S. Singh, S.C. Wilks, A. MacKinnon, A. Offenberger, D.M. Pennington, K. Yasuike, A.B. Langdon, B.F. Lasinski, J. Johnson, M.D. Perry, E.M. Campbell, Phys. Rev. Lett. 85, 2945 (2000).
11. S.C. Wilks, A.B. Langdon, T.E. Cowan, M. Roth, M. Singh, S. Hatchett, M.H. Key, D. Pennington, A. MacKinnon, R.A. Snavely, Phys. Plasmas 8, 542 (2001).
12. T. Esirkepov, M. Borghesi, S.V. Bulanov, G. Mourou, T. Tajima, Phys. Rev. Lett. 92, 175003 (2004)
13. A. Henig, S. Steinke, M. Schnrer, T. Sokollik, R. Hrlein, D. Kiefer, D. Jung, J. Schreiber, B.M. Hegelich, X.Q. Yan, J. Meyer-ter-Vehn, T. Tajima, P.V. Nickles, W. Sandner, D. Habs, Phys. Rev. Lett. 103, 245003 (2009).
14. A. Upadhyay, K. Patel, B.S. Rao, P.A. Naik, P.D. Gupta, Pramana J. Phys. 78, 613 (2012).

Work done during financial year 2016-2017:

a) To investigate proton acceleration from magnetized overdense plasmas.

Huge magnetic fields of the order of 10^8G are produced during the interaction of an intense ultrashort laser pulse with a solid target [1-3]. These magnetic fields have more impact on the high energy electron flow as they get nonlinearly saturated. Recently, the study of laser plasma interactions in the presence of strong magnetic field has gained the interest of researchers. Sharma et al. [4] have studied the generation of high energetic ions from an overdense plasma target in the presence of an axial magnetic field. They have reported that the polarization of the laser pulse has a remarkable effect on ion acceleration. Right circular polarization (RCP) and left circular polarization (LCP) have different effects on ion acceleration in the presence of an axial magnetic field as the plasma dielectric constant gets changed due to cyclotron effects, which in turn enhances or reduces the ponderomotive force. They have also reported that the optimum thickness of the foil is sensitive to the left and right circular polarization as well as the applied axial magnetic field.

We have investigated the acceleration of protons from an overdense plasma target in the presence of an axial magnetic field with the help of three dimensional (3D) particle-in-cell (PIC) simulations using the code Picpsi-3D. The conclusions drawn are as follows:

1. The laser ponderomotive force gets enhanced by an axial magnetic field in the case of RCP due to cyclotron effects and hence generates more energetic electrons which leave the electron sheath and travel through the upstream plasma and on reaching the target rear side accelerates protons via TNSA process. Whereas in the case of LCP the electrons get more accumulated in the electron sheath which increases the radiation pressure and accelerates protons more effectively to higher energies from target front side.
2. An axial magnetic field favours TNSA in the case of RCP, whereas protons are accelerated more effectively by the radiation pressure in case of LCP.

3. The transverse motion of the protons gets reduced in the presence of an axial magnetic field due to cyclotron effects.
4. The protons accelerated by the LCP laser pulse in the presence of axial magnetic field have highest collimation and hence a comparatively smaller spot size.
5. The maximum proton energy obtained is higher for LCP and lower for RCP in the presence of an axial magnetic field as compared to the energy obtained in the absence of magnetic field.
6. The optimum thickness of the target at which the energy gain is maximum increases slightly in the presence of an axial magnetic field both for RCP and LCP laser pulses. However, the maximum energy obtained at optimum thickness is still higher for LCP laser pulse.

References:

1. S. C. Wilks, W. L. Kruer, M. Tabak, and A. B. Langdon, Phys. Rev. Lett. 69, 1383 (1992).
2. A. S. Sandhu, A. K. Dharmadhikari, P. P. Rajeev, G. R. Kumar, S. Sengupta, A. Das, and P. K. Kaw, Phys. Rev. Lett. 89, 225002 (2002).
3. S. Mondal, V. Narayanan, W. J. Ding, A. D. Lad, B. Hao, S. Ahmad, W. M. Wang, Z. M. Sheng, S. Sengupta, P. Kaw, A. Das, and G. R. Kumar, Proc. Natl. Acad. Sci. U.S.A. 109, 8011 (2012).
4. A. Sharma, C. S. Liu, and V. K. Tripathi, Phys. Plasmas 17, 013101 (2010).

b) To investigate the role of angle of incidence of a short pulse laser in magnetic field generation from overdense plasmas.

The generation of high magnetic fields has been an active area of research since many years in the field of laser plasma interactions [1-3]. The interaction of multiterawatt lasers with focused intensities of the order of 10^{19} W/cm^2 and dense solid targets generates hot electrons, which penetrate deeply into the target and excites return shielding currents. The hot electrons on propagating through the overdense plasma makes the system unstable and results in the generation of a relativistic electromagnetic two-stream instability or more commonly known as the Weibel instability [4], which is mostly responsible for the generation of quasi-static magnetic fields. The other possible sources of magnetic field generation are the non-parallel temperature and density gradients. Due to Weibel instability, the forward and return currents get separated, which causes the generation of quasi-static ordered magnetic field configurations. This is followed by the tearing and coalescence instabilities, which produce current channels and hence filamentary magnetic field structures [5].

We have investigated the role of the angle of incidence of a short pulse laser on magnetic field generation in overdense plasmas with the help of 3D-PIC simulations using the code Picpsi-3D. The simulations have been done for three different angles of incidence. The formation of current filaments as well as filamentary magnetic field structures have been observed. The conclusions drawn are as follows:

1. Huge magnetic fields of the order of ≈400 MG are generated when the laser is incident normally on the target. The laser pulse gets focused up to a very short length of 2 μm inside the target and the axial intensity rises up to a maximum of ≈11 times the fundamental laser intensity.
2. At θ = 30°, the laser pulse penetrates up to some distance inside the plasma and a part of it gets reflected, whereas at θ= 60°, the penetration in plasma is much less and the laser pulse as a whole gets reflected and propagates almost parallel to the surface through vacuum.
3. Periodic density ripple-like structures are formed due to emission of energetic electron jets from the plasma surface, which may be due to vacuum heating. These ripples carry forward and return currents that are responsible for the formation of periodic magnetic field structures on the plasma surface.
4. The formation of density ripples are found to be more prominent at θ = 60° due to efficient vacuum heating, and the inter spacing distance coincides with the laser wavelength (λ = 1 μm).

References:

1. S. C. Wilks, W. L. Kruer, M. Tabak, and A. B. Langdon, Phys. Rev. Lett. 69, 1383 (1992).
2. A. S. Sandhu, A. K. Dharmadhikari, P. P. Rajeev, G. R. Kumar, S. Sengupta, A. Das, and P. K. Kaw, Phys. Rev. Lett. 89, 225002 (2002).
3. S. Mondal, V. Narayanan, W. J. Ding, A. D. Lad, B. Hao, S. Ahmad, W. M. Wang, Z. M. Sheng, S. Sengupta, P. Kaw, A. Das, and G. R. Kumar, Proc. Natl. Acad. Sci. U.S.A. 109, 8011 (2012).
4. E. S. Weibel, Phys. Rev. Lett. 2, 83 (1959).
5. A.M. Pukhov and, J. Meyer-teyer-vehn, Phys. Rev. Lett. 79, 2686 (1997).

Particulars such as the title of the project, funding agency duration of other projects under your charge.

Title of the Research Project: A study of dynamics of dust particles in strongly coupled plasma
Sponsoring organization: University Grants Commission (UGC)
Sanction No. F. No. 42 – 795/2013 (SR) dated March 22, 2013
Period of the project: From 01.04.2013 to 31.03.2016
Total grant: Rs. 9,65,800.00/-

Declaration by the PI and the head of the institution that the contents are original work carried out under the supervision of the PI.

It is hereby solemnly and sincerely declared that, a project entitled *"Study of the role of collisions and their effect on instabilities in high density laser-plasma interactions as well as low-density plasma transport"* funded by DAE-BRNS, with sanction No. 2012/34/61/BRNS dated 1st March, 2013 has been carried out under the supervision of the PI and the contents are original work for the best of our knowledge.

Nilakshi ... 8/9/2017.

Signature & Seal: Principal Investigator

14/9/17

Signature & Seal: Head of the Institution

Registrar

Annexure-I

List of Publication in referred journals

1. **Role of target thickness in proton acceleration from overdense plasmas**
   Deep Kumar Kuri, Nilakshi Das and Kartik Patel
   Appl. Phys. B **123**, 201 (2017); doi: https://doi.org/10.1007/s00340-017-6779-7
2. **Formation of periodic magnetic field structures in overdense plasmas**
   Deep Kumar Kuri, Nilakshi Das and Kartik Patel
   Laser. Part. Beams. **35** (3), pp 467-475 (2017);
   doi: https://doi.org/10.1017/S0263034617000453
3. **Proton acceleration from magnetized overdense plasmas**
   Deep Kumar Kuri, Nilakshi Das and Kartik Patel
   Phys. Plasmas **24**, 013112 (2017); doi: http://dx.doi.org/10.1063/1.4974171
4. **Second Harmonic generation by an obliquely incident s-ploarized laser from a magnetized plasma**
   Deep Kumar Kuri and Nilakshi Das
   Laser. Part. Beams. **34** (2), pp 276-283 (2016);
   doi: https://doi.org/10.1017/S0263034616000070
5. **Electron-ion collisional effect on Weibel instability in a Kappa distributed unmagnetized plasma**
   Deep Kumar Kuri and Nilakshi Das
   Phys. Plasmas **21**, 042106 (2014); http://dx.doi.org/10.1063/1.4870083

FORM–III

Department of Atomic Energy (DAE)
Board of Research in Nuclear Sciences (BRNS)
BARC, Trombay, Mumbai-400085

UTILIZATION CERTIFICATE

Certified that Grant-in-aid of **Rs. 24,53,235/- (Rupees twenty four lakh fifty three thousand two hundred thirty five only)** was sanctioned by the **Government of India, Department of Atomic Energy, Mumbai-400 001** vide their letter No. **2012/34/61/BRNS** dated **1st March, 2013** and **Rs. 25,73,846/- (Twenty five lakhs seventy three thousand eight hundred forty six only)** were paid on date(s) **1st March, 2013, 1st Dec. 2014, 30th Nov. 2015 and 5th Oct. 2016** respectively for the year(s) **2013-2014, 2014-2015, 2015-2016 and 2016-2017** of which **Rs. 24,97,387/-** has been utilized and there is an unutilized balance of **Rs. 76,459/-** of the said grant as on **31st March, 2017** in respect of the Research Project **"Study of the role of collisions and their effect on instabilities in high density laser-plasma interactions as well as low-density plasma transport"**

8/9/2017
Signature & Seal: Principal Investigator

Signature & Seal: Registrar/Head of Institution
Registrar
Tezpur University

14.9.17
Finance Officer
Finance Officer
Tezpur University

Signature & Seal: Statutory Auditor (Govt.)/ Chartered Accountant
Internal Audit Officer
Tezpur University

BRNS FORM-IV

STATEMENT OF ACCOUNTS (SA) as on 31st March, 2017.

Sanction No: 2012/34/61/BRNS Dated: 1st March 2013

Sr.No.		Sanctioned	Opening Balance	Received (after adjusting interest)	Total (4+5)	Spent	Unspent (Carried Forward)
1st Year	(2013-2014)						
1	2	3	4	5	6	7	8
1.	Equipment	11,58,900	NIL	11,58,900	11,58,900	9,66,225	1,92,675
2.	Staff Salaries	1,92,000	NIL	1,92,000	1,92,000	1,31,097	60,903
3.	Techn. Asst.		NIL				
4.	Consumables	50,000	NIL	50,000	50,000	20,449	29,551
5.	Travel	40,000	NIL	40,000	40,000	27,556	12,444
6.	Contingencies	40,000	NIL	40,000	40,000	28,627	11,373
7.	Overheads	1,08,068	NIL	1,08,068	1,08,068	1,04,843	3,225
8.	Interest Earned		NIL	10,618	10,618		10,618
9.	TOTAL:	15,88,968	NIL	15,99,586	15,99,586	12,78,797	3,20,789
2nd Year	(2014-2015)						
1.	Equipment		1,92,675		1,92,675	17,500	1,75,175
2.	Staff Salaries	1,92,000	60,903	1,92,000	2,52,903	1,92,000	60,903
3.	Techn. Asst.		NIL				
4.	Consumables	40,000	29,551	40,000	69,551	10,886	58,665
5.	Travel	50,000	12,444	50,000-10,618=39,382*	51,826	7,000	44,826
6.	Contingencies	40,000	11,373	40,000	51,373	16,765	34,608
7.	Overheads	21,150	3,225	21,150	24,375	13,219	11,156
8.	Interest Earned		10,618 (2013-2014)	13,858	24,476	0	24,476
9.	TOTAL:	3,43,150	3,20,789	3,46,390	6,67,179	2,57,370	4,09,809
3rd Year	(2015-2016)						
1.	Equipment	0	0	0	0	20,732	-20,732
2.	Staff Salaries	0	2,36,078#	0	2,36,078	2,28,000	8,078
3.	Techn. Asst.		NIL				
4.	Consumables	0	58,665	0	58,665	43,922	14,743
5.	Travel	0	44,826	0	44,826	20,076	24,750
6.	Contingencies	0	34,608	0	34,608	10,598	24,010
7.	Overheads	0	11,156	0	11,156	0	11,156
8.	Interest Earned		24,476 (2014-2015)	3,027	27,503	0	27,503
9.	TOTAL:		4,09,809	3,027	4,12,836	3,23,328	89,508
4th Year	(2016-2017)						
1.	Equipment	0	-20,732	0	-20,732	0	-20,732
2.	Staff Salaries	4,76,833	8,078	4,76,833	4,84,911	4,86,900	-1,989
3.	Techn. Asst.						
4.	Consumables	40,000	14,743	40,000	54,743	54,708	35
5.	Travel	50,000	24,750	50,000-16,885=33,115**	57,865	2,940	54,925
6.	Contingencies	40,000	24,010	40,000	64,010	64,000	10
7.	Overheads	31,950	11,156	31,950	43,106	29,344	13,762
8.	Interest Earned		27,503 (2015-2016)	2,945	30,448	0	30,448
9.	TOTAL:	6,38,783	89,508	6,24,843	7,14,351	6,37,892	76,459
	GRAND	25,70,901	6,44,931	25,73,846		24,97,387	

*Amount of interest adjusted from the "Travel" Head (Letter No. 2012/34/61/BRNS/1973 dated 01/12/2014)

**Amount of interest adjusted from the "Travel" Head (Letter No. 2012/34/61-BRNS/34303 dated 05/10/2016)

#Re-appropriation of Rs. 1,75,175/- from "Equipment" head to "Salary" head (Revalidation Letter No. 2012/34/61/BRNS/11261 dated 30/11/2015).

Nilakshi... 8/9/2017
Principal Investigator

Head of the Institution
Registrar
Tezpur University

Finance Officer 14.9.17
Finance Officer
Tezpur University

21.09.2017
Auditor/Chartered Accountant/Accountant General
Internal Audit Officer
Tezpur University