BECQI'03

Workshop on

Bose-Einstein Condensation and Quantum Information

16-20 February 2003

Rydges Oasis Resort - Caloundra
Sunshine Coast, Queensland, Australia

AUSTRALIAN CENTRE FOR QUANTUM-ATOM OPTICS

Organized and hosted by:
BEC and Quantum Optics Group,
Australian Centre for Quantum-Atom Optics,
Department of Physics,
The University of Queensland,
Brisbane, Queensland, Australia

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

http://www.physics.uq.edu.au/BECQI

PROGRAM

The workshop program will include a number of invited and contributed talks, as well as poster presentations – all in a relaxed informal atmosphere on the sunny Sunshine Coast. You can also surf, swim, play tennis, rock climb nearby (20 min drive to the breathtaking Glass House Mountains), and do more PHYSICS in between!

Scope

The workshop will cover hot topics in BEC and Quantum Information, from both theory and experiment. A particular focus will be on quantum aspects of matter waves and macroscopic quantum states, going beyond the methods and predictions of mean-field theory. This will include advances in analytical and computational methods, the latest experimental results probing the quantum nature of BECs, and applications of BEC to quantum information.

The topics include:

- Recent theoretical and experimental advances in Bose-Einstein condensation
- Novel computation methods for BEC
- BEC in lattices
- Atom-molecular BEC
- Degenerate Fermi gases and Fermi-Bose gas mixtures
- Atom lasers/ monitored BEC
- Quantum information and BEC
- Nonclassical states in a BEC
- Coherent atom/light coupling and entanglement
- Quantum optics and quantum information processing
- Macroscopic tests of quantum mechanics
- Quantum and classical solitons

Invited Speakers

- **Howard Carmichael** (Auckland University, New Zealand)
- **Iacopo Carusotto** (École Normale Supérieure, France)
- **Crispin Gardiner** (Victoria University of Wellington, New Zealand)
- **Gerd Leuchs** (Universitaet Erlangen-Nuernberg, Germany)
- **Ken O'Hara** (NIST, Maryland, USA)
- **Kazimierz Rzążewski** (Center for Theoretical Physics, Polish Academy of Sciences)
- **Chris Search** (University of Arizona, USA)
- **Gora Shlyapnikov** (Institute for Atomic and Molecular Physics, The Netherlands)
- **Kevin Strecker** (Rice University, USA)
- **Wojciech Zurek** (Los Alamos National Laboratory, USA)

Local Organising Committee

- **Peter Drummond** (Chairman), *The University of Queensland*
  E-mail: drummond@physics.uq.edu.au Phone: (+61 7) 33653420
- **Karen Kheruntsyan** (Vice-chair), *The University of Queensland*
  E-mail: kherunts@physics.uq.edu.au Phone: (+61 7) 33653420
- **Joel Corney** (Secretary), *The University of Queensland*
  E-mail: corney@physics.uq.edu.au Phone: (+61 7) 33469398
- **Matthew Davis**, *The University of Queensland*
  E-mail: mdavis@physics.uq.edu.au Phone: (+61 7) 33653420

Mailing address:

Department of Physics,
The University of Queensland,
Brisbane, QLD 4072, AUSTRALIA

Phone: (+61 7) 33653405 Fax: (+61 7) 33651242

ACCOMMODATION

The workshop venue, **Rydges Oasis Resort - Caloundra**, is an hour's drive north of Brisbane on Queensland's beautiful **Sunshine Coast**, and only a 3 minutes walk to the sun-drenched sand and clear ocean waters of **Golden Beach**. This family resort, set in 10 acres of landscaped gardens and colorful waterlily lagoons, offers a swimming pool, outdoor heated spa, tennis court, golf putting green, games room, 24 hour reception, "The Deck" Restaurant and Legends bar.

The rooms include individually controlled air conditioning, free in house movies, sky channel, tea and coffee making facilities and direct dial phones.

- Single/Twin Room: AU$80.00 p/room p/night
- One Bedroom Suite: AU$99.00 p/room p/night

RYDGES
OASIS RESORT • CALOUNDRA

Rooms at these special rates for participants have been negotiated through the conference agent. The **OzAccom Group** has been appointed to manage accommodation bookings on behalf of the workshop organising committee, and bookings can be made using the Accommodation Booking Form available at the workshop website: http://www.physics.uq.edu.au/BECQI.

Alternatively, you can contact **The OzAccom Group** at: (+61-7) 38541611, toll free (within Australia) 1800-814-611; fax: (+61-7) 38541507; e-mail: ozaccom@ozaccom.com.au.

OZACCOM & OZWINGS
PO Box 164, Fortitude Valley
QLD 4006 Australia

REGISTRATION

Registration Fees

- Delegate: AU $300 (incl. GST)
- Full-time Student: AU $175 (incl. GST)

The registration fee includes venue charges and admission to all workshop sessions, refreshment breaks, daily business lunch, and the reception-dinner for workshop participants on Sunday 16 February 2003. Registrations can be made using the Registration Form available at the workshop website:
http://www.physics.uq.edu.au/BECQI.

TRAVEL

Rydges Oasis Resort - Caloundra is just an hour's drive north of Brisbane on Queensland's beautiful **Sunshine Coast**.

RYDGES OASIS RESORT - CALOUNDRA
Landsborough Parade, Caloundra, QLD
PO Box 866, Caloundra, QLD 4551
Phone: (61 7) 5491 0333; Toll Free (within Australia): 1800 072096
Fax: (61 7) 5491 0300
Email: functions_caloundra@rydges.com

Distance from Airport: 87 km (1 hour drive) north of Brisbane International & Domestic Airports, or 30km (20 minutes) south of Maroochydore Airport.

Driving directions:

- *From Brisbane - follow signs to Sunshine Coast from Airport Road, take the Caloundra exit from the freeway, continue to 5th set of traffic lights and turn right, Rydges Oasis Resort - Caloundra is 1st right.*
- *From Maroochydore - take the Sunshine Coast Highway to Caloundra, turn left into Caloundra Road at roundabout and continue to 2nd set of lights, turn right and the Resort is the 1st right*

Shuttle buses: Three bus services – Suncoast Pacific, Sun Air, and Airport Bus Service – operate from Brisbane (Roma Street Transit Centre) and the Brisbane Domestic and International Airports, approximately on an hourly basis. For bookings (which is highly recommended, 2-3 days in advance) or further information – depending on your arrival date/time – please contact:

- ***Suncoast Pacific:*** (61 7) 32361901 / 54912555 / 54431011 – operates on schedule; approx. AU$20 one way
- ***Sun Air:*** (61 7) 54782811 – operates from the Airport on individual bookings basis, close to your arrival time; approx AU$38 one way
- ***Airport Bus Service:*** (61 7) 54433678 – operates from the Airport on individual bookings basis, close to your arrival time; approx AU$38 one way

MAPS

BATTERY
DICKY BEACH
SS Dicky
MOFFAT BEACH
Moffat Head
SHELLY BEACH
CALOUNDRA WEST
KINGS BEACH
Caloundra Headland (WICKHAM PT)
BULCOCK BEACH
HAPPY VALLEY
Deepwater Point
GOLDEN BEACH
BRIBIE ISLAND
PUMICESTONE PASSAGE
RYDGES OASIS RESORT
CALOUNDRA GOLF COURSE
Central Park
CEMETRY
BEN BENNETT PARK & BOTANICAL GARDENS
CALOUNDRA HIGH SCHOOL
CALOUNDRA CHRISTIAN COLLEGE
CALOUNDRA HOSPITAL
ROY HENZELL PARK
KINGS BEACH PARK
LEACH PARK
CAMP CAL YOUTH CAMP
RETIREMENT VILLAGE
ANDREA AHERN PRIVATE HOSPITAL
RUSSELL BARKER MEMORIAL PARK
INDOOR STADIUM
AUSTRALIAN RULES OVAL
RECREATIONAL RESERVE
CALOUNDRA & DISTRICT RUGBY LEAGUE
GOLDEN BEACH STATE SCHOOL
PROPOSED SCHOOL SITE
Lake Magellan
Lamerough Canal
NICKLIN WAY
SUGARBAG RD
CALOUNDRA ROAD
BOWMAN RD
BULCOCK ST
QUEEN ST
BUCCLEUGH ST
ELIZABETH ST
EDMUND ST
MORETON PDE
ARTHUR ST
KING ST
BEERBURRUM ST
LANDSBOROUGH PDE
NELSON ST
PELICAN WATERS BVD
Tooway Creek
N
S
E
W
LEGEND
Post Offices
Police Stations
Ambulance
Fire Brigade
Hospitals
Churches
Shopping
Caravan Parks
Boat Ramps
SLSC
Libraries
Bowls Clubs
Traffic Lights
Roundabout
Playground
Information

TECHNICAL PROGRAM

Sunday, February 16	
	Swimming Pool Area
18:45-20:45	**Get-together drinks and outdoor BBQ**

Monday, February 17	
	State/Verandah Room
08:45-09:00	***Opening address by Hans Bachor***
09:00-09:45	**Gora Shlyapnikov** (Keynote, Invited), *Inst. for Atomic & Molecular Physics, The Netherlands* **Bose-Einstein condensation in dilute gases: Recent developments and prospects** I will start with a general introduction to the subject of Bose-Einstein condensation (BEC) and describe the first generation of BEC studies, after the discovery of BEC in alkali atom clouds at JILA and MIT in 1995. It will be emphasized that first experiments have revealed a profound collective (condensed matter) behavior of these extremely dilute systems, originating from the dominant role of the interparticle interaction. I will briefly discuss theoretical approaches that are commonly used for the analysis of trapped Bose-condensed gases (Gross-Pitaevskii equation, Bogoliubov-de Gennes equations etc.). The next step will be the description of phase coherence studies in trapped condensates. Aside from fundamental aspects, these studies are important for future applications, such as atom lasers and atom interferometry. The common knowledge assumes that three-dimensional condensates should be phase coherent, which is, however, not always the case. I will discuss why and how trapped Bose-condensed gases at finite temperature can be phase decoherent and introduce a notion of a quasicondensate or condensate with fluctuating phase. As an example, I present the recent experimental results obtained at Hannover and at Orsay. The discussion will be completed by the description of novel quantum states in low-dimensional trapped gases. Such gases can be created by (tightly) confining the motion of particles in one or two directions to zero point oscillations. Attention will be focused on the one-dimensional case, where one expects to observe "fermionization" of a Bose system. In conclusion, I will briefly discuss various prospects for fundamentals and applications in the field of cold quantum gases.
09:45-10:30	**Ken O'Hara** (Keynote, Invited), *NIST, Maryland, USA* **Experiments with a Strongly-Interacting Fermi Gas** We have produced a highly-degenerate Fermi gas of atoms near a Feshbach resonance, providing a test bed for nonperturbative theories of strongly-interacting Fermi systems. Temperatures as low as 0.1 T_F are achieved via rapid forced evaporative cooling in an optical trap. We find that the gas is stable at a density far exceeding that predicted previously for the onset of mechanical instability. Upon release from the trap, we observe dramatic anisotropic expansion, a possible first signature of the onset of a new type of high-temperature superfluidity. From the release energy, we determine an important, universal many-body parameter: the ratio of the mean-field energy to the local Fermi energy.
10:30-11:00	***Coffee break***
11:00-11:35	**Christopher Search** (Invited), *University of Arizona, Optical Sciences Center, USA* **Atom Optics with Fermions** While the realization of Bose-Einstein condensates have exploited close analogies with conventional optics to extend the field of atom optics to the nonlinear and quantum regime, it has not been clear whether similar ideas can be usefully extended to fermionic atoms. We will address this point by discussing recent results in fermionic atom optics, including the quantum noise limits in atom interferometry and a detailed study of purely fermionic four-wave mixing. Our results indicate that fermionic atom optics shows significant potential.
11:35-12:00	**Stephen Bartlett**, *Macquarie University, Australia* **Quantum noise measurements in electron systems via phase sensitive detection** We introduce electron field coherent states that exhibit full coherence; as multimode states, they are fermionic counterparts to bosonic coherent states employed in optics. We employ these electron coherent states in developing a theory of phase-sensitive homodyne detection and measuring the current noise benchmarked against the standard quantum noise limit, and discuss the experimental creation of electron coherent states in a beam or 2-D degenerate Fermi gas.
12:00-12:25	**Craig Savage**, *Australian National University* **Skyrmions and other topologically singular structures in multi-component BECs** We present numerical studies of the topological solitons in two-component trapped BECs known as Skyrmions. Our focus is on mapping out experimentally relevant conditions for their stability. We also present studies of the dynamics and stability of other topologically interesting structures in spinor BECs, such as Anderson-Toulouse coreless vortices, Dirac monopoles, and monopole anti-monopole pairs called monopolium.
12:25-13:30	***Lunch break***

Monday, February 17 *(continued)*	
State/Verandah Room	
13:30-13:55	**Elena Ostrovskaya**, *Australian National University* **Nonlinear localization of Bose-Einstein Condensates in two-dimensional optical lattices** Bose-Einstein condensate in an optical lattice can form a fully reconfigurable periodic nonlinear system - an ``atomic bandgap structure'', which can potentially allow high-precision control and manipulation of coherent matter waves. We present a theory of 2D nonlinear atomic bandgap structures, and address an open problem of nonlinear localization of BEC in the form of 2D gap solitons. We analyze existence and stability of 2D matter-wave gap solitons and show that their accurate description requires a full continuous mean-field model, beyond the single-band tight-binding approximation or single-gap coupled-mode theory.
13:55-14:20	**Andrew Truscott**, *Australian National University* **Simulation of bright matter wave soliton trains and comparison with experiment** Recent experiments at Rice University show that a BEC of Li atoms with an attractive interaction can produce coherent matter wave pulses that propagate without dispersion. In such bright solitons, the kinetic energy which causes an untrapped condensate to expand is exactly counter-balanced by the inward pull of the mutually attractive atoms. In this paper we successfully simulate the results of this experiment to demonstrate that a mean-field approach is capable of describing an attractive condensate in an area of nonlinear behavior such as soliton creation. We also investigate interactions between the solitons by extending the experimental parameters.
14:20-14:45	**Paul Kinsler**, *Imperial College, UK* **Solitons and the Few-Cycle Regime** Solitons are often proposed for use in communications and optical logic. However, the usual NLS soliton propagation relies on the slowly varying (SVEA) regime, which fails for ultrashort solitons. Would the extra phase twist imposed on the propagation of a few-cycle [1] pulse destroy or alter any soliton character? I present theory and simulations demonstrating the altered propagation for both lone solitons and soliton collisions, and discuss the implications. The effect on chi2 solitons may also be discussed. [1] P. Kinsler, G.H.C. New, Phys.Rev.A., to appear.

Tuesday, February 18

State/Verandah Room

08:45-09:30	**Wojciech Zurek** (Keynote, Invited), *Los Alamos National Laboratory, USA* **Dynamics of Second Order Phase Transitions: Vortex Formation in a Quench** Abstract not available at the time of printing.
09:30-10:15	**Howard Carmichael** (Keynote, Invited), *University of Auckland, New Zealand* **Collective Spontaneous Emission: An Exercise in Disentangling the Entangled** A multimode treatment of collective spontaneous emission is formulated within the framework of quantum trajectory theory. Exact trajectories are uncomputable, even for moderate numbers of atoms, due to the vast number of states required to account for an N-particle entanglement. Through physical intuition and the art of approximation we are guided towards a computable model that captures the essential physics; this includes a stochastic evolution from nondirected to directed superradiant emission and the occasional population of long-lived subradiant states.
10:15-10:45	***Coffee break***
10:45-11:10	**Howard Wiseman**, *Griffith University, Australia* **The entanglement of indistinguishable particles shared between two parties** Using an operational definition we quantify the entanglement, E_P, between two parties who share an arbitrary pure state of N indistinguishable particles. We show that E_P is less than or equal to E_M, the bipartite entanglement calculated from the mode-occupation representation. Unlike E_M, E_P is *super-additive*. For example, E_P = 0 for any single-particle state, but the state |1>|1>, where both modes are split between the two parties, has E_P = 1/2. We discuss how this relates to quantum correlations between particles, for both fermions and bosons.
11:10-11:35	**Ping Koy Lam**, *Australian National University* **Optical Squeezing, Entanglement, and Quantum Teleportation** We generated two squeezed beams from a pair of MgO:LiNbO3 optical parametric amplifiers. We combined these beams on a beam splitter to produce a pair of quadrature entangled beams. These beams were characterised using both a criterion for the Einstien-Podolsky-Rosen paradox, and an inseparability criterion. The effect of decoherence on both criteria was investigated, and the beams were used to perform continuous variable quantum teleportation. We observed a teleportation fidelity of 0.645, and further, characterised it in terms of signal transfer and reconstruction noise. The results of our experiment are discussed in the context of the no-cloning theorem.
11:35-12:00	**Juan Jose Garcia-Ripoll**, *Max-Planck-Institut for Quantum Optics, Garching, Germany* **Quantum computation with cold bosonic atoms in optical lattices** In this talk we analyze an implementation of quantum computing using atoms confined in optical lattices. These systems have interesting features for quantum computing. Namely, a large number of atoms can be trapped in the lattice at a very low temperature, which provides a large number of qubits. Also, neutral atoms interact weakly with the environment, which leads to a relatively slow decoherence. However, the same setups pose also important experimental challenges, such as being able to load the lattice with one atom per site or being able to measure the interaction and tunneling constants of these systems with high accuracy. These obstacles, together with the uncertainties in the atom-laser interaction, must be overcome to implement current proposals for quantum computing with neutral atoms. We will analyze a way that solves the above mentioned problems and show how to achieve a very high gate fidelity even when most of the parameters describing the atomic ensemble (number of atoms per lattice site, tunneling rate, Rabi frequencies, etc) cannot be adjusted to precise values, and even have uncertainties of the order of the parameters themselves. Our method, which is described in (arXiv:quant-ph/0208143) combines the technique of adiabatic passage with ideas of quantum control theory.
12:00-12:25	**Margaret Reid**, *University of Queensland, Australia* **Criteria for continuous variable macroscopic entanglement** Criteria, based on continuous variable measurements x and p, are derived that are sufficient to prove the existence of an entangled superposition of two macroscopically distinct quantum states, that (always) have macroscopically distinct predictions for the measurement x. The criteria can be applied to prove such entanglement in experimentally-achievable Gaussian states exhibiting continuous variable entanglement. Initially the criteria could be used to prove the existence of an entangled superposition of states with a certain degree of distinctness, that may not be macroscopic. For Gaussian states a macroscopic entanglement can be proved as the degree of squeezing increases. It is discussed how this proof of such entanglement is a realisation of a macroscopic version of the Einstein-Podolsky-Rosen paradox.
12:25-13:30	***Lunch break***
13:30-15:00	**Poster Session**
15:00-19:30	***Free time***
19:30-21:00	**Informal discussions (posters may remain displayed)**

Wednesday, February 19	
State/Verandah Room	
08:45-09:30	**Crispin Gardiner** (Keynote, Invited), *Victoria University of Wellington, New Zealand* **A phase space method for atoms trapped in an optical lattice** It is shown how an approximate method based on the Q-function gives efficient estimates of the ground state energy of the mean-field Bose-Hubbard model, and how this might be developed into an approximation method for the dynamics.
09:30-10:15	**Iacopo Carusotto** (Keynote, Invited), *École Normale Supérieure, France* **An exact stochastic wavefunction approach to the N-body problem and its first applications** Recently, a Quantum Monte Carlo method alternative to the Path Integral Monte Carlo method was developed for the numerical solution of the quantum N-body problem; it is based on the stochastic evolution of Hartree-Fock states. The occupation statistics of the condensate mode in a weakly interacting trapped one-dimensional Bose gas has been determined for temperatures across the critical region and even below the trap level spacing. The behaviour of the superfluid fraction of a one-dimensional finite-size ring of BEC as a function of temperature and rotation speed has been studied. First numerical results for three-dimensional systems are presented, for both the bosonic and the fermionic cases.
10:15-10:45	***Coffee break***
10:45-11:20	**Kazimierz Rzążewski** (Invited), *Center for Theoretical Physics, Polish Academy of Sciences* **Cold bosons: Probing the classical field approximation** I will review our version of a classical field approximation to the dynamics and thermodynamics of quantum degenerate Bose gas at nonzero temperatures. Two cases are considered. One is a periodic box, the other is a 3D harmonic trap. We stress the role of the time-average single particle density matrix in correctly splitting the system into condensed and uncondensed parts. We investigate the role of short wavelength cut-off which is essential in the method. We also make remarks concerning the definition of temperature in the method. We also investigate the dissipative dynamics with the help of classical field approximation.
11:20-11:45	**Matthew Davis**, *University of Queensland, Australia* **A thermometer for BEC: determining the temperature of the classical Bose field in the non-perturbative regime** Treating the dynamics of the fully quantum Bose field at finite temperature is a very difficult task indeed. However, the recent work of several authors has demonstrated that the classical approximation to the full equation of motion for the Bose field operator can accurately represent the dynamics of the field when the modes are highly occupied, i.e. N_k>>1. One of the difficulties of this approach is in determining quantities such as the temperature of the field at equilibrium. In this talk we will introduce a general technique for measuring the temperature of a classical Hamiltonian system by considering its dynamics. We will then discuss the application of this method to Bose-Einstein condensates in the classical regime. This allows us to investigate properties such as the shift in the BEC critical temperature with interaction strength, a topic that has created some controversy in the recent literature.
12:45-12:10	**Joel Corney**, *University of Queensland, Australia* **Advances in quantum simulation techniques for bosons** We report on progress towards novel phase-space simulation techniques based on squeezed-state expansions. Squeezed states provide a more 'natural' basis for systems with strong interparticle interactions. They may thus lead to more efficient simulations than the usual coherent-state based approaches, which for BEC dynamics are limited to short-time simulations. Our calculations show that operator mappings exist for this squeezed-state representation, and that they lead to viable stochastic equations for standard BEC problems. Preliminary single-mode calculations show that the new methods can give improved statistics and hence longer-time simulations for certain situations.
12:10-13:10	***Lunch break***
13:10-13:35	**Chris Vale**, *University of Queensland, Australia* **Bose-Einstein condensation and surface effects on atom chips** Ultra-cold neutral atoms and Bose-Einstein condensates (BECs) offer fascinating possibilities for quantum information processing. Long decoherence times, easy qubit addressing and the potential for scalability are some advantages. Storing and manipulating atoms in magnetic microtraps or "Atom Chips" provides a promising base on which quantum logic operations could be performed. A primary source of decoherence in atom chip experiments arises from the interaction of the micro-Kelvin atoms with the room temperature chip surface. We have experimentally investigated these interactions and observe two interesting effects. Firstly, ultra-cold clouds are seen to fragment into clumps when brought within 100 microns of the chip surface. Secondly, the lifetime of atom clouds is seen to drop off near the surface due to spin flip transitions. These are caused by radio-frequency thermal fluctuations of the magnetic field as predicted but not previously observed.
13:35-14:00	**Nick Robins**, *Australian National University* **Progress towards a continuously pumped atom laser** We present details of our continuing experimental development of a continuously pumped atom laser. In particular we will outline a number of advances in magnetic trap design that allow for a more flexible approach to BEC and atom laser technology, including the possibility to create a tightly confining macro-magnetic trap (320Hz*320Hz*20Hz) that operates at 25A and dissipates only 53W.
14:00-14:25	**Andrei Sidorov**, *Swinburne University of Technology, Australia* **Magnetic Microstructures in Integrated Atom Optics** We report progress in our project on Integrated Atom Optics. We are exploring methods of producing surface-based microscopic atom optical elements that are made from permanent magnetic films and current-carrying microwires. We will discuss different configurations of microtraps, waveguides and couplers that can manipulate atomic de Broglie waves on the surface of a substrate. In particular we will describe the characteristics of a mirror magneto-optical trap that has allowed trapping of rubidium atoms in vicinity of a surface.

Thursday, February 20	
St George Room	
08:45-09:30	**Gerd Leuchs** (Keynote, Invited), *Universitaet Erlangen-Nuernberg, Germany* **Optical fiber soliton based multipartite quantum correlations** The non-linear quantum dynamics of fiber solitons leads to amplitude uncertainty reduced light fields. These squeezed fields combined with Bell state measurements are used to generate continuous variable multipartite quantum correlations and entanglement. The continuous variables used are either the amplitude and phase quadratures or the Stokes variables.
09:30-10:15	**Kevin Strecker** (Keynote, Invited), *Rice University, USA* **Tunable Interactions in Ultra-Cold Bose And Fermi Gases** Using a Feshbach resonance we have been able to investigate the behavior of 7Li with both attractive and repulsive interactions. The ability to tune the interactions has allowed us to explore Bose condensates with attractive interactions in the 1-dimentional limit. This led to the observation of bright matter-wave soliton trains, and the study of soliton-soliton interactions in Bose Einstein condensates. Further, we have used the bosons as a refrigerant to sympathetically cool fermionic 6Li. This has allowed both the observation of quantum degenerate fermi gas and the study of fermionic Feshbach resonances.
10:15-11:10	***Coffee break and hotel check-out***
11:10-11:35	**Jessica Lye**, *Australian National University* **Non-destructive, dynamic detectors for Bose-Einstein condensates** This paper presents an analysis of a series of non-destructive, dynamic detectors for BECs. These detectors are compatible with real time feedback to the condensate, which may be crucial for the stabilisation of an atom laser beam. The signal to noise ratio (SNR) of different detection schemes are compared subject to the constraint of minimal heating due to photon absorption. We find that the signal does not improve with increased detuning for separated path interferometers, and that non-resonant interferometry causes as much destruction as absorption for optically thin clouds. We propose a cavity-based measurement of atomic density which can, in principle, be made arbitrarily non-destructive for a given SNR.
11:35-12:00	**Joseph Hope**, *Australian National University* **Mean-field dynamics and modal stability of cw atom lasers** Mode selection in cw atom lasers is complicated by the strong nonlinear interactions which alter the spatial eigenmodes, and therefore the loss and gain rates of these modes, which are spatially dependent. We examine a mean-field atom laser model with spatially dependent, saturable gain and loss due to n-body collisions. We show that the modal stability depends on the pumping rate, the strength of the atomic interactions and the spatial extent of the atomic gain.
12:00-12:25	**Hans Bachor**, *Australian National University* **The quantum laser pointer and other applications of squeezed light** Beam displacement measurements performed with a quadrant detector are limited in sensitivity - for a coherent laser beam - by the shot noise of light. We have surpassed the quantum limit by the use of a multi-mode laser beam with spatial quantum correlations - synthesized from a coherent beam mixed with squeezed vacua of appropriate anti-symmetric phase, combined on a resonant cavity. We demonstrate this technique in 2 dimensions, and present results for the improved detectivity of a periodic beam displacement, by a factor of 2.0 in one direction and simultaneously by a factor of 1.7 in the other. This experiment is only one of several applications of the entanglement. Other examples we have are the generation of polarisation squeezed light and of EPR entangled beams used for optical quantum teleportation.
12:25-13:30	***Lunch, Workshop Close***

Poster Session (13:30-15:00 pm, Tuesday, 18 February)
State/Verandah Room

1. Pearl Louis, *Australian National University*
Bose-Einstein Condensates in Optical Lattices: Band-gap structure, solitons and superlattices
Bose-Einstein condensates in optical lattices offer a unique opportunity to study a macroscopic quantum system of coherent nonlinear matter waves in a defect-free periodic or quasi-periodic potential whose properties can be easily and precisely controlled. In this work, we present the results of a study of the existence and linear stability properties of stationary Bloch-type waves and localised gap states in a quasi-1D system in the framework of a continuous mean-field model for both repulsive and attractive interactions. The transmission properties of an optical superlattice with respect to a moving BEC wavepacket will also be discussed.

2. Bryan Dalton, *Swinburne University of Technology, Australia*
Scaling of Decoherence Rates in Quantum Computers
The scaling of decoherence rates with qubit number N is studied for simple models of quantum computers (eg, N spin 1/2 systems in trapping potentials), for environments involving both external systems (eg, EM field modes) and other internal degrees of freedom (eg, vibrational motions of trapped spins). Phase and population destroying system-environment interactions are considered. Decoherence is specified via the short time behaviour of the fidelity. Non-Markovian methods are used for times small compared to reservoir correlation times. Independent and collective decoherence situations are examined. Quantum computer states such as: (a) generalised Hadamard states (b) generalised GHZ states are treated.

3. James Clemens, *University of Auckland, New Zealand*
Angular dependence of superradiant emission from small assemblies of atoms
Monte-Carlo simulations of spontaneous emission from assemblies of a few hundred to a few thousand atoms have been performed based on an approximation scheme within quantum trajectory theory. The spontaneous growth of directed emission can occur depending on the density and spatial distribution of the atoms. Angular photon distributions and correlation functions are computed.

4. Andrew Lance, *Australian National University*
Continuous Variables (2,3) Threshold Quantum Secret Sharing Schemes
We present two schemes to perform continuous variable (2,3) threshold quantum secret sharing on the quadrature amplitudes of bright light beams. Both schemes require a pair of entangled light beams. The first scheme utilizes two additional phase sensitive optical amplifiers, whilst the second uses only an electro-optic feed-forward loop for the reconstruction of the secret. We examine the efficacy of quantum secret sharing in terms of fidelity, as well as the signal transfer coefficients and the conditional variances of the reconstructed output state. We show that both schemes in the ideal case yield perfect secret reconstruction.

5. Tien Kieu, *Swinburne University of Technology, Australia*
Numerical simulations of Quantum Adiabatic Processes for Hilbert's tenth problem
Hilbert's tenth problem asks for a general procedure to decide whether or not an arbitrarily given Diophantine equation has any integer solution. It is one of the most fundamental problems of Mathematics and Theoretical Computer Science. Quantum Adiabatic Process has recently been proposed elsewhere as the general procedure solving the Hilbert's tenth problem in the positive. Following that proposal, we carried out numerical simulations of the quantum adiabatic processes for several Diophantine equations in Hilbert spaces with infinite dimensions. In all instances studied, the numerical results so-obtained successfully determine the existence and, more importantly, the non-existence of solutions in the infinite domain of non-negative integers.

6. Andrew Hines, *University of Queensland, Australia*
Entanglement of two-mode Bose-Einstein condensates
We investigate the entanglement characteristics of two general bimodal Bose-Einstein condensates - a pair of tunnel-coupled Bose-Einstein condensates and the atom-molecule Bose-Einstein condensate. We argue that the entanglement is only physically meaningful if the system is viewed as a bipartite system, where the subsystems are the two modes. The indistinguishibility of the particles in the condensate means that the atomic constituents are physically inaccessible and thus the degree of entanglement between individual particles, unlike the entanglement between the modes, is not experimentally relevant so long as the particles remain in the condensed state. We calculate the entanglement between the two modes for the exact ground state of the two bimodal condensates and consider the dynamics of the entanglement in the tunnel-coupled case.

7. Joseph Hope, *Australian National University*
Non-destructive atomic detection using dark states
Using single photon processes for measuring atomic density always leads to a fixed signal to noise limit for a given value of the spontaneous emission rate. This is true for measurements of both absorption and dispersion, and means that there is a limit to the sensitivity of a non-destructive measurement of atomic density. Using two-photon processes, it is possible to measure the phase shift of one or both of the laser beams while maintaining the atoms in a dark state, which has no excited state population. This allows the construction of a truly non-destructive density measurement.

8. Cameron Fletcher, *Australian National University*
A Self-Locked Magneto-Optic Trap
We present a novel technique to lock the frequency of the trapping laser of a magneto-optic trap (MOT) using a signal generated from the ultracold atoms in the MOT itself. This technique utilizes the large number of very cold, slow-moving atoms in the MOT to generate a signal free of Doppler-broadening. A system analogous to Pound-Drever-Hall locking allows an error signal to be generated on resonance without significantly perturbing the MOT. We have stabilized the frequency of the main trapping laser of a 87Rb MOT using this technique to generate a self-locked MOT.
Fletcher et al., Opt. Comm., Vol. 212 (2002) p. 85.

9. Peter Drummond, *University of Queensland, Australia*

Quantum dynamics with stochastic gauge simulations

The general idea of a stochastic gauge representation is introduced and compared with more traditional phase-space expansions, like the Wigner expansion. Stochastic gauges can be used to obtain an infinite class of positive-definite stochastic time-evolution equations, equivalent to master equations for many systems, including quantum time-evolution. The method is illustrated with a variety of examples ranging from genetics and astrophysical molecular hydrogen production, through to the topical problem of Bose-Einstein condensation and the dynamics of an atom laser.

10. Ben Upcroft, *University of Queensland, Australia*

Towards a Bose-Einstein Condensate using a Surface Magneto-optical Trap

A surface magneto-optical trap (MOT) is a variation to the conventional MOT which allows flexibility and freedom to manipulate the atoms in ways that are not possible using the conventional setup. In a surface-MOT the initial cooling and trapping of atoms happens in close proximity to the surface of a gold mirror. In this configuration two of the six laser beams in a typical MOT are replaced by reflections from this mirror. By etching wires into the gold surface of the mirror, complex magnetic fields for trapping and manipulating the atoms can be produced. In addition these fields can be used for the creation of a Bose-Einstein condensate (BEC). I will show experimental results for the creation of a surface-MOT and our efforts towards creating a BEC using this particular setup.

11. Karen Kheruntsyan, *University of Queensland, Australia*

Pair correlations in a finite-temperature 1D Bose gas

We calculate the two-particle local correlation function for the 1D Bose gas at finite temperatures. We present the exact numerical solution by using the Yang-Yang equations and Hellmann-Feynman theorem and develop analytical approaches for describing various physical regimes. Our results draw prospects for identifying the regimes of coherent output of an atom laser, and of ``fermionization'' through the measurement of the rates of 2-body inelastic processes, such as photo-association.

12. Dimitri Gangardt, *École Normale Supérieure, France*

Stability and phase coherence of trapped 1D Bose gases

We discuss stability and phase coherence of 1D trapped Bose gases and find that inelastic decay processes, such as 3-body recombination, are suppressed in the strongly interacting (Tonks-Girardeau) and intermediate regimes. This is promising for achieving these regimes with a large number of particles. "Fermionization" of the system reduces the phase coherence length, and at $T=0$ the gas is fully phase coherent only deeply in the weakly interacting (Gross-Pitaevskii) regime.

13. Michael East, *Australian National University*

Atomic Tilt Locker

A spin-off of our recent research into non-destructive, dynamic detection of BECs has been the development of a compact, low cost, interferometric method for the stabilisation of lasers to an atomic transition. The device, based on tilt locking to an atomic sample in a Sagnac interferometer, provides a Doppler-free, true zero-crossing error signal without modulation. To our knowledge, it is the only device of its type. Tilt locking has significant advantages over previously described methods, as it requires only a small number of low-cost optical components and a detector. As the technique requires no modulation or locking electronics, the bandwidth is potentially very high, limited by optical pumping time-scales in the sample. Although the device has been developed on cesium, we will extend its applicability to communications wavelengths by locking to appropriate molecular transitions. We hold a provisional patent on the device and are currently pursuing commercialization.

14. Wayne Rowlands, *Swinburne University of Technology, Australia*

Towards a Molecular BEC

Following the achievement of Bose-Einstein condensation (BEC) in atomic vapours, a great deal of interest has been shown in producing the same effect in molecular systems. The more complex structure of molecules should allow for a richer variety of applications of a molecular Bose-Einstein condensate (MBEC), including coherent stimulation of chemical pathways ("superchemistry") and the production of quantum-correlated atomic beams. We will give an overview of our new experimental programme to produce a MBEC, outlining some proposed production schemes and applications.

15. S.P. Tewari, *University of Delhi, India*

Crossover of three dimensional Bose-Einstein condensate to quasi-one dimension

Very recently experiments have been reported on the occurrence of Bose Einstein condesation in Na-23 [1] and Li-7 [2] bosonic weakly interacting rare gas assemblies in highly anisotropic traps. An attempt has been made, therefore, to theoretically study, using the Ginzburg-Pitaevskii-Gross equation, the crossover of three dimensional Na-23 bosonic condensate having total number of particles in the condensate equal to 20,000 when the aspect ratio is made highly anisotropic. The aspect ratio essentially reflects the anisotropy in the magnetic trap. One finds that as the aspect ratio is varied from 1.0 to its lowest achievable value of 0.015, the condensate blob acquires the shape of a highly elongated cigar. The ratio of the cigar length to the radial length is nearly 30 for aspect ratio equal to 0.015. While the ratio of the length of the cigar to the healing length is much larger, equal to around 159 in comparison with around 5 for the ratio between the radial length and the healing length. All lengths are in harmonic oscillator length units.

[1] A.Gorlitz et al., Phys. Rev. Lett. 87, 130402 (2001).
[2] F.Schreck et al., Phys. Rev. Lett. 87, 080403 (2001).

BECQI'03 Workshop: Schedule at a Glance

Sunday, 16 February 2003	
18:45-20:45	***Get together drinks and outdoor BBQ (Swimming Pool Area)***

Monday, 17 February 2003 (State/Verandah Room)	
08:45-09:00	**Opening address by Hans Bachor**
09:00-09:45	**1. Gora Shlyapnikov** *(Keynote, Invited, 45 min)*
09:45-10:30	**2. Ken O'Hara** *(Keynote, Invited, 45 min)*
10:30-11:00	***Coffee break***
11:00-11:35	**3. Christopher Search** *(Invited, 35 min)*
11:35-12:00	**4. Stephen Bartlett** *(25 min)*
12:00-12:25	**5. Craig Savage** *(25 min)*
12:25-13:30	***Lunch***
13:30-13:55	**6. Elena Ostrovskaya** *(25 min)*
13:55-14:20	**7. Andrew Truscott** *(25 min)*
14:20-14:45	**8. Paul Kinsler** *(25 min)*

Tuesday, 18 February 2003 (State/Verandah Room)	
08:45-09:30	**9. Wojciech Zurek** *(Keynote, Invited, 45 min)*
09:30-10:15	**10. Howard Carmichael** *(Keynote, Invited, 45 min)*
10:15-10:45	***Coffee break***
10:45-11:10	**11. Howard Wiseman** *(25 min)*
11:10-11:35	**12. Ping Koy Lam** *(25 min)*
11:35-12:00	**13. Juan Jose Garcia-Ripoll** *(25 min)*
12:00-12:25	**14. Margaret Reid** *(25 min)*
12:25-13:30	***Lunch***
13:30-15:00	**Poster Session**
15:00-19:30	***Free time***
19:30-21:00	**Informal Discussions (posters may remain displayed)**

Wednesday, 19 February 2003 (State/Verandah Room)	
08:45-09:30	**14. Crispin Gardiner** *(Keynote, Invited, 45 min)*
09:30-10:15	**15. Iacopo Carusotto** *(Keynote, Invited, 45 min)*
10:15-10:45	***Coffee break***
10:45-11:20	**16. Kazimierz Rzążewski** *(Invited, 35 min)*
11:20-12:45	**17. Matthew Davis** *(25 min)*
12:45-12:10	**18. Joel Corney** *(25 min)*
12:10-13:10	***Lunch***
13:10-13:35	**19. Chris Vale** *(25 min)*
13:35-14:00	**20. Nick Robins** *(25 min)*
14:00-14:25	**21. Andrei Sidorov** *(25 min)*

Thursday, 20 February 2003 (St George Room)	
08:45-09:30	**22. Gerd Leuchs** *(Keynote, Invited, 45 min)*
09:30-10:15	**23. Kevin Strecker** *(Keynote, Invited, 45 min)*
10:15-11:10	***Coffee break and hotel check-out time***
11:10-11-35	**25. Jessica Lye** *(25 min)*
11:35-12:00	**26. Joseph Hope** *(25 min)*
12:00-12:25	**27. Hans Bachor** *(25 min)*
12:25-13:30	***Lunch, Workshop Close***