Project report – XI th plan:

1. Project: Physics of complex system under extreme conditions (PIC no: 11-R&D-SIN-5.02-0100)
3. Brief report about achievement /highlights with reference to programme as proposed in XIth plan DPR. (Annexure- I):
4. List of major capital equipment’s procured as proposed in DPR and present status.
   The following major capital Equipment’s have been procured and Installed successfully.
   a. Atomic Force Microscopy-Magnetic Force Microscopy, Mask aligner
   b. DC-RF sputtering under high vacuum (UHV system)
   c. XRD at low temperature with 18KW power
   d. Cryostats for Physical property measurements system (5 T- 9T)
   e. Room Temp. Bore magnet (9 T) with VTI
   f. Furnaces- small and medium
   g. Field Sweep magnet for NMR (9T)
   h. High pressure – Hydrostatic- 3GPa (max.) at LT, Dimond Anvil Cell
   i. SQUID-VSM
5. Reasons for not achieving the target as fixed for the project (any major deviation)
   Scanning electron microscope with elemental analysis could not be procured for technical reasons and as and when required this measurements have been carried out in collaboration with other institute. Some of the experiments are possible with newly installed 300TEM equipment at SINP.
7. Details of Overall expenditure :
   Consolidated expenditure statement : 1-Apr-2007 to 10-Sep-2013
   Project: Physics of Complex System Under Extreme Conditions
Annexure I

Project (XI\textsuperscript{th} plan): Physics of complex system under extreme conditions

Salient Scientific/Technical features of the Project as in DPR:

[1] Experimental investigations of super-hard materials, composite magnets, negative TCR & negative thermal expansion materials at high pressure with a focus on isotropic cubic materials. Experimental investigations of exchange coupling between grains and dipoles in composite magnets consisting of soft and hard phases for high energy product, $(BH)_{max}$ material.


The following are the specific programmes covering the above mentioned research area as proposed in the project.

1. **Programmes focusing on Intermetallic alloys:**

   1.01 Intriguing properties of cubic intermetallic inverse perovskite containing Rare-earths and low-Z elements excluding oxygen
   1.02 Experimental investigations of exchange coupling between grains and dipoles in composite magnets consisting of soft and hard phases for high energy product, (BH)max, material.
   1.03 Effect of Si/Ge ratio on resistivity and thermoelectric power in Gd$_5$Si$_x$Ge$_{4-x}$ magnetocaloric compounds:
   1.04 Electronic transport minimum in SmCuAs$_2$ at low temperature and structural anomalies.
   1.05 Large variations in the magnetic ordering behavior of EuCu$_2$As$_2$ with the application of external pressure and magnetic field.
   1.06 $^{27}$Al and $^{63}$Cu NMR studies in polycrystalline sample of CeCu$_3$Al$_2$
   1.07 $^{93}$Nb NMR studies in single crystal NbSe$_2$
   1.08 $^{75}$As NMR study of oriented CeFeAsO and CeFeAsO$_{0.84}$F$_{0.16}$
   1.09 Interplay between Co 3d and Ce 4f magnetism in CeCoAsO
   1.10 Effect of Pt on the superconducting and magnetic properties of ErNi$_2$B$_2$C
   1.11 Crystalline electric field effects in PrNi$_2$B$_2$C: Inelastic neutron scattering
   1.12 $^{27}$Al and $^{63}$Cu NMR studies on intermetallic Kondo compound CeCu$_3$Al$_2$
   1.13 $^{11}$B and $^{195}$Pt NMR study of heavy-fermion compound CePt$_2$B$_2$C
   1.14 Comparative studies of magnetocaloric effect and magnetotransport behavior in GdRu$_2$Si$_2$ compound
   1.15 Contribution of energy-gap in the ferromagnetic spin-wave spectrum on magnetocaloric parameters of CeRu$_2$Ge$_2$
   1.16 Magnetoresistance studies on RPd$_2$Si (R = Tb, Dy, Lu) compounds
   1.17 Giant magnetocaloric effect in antiferromagnetic ErRu$_2$Si$_2$ compound

2. **Programmes focusing on oxide materials:**

   2.01 Magnetism of AFM Nano particles: Core-shell model and “Unconventional relaxation in antiferromagnetic CoRh$_2$O$_4$ nanoparticles”
   2.02 Complex magnetic materials focusing on oxide nano particle in crystalline and amorphous samples
   2.03 Suppression of spin-lattice coupling for the observation of Geometrically frustrated magnets in magnetic ordering and JT ion system- as an example NiCr$_2$O$_4$.
   2.04 Glassy behavior of the phase segregated state of the layered perovskites La$_{2-x}$Sr$_x$CoO$_4$ (1.1 ≤ x ≤ 1.3)
   2.05 Disordered spin liquid ground state of the Haldane gap compound SrNi$_2$V$_2$O$_8$
   2.06 $^{31}$P nuclear-magnetic-resonance in trimer spin chain compound Ca$_3$CuNi$_2$(PO$_4$)$_4$
   2.07 Resistivity and $^{75}$As nuclear magnetic resonance (NMR) of superconducting CeFeAsO$_{0.84}$F$_{0.16}$
   2.08 NMR studies on LaCoPO
   2.09 Studies of interfacial hydrogen bonding organic liquids, ethylene glycol [(CH2OH)2] and isopropanol [CH3CH(OH)CH3]
   2.10 Anisotropic spin-fluctuations in SmCoPO revealed by $^{31}$P NMR measurement
   2.11 $^{31}$P NMR studies on Ca$_3$Cu$_2$Ni(PO$_4$)$_4$
   2.12 Magnetic, transport and thermal properties of Sm$_{0.52}$Sr$_{0.48}$MnO$_3$ single crystal
   2.13 Transport, magnetic and thermal properties of Iron based superconductors
   2.14 Anisotropic magnetic properties and giant magnetocaloric effect in antiferromagnetic RMnO$_3$ crystals (R = Dy, Tb, Ho, Yb)
   2.15 Phase transition and magnetoelectronic phase separation in the La$_{1-x}$Sr$_x$CoO$_3$ (0.10 ≤ x ≤ 0.33) single crystals
2.16 Cluster glass behavior in Co-substituted double perovskite Ca$_2$FeMoO$_6$
2.17 Spin glass-like behavior and magnetic enhancement in nanosized Ni-Zn ferrite system
2.18 Spin glass-like behavior in Fe-rich phases of Sr$_2$Fe$_{1-x}$Mn$_x$MoO$_6$ (0.1 ≤ x ≤ 0.4)
2.19 Magnetic frustration effect in Mn-rich Sr$_2$Mn$_{1-x}$Fe$_x$MoO$_6$ system
2.20 Thermoelectric power of RFeAsO (R = Ce, Pr, Nd, Sm, and Gd)
2.21 Magnetism of crystalline and amorphous La$_{0.65}$Ca$_{0.33}$MnO$_3$ nanoparticles
2.22 Evidence of disorder induced magnetic spin glass phase in Sr$_2$FeMoO$_6$
2.23 Studies of the magnetic frustration effect in Sr$_2$Fe$_{1-x}$Mn$_x$MoO$_6$ (0.1≤x≤0.4) system
2.24 Exchange bias effect in LaFeO$_3$ nanoparticles
2.25 Electrical transport and magnetic properties of Co-substituted Ca$_3$FeMoO$_6$
2.26 Surface Spin Glass and Exchange bias effect in nano particles of Sm$_{0.5}$Ca$_{0.5}$MnO$_3$ manganites
2.27 Evidence of exchange bias effect and surface spin glass ordering in electron doped Sm$_{0.09}$Ca$_{0.91}$MnO$_3$ nanomanganites
2.28 Field induced ferromagnetic phase transition and large magnetocaloric effect in Sm$_{0.55}$Sr$_{0.45}$MnO$_3$ phase separated manganites:
2.29 Scaling of non-Ohmic conduction in strongly correlated systems
2.30 Evidence of a structural phase transition in superconducting SmFeAsO$_{1-x}$F$_x$ from $^{19}$F NMR
2.31 NMR study of rare-earth transition metal oxypnictides
2.32 NMR study of spin-trimer compound Ca$_3$CuNi$_2$(PO$_4$)$_4$
2.33 Freezing/melting behavior of nanoconfined liquids probed by $^1$H NMR
2.34 NMR study of rare-earth transition metal oxypnictides
2.35 The metal–insulator transition in nanocrystalline Pr$_{0.67}$Ca$_{0.33}$MnO$_3$: the correlation between supercooling and kinetic arrest
2.36 Inverse magnetocaloric effect in polycrystalline La$_{0.125}$Ca$_{0.875}$MnO$_3$
2.37 Magnetocaloric properties of nanocrystalline La$_{0.125}$Ca$_{0.875}$MnO$_3$
2.38 Low temperature conductivity in ferromagnetic manganite thin films: quantum corrections and inter-granular transport
2.39 Colossal enhancement of magnetoresistance in La$_{0.67}$Sr$_{0.33}$MnO$_3$ thin films: possible evidence of electronic phase separation
2.40 Colossal enhancement of magnetoresistance in La$_{0.67}$Sr$_{0.33}$MnO$_3$/Pr$_{0.67}$Ca$_{0.33}$MnO$_3$ multilayers: Reproducing the phase separation scenario
2.41 Influence of charge ordering on magnetocaloric properties of nanocrystalline Pr$_{0.65}$(Ca$_{0.7}$Sr$_{0.3}$)$_{0.33}$MnO$_3$
2.42 Magnetocaloric properties of nanocrystalline Pr$_{0.65}$(Ca$_{0.6}$Sr$_{0.4}$)$_{0.35}$MnO$_3$
2.43 Observation of large low field magnetoresistance and large magnetocaloric effects in polycrystalline Pr$_{0.65}$(Ca$_{0.7}$Sr$_{0.3}$)$_{0.35}$MnO$_3$
2.44 Low-temperature magnetotransport properties in granular ferromagnetic manganites
2.45 Unified description of spin-dependent transport in granular ferromagnetic manganite
2.46 Magnetic and transport properties of nanocrystalline Nd$_{0.5}$Sr$_{0.5}$MnO$_3$
2.47 Magnetocaloric effect in Ho$_3$Pd$_2$: Evidence of large cooling power
2.48 Magnetotransport properties of nanocrystalline Pr$_{0.65}$(Ca$_{1-x}$Sr$_x$)$_{(0.35)}$MnO$_3$ (y similar to 0.4,0.3): Influence of phase coexistence

3. Other related programmes:
3.01 Soft condensed Matter
3.02 Studies on broadband microwave absorption and dielectric properties of low-d materials and their composites and development of electromagnetic interference (EMI) shields.
3.03 Microwave spectroscopy studies
   3.03.1 Conventional microwave and millimeterwave spectroscopic studies of organic molecules of chemical and astrophysical interest
   3.03.2 Millimeter-wave spectroscopic studies of DC discharge produced stable and transient molecules of chemical and astrophysical interest
   3.03.3 Studies on broadband microwave absorption and dielectric properties of low dimensional materials.
4. **Programmes focusing on theoretical studies:**

4.01 Studies of nonequilibrium continuum model systems using field theoretic tools with an aim to uncover their universal scaling properties and their dependences (if any) on the nature and strength of the external drives.

4.02 Studies of statistical mechanics aspects of fluid and magnetohydrodynamic turbulence with a focus to find the universal multiscaling exponents and setting up the exact hierarchical relations among the structure functions of various orders.

4.03 Studies of active or “living matter” in terms of continuum descriptions for driven nematic or polar ordered systems to understand a coarse-grained picture of several cell biology experiments concerning fluctuations in the cytoplasm-cell membrane combine.

4.04 Studies of simple one-dimensional discrete lattice-gas based driven models executing exclusion process using mean-field theories and Monte-Carlo simulations to explicitly calculate the nonequilibrium steady states in simple systems and contrast them with corresponding equilibrium systems.

4.05 Exact studies on the properties of Holstein polarons and JT polarons: effect of disorder and second nearest-neighbor hopping.

4.06 Stability of Holstein and Frohlich bipolarons in presence of extended electron-electron interaction.

4.07 Fermions in optical lattices under anisotropic harmonic trap.

4.08 Bose condensation and other thermodynamic properties of Bosons in optical lattices under harmonic and quartic traps and the effects of Aubry potential on properties of lattice bosons.

4.09 Physics of Fracture: Study of earthquake dynamics & models

4.10 Study of Quantum Annealing and thermal annealing for new generation of quantum (annealing) computers

4.11 Econophysics: A new area of research has been developed for the first time as an interdisciplinary subject of Economics and Statistical Physics.

4.12 An exact solution of the CCM model and explained the origin of Pareto’s law have been provided.

4.13 A method has been proposed to obtain steadystate weights and the spatial correlations exactly in a class of non-equilibrium models.

4.14 Studies of Protein production in the cell is inhibited by micro RNAs.

4.15 Studies and development of APT models.

4.16 Studies of coexistence of superconductivity and charge-density-wave using Hubbard-Holstein model in one-dimensions.

4.17 Studies of cooperative electron-phonon interaction physics in one-dimensions.

4.18 Studies of supersolidity for a system of hard-core-bosons coupled to optical phonons in a lattice.

4.19 Studies of the ground state orbital ordering of LaMnO$_3$ at weak electron-phonon coupling.

4.20 Analytically study of the Peierls instability condition in the Holstein model.
Annexure II

List of publications- Experimental studies

2007


13. Magnetotransport properties of nanocrystalline Pr_{0.65}(Ca_{1−y}Sr_y)_{0.35}MnO_3 (y ~ 0.4,0.3): Influence of phase coexistence: Anis Biswas and I. Das, Appl.Phys. Lett., 91, 013107 (2007).


24. Modification of the spin state in Sm$_{0.52}$Sr$_{0.48}$MnO$_3$ by external magnetic field, P. Sarkar and P. Mandal, Appl. Phys. Lett. 92, 052501 (2008).
25. Large magnetocaloric effect in Sm$_{0.52}$Sr$_{0.48}$MnO$_3$ in low magnetic field, P. Sarkar, P. Mandal, and P. Choudhury, Appl. Phys. Lett. 92, 182506 (2008).
26. Hydrostatic pressure effect on archetypal Sm$_{0.52}$Sr$_{0.48}$MnO$_3$ single crystal K. Mydeen, P. Sarkar, P. Mandal, A. Murugeswari, C. Q. Jin, and S. Arumugam Appl. Phys. Lett. 92, 182510 (2008).
29. NMR study of the impurity induced ordered state in the doped Haldane chain compound SrNi$_{1.91}$Mg$_{0.07}$ V$_2$O$_5$: B. Papari, K. Ghoshray, R. Sarkar, and A. Ghoshray; Phys. Rev. B77, 224429 (2008).
36. Magnetocaloric properties of nanocrystalline Pr$_{0.65}$(Ca$_{0.68}$Sr$_{0.32})$MnO$_3$: Anis Biswas, Tapas Samanta, S. Banerjee and I. Das; J. Appl. Phys. 103, 013912 (2008).
37. Observation of large low field magnetoresistance and large magnetocaloric effects in polycrystalline Pr$_{0.65}$(Ca$_{0.68}$Sr$_{0.32})$MnO$_3$: Anis Biswas, Tapas Samanta, S. Banerjee and I. Das; Appl. Phys. Lett. 92, 012502 (2008).
39. Colossal enhancement of magnetoresistance in La$_{0.65}$Sr$_{0.35}$MnO$_3$/ Pr$_{0.65}$(Ca$_{0.68}$Sr$_{0.32})$MnO$_3$ multilayers: reproducing the phase-separation scenario: Soumik Mukhopadhyay and I.Das; Europhys. Lett. 83, 27003 (2008).
45. Intermediate valence behavior in Ce$_{0.35}$Eu$_{0.5}$Pd$_{1.78}$, Abhishek Pandey, C. Majumdar, R. Ranganathan, AIP conf. Proc. 1003, 216 (2008)


49. Re-entrant Spin-Glass Phenomenon in Ca2Fe1-xCo4MoO6 (0.1≤x≤0.4), Asok Poddar and Chandan Mazumdar, AIP Conf. Proc. 1003, 292 (2008).


2009


62. Negative pressure driven valence instability of Eu in cubic Eu0.5La0.5Pd3; Abhisheik Pandey, Chandan Mazumdar, R. Ranganathan, J. Phys. Condens. Matter 21, 216002 (2009).


70. Effect of uniaxial pressure on metal-insulator transition in (Sm1-xNd)x0.52Sr0.48MnO3 single crystals: A. Murugeswari, P. Sarkar, S. Arumugam, N. Manivannan, P. Mandal, T. Ishida, and S. Noguchi, Appl. Phys. Lett. 94, 252506 (2009).


75. 90 MeV O-16 heavy-ion irradiation effects on La$_{0.85}$Pb$_{0.15}$MnO$_3$ single crystals: M. R. Babu, X. F. Han, P. Mandal, et al. Materials Chemistry and Physics 117, 113 (2009).


81. Thermoelectric power of RFeAsO (R = Ce, Pr, Nd, Sm, and Gd), Asok Poddar, Sanjoy Mukherjee, Tamnay Samanta, Rajat S. Saha, Rajarshi Mukherjee, Papri Dasgupta, Chandan Mazumdar, and R. Ranganathan, Physica C469 (2009) 789.


**2010**

88. $^{27}$Al and $^{63}$Cu NMR studies on intermetallic Kondo compound CeCu$_3$Al$_2$, B. Bandyopadhyay, M. Majumder, A. Ghoshray, and K. Ghoshray, Physica B 405, 4691, (2010)


91. Magnetism and transport studies in off-stoichiometric metallic perovskite compounds GdPd$_3$B$_x$ (x = 0.25, 0.50 and 0.75), A. Pandey, Chandan Mazumdar, and R. Ranganathan, J. Magn. Magn. Mater, 322 (2010) 3765.


99. Spin glass-like behaviour in Fe-rich phases of Sr$_2$Fe$_{1-x}$Mn$_x$MoO$_6$ (0.1 < x < 0.4): Asok Poddar and Chandan Mazumdar, J. Alloys Compd. 502 (2010) 15.


102. Effect of hydrostatic pressure on magnetic phase transition and magnetocaloric properties of (Sm$_{0.8}$Nd$_{0.2}$)$_{0.52}$Sr$_{0.48}$MnO$_3$, S. Arumugam, P. Sarkar, P. Mandal, A. Murugeswari, K. Matsubayashi, C. Ganguli, and Y. Uwatoko, J. Appl. Phys. 107, 113904 (2010).

103. Millimeter-wave spectrum of Chlorocyanocetylene (CICCCN) generated by DC glow discharge technique, P. R. Varadwaj and A. I. Jaman, Asian J. Spectroscopy (accepted).


2011

105. Valence behavior of Eu-ions in intermetallic compound Ce$_{0.5}$Eu$_{0.5}$Pd$_3$B$_{0.5}$, Abhishek Pandey, Chandan Mazumdar, R. Ranganathan, V. Raghavendra Reddy and Ajay Gupta, J. Magn. Magn. Mater., 323 (2011) 3281.

106. Surface spin glass and exchange bias effect in Sm$_{0.8}$Ca$_{0.2}$MnO$_3$ manganites nano-particles, S. K. Giri, A. Poddar and T. K. Nath, AIP Advances 1, 032110 (2011).


110. Effect of magnetic field and pressure on charge-orbital ordering in Pr(Sr$_{1-y}$Ca$_y$)$_2$Mn$_2$O$_7$ (x=0.4 and 0.9) single crystals, R. Thiyagarajan, G. Deng, S. Arumugam, D. M. Radheep, U. Devarajan, A. Murugeswari, P. Mandal, E. Pomjakushina, and K. Conder, J. Appl. Phys. 110, 093905 (2011).


113. The magnetization of PrFeAsO$_{0.60}$F$_{0.12}$ superconductor, D. Bhoi, P. Mandal, P. Choudhury, S. Dash, A. Banerjee, Physica C: Superconductivity, 471, 258 (2011).


2012


124. The metal-insulator transition in NanocrystallinePr$_{0.67}$Ca$_{0.33}$MnO$_3$: the correlation between supercooling and kinetic arrest, R Rawat, P Chaddah, Pallab Bag, Kalipada Das and I Das, J. Phys.: Condens. Matter 24, 416001 (2012).


127. Hall effect in the metallic antiferromagnet Na$_3$CoO$_2$ (0.72≤x≤0.90), P. Mandal and P. Choudhury, Phys. Rev. B 86, 094423 (2012).


130. Millimeter-wave rotational spectra of trans-acrolein (propenal) (CH$_2$CHCOH): a DC discharge product of allyl alcohol (CH$_2$CHCH$_2$OH) vapour and DFT calculation. A. I. Jaman and Rangana Bhattacharya. J. of Atomic, Molecular and Optical Physics (Communicated)

131. Ionic Conductivity studies of Solid-State PEG-PU based electrolytes for energy applications. Naresh Chilaka, Shekar Bheemanapalli, K. Rajani Kumari, A.I Jaman and Sutapa Ghosh. (Communicated)
List of publications:- Theoretical studies

2007


2008


2009


2010


2011


2012

International conference – organized by Experimental faculties


Conferences/Symposia/Workshops: organised by Theoretical faculties


2. School on Low dimensional nanoscopic physics, 28 January - 9 February 2008, Harish-Chandra Research Institute, Allahabad, India, organized jointly with Harish-Chandra Research Institute, Allahabad, Institute of Physics, Bhubaneswar and Institute of Mathematical Sciences, Chennai.


6. STATPHYS-Kolkata VII, 26 - 30 November, 2010, Saha Institute of Nuclear Physics, Kolkata, India.


8. International School and Conference on Functional Materials, March 28 to April 1, 2011 at HRI, Allahabad as a joint program of HRI SINP.


10. RCBAMM2012 - An Indo-Singapore Joint Workshop on Role of Computational Biology in Advancing Modern Medicine, February 2-3, 2012, Saha Institute of Nuclear Physics, Kolkata, India.

Human Resource: No., of Ph.d produced: Experimental 8, Theory 7: Total 15
MEMORIAL LECTURES

1. The Sixth J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Allan H MacDonald, Sid W. Richardson Foundation Regents Chair Professor, Dept of Physics, University of Texas at Austin, USA on "Quantum Hall Superfluids" on 5th April, 2011.

2. The Fifth Ramanujan Lecture of the CAMCS, SINP, will be delivered by Prof. Masuo Suzuki, Professor of Applied Physics, Tokyo University of Science, Japan, on "Quantum-Classical Correspondence in Statistical Mechanics" on 25th November, 2010.

3. The Fifth J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Klaus von Klitzing, Max Planck Institute for Solid State Research, Stuttgart, Germany on "The Quantum Leap from Micro- to Nanoelectronics" on 2nd November, 2010.

4. The Fourth J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Sidney R. Nagel, Stein-Freiler Distinguished Service Professor, University of Chicago, USA on "Jamming and the Emergence of Rigidity" on 8th March, 2010.

5. The Fourth Ramanujan Lecture of the CAMCS, SINP, was delivered by Prof. Anthony J. Leggett, the John D. and Catherine T. MacArthur Professor and Center for Advanced Study Professor of Physics, University of Illinois, USA on "Superfluid 3-He: The early days as seen by a theorist [Nobel Lecture 2003] " on 29th January, 2010.

6. The Third J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Anthony J. Leggett, the John D. and Catherine T. MacArthur Professor and Center for Advanced Study Professor of Physics, University of Illinois, USA on "Bell's theorem, entanglement, quantum teleportation, and all that" on 28th January, 2010.

7. The Third Ramanujan Lecture of the CAMCS, SINP, was delivered by Prof. Peter A. Markowich, Professor of Applied Mathematics, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK, and Professor of Applied Analysis, Faculty of Mathematics University of Vienna, Austria on "Reaction-Diffusion (-Convection) Equations, Entropies and Sobolev Inequalities" on 10th March, 2009.

8. The Second Ramanujan Lecture of the CAMCS, SINP, was delivered by Prof. Sir Michael Berry, Royal Society Research Professor of the University of Bristol, UK on "The music of the primes: quantum mechanics, chaos and the Riemann zeros" on 27th January, 2009.

9. The Second J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Gabriel Aeppli, Quain Professor of Physics and the Director of the London Centre for Nanotechnology, UK on "Interdisciplinarity continued from semiconductor physics to pharmaceutical assays" on 5th February, 2009.

10. The First Ramanujan Lecture of the CAMCS, SINP, was delivered by Prof. H. Nishimori of the Tokyo Inst. Tech., Tokyo, on "Spin Glasses and Information" on 9th January, 2007.

11. The First J. C. Bose Memorial Lecture of the CAMCS, SINP, was delivered by Prof. Jainendra Jain of the Penn. State Univ, Pennsylvania, on "Lessons of the Fractional Quantum Hall Effect for Outsiders" on 3rd December, 2007.
The following major capital Equipment’s have been procured and Installed successfully:

a. Atomic Force Microscopy-Magnetic Force Microscopy
b. DC-RF sputtering under high vacuum (UHV system)
c. MFM, Mask aligner
d. XRD at low temperature with 18KW power
e. Cryostats for Physical property measurements system (5 T-9T)
f. Room Temp. Bore magnet (9 T) with VTI
g. Furnaces - small and medium
h. Field Sweep magnet for NMR 9T
i. High pressure – Hydrostatic- 3GPa (max.) at LT, Diamond Anvil Cell
j. SQUID-VSM
Some Important results - examples

The nano composite magnets consist of soft and hard magnetic phase alloys for high energy product magnets (BH) max.

Magnetic relaxation of AFM nanoparticles of CoRh$_2$O$_4$ at low temperatures.

The Ni(0) data in the expanded scale for different particle sizes.

Field on state.

For particle size <10nm, M decreases with time.

Field-OrIGIN: Unusual (negative magnetization growth with time).

Note 15nm change unusual (positive magnetization growth with time).

A schematic diagram to show the competition between antiferromagnetic exchange interaction (H$_{ex}$) and surface anisotropic field (H$_{an}$) in presence of applied magnetic field (H$_{mag}$) along a axis (spin up direction) for bulk and nanoparticle samples (top). 

μ is the resultant of two spins. M is the effective component of spins along - z direction.

The effective magnetic field along the + z axis:

H$_{eff}$ = H$_{mag}$ + H$_{an}$ - H$_{ex}$

Where μ, H$_{mag}$, H$_{an}$ and H$_{ex}$ refers to magnetic moment, applied magnetic field, anisotropic field and antiferromagnetic exchange field.

Determination of Crystalline Electric Field levels of PrNi$_2$B$_2$C using Inelastic Neutron Spectroscopic studies.

Standard model of magnetism with appropriate crystalline electric field level schemes can explain the magnetic data of PrNi$_2$B$_2$C adequately.

Spin dynamics in 1D trimer cluster compound Ca$_2$Cu$_2$Ni(PO$_4$)$_3$ probed by $^{31}$P NMR

M. Ghosh, M. Majumder, K. Ghoshroy, A. Ghoshroy

The variation of $1/T_1$ with $T$ shows negligible field dependence in the temperature range 50-300 K, suggesting Curie-Weiss type temperature dependence of the dynamic susceptibility.

In the range 15-50 K, $1/T_1$ decreases exponentially as $e^{-\lambda T_1}$. In this temperature region $1/T_1$ shows a field dependence, with $1/T_1 \propto H^{-1}$. Such a field dependence was predicted theoretically when the dominant contribution to $1/T_1$ is due to the two magnon nonadiabatic exchange enhanced Raman process over that of the three magnon process.

In the range 4-15K, $1/T_1$ shows continuous increment with $1/T_1 \propto H^{-1}$, which is a signature of the development of short range magnetic correlation, though the system does not show long range magnetic order down to 1.8 K as revealed from the magnetic susceptibility. The power law indicates spin diffusion process governs the nuclear relaxation below 15K.

**Non-linearity exponents – Quantization!!!**

$x_M$ is an integral multiple of 0.08

$N=1$ $x_M = 0.08$, $N=2$ $x_M = 0.16$ and so on

Experiments cover a wide variety of systems – amorphous/doped semiconductors, conducting polymers, organic crystals, manganites, composites, ‘dirty metals’, double perovskites

*strongly localized systems to weakly localized ones to correlated systems*

**Non linearity exponents in various CMR manganites**

Onset Field $F_o$ follows a Power-law relation with Ohmic conductivity with an exponent $x_f$

non-linearity exponent $x_f$ for various CMR manganite systems.

<table>
<thead>
<tr>
<th>System</th>
<th>Abbreviation</th>
<th>Type</th>
<th>$T_{M}$/K</th>
<th>$\Delta T_{M}$/K</th>
<th>$x_f$</th>
<th>$x_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>STO</td>
<td>Y100</td>
<td>Single crystal</td>
<td>300</td>
<td>0.2</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>LCMO</td>
<td>LC0.3</td>
<td>Single crystal</td>
<td>300</td>
<td>0.2</td>
<td>0.06</td>
<td></td>
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<tr>
<td>LCMO</td>
<td>LCMO0.3</td>
<td>Single crystal</td>
<td>300</td>
<td>0.2</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>LCMO</td>
<td>LCMO0.3</td>
<td>Single crystal</td>
<td>300</td>
<td>0.2</td>
<td>0.06</td>
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<tr>
<td>LCMO</td>
<td>LCMO0.3</td>
<td>Single crystal</td>
<td>300</td>
<td>0.2</td>
<td>0.06</td>
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</tr>
</tbody>
</table>

Scaling of non-Ohmic conduction in strongly correlated systems

First observation of electronic phase co-existence in nano-particles and low field melting of charge ordered state by magnetic field

Pr$_{65}$(Ce$_8$S$_{12}$)$_{0.75}$Mn$_2$O$_3$
(Nanocrystalline Samples)

- Hysteresis in M(T) and R(T) is indication of phase co-existence
- Low Field MR decreases with decrease of temperature below T_{co}
- Large LFMR due to charge order nothing

Anis Biswas & I. Das

Largest Magnetic Cooling Power in Ho$_2$Pd$_2$

H$_{co}$=5 Tesla

RCP (J/cm$^3$)

Relative cooling power:

RCPP = T F_{DEP}$\alpha$

Relative Cooling Power (RCP) is Largest among the reported best known magnetic refrigerant materials.

Tapas Samanta, I. Das & S. Banerjee

$^{27}$Al and $^{65}$Cu NMR spectra and Knight shift ($\chi$) in CeCu$_2$Al$_2$

$\chi(T) = \chi(0) + H_{2g}(T)\chi_0$

Hysteresis at $T_c$ Al-Cu model from spin polarized conduction electrons by the presence of electrons

$H_{2g} = 1.67(5)$ kOe/O$_2$ at Al(g)
$H_{2g} = 2.02(5)$ kOe/O$_2$ at Cu(g)
$H_{2g} = 3.83(5)$ kOe/O$_2$ at Cu(c)

Anisotropic Spin-Fluctuations in SmCoPO Revealed by $^{31}$P NMR Measurement

M. Meghamud, K. Ghoshray, A. Ghoshray, A. Pati*, and V. P. S. Awana*

SmCoPO undergoes three magnetic transitions: $T_{CO}$ at 80K, Sm$^{3+}$/Co$^{4+}$ interplayed AFM transition at 20K, and Sm$^{3+}$/AFM ordering at 5.4K.

IT$_1$ shows large anisotropy confirming a significant contribution of Sm$^{3+}$/electron spin fluctuations to $T_{CO}$ arising from indirect RKKY type exchange interaction indicating a non-negligible hybridization between 5m-5f orbitals and the conduction band, over the itinerant character of the Co-3d spin. This anisotropy originates from the orientation dependence of $\chi$ ($\chi_o$).

The 3d-spin fluctuations in the ab-plane is 2D FM (Ko < 1) in nature, while along the c-axis, a signature of a weak AFM (Ko > 1) spin fluctuations superimposed on weak FM spin-fluctuations even in a field of 7 T and far above $T_{CO}$ is observed. The enhancement of this AFM-fluctuations of the Co-3d spins along c-axis, at further low temperature is responsible to drive the system to an AFM ordered state.

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Role of internal and external perturbation on magnetic and electronic phase transition on narrowband single crystal

Magnetic, transport, and thermal properties of $Sm_{0.1}Sr_{0.9}MoO_3$ (SSMO) single crystal are very unusual due to large quenched disorder and narrow bandwidth. Our study shows:

1. At ambient condition, SSMO exhibits a strong first-order ferromagnetic (FM) metal to paramagnetic (PM) insulator phase transition at the Curie temperature $T_C \approx 120 \, K$ with large thermal hysteresis (left panel).

2. The application of magnetic field increases $T_C$ almost linearly at the rate of $11.3 \, K/T$ (up to $9.4 \, T$), diminishes the first-order character of the transition and above a critical point ($H_c \approx 8 \, T$, $T_C \approx 160 \, K$), the transition becomes a crossover.

3. Qualitatively similar behavior has been observed with increasing external pressure $P$ and chemical or internal pressure $y$, i.e., substitution of Nd at 5 site ($Sm_{0.1}Nd_{0.9}Sr_{0.9}MoO_3$) (middle and right panel).

Acoustic and magnetostrictive properties and huge magnetocaloric effect in $BaMnO_3$, $Ba_{0.9}Sr_{0.1}MnO_3$ and $Yb$ crystals

Plots of $T$ and $P$ dependence of $M$ for DyMnO$_3$ with field parallel to $c$ and $a$ axes are shown below:

- Magnetic structure of DyMnO$_3$ is highly magnetically anisotropic and it exhibits a field-induced metamagnetic transition.
- Huge (negative) magnetic entropy change with increasing $H$ suggests that PM is favorable at low temperatures.

Giant magnetostrictive effect in magnetically frustrated EuHo$_2$O$_4$ and EuHo$_3$O$_7$ compounds

These compounds exhibit field-induced metamagnetic transition from AFM to FM state which leads to a giant negative entropy change. In both cases, the entropy change remains very large down to $T_C$. This unusually large magnetostriction effect is due to the magnetic frustrations.

Spin glass behavior in oxide systems

$SrFe_{0.9}MnMoO_3$ $SrFe_{0.9}CoMoO_3$

$Fe_{1-x}(Mn/Co)MoO_3 \rightarrow$ Ferromagnetic $Fe_1^+$-Mo$_7^-$-Fe$_1^+$-

Antiferromagnetic $(Mn/Co)$(M)-(Mn/Co) Interactions

Magnetic Frustration $\rightarrow$ Highly frequency dependent peak in $\chi''(T)$

Exchange bias effect in oxide nanoparticles

$LaFeO_3$ $Sm_{0.5}Ca_{0.5}MnO_3$

Field cooled ($H_c$) M-H loop $\rightarrow$ Shifts in negative direction $\rightarrow$ EB effect

EB $\rightarrow$ Exchange coupling between FM shell & AFM core of particles

EB effect can be tuned by $H_c$ $\rightarrow$ Useful in Multifunctional Devices
Some examples:

**Important TCMP publications - highlights**

1) Quantum Annealing and Analog Quantum Computations (with A. Das), Rev. Mod. Phys. 80 (2008) 1061


[According to the Publisher, the first textbook in this new field: "Mandatory" Course Book for the Econophysics Course started this year in Leiden University; http://www.physics.leidenuniv.nl/edu/bachelor/courses_variatie/EF.asp ... Dutch "Verplicht", English "Mandatory".]

4) For hard-core-bosons coupled to optical phonons, we show that (due to next-nearest-neighbor hopping in the effective Hamiltonian) there is a striking superfluid-to-supersolid transition. "Supersolidity for hard-core-bosons coupled to optical phonons", S. Datta and S. Yarlagadda, Solid State Communications vol. 150, p. 2040 (2010)


