

## CHAPTER 47

### PHYSICS AND ASTROPHYSICS

#### Doctoral Theses

01. BHATIA (Arshdeep Singh)  
**Cosmological Implications of Metric-Torsion Theories of Gravity.**  
Supervisors: Dr. Sourav Sur and Dr. Sanjeev Kumar Verma  
Th 23644

*Abstract*  
(Not Verified)

The standard cosmological paradigm based on classical General Relativity (GR) has been overly successful in dealing with observational results. Yet it is found wanting when confronted with pertinent issues, notably the late-time cosmic acceleration driven by the so-called dark energy (DE). The DE conundrum has created a niche in the theories of gravity that stretch beyond the geometric principles of GR. One such group of theories include those that allow for torsion in space-time, in addition to curvature. In the works presented we study the cosmological implications of such metric-torsion theories of gravity, emphasizing on the emergence of viable DE models. However, in view of several shortcomings of the conventional Einstein-Cartan theory and its variants, we resort to the formalisms not of the standard Palatini type, but those in which one or more of the torsion mode(s) is(are) sourced by external fields. We begin by looking into the general aspects of space-time symmetries in presence of torsion and how the latter is affected by such symmetries. Focussing particularly on space-time manifolds that are either maximally symmetric, or could be decomposed to maximally symmetric subspaces, we work out the constraints on torsion in two theoretical schemes which are in general different. Such constraints are of particular importance in the standard cosmological setup, under the demand that torsion should uphold the maximal symmetry of the constant time hypersurface foliations of the Friedmann-Robertson-Walker (FRW) space-time manifold. Specifically, in such a setup we study the plausible emergence of a dynamical DE, assuming a non-minimal scalar field coupling with curvature and torsion

#### *Contents*

1. Introduction. 2. Torsion in maximally symmetric (sub) spaces 3. Metric- scalar-Torsion coupling and the dark energy problem 4. Dynamical analysis of metric-scalar-torsion cosmologies 5. Conclusion. Appendix and bibliography

02. BHARDWAJ (Anupam)  
**Light Curve Analysis of Variable Stars.**  
Supervisor: Prof. H.P.Singh  
Th 23641

*Abstract*  
(Verified)

Our understanding of the universe mostly depends on our knowledge of stars, in particular, when we look beyond our solar system. Variable stars represent one such group as they vary in luminosity and spectral features. Analysis of high-quality photometric and spectroscopic data of variable stars from large-scale wide-field stellar variability surveys at multiple wavelengths

allows us to rigorously test our understanding of the underlying physics of stellar pulsation and evolution and to obtain a deeper insight into their application to cosmological age and distance scales. This thesis consists of several studies on radially pulsating stars, namely, Cepheid and RR Lyrae variables. These variables are fundamental stellar tracers of metallicity, extinction and structure of their host galaxy and provide cosmological age and distance scales that are independent of the cosmic microwave background by Planck. Light curve analysis of Cepheid variables is discussed using Fourier decomposition and principal component analysis methods to explore strong constraints for stellar pulsation codes by an extensive comparison of their observed light curves and pulsation properties with theoretical models. The pulsation properties of Cepheid variables are studied in detail using near-infrared observations from a synoptic survey of the central bar of the Large Magellanic Cloud. Period-Luminosity and Period-Wesenheit relations are derived with 10 times better constraint on the slopes and zero-points relative to any previous study. A statistical analysis of possible non-linearities in these relations at multiple wavelengths is carried out. Study of Period-Luminosity, Period-Color and Amplitude-Color relations at the maximum and minimum light is used to examine the interaction between the stellar photosphere and the hydrogen ionization front for Cepheid and RR Lyrae variables. These analyses provide challenges and constraints for stellar pulsation models and precision cosmology.

### *Contents*

1. Introduction 2. Multiwavelength light curve analysis of cepheid variables 3. Near-infrared leavitt laws for cepheid variables and the distance scale 4. Non-linear leavitt laws for classical cepheids in the magelanic clouds 5. Empirical period-color and amplitude-color relations for cepheid and RR lyrae stars 6. Conclusions and future prospects. Bibliography

03

CHOUDHARI (Tarun)

### **On Dirac Fermion Bound States and Transport Properties in Graphene and Topological Insulators**

Supervisor: Dr. Nivedita Deo

Th 23633

### *Abstract*

(Verified)

In this thesis, we focus on the study of unusual Dirac fermion bound states and its transport in nanostructures of graphene and topological insulators, which host gapless edge and surface Dirac states. Graphene exhibits a special topological defect, called wedge disclination, which changes the graphene lattice from flat to conical. We first examine the scenario, of the spinfull Dirac fermions trapped at the wedge disclination induced defects in graphene with curvature modified spin orbit couplings. This trapping is attributed to the existence of Kramer's degenerate midgap localized spin separated fluxon states of the Dirac fermion around the defect. This defect acts as a source of fictitious spin dependent magnetic flux and the introduction of an external magnetic flux piercing the defect facilitates control over these localized fluxon states. Next, we study the formation of helical Andreev bound states by Dirac fermions via Andreev reflection in the topological insulator based step and planar Josephson junctions. The junction angle dependency of Andreev reflection is probed, which we find leads to the junction barrier potential controllable Josephson current. This Josephson current is mediated by the helical Andreev bound states of the Dirac fermion in both step and planar geometry of the Josephson junctions. Lastly, the effect of the hexagonally warped anisotropic Fermi surface on the Floquet-Dirac states and the anomalous

thermoelectric properties of the topological insulator surface is investigated, on illumination with linearly and elliptically polarized off-resonant electromagnetic radiation. Due to hexagonal warping, the radiation couples anisotropically with the Dirac fermion surface states of the topological insulator in momentum space. This leads to a radiation parameter (polarization and amplitude) dependent spin texture of surface states, Berry curvature, Berry phase, orbital magnetic moment, the anomalous transverse Ettingshausen, Nernst and thermal conductivities.

#### *Contents*

1. Introduction. 2. Graphene 3. Graphene with wedge disclination in the presence of intrinsic and Rashba spin orbit couplings 4. Topological insulators 5. Andreev reflection and bound states in planar and step Josephson junctions 6. Effect of hexagonal warping on the anomalous thermoelectric effects in off-resonant irradiated topological insulator 7. Conclusion. Appendices and bibliography

- 04 GURPREET KAUR  
**Realization of Microfluidic Optical and Electrochemical Biosensing Devices using ZnO and NiO Thin Films**  
 Supervisor: Prof. Vinay Gupta  
Th 23631

#### *Abstract* (Verified)

Development of fast, low cost and highly precise detection techniques is the need of the hour for point-of-care diagnostics. In this context, biosensors provide an attractive alternative to conventional detection techniques. Microfluidics has the ability to control small fluid volumes and its integration with biosensors leads to potential for lab-on-a-chip technology. ZnO has been deposited over gold coated glass prisms using sputtering technique. ChOx enzyme and single stranded meningitis probe DNA (ssDNA) have been immobilized separately on the prism system for detection of cholesterol and meningitis respectively using SPR with low detection limit of 5 ng/ $\mu$ l and 0.11 mM. For realization of electrochemical biosensors, nanostructured NiO thin film has been grown by sputtering in glancing angle deposition configuration. Catalytic and affinity based electrochemical biosensors have been developed after immobilization of bioreceptors on NiO for free cholesterol and meningitis DNA respectively with a high sensitivity of 150  $\mu$ A (ng/ $\mu$ l) and 0.043 mA mM. Three immobilization strategies have been studied and covalent bonding using EDC-NHS chemistry shows improved sensing results. Nanostructured NiO thin film has been grown using both chemical and physical deposition techniques under optimized conditions for realization of reagentless biosensors utilizing the redox property of matrix itself (Ni  $\leftrightarrow$  Ni<sup>2+</sup>). Reagentless biosensors have been developed for free and total cholesterol as well as LDL. Flexible substrates based on CuO nanoparticles modified carbon nanofibers (obtained from Korea Institute of Technology) have been utilized for electrochemical detection of free cholesterol. An integrated biosensor has been developed by miniaturizing the three electrode system on single chip. Polydimethylsiloxane microchannels of different dimensions have been fabricated under optimized conditions and integrated with the electrochemical cholesterol biosensor and SPR meningitis DNA biosensor with sensitivities of 45  $\mu$ A mM cm and 0.03° (ng/ $\mu$ l). Finally, a low cost paper based self-pumping microfluidic biosensor has been patterned using photolithography.

#### *Contents*

1. Introduction 2. ZnO thin film based surface plasmon resonance biosensors 3. GLAD deposited nanostructured NiO thin film based electrochemical biosensors 4. Nanostructured NiO thin film based reagentless and label free electrochemical

biosensor for complete cholesterol detection 5. Reagentless and label free electrochemical biosensor using sputtered NiO thin film for complete cholesterol detection 6. Towards wearable, integrated, miniaturized and microfluidic biosensors

05. GUPTA (Rajkumar)  
**Study of Thermoelectric Properties of Calcium Cobalt Oxide ( $\text{Ca}_3\text{Co}_4\text{O}_9$ ) Materials.**  
 Supervisors: Prof. R.P. Tandon and Dr. Ajit Kumar Mahapatro  
Th 23634

*Abstract*  
(Not Verified)

With the emerging global requirement for energy production and conservation has intensified interest in sustainable energy technologies. A large variety of thermoelectric materials, such as Zintl phases, clathrates, skutterudites, layered cobalt oxides, etc. have been investigated for higher thermoelectric efficiency. Among the layered cobalt oxides,  $\text{Ca}_3\text{Co}_4\text{O}_9$ , has been extensively explored owing to its good thermal and chemical stability at high temperatures. The present thesis work is in seven chapters as follows: Chapter One, gives an introduction of the thermoelectric materials and also, describes a parameter called dimensionless figure of merit (ZT) which shows performance of the thermoelectric material. Chapter Two, provides the details of the method of synthesis used for the fabrication of the samples. A concise discussion of the hot pressing machine used for sintering of the samples is given. Chapter Three, details of synthesis and characterization of  $\text{Ca}_3\text{Co}_4\text{O}_9/\text{ZrO}_2$  composite series have been provided and the effect of dispersion of varying content of  $\text{ZrO}_2$  particles on the thermoelectric properties has been examined. Chapter Four, details of preparation of a series of Tb and Zn co-doped  $\text{Ca}_3\text{Co}_4\text{O}_9$  samples i.e.  $\text{Ca}_{3-x}\text{Tb}_x\text{Co}_4\text{O}_9$  by solid state reaction method followed by conventional sintering and the variation of thermoelectric properties with temperature are provided. Chapter Five, describes the impact of simultaneous substitution of Lanthanum at Calcium site and Nickel at cobalt site of the  $\text{Ca}_3\text{Co}_4\text{O}_9$  ceramics on its thermoelectric performance. The samples are prepared by conventional solid state reaction method followed by hot pressing. Chapter Six, the effect of simultaneous substitution of Samarium (Sm) and Dysprosium (Dy) at Ca-site in  $\text{Ca}_3\text{Co}_4\text{O}_9$  ceramics is investigated in detail. The variation of Seebeck coefficient, electrical resistivity and thermal conductivity as a function of temperature is measured and calculated power factor and figure of merit for the prepared samples is obtained. Chapter Seven, gives the conclusions of the thesis work.

*Contents*

1. Introduction. 2. Experimental techniques 3. The effect of  $\text{ZrO}_2$  dispersion on the thermoelectric power factor of  $\text{Ca}_3\text{Co}_4\text{O}_9$  4. Influence of terbium and zinc co-doping on the thermoelectric properties of  $\text{Ca}_3\text{Co}_4\text{O}_9$  ceramics 5. Thermoelectric transport properties in lanthanum and nickel substituted calcium cobalt oxide ( $\text{Ca}_{3-x}\text{La}_x\text{Co}_{4-y}\text{Ni}_y\text{O}_9$ ) 6. Enhancement of ZT by incorporation of samarium and dysprosium doped calcium cobalt oxide ( $\text{Ca}_{3-x-y}\text{Dy}_x\text{Sm}_y\text{Co}_4\text{O}_9$ ) system 7. Conclusion and future work

06. GUPTA (Reema)  
**Development of Multi-Component Materials for Energy Harvesting and Microwave Resonator Devices.**  
 Supervisor: Prof. Vinay Gupta  
Th23754

*Contents*

1. Outline of the present work 2. Growth and characterization of PZT thin films 3. ME effect in PZT / Ni: Magnetic energy harvesting 4. PZT / Ni cantilever: Dual energy harvester for mechanical and magnetic energies 5. Towards miniaturization of energy

harvester: MEMS piezoelectric cantilever 6. Lithium ion battery for energy storage 7. Fabrication of tunable microwave resonator for wireless communication. Appendices and scope references.

07. GUPTA (Vartika)  
**Dynamical Gravitational Constant and Its Implication.**  
 Supervisor: Prof. Daksh Lohiya  
Th 23636

*Abstract*  
 (Not Verified)

The first part of this thesis deals with a class of generalized scalar-tensor theories. In general, such theories give rise to a varying Gravitational "constant" in the "Jordan Frame". A conformal transformation from such a Jordan frame to the "Einstein frame" is not possible for a non-minimal coupling function which diverges at some value of the scalar field. We observe that such non-minimally coupled scalar field induced gravity theories can support interesting non-topological soliton solutions. These could arise out of a first order phase transition. These configurations are similar to Lee-Wick stars. These have a vanishing effective gravitational constant with a flat spacetime in the interior and canonical gravitational constant and a spacetime described by a Schwarzschild metric in the exterior. We explore properties of such soliton stars at arbitrary temperatures. In the second part, we consider the interaction between dark matter and dark energy, with the dark energy described by a scalar field having a double exponential effective potential. These type of non-polynomial potentials could again arise in scalar-tensor theories. We discover conditions under which such a scalar field driven solution is a late time attractor. We observe a realistic cosmological evolution which consists of sequential stages of dominance of radiation, matter and dark energy, respectively.

*Contents*

1. Introduction. 2. Non-Topological Solitons in a non-minimally coupled scalar field induced gravity theory 3. Dynamics of a scalar field, with a double exponential potential, interacting with dark matter 4. Summary and future prospects. Appendix and references

- 08 GOYAL (Arun)  
**Atomic Structure Calculations and Collisional Excitation in Multi-Electron Systems with Applications in Plasma Physics**  
 Supervisors: Dr. Avnindra Kumar Singh and Prof. Man Mohan  
Th 23629

*Abstract*  
 (Not Verified)

The importance and advantage of atomic parameters revealed from the fact that they are not only required for the comparison between theoretical and experimental models, but they are also the main ingredient of many applications belonging to atomic physics as well as many other disciplines. Moreover, the atomic data have a major significant contribution in the local and non local thermodynamic equilibrium calculations. Therefore, many methods for atomic structure computations have been developed in the last few years for low Z and high Z atoms. In chapter 1, we have provided usual and common introductions about the significance, the need and

relevance of atomic data. In chapter 2, we have presented the energy levels, lifetimes and radiative data for Cu-like lanthanide ions from MCDF method for the lowest 27 fine-structure levels. Our calculated SXR wavelengths are incredibly advantageous in several applications such as spectroscopy, material science and high-resolution biological and molecular imaging. In chapter 3, we have calculated collision strengths and effective collision strengths for F-like W and F-like Ba using relativistic R-matrix method. Comprehensive theoretical study of our presented results for collision and effective collision strengths will be beneficial for plasma modeling in fusion reactors and other plasma physics applications in future. In chapter 4, we have investigated and scrutinized graphically the behavior of line intensity ratio along with plasma parameters such as, electron density, plasma frequency and skin depth of highly ionized Al-like ions with plasma temperature and nuclear charge for optically thin plasma in LTE. We have discussed the spectroscopic properties and plasma characteristics of Al-like ions in the plasma atmosphere by employing GRASP2K package. As a conclusion, we concede that the work presented in this paper is reliable examination of spectroscopic properties and plasma characteristics will be useful in the modeling and characterization of plasma.

#### *Contents*

1. Introduction 2. Atomic structure calculations of culike ions using multi-configuration dirac fock methods 3. Collisional excitation calculations for high Z ions using R-matrix method 4. Study of plasma parameters using atomic parameters for high ions

09. GOYAL (Ranjan)

**Magnetization Reversal Mechanism and Exchange Coupling in Transition Metal Based Nanocomposites and Multilayers**

Supervisor: Prof. S. Annapoorni and Dr. Subhalakshmi Lamba

Th 23627

#### *Contents*

1. Introduction. 2. Experimental and computational methods 3. Anisotropy variation and reversal mechanism of cobalt embedded in Al<sub>2</sub>O<sub>3</sub>: Thermal annealing and electronic excitations 4. Nucleation controlled magnetization reversal mechanism in oriented L1<sub>0</sub>-FeCoPt Ternary alloys 5. Tuning of inter-granular exchange coupling in L1<sub>0</sub>-Al FePt nanocomposite 6. Exchange hardening in FePt/Fe<sub>3</sub>Pt dual exchange spring magnet: Monte carlo modeling 7. Modeling of indirect exchange coupling in FePt / Al<sub>2</sub>O<sub>3</sub> / Fe<sub>3</sub>Pt trilayer sandwich structure 8. Summary and conclusions. Publications

10. KAUSHAL

**Analysis of Stellar Spectra.**

Supervisor: Prof. H.P. Singh and Prof. Philippe Prugniel

Th 23753

#### *Contents*

1. Introduction. 2. New atmospheric parameters and spectral interpolator for the miles cool stars 3. The hot  $\gamma$ -Doradus and maia stars 4. High-resolution spectroscopy and spectropolarimetry of selected  $\delta$ -Sct pulsating variables 5. conclusions and future prospects. bibliography

11. KHATRI (Indu)  
**Atomic Structure Calculations Applied to Photoionization Processes**  
 Supervisors: Dr. Avnindra Kumar Singh and Prof. Man Mohan  
Th 23640

*Abstract*  
 (Not Verified)

Accurate atomic data is needed urgently for the prediction and analysis of experimental data obtained by several space missions (e.g. AXAF, SOHO, Chandra, XMM, Hubble-Space Telescope etc.). The elements which had not been detected from ground based instruments have now been observed in stellar objects, particularly the heavy elements. Atomic parameters are useful in approximating the temperature and densities of species in the galaxies, stars, and nebulae atmospheres and in obtaining stellar envelope opacities. The excitation energies and oscillator strengths of highly stripped ions help in approximating the energy loss through impurity ions in fusion plasmas and for diagnostic and modeling of high temperature plasmas in future fusion research programmes like ITER. The present study has been motivated due to their applications in Astrophysics, laser physics, plasma physics and spectroscopy. The objective of our work on these ions is to upgrade the database of these ions to the accuracy required to exploit the high quality of observations from the current space and ground based telescopes. These ions have received a great deal of attention both theoretically and experimentally. Spectral lines belonging to Ni X – Ni XIII ions were identified in solar spectra. For the knowledge of impurities injected into the Tokamak plasmas from the nickel alloy liner, a study of Nickel spectrum is required. Lines from fluorine-like ions have been observed in solar flares, planetary nebulas and laboratory plasmas. The 2s 2p -2s2p transitions of F-like ions are observed in high-temperature plasmas and can thus be used for plasma diagnostic purposes. Tungsten will be employed as plasma facing material in ITER fusion reactor and fusion device ASDEX Upgrade, presently under construction. Tungsten will be used for investigating erosion of heavy species into the plasma.

*Contents*

1. Introduction. 2. Atomic structure calculations using configuration interaction method 3. Multiconfigurational dirac-fock energy levels and radiative rates for F-like Rb XXIX and Ba XLVIII 4. Photoionization processes in complex Ions 5. Conclusions 6. References

12. KRISHNA GOPAL  
**Ultrafast Laser Interactions with Plasmas Relevant to Particle Acceleration**  
 Supervisor: Dr. Devki Nandan Gupta  
Th 23637

*Abstract*  
 (Verified)

The major objective of this thesis work is to present the analytical and simulation study of ultrafast laser interactions with plasmas relevant to the particle acceleration. The main objective of this thesis is to inquire about the beam quality in laser wakefield acceleration that has significant application in terms of ultra-short radiation sources. Some nonlinear phenomena such as the nonlinear force due to inhomogeneous laser pulse electric field, the laser pulse evolution in a plasma, the plasma wave formation and steepening, the electron trapping and injection, and the acceleration of electrons in the wakefield have been explored. Present thesis work can be classified in two categories, in first category, the inhomogeneous

plasmas have been considered in the form of density ripple to study the electron acceleration. Single particle approach has been considered in analytical calculation for electron acceleration in density modulated plasma. Two dimensional "particle-in-cell (PIC)" simulations have also been reported to inquire the beam quality in laser wakefield acceleration in the presence of density ripple. Secondly, the simulation study with reasonable analytical consideration has been done for shaped laser pulse to study the self-generated magnetic field and to improve the beam quality in laser wakefield acceleration (LWFA). Temporally asymmetric laser pulse propagates through an inhomogeneous plasma to generate net-nonlinear currents within the laser pulse body, which produces magnetic field of quasistatic nature. Apart from the self-generated magnetic field, the variation in pulse asymmetry has been considered in case of laser wakefield acceleration. Later, this simulation study has been extended to get the optimum pulse length at particular pulse asymmetry for better beam quality. At the end, the combined effect of external magnetic field with shaped laser pulse has been introduced in the laser wakefield acceleration to study beam parameters such as injected charge, emittance and mean energy.

#### *Contents*

1. Introduction 2. Single particle theory for electron acceleration in density rippled plasma 3. Laser wakefield acceleration of electrons in a density-modulated plasma 4. Laser wakefield acceleration of electrons by asymmetric laser pulses in plasmas 5. Self-generated magnetic field by asymmetric laser-pulse interactions with a plasma in low-intensity regime 6. Magnetic field assisted laser wakefield acceleration of electrons by asymmetric laser pulses in plasmas 7. Summary. References

13. LALITA  
**Structural, Electrical and Magnetic Properties of NiFe<sub>2</sub>O<sub>4</sub> powders and Ceramics.**  
 Supervisor: Prof. K. Sreenivas  
Th 23643

#### *Contents*

1. Nickel ferrite (NiFe<sub>2</sub>O<sub>4</sub>) powders and ceramics 2. Statement of the problem and thesis objectives 3. Experimental techniques 4. Sol gel autocombustion synthesis of nickel ferrite 5. conduction mechanism of NiFe<sub>2</sub>O<sub>4</sub> ceramics 6. Dy substituted NiFe<sub>2</sub>O<sub>4</sub> powders and Ceramics. Scope and suggestion for future work

14. MANINDER KAUR  
**Numerical Simulations of High Intensity Laser Plasma Interactions.**  
 Supervisor: Dr. Devki Nandan Gupta  
Th 23635

#### *Abstract* (Not Verified)

This thesis presents the numerical simulations of interactions of high-intensity laser pulse with plasmas. The main objective of the thesis is to understand the physics of nonlinear phenomena arising due to high-intensity laser plasma interactions and their applications in laser-driven plasma based accelerators, laser inertial confinement fusion and synchrotron radiation sources. The aim of the work of thesis is basically to explore the laser-plasma based nonlinearities and their effects on particle acceleration. This work may be useful in excitation of the large-amplitude plasma wave and subsequent acceleration of particles to higher energies. During laser plasma interactions, the evolution of laser pulse shape in a plasma is of utmost importance that excites a large amplitude



plasma wave. In our study, we have proposed a way to control the laser pulse shape distortion by considering the propagation of a laser through a parabolic plasma channel. We have studied the factors responsible for excitation of a large amplitude plasma wave. The study of laser-plasma interactions becomes highly nonlinear and complex at relativistic intensities of the lasers. To explore the nonlinear dynamics of laserplasma interactions, numerical simulations play an important role in providing relevant information which cannot be simplified using theoretical models. We have used a particle-in-cell (PIC) method for this study. Our simulation results are relevant to laser-plasma based accelerators for generating an energetic electron beam. Our findings can be useful in understanding the unique characteristics of accelerated bunch obtained from laser-plasma accelerator such as high energy gain, small energy spread and small divergence. The work in the thesis can be considered as detailed description of high-intensity laser-plasma interactions through numerical simulations. The research progress in laser-plasma interactions studies has been growing in recent years for various applications to mitigate the real-world problems.

#### *Contents*

1. Introduction 2. Particle-in-cell (PIC) simulations 3. Laser – pulse shape distortion in a plasma channel 4. Plasma beat-wave dynamics in collisional relativistic plasmas 5. Electron acceleration by a plasma wave in a magnetic plasma channel 6. Plasma electron acceleration from laser wakefield in bubble regime 7. Electron acceleration by a radially polarized laser in an ion-channel 8. Summary

15. MISHRA (Nagender)  
**Dynamics of Neuronal Networks.**  
 Supervisors: Prof. H.P. Singh and Prof. B. Biswal  
Th 23630

#### *Abstract* (Verified)

The thesis addresses the question of presence of determinism, possibility of short term prediction and control, and linking the network topology with the underlying neuronal dynamics of epileptic brain slices. A modified hybrid method of unstable periodic orbits (UPOs) detection is developed that in conjunction with appropriate surrogate method establishes determinism in short datasets with low noise. The parameters of UPOs determined from this geometrical analysis match well with the actual values. This method can be used for searching statistically significant UPOs in noisy biological data. Through computer simulation of kindling of epilepsy in hippocampal brain slices in a stochastic neural network model, we establish that the apparent success of control reported in real brain slices does not necessarily conclude presence of determinism. We show that similar success in chaos control can be achieved in a neuronal system with stochastic dynamics, showing further that control deteriorates rapidly if a small amount of noise is present in the system's dynamics. A biologically realistic neuronal network model for epileptic burst dynamics in chemically kindled rat hippocampal slices is proposed using coupled Hindmarsh-Rose neurons. Initial synaptic configuration is chosen on Small World, Random, Scale Free and Modular Network topology. Creation of new synapses or strengthening of existing synapses observed in the kindled brain slices is modelled through a Hebbian learning mechanism that is switched on during the kindling. Unkindled networks shows low activity oscillation without population bursts. Subthreshold, critical threshold, and supra-threshold stimulation leads to low activity, population bursts, and seizure states respectively. We observe that different topologies lead to seizure generation by the same mechanism of formation of modular clusters that fire simultaneously during population bursts. We believe that this computer model for focal epilepsy shall be useful in future epilepsy research.

*Contents*

1. Introduction. 2. UPO detection in biological time series 3. Chaos Control 4. Computational modelling of epilepsy 5. Conclusions and future work. Bibliography

16. RAKESH

**Studies in Inflationary Cosmology with Scalar Field Models**

Supervisors: Prof. Amitabha Mukherjee and Prof. Daksh Lohiya

Th 23642

*Abstract*

(Not Verified)

In the present thesis, we explore three closely related aspects of inflationary cosmology using scalar field models. Firstly, we ask the question whether the old inflation can be revived if potential is considered to be time-dependent. Our study showed that for slowly varying potential, the tunnelling rate is small, whereas for the rapidly varying potential, it is large. We have further shown how the graceful exit problem plaguing the old inflation, can be resolved within this scenario. Secondly, we consider the phenomenology for the quartic potential inflationary model within the slow-roll formalism. In particular, we study the effects of lifting the degeneracy between the two vacua on the inflationary observables, i.e., spectral index  $n_s$  and tensor-to-scalar perturbation ratio  $r_T$ . We find that removing the degeneracy allows the model to satisfy the upper limit constraints on  $r_T$  from Planck data, provided the field starts near the local maximum. Finally, we address the problem of reheating and put constraints on the duration of reheating and the temperature at the end of reheating for different models of inflation. We find that the details of the potential are irrelevant if the analysis is done strictly within the slow-roll formalism. In addition, we extend the de-facto analysis generally done only for the pivot scale to all the observable scales which crossed the Hubble radius during inflation. Our ongoing work on the multi-field potential considers the problem of finding a (successful) background trajectory which can give 60 e-folds of inflation within the context of hybrid potential. Although sum-separable potentials can be handled by delta-N formalism, however, the FRW equations becomes stiff and chaotic when there are interactions among the fields, as in hybrid inflation. We identify the regime where the potential is very flat, and in which inflation continues for more than about 60 e-folds.

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1. Introduction. 2. Tunnelling 3. Reanalyzing the upper limit on  $r_T$  in a quartic potential inflationary model 4. in a time dependent quartic potential: Decay rate strongly dependent on time scale Constrains on reheating 5. Some ongoing studies in hybrid inflation 6. Summary and future perspective. Appendix and bibliography

17. ROOPAM GAUR

**Synthesis and Characterization of Alkaline Niobate Based Lead-Free Piezoceramics**

Supervisor: Dr. K. Chandramani Singh

Th 23628

*Contents*

1. Introduction and literature survey 2. Experimental and characterization techniques 3. Effect of lithium and antimony doping on KNN ceramics 4. Effect of vanadium doping on KNN ceramics 5. Effect of barium doping on KNN ceramics. Conclusions and future prospects

18. SHARMA (Vishal)  
**Fabrication and Characterization of Organic Solar Cells and Investigation of Perovskite Materials for Photovoltaic Applications.**  
 Supervisors: Prof. R.P. Tandon and Dr. Swati Arora  
Th 23638

*Abstract*  
 (Not Verified)

Present research work focused on the fabrication, optimization and characterization of organic solar cells (OSCs) as well as synthesis of perovskite materials in the ambient conditions for low-cost, efficient and industrial scale perovskite solar cells. Organic Bulkheterojunction solar cells were fabricated in the ambient conditions. Starting with the fabrication of most researched solar cells i.e. P3HT:PC BM with the optimization conditions taken from the literature, we substitute PCDTBT instead of P3HT and PC BM instead of PC BM with the intend to increase the photovoltaic performance of fabricated devices. Optimization of the active layer was carried out by using different blend ratios and concentration to achieve better performance, and it was observed that the highest efficiency was obtained at the optimized blend ratio of 1:4 and a concentration of 12 mg/ml. The aging studies of the champion device were performed in the ambient conditions. Theoretical analysis of OSC showed that the dominant current conduction mechanism in freshly prepared devices is drift-diffusion and in the degraded devices it can be attributed to the drift-diffusion as well as the trap assisted SCLC theory. The work was further extended towards the bulk synthesis of Organic-inorganic hybrid perovskite materials in the ambient conditions. Here, we are successful in synthesizing all perovskite composition (FA MA LI) ranging from methylammonium lead iodide (MALI,  $x=0$ ) to formamidinium lead iodide (FALI,  $x=1$ ) using ball milling techniques in the ambient conditions. The structural, morphological, optical and electrical properties of all synthesized perovskites materials were analysed as a function of FA/MA composition. Furthermore, solar PV device of newly synthesized mixed cation perovskite materials were fabricated. It was observed that the devices fabricated using ball milled powder (BMP) showed better photovoltaic performance and stability as compared to the devices fabricated using conventional solution processable (CSP) method.

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1. Introduction. 2. Experimental and characterisation techniques 3. Organic solar cells: Fabrication, optimization and aging studies 4. Theoretical insight of organic solar cells: Comparison of experimental and computational results 5. Synthesis of perovskite materials and device fabrication 6. Conclusions and future work

19. SINGH (Rajveer)  
**Investigations on Strontium Bismuth Niobate Ferroelectric Ceramic**  
 Supervisors: Dr. Vandna Luthra and Dr. R.P. Tandon  
Th 23639

*Contents*

1. Introduction. 2. Experimental and characterization techniques 3. Synthesis and characterization of non-stoichiometric  $Sr_{1-x}Bi_{2+2x/3}Nb_2O_9$  ferroelectric ceramics 4. Synthesis and characterization of non-stoichiometric  $Sr_{0.8}Bi_{2.2-x}Sb_xNb_2O_9$  ferroelectric ceramics 5. Synthesis and characterization of non-stoichiometric  $Sr_{0.8}Bi_{2.2}(Nb_{1-x/3})$

Tax/<sub>3</sub>)<sub>2</sub> O<sub>9</sub> ferroelectric ceramics 6. Microwave-assisted sintering of non-stoichiometric strontium bismuth niobate ceramic: Structural and dielectric properties 7. Conclusion and future scope.

20. SONU

**Growth of Organic and Inorganic Single Crystals by Czochralski and Solution Techniques and their Structural, Electrical and Mechanical Characterization.**

Supervisor: Prof. Binay Kumar

Th 23632

*Abstract*  
(Not Verified)

In the present thesis, both organic and inorganic single crystals were grown by Czochralski (Cz) and solution growth techniques. In this thesis Cz growth technique for various crystals has been discussed in detail and a suitable modification has been incorporated to solve the problem of low melting point materials. In the process, a novel modified Czochralski technique was designed and fabricated. In the present work (i) organic 8-Hydroxyquinoline, (ii) inorganic K<sub>2</sub>ZnCl<sub>4</sub> and (iii) pure and BFO doped KCl single crystals were grown by conventional/modified Cz technique. All the chosen materials have a large difference in their melting point from each other so this work can be useful in growing single crystals for a variety of materials using Cz technique. Slow evaporation solution growth technique was used to grow L-prolinium tartrate (LPT) single crystals. All the grown crystals were subjected to various characterizations depending on the properties associated with them. Further, pure and BiFeO<sub>3</sub> (BFO) doped KCl single crystals were used to design and fabricate microstrip patch antenna in GHz frequency range for communication applications.

*Contents*

1. Introduction 2. Literature survey and objectives of work 3. Experimental techniques 4. Growth and characterizations of K<sub>2</sub>ZnCl<sub>4</sub> single crystal 5. Growth and characterization of pure and BiFeO<sub>3</sub> doped KCl 6. Growth and characterization of 8-Hydroxyquinoline single crystal 7. Growth and characterizations of L-prolinium tartrate single 8. Conclusion and scope for future work