The Indian Road-Map for Gravitational Wave Astronomy
IndIGO - ACIGA meeting on LIGO-Australia.
Feb 8 -10 2011, New Delhi, India

ABSTRACTS

8th Feb - India International Centre
Conference Room II
0930 - 1830

Advanced LIGO, LIGO-Australia and the International Network
Stan Whitcomb (LIGO - Caltech)
Advanced LIGO represents a new generation of interferometer gravitational wave detector that will help usher in a new era of gravitational wave physics and astronomy. Technology developments have made possible a factor of 10 improvement in sensitivity over initial LIGO as well as extension of its low frequency coverage to 10 Hz. Advanced LIGO will operate as part of an international network of such detector, enabling source localization and other studies with capabilities far beyond those of the individual members of the network. LIGO and its Australian collaborators have proposed a joint project to build a southern hemisphere detector there ("LIGO-Australia") to complement the currently planned network. If successful, LIGO-Australia will multiply the capabilities of the world network, and provide a regional focus for gravitational wave research over the next 20 years.

LIGO-Australia: The Nuts and Bolts
Jesper Munch (The University of Adelaide)
The details of the proposed LIGO-Australia project will be discussed, including a summary of components to be provided by LIGO Laboratory and the infrastructure which will need to be built in Australia to house and operate the detector. Particular attention will be given to the design and construction of the vacuum system, but other topics such as buildings, site, staffing issues and proposed organizational and operational structures will also be addressed.

IndIGO and LIGO-Australia
C.S. Unnikrishnan (TIFR, Mumbai)
The Indian gravitational wave research community's long-standing wish to initiate and substantially contribute to experimental activity in the field, in association with the very mature theoretical and data analysis capabilities, can be realized by joining in the construction and operation of large scale detector. The possibility of collaborating in the Australian-AIGO had been discussed extensively in the past and today, with the LIGO-Australia proposal, the opportunity is real if there is encouragement and support at the national level. Some important first steps have been taken already, especially the approval and funding support for an advanced prototype detector. I will outline a roadmap for a meaningful international collaboration in the context of LIGO-Australia that will revive experimental gravitational physics in India and will develop expertise and technology capabilities here relevant for future generation GW detectors as well as for applications involving optics, lasers and high-end computing.

Research Challenges as GW Detectors Enter the Quantum Regime
David Blair (University of Western Australia, Perth)
This talk will review the technical issues which prevent gravitational wave detectors being full quantum instruments, and discuss experiments and proposed techniques which can pave the way towards

detector sensitivity below the standard quantum limit. The importance of these new techniques for obtaining science outcomes will be discussed.

GW Data Analysis and IndIGO
Sanjeev Dhurandhar (IUCAA, Pune)
Significant contributions made by the IUCAA group to GW data analysis over the last two decades will be reviewed. This will be followed by an overview of the IndIGO plans in GWDA in the coming years in the context of its participation in Advanced LIGO and LIGO-Australia.

Outreach Lecture (Jamia Milia Islamia)
Seminar hall of the Faculty of Engg. and Technology,

Exploring the Dark Side of the Universe in Gravitational waves
David Blair (University of Western Australia, Perth)
Einstein's gravitational waves offer humanity a brand new sense with which to probe the universe. Gravitational waves are akin to sound waves but they travel through space at the speed of light. They are unstoppable by matter, and offer humanity an opportunity to probe hidden and extreme states of matter, from black holes and neutron stars to the very moment of the birth of the universe itself. In the next few years an array of large scale detectors will come into operation. Gravitational waves are expected to be observed for the first time, offering an enormous new wealth of discovery about the dark side of the universe. This talk, which will include a short movie, will explain the new detectors and the discoveries expected as we begin to explore Einstein's spectrum.

David Blair is director of the Australian International Gravitational Research Centre, author of a popular books, founder of the Gravity Discovery Centre and winner of numerous awards.

9th February (Jamia Milia Islamia)
FTK-CIT conference hall
(Next to Guest House and Ansari Auditorium)
900 to 1300
Session on Vacuum System Deliverables

The LIGO Vacuum System and plans for LIGO-Australia
Stan Whitcomb (LIGO, Caltech)
The two LIGO vacuum systems in the US are among the largest and most challenging in the world. The 1.2m diameter arms must be kept below 10^{-9} torr over their full 4 km length, with limited pumping from the ends only. A network of chambers at the corners and ends hold the sensitive interferometer components, and must meet stringent cleanliness requirements, while providing isolated mounting locations and convenient access. The vacuum system for LIGO-Australia will have similar requirements.

Development of UHV Systems at UHVTD, RRCAT Indore
S.K Shukla, (RRCAT, Indore)
Synchrotron radiation sources Indus-1 and Indus-2 are the major activities of RRCAT, Indore and UHVTD is primarily responsible for the design, development, installation, commissioning and operation of the UHV systems for these machines. Indus-1 is a small e- storage ring for 450MeV, 100mA, with a circumference of 18.96 m. However, Indus-2, a 2.5 GeV 300 mA e- storage ring with a circumference of

172.474 m, has the largest indigenously developed UHV system in the country operating in 10-10 mbar range. As indigenization was important criterion, most of its vacuum hardware was designed, developed and produced in large numbers in-house. Important components included Bending magnet chambers, Straight section chambers, Septum magnet chamber, Photon absorbers, r.f contact bellows, Water cooled end flanges, Sputter ion pumps, Titanium Sublimation pumps etc. For the first time in the country large UHV chambers were fabricated from the Aluminium alloys and therefore the UHV cleaning procedures and conditioning techniques were formulated after conducting the required experimentation in the laboratory. Systems were also developed in-house for out-gassing rate measurements, electron stimulated desorption studies and glow discharge cleaning studies etc. In addition to these, many electronic systems like UHV Gate valve controllers, 32 channel baking system, 160 channel temperature monitoring system, Pressure monitoring systems, Titanium Sublimation Pump controllers, BA Gauge controllers, Sputter Ion pump controllers and pressurized hot water generator system for baking of Aluminum chambers of Indus-2 were also developed. Indus-2 UHV system is successfully operating for more than five years now and this confidence has led to the recent efforts in realizing Extreme High Vacuum (XHV). As a first step, Non Evaporable Getter (NEG) coating technology was attempted with the development of cylindrical magnetron sputtering system, NEG pumping speed measurement system and the system for activation studies on NEG coated chambers. The initial results on TiZrV NEG coatings are very encouraging as an ultimate vacuum 2.4×10^{-11} mbar has been recently achieved with a NEG coating activated at 200^{o}C for 2 Hrs only. This presentation provides a glimpse of the some of these developments.

Ultra High Vacuum Experience at IPR

S. B. Bhatt (IPR, Gandhinagar)

ADITYA Tokamak is the first Indian Tokamak installed at Institute for Plasma Research, Bhat, Gandhinagar, in 1989. ADITYA vacuum system of ADITYA Tokamak was one of the rare available Ultra high vacuum systems in 1989. During 1983-1989, IPR designed one of the large size UHV vessel, of 2 m3 and 68 m2 surface Area, We carried out erection of this UHV vessel, helium leak testing, and pumping of the vessel after pre-treatment and achieved vacuum better than 10-9 torr. We had designed UHV pumping system of ADITYA Tokamk, which consists of turbomolecular pumps, cryopumps, ultrahigh vacuum gauges, rotary vacuum pumps, UHV gate valves with interlocks and related sub systems. We had developed electropolishing and ultrasonic techniques for surface treatment of big and small vessel components, wall conditioning techniques for Tokamak Vacuum Vessel, viz. glow discharge cleaning techniques, ECR Discharge cleaning, pulse discharge cleaning, ECR-PDC cleaning etc. Different types of gas puffing by gas leak valves, molecular beam injection, different types of limiters etc. for vacuum systems, UHV compatible Wilson feed through, lithium conditioning by in-situ lithium coating etc., have been developed by us during this period. We had also designed UHV test stand, which is used to qualify UHV chambers for diagnostic subsystem before installation on ADITYA Vacuum Vessel. We organize of installation, helium leak testing and ultrahigh vacuum testing of the diagnostic systems, as and when required in consultation with the concerned scientists. We were also involved in discussion for UHV vacuum vessels for SST1 Tokamak, NBI Injection system and LVPD system at IPR. The design of SST1, superconducting Tokamak was started in 1996. The vacuum vessel of SST1 Tokamak consists of double wall vessel. The volume of the inner vacuum vessel is 16 m3 with 68 m2 surface Area. This vessel will have 16 UHV Pumping lines with 62,000 l/s net hydrogen pumping speed. The poloidal cross-section of this vessel is close to ‘D’ shape. This vessel is surrounded by another vessel called Cryostat with Volume of 40 m3 with 72 m2 surface Area. We have also designed, fabricated and installed a no. of relatively small UHV systems for diagnostic system and lab experiments.

9th February (Jamia Milia Islamia)
1400 - 1830
Session on GW Data Analysis

Title: Multi-detector Gravitational Wave Coherent Search Veto
Archana Pai (IISER, Thirivananthapuram)

The Gravitational Wave (GW) hunt in the science run data from the worldwide network of initial GW detectors continues. This multi-detector GW search is two-pronged; devising optimal, robust detection scheme and veto schemes. Optimal and robust methods exist for searching coalescing compact binaries in the multi-detector data, some of which are already implemented in the existing LSC pipeline. Here, we lay out proposed plan to devise coherent veto strategies for the binary search.

Vetoes for gravitational-wave transients using instrumental coupling models
P. Ajith (Caltech)

Since modern interferometric gravitational-wave (GW) detectors are highly complex instruments, the data is often plagued with a large number of noise transients, which are not easily distinguishable from possible GW signals. In order to perform a sensitive search for transient GW signals, it is important to identify these noise artifacts. Thus, data from many instrumental subsystems are also continuously recorded along with the "GW channel". A robust method has been developed to "veto" noise transients making use of our understanding of the coupling of different noise sources to the GW channel. Here, we check the consistency of glitches in the GW channel with those in a linear/bilinear combination of instrumental channels, thus establishing (with some confidence) the instrumental origin of these glitches.

Advantage of an extended network of detectors in radiometric searches for GW
Sanjit Mitra (JPL, Caltech)

Quantitative analysis of the performance of a network of gravitational wave (GW) detectors is useful for studying the importance of the network and to identify potential scientific results that can be extracted from data. Here we employ a ``radiometer algorithm'', designed for making sky maps of a Stochastic Gravitational Wave Background (SGWB), to study the performance of a network in terms of different figures of merit. Simplicity of this method leads to results which are relatively straightforward to compute, yet provide vital understanding of the overall network performance.

Test of General Relativity & Alternative theories of gravity using GW observations
K.G. Arun (CMI, Chennai)

I will discuss some of the important ideas in the literature to test General Relativity and other relativistic theories of gravity. These tests include the proposal to measure the consistency between various post-Newtonian coefficients in the phasing formula, constrain the dipole parameter of Brans-Dicke theory and bounding the mass of the graviton using GW observations of inspiralling compact binaries. The expected improvement due to world wide network will be highlighted.

Design considerations for the IndIGO Data Analysis Centre
Anand Sengupta (Delhi Univ, Delhi)

A common ground shared by many members of the IndIGO consortium is their experience and expertise in gravitational wave data analysis. This is borne by their consistent contribution in this field of research over the last two decades. This can be substantially consolidated by the creation of a large computational facility, tentatively called 'IndIGO Data Analysis Centre'. Such a facility would not only cater to the storage and archival of gravitational wave data from the experimental sites and provide necessary computational infrastructure for its prompt analysis but would also provide a platform for training a new generation of Indian graduate students in this relatively new and exciting field of research. Sharing it with the larger community of GW scientists worldwide could also leverage the case for IndIGO members to join the LIGO Scientific Collaboration. We present the baseline requirements and preliminary design consideration for the setup of this large, collaboration-wide, high performance computational facility.

Cosmology-GW Astronomy connection
Tarun Souradeep (IUCAA, Pune)
Gravitational wave astronomy holds promise for cosmology. Stochastic GW background from inflation, phase transition and cosmic strings are interesting probe of Early universe. GW sources would provide cosmology with standard sirens that measure the evolution of the universe and address the puzzle of dark energy. On another side, GW astronomy also stands to benefit from the analysis methods developed in cosmology, specifically CMB anisotropy measurements.

Tomographic method in gravitational wave data analysis
Rajesh Nayak (IISER, Kolkata)
A Tomographic approach was recently proposed by Mohanty and Nayak for resolving Galactic binaries, both spatially and in source frequency, in the LISA data stream. Using Doppler modulation alone, the method can unambiguously resolve binaries with a matched filtering signal to noise ratio higher than about 7. Here, we explore the possibility of extending the tomographic method to include multiple data streams and longer time-series to improve the angular and frequency resolution.

10th February (Jamia Milia Islamia)
Session on GW Interferometers
1130 - 1300

Opto-mechanical interactions in advanced gravitational wave detectors
Ju Li (University of Western Australia, Perth)
Parametric instabilities have been predicted to occur in advanced gravitational wave detectors in which the optical power in the main cavities reaches ~1 MW. At the ACIGA high optical power facility at Gingin, Western Australia, we have studied 3 mode interaction phenomena which give rise to the instabilities. In this talk, we will present the experiments on observation of the 3 mode interactions and possible methods for instability control. Latest results will be presented.

Breaking the quantum measurement barrier
Chunnong Zhao (University of Western Australia, Perth)
Most of the noise in the next generation gravitational wave detectors will be of fundamental quantum origin. Only small improvements in optical coating noise are needed for the entire instrument sensitivity to be of quantum origin. To further improve the detector sensitivity new quantum measurement schemes is necessary to surpass the quantum noise limit set by the uncertainty principle. This presentation will give a brief introduction to the quantum noise limit in the laser interferometer for gravitational wave detectors, and potential quantum measurement schemes for surpassing the quantum noise limit. Proposed experiments at Gingin for testing some of those schemes will be presented.

Exploring fundamental questions in physics with proto-type GW detectors.
G. Rajalakshmi (TIFR, Mumbai)
Interferometric gravity wave detectors measure down to 10^{-18}m/sqrt{Hz} changes in the path lengths

of the interferometer arms. They are ideal transducers for probing extremely small effects in the physics. In this talk I will describe experiments where proto-type gravitational wave detectors can be used to test predictions of Quantum Electro Dynamics (QED). An experimental proposal to measure the Casimir force between parallel mirrors to unprecedented sensitivity will be presented. The experiment also provides insight into higher dimensional physics and modified short range gravity. Another experiment that probes the birefringences of quantum vacuum in the presence of external magnetic field will be described.

Advanced Lasers and Adaptive Optics

Jesper Munch (The University of Adelaide)

The high power laser is one of the most critical enabling components of interferometric detection of gravitational waves. While LIGO-Australia comes complete with the 180W Nd:YAG laser from Advanced LIGO, efforts to improve the lasers for later upgrades or for third generation interferometers are expected to continue. I shall review current technology trends including the possibilities of using fiber lasers and new wavelengths and optics. The challenges for handling high optical power will also be addresses, including the need for wave- front sensing and adaptive optics. The high power laser is one of the most critical enabling components of interferometric detection of gravitational waves. While LIGO-Australia comes complete with the 180W Nd:YAG laser from Advanced LIGO, efforts to improve the lasers for later upgrades or for third generation interferometers are expected to continue. I shall review current technology trends including the possibilities of using fiber lasers and new wavelengths and optics. The challenges for handling high optical power will also be addresses, including the need for wave- front sensing and adaptive optics.