

Dodd-Walls Symposium 2010

Program and Abstracts



General Information

Location

Weir House is located on Gladstone terrace, on the Kelburn campus of Victoria University of Wellington. Directoins and maps can be found at: <http://www.victoria.ac.nz/weirhouse/about/location.aspx>

Internet

Wireless internet is available in the sky lounge and the dining hall at Weir House

Catering during the conference

All catering at Weir House will be served in the dining hall

Meal times are as follows

- Breakfast – 7am – 9am
- Lunch – 12.30pm – 1.30pm
- Dinner – 5.30pm – 6.30pm

Conference Dinner

The Conference dinner will be held at the Travelodge Wellington on the 2nd of February at 7pm.

Notes to presenters

Please see the chair of each session before you are due to give your presentation to organize anything that will be needed.

Poster Presentations

Poster boards will be located at both Weir house in the Sky lounge and Travelodge in the break-out room.

Please put your poster up next to your poster number on the morning of the 1st of February in the Weir House sky lounge. Then please take your poster to Travel lodge in the lunch break on Tuesday 2nd February and put it up next to your poster number in the breakout room by 2.45pm. This will be signposted.

Poster numbers are in the abstract section of the programme. The presenters of the odd numbered posters should be at their posters for the first session and the presenters of even numbered posters at their posters for the second. It is requested however, that all posters be displayed in both locations.

Session and Event Information

Panel Discussions

Two panel discussions will be held during the conference

Strategic Direction

Chair: Cather Simpson

Panel members: Rob Ballagh, John Harvey, Ben Eggleton, David Sampson.

Education Strategy

Chair: John Harvey

Panel Members: Ken Baldwin, Matt Sellars, David Sampson, Mikkel Andersen.

At these events the activities and future plans for the Dodd-Walls center will be discussed by the panel and the audience. Discussion topics will be circulated beforehand; if you have a point you would like to see discussed please contact the session chairs.

The Lighthouse Platform (www.lighthouseplatform.co.nz)

The Lighthouse Platform aims to link research and industry across New Zealand in the area of photonics. The Lighthouse partners are the Dodd-Walls Centre and Industrial Research Limited, with participation from the companies Southern Photonics, Photonic Innovations and Harmonic.

Poster Session 2 will include Lighthouse partners from Industrial Research Limited, and will be followed by a Meet and Greet Session for industry, research, skilled workers and funders in the high technology sector.

The aims of these sessions are to introduce people to one another, to learn about the range of optics and photonics projects in New Zealand, and to find out how to bring industry and research closer together. The Lighthouse Platform aims to build a network so that in time there will be opportunities for industry to find skilled workers and for researchers to find practical outputs from their research.

Invited Speakers



Professor David Sampson is Director of the Centre for Microscopy, Characterisation and Analysis, which is the University of Western Australia's micro-imaging core facility, and a node of the Australian Microscopy and Microanalysis Research Facility. He also heads the Optical+Biomedical Engineering Laboratory in the School of Electrical, Electronic and Computer Engineering and is Director of the Western Australian Centre of Excellence in eMedicine. His personal research interests are in optics and photonics applied to medicine and biology – the fields of biomedical optics and biophotonics. His interests span the spectrum from the fundamental – novel methods in optical microscopy and light propagation in tissue, to the engineering of optical instruments, to the application of novel optical imaging methods in clinical medicine. He is particularly motivated to promote and engage in interdisciplinary research, interests which have crystallised in his leadership of the University of Western Australia's Bioimaging Initiative. Current research highlights include the development of synthetic aperture holographic microscopy, and the application of anatomical optical coherence tomography in lung cancer and breast cancer. Prof. Sampson is an Associate Editor of *IEEE Photonics Journal* and sits on the editorial board of Opticalfibersensors.org. He is an elected member of the Australian Optical Society Council.



Professor Benjamin Eggleton is currently an ARC Federation Fellow and Professor of Physics at the University of Sydney. He is Research Director of the Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), an ARC Centre of Excellence and Director of the Institute of Photonics and Optical Science (IPOS). He studied at the University of Sydney, obtaining his BSc (Hons 1) in 1992 and his PhD in Physics in 1996. After graduation, he went to the United States to join the world's leading research institute in his field, Bell Laboratories, as a Postdoctoral Fellow in the Optical Physics Department. He then transferred to the Optical Fiber Research Department as a Member of Technical Staff and was subsequently promoted to Research Director of the Specialty Fiber Business Division of Bell Lab's parent company, Lucent Technologies where he drove Lucent's research program in optical fibre devices. He has co-authored more than 250 journal papers (with over 6000 citations and an h-number of 40), presented more than 60 invited and plenary presentations at international conferences, and has filed 35 patents. He has received several significant awards, most notably, the Pawsey Medal from the Australian Academy of Sciences, the Prime Minister's Malcolm McIntosh Science Prize for Physical Scientist of the Year, the ICO Prize (International Commission for Optics), and the Adolph Lomb Medal from the OSA. Other achievements include the distinguished lecturer award from IEEE/LEOS, a R&D100 award, and appointment as Fellow to the OSA, IEEE and ATSE societies. He was an Associate Editor for IEEE Photonic Technology Letters from 2003 -- 2007, and is currently Editor for Optics Communications. He currently serves as the President of the Australian Optical Society.

Invited Speakers



Professor Ken Baldwin is a laser physicist at the Australian National University, where he is Deputy Director of the Australian Research Council Centre of Excellence for Quantum-Atom Optics, and Deputy Director of the Research School of Physics and Engineering.

His interests lie in developing new laser technologies for precision measurement to test quantum theories of atomic and molecular structure. He is also a pioneer in atom optics – a field which uses lasers to create new technologies for atoms which are the analogue of optical elements for light. Lasers can also be used to cool atoms to the lowest temperatures in the universe, at which point they behave more like waves than particles, enabling them to be used as sensitive detectors e.g. of changes in the earth's gravitational field. In 2007 his contributions to optics were recognized by the award of the W.H. "Beattie" Steele Medal – the highest honour of the Australian Optical Society.

Professor Baldwin has also been a major contributor to science policy and outreach. He was President of the Australian Optical Society, and is the first Australian to be appointed as a Director of the Board of the Optical Society of America. Most recently he was President of the Federation of Australian Scientific and Technological Societies. In 2004 he won the Australian Government Eureka Prize for Promoting Understanding of Science, for his role in initiating and championing "Science meets Parliament".



Dr. Matthew Sellars is a researcher at the Australian National University. His research interests are in the area of coherent laser spectroscopy of rare earth ion dopants. He has made pioneering contributions using high resolution lasers and cryogenic rare earth ion dopants for quantum information applications. His group's achievements include the first optical solid state quantum logic demonstrations, increasing the storage times of EIT based quantum memories to useful timescales, and the first demonstration of an efficient quantum memory.

Timetable

Sunday

Check-in at Weir House.

Dinner served from 5.30-6.30PM in the Weir House dining hall.

Monday: Weir House

Session 1: Chair Prof. Rob Ballagh

8:50		<i>Opening remarks</i>	10min
9:00	Talk 1	K. Baldwin , Australian National University: <i>Metastable Helium Experiments in ACQAO</i> (Invited Speaker)	40min
9:40	Talk 2	B. Eggleton , University of Sydney: <i>Frontiers in nanophotonics</i> (Invited Speaker)	40min
10:20	Talk 3	D. Hudson , DWC, University of Otago: <i>Spectral Phase Clamping in Waveguide Arrays</i>	30min

10:50 - 11:15 Break (25 min)

11:15-12:15	Panel Discussion: Strategic Direction	The Dodd-Walls Center - Strategic Direction <i>Chair:</i> Cather Simpson <i>Panel members:</i> Rob Ballagh, John Harvey, Ben Eggleton, David Sampson.	60min
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Lunch served from 12:30-1.30PM in the Weir House dining hall.

Session 2: Chair Prof. John Harvey

1:30	Talk 4	M. Sellars , Australian National University: <i>Demonstration of an efficient quantum memory for light.</i> (Invited Speaker)	40min
2:10	Talk 5	C. Simpson , DWC, University of Auckland: <i>Photophysics and Photochemistry of Solar Energy Conversion System</i>	30min

2:40 - 3:00 Break (20min)

3:00	Panel Discussion: Education Strategy	The Dodd-Walls Center – Education Strategy <i>Chair:</i> John Harvey <i>Panel Members:</i> Ken Baldwin, Matt Sellars, David Sampson, Mikkel Andersen.	60min
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4:00	Poster Session 1	To be held in Sky Room (All posters displayed, odd-numbered posters presented)	60min
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Dinner served from 5.30-6.30PM in the Weir House dining hall.

Tuesday

Weir House events:

Session 3: Chair Dr Cather Simpson

9:00	Talk 6	D Sampson , University of Western Australia: <i>Optical coherence tomography in cancer</i> . (Invited Speaker)	40min
9:40	Talk 7	S. Murdoch , DWC, University of Auckland: <i>All-fiber source for multiplex CARS applications</i> .	30min

10:10 - 10:40 Break (30 min)

Session 4: Chair Dr Jevon Longdell

10:40	Talk 8	I. Meglinski , DWC, University of Otago: <i>Development of vanishing 'tattoo' sensor as a tool for non-invasive diagnostics</i> .	30min
11:10	Talk 9	D. Hallwood , Massey University: <i>Robust Quantum Superpositions of Mesoscopic Atomic Flow</i>	30min
11:40-12:10	Talk 10	M. Andersen , DWC, University of Otago: <i>Atom Interferometers and Optical Micro-Traps</i>	30min

Lunch served from 12.30-1.30 in the Weir House dining hall.

Posters to be disassembled and reassembled at Travelodge, a 15-minute downhill walk from Weir House. Please set up by 2.45 PM.

Travelodge Events:

3:00-5:00	Poster Session 2	Open to The Lighthouse Platform industry partners and invited guests (All posters displayed, even numbered posters presented)	
5:00-7:00	Meet and Greet	Includes all Symposium attendees, the Lighthouse Platform partners and invited guests. Meet and Greet Session for industry, research, skilled workers and funders in the high technology sector	

7:00 Dinner for all Symposium attendees at Travelodge.

Wednesday morning

A meeting will be held for DWC Principal Investigators in Weir House Common Room, followed by lunch. An agenda will be distributed at the Symposium.

Abstracts

Oral Presentations

Talk 1 (Invited Speaker)

Metastable Helium Experiments in ACQAO: Atomic physics, Atom optics and Quantum statistics

K.G.H. Baldwin

*ARC Centre of Excellence for Quantum-Atom Optics (ACQAO),
Research School of Physics and Engineering,
Australian National University, Canberra, ACT 0200, Australia*

ACQAO has as its mission the pursuit of fundamental studies at the interface of quantum optics and atom optics that will underpin the first generation quantum technologies. Recently, ACQAO and the Dodd-Walls Centre signed a memorandum of understanding aimed at furthering research across the Tasman in this field of common interest.

A major experimental programme in atom optics using helium atoms is a key component of the research portfolio in ACQAO. Helium - when excited to the metastable 2 triplet S state - possesses the longest lifetime of any excited neutral atom yet measured [1]. We have determined this lifetime to the greatest precision thus far (7870 ± 510 s) [2], and have also measured the lifetime of the 2 triplet P manifold for the first time [3,4]. All these measurements are in excellent agreement with quantum electrodynamic (QED) theory.

The metastable state has infrared transitions (H1083nm) to the 2 triplet P manifold, which enable the use of laser cooling and trapping techniques to manipulate the atomic de Broglie wavefunction for experiments aimed at understanding the quantum behaviour of matter waves. We have created a Bose-Einstein condensate (BEC) of metastable helium atoms from which we have developed a metastable helium atom laser. We have been able to guide the atom laser in a dipole potential which has created the analogue of single mode optical fibre guiding for matter waves [5]. We have also been able to image atomic speckle for the first time. The single mode guiding of atomic de Broglie waves may lead to future applications, such as the realisation of more sensitive atom interferometers.

More recently we have exploited the high internal energy (H20eV) stored in the metastable state to enable the detection of single atoms for studying the quantum statistics of atomic ensembles. We have measured the second order correlation function for both thermal and Bose-condensed atoms, and have been able to demonstrate atom bunching for the thermal ensemble, and uncorrelated behaviour for the coherent BEC.

References

1. K.G.H. Baldwin, *Contemporary Physics* **46** (2), 105 – 120 (2005).
2. S.S. Hodgman, R. G. Dall, L.J. Byron, K. G. H. Baldwin, and A.G. Truscott, *Physical Review Letters* **103**, 053002 (2009).
3. R. G. Dall, K. G. H. Baldwin, L.J. Byron and A.G. Truscott, *Physical Review Letters* **100**, 023001 (2008).
4. S.S. Hodgman, R.G. Dall, K. G. H. Baldwin, and A.G. Truscott, *Physical Review A* **80**, 044501 (2009).
5. R.G. Dall, S.S. Hodgman, M.T. Johnsson, K. G. H. Baldwin, and A.G. Truscott, *Physical Review A Rapid Communications*, in press (2009).

Talk 2 (Invited Speaker)

Frontiers in nanophotonics

Benjamin Eggleton
School of Physics, University of Sydney
Director, CUDOS ARC Centre of Excellence
Institute of Photonics and Optical Science

My talk will review recent highlights of the CUDOS research program demonstrating both fundamental and applied breakthroughs in nanophotonics and nonlinear optics. In our fundamental research program we are exploring new nanophotonic materials and principles for controlling light, including metamaterials, plasmonics and hybrid silicon integrated circuits, that allow CUDOS researchers to control light on the sub-wavelength scale at time scales of only a few cycles of light and at single-photon power levels. In our applied research programs we are exploring new directions within the centre that apply the photonic chip paradigm to new application areas and end-users, such as photonic analogue to digital conversion, quantum integrated circuits and mid-infrared integrated bio-sensors.

Talk 3

Spectral Phase Clamping in Waveguide Arrays

Darren D. Hudson
Jack Dodd Centre for Photonics and Ultra-Cold Atoms, Department of Physics, University of Otago,
Dunedin, NZ
Qing Chao, Thomas R. Schibli and Steven T. Cundiff
JILA/University of Colorado, Boulder, CO
Demetrios N. Christodoulides
CREOL, University of Central Florida, Orlando, FL
Roberto Morandotti
Institut National de la Recherche Scientifique, Universite du Quebec, Varennes, Canada
J. Nathan Kutz
Department of Applied Mathematics, University of Washington, Seattle, WA

Waveguide arrays and ultrashort optical pulses were two very unrelated fields until the late 1990s. In 1998, Eisenberg et al. demonstrated experimentally that sufficiently intense pulses could overcome the discrete diffraction in waveguide arrays and self-focus, thereby forming spatial solitons. This observation was a confirmation of a theoretical prediction made 10 years earlier by Joseph and Christodoulides, and led to many experiments focusing on the spatial distribution of light at the output of the waveguide array. Recent experiments on the temporal effects of waveguide arrays on ultrashort pulses have yielded interesting results such as the formation of X-waves and temporal pulse chopping. However, until now these time-domain experiments have focused on intensity autocorrelations and cross-correlations and have not explored the extended parameter space of input pulse chirp and average power.

In this work we carefully examine the waveguide array's effect on the full electric field of an ultrashort pulse as a function of both input chirp and average power. Surprisingly, we find that the waveguide array has the ability, at sufficiently high peak power, to set the output pulse's chirp to a set value, regardless of the chirp on the input pulse. While the physical picture of this spectral phase attractor is not yet understood, we believe this phenomenon could be used in a number of practical applications including dispersion compensating devices or pulse cleanup. This presentation will cover the basics of waveguide arrays, detail the spectral phase measurements that were done using the Frequency-Resolved Optical Gating technique, and briefly discuss the theoretical and numerical work that is currently underway to aid in understanding this process.

Talk 4 (Invited Speaker)

Demonstration of an efficient quantum memory for light

Morgan Hedges¹, Jevon J. Longdell², Yongmin Lee³ and Matthew J. Sellars¹

¹*Laser Physics Centre, Research School of Physics, Australian National University, Australia*

²*Jack Dodd Center, Physics Department, University of Otago, Dunedin, New Zealand.*

³*State Key Laboratory of Quantum Optics and Quantum Optics Devices, Institute of Opto-Electronics, Shanxi University, Taiyuan 030006, China*

Storing and retrieving a quantum state of light without corrupting the information it carries is an important challenge for the field of quantum information processing. Classical measurement and reconstruction strategies for storing coherent states are limited in the measurement process by the Heisenberg uncertainty principle. There has been significant effort directed towards the development of quantum memories capable of storing information with a fidelity higher than this classical limit. Successful demonstrations of non-classical storage to date have utilized atomic vapours with low efficiencies of 1-15%, and were limited to storage of weak quantum states with pulses containing less than a few photons. In this talk I report on the efficient quantum storage of light using a memory based on a solid state medium. The memory exhibits low noise operation and an efficiency of up to 69%, enabling the demonstration of storage and recall, above the classical limit, of weak coherent states at the single photon level and bright states containing on average more than 100 photons. The memory is shown to operate in the more stringent no-cloning regime for states containing 30 photons and less. The memory is based on a gradient echo technique operating on the 606 nm optical transition in Pr:YSO. A narrow spectral feature, 100 kHz wide, is prepared using persistent spectral hole burning. An applied electric field gradient Stark-shifts this feature linearly as a function of depth along the propagation direction. To create a 1.8 MHz wide feature with 13 dB of absorption. An optical pulse absorbed by this feature is recalled by reversing the applied field gradient. Homodyne detection was used to analyze the output of the memory.

Talk 5

Photophysics and Photochemistry of Solar Energy Conversion System

Cather Simpson, Peter Boyd, Frederique Vanholsbeeck, Charles Rohde, Dani Lyons, John Paauwe and Julie Kho

Departments of Chemistry and Physics, The Photon Factory, The Dan Walls Centre for Pure and Applied Optics, The University of Auckland.

The natural attraction between fullerenes (e.g. C60 and C70) and porphyrins [1] has motivated a research programme to develop supramolecular synthetic mimics for biological photosynthetic systems, led by A/Prof Peter Boyd[2, 3]. In photosynthetic bacteria, efficient conversion of light to chemical energy begins with photon absorption. Excitation energy initiates a rapid electron transfer within the bacteriochlorophyll “special pair” that is followed by charge migration through a series of active species. The resultant charge-separated state remains stable for a very long time (<1 s), and drives useful chemical reactions[4]. Given current environmental and security issues surrounding dependence upon fossil fuels, it is not surprising that major efforts are underway to develop robust synthetic models of this superbly efficient natural system[5, 6].

We have begun a collaboration to optimize these multi-chromophore architectures for photovoltaic devices. Hierarchical assemblies of fullerenes, porphyrins, and secondary donors are being made and their photoproperties tested using nanosecond [7-9] to femtosecond [10, 11] transient absorption, resonance Raman and fluorescence decay spectroscopies. The nanosecond transient absorption utilizes a new fibre-based design for supercontinuum generation [12-14]. Light harvesting by the porphyrin

should be very efficient. Photoexcitation will lead to an initial porphyrin-fullerene charge separation, followed by a vectorial electron flow along the prearranged redox gradient. While the porphyrin-fullerene electron transfer should be quite rapid, perhaps in 10's of ps, the ultimate charge separated state should have a lifetime in the millisecond regime.

Preliminary results of our ultrafast time-resolved experiments will be presented, as will the construction and testing of a nanosecond transient absorption system, with continuum generated in the visible to near IR.

References

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2. Boyd, P.D.W. and C.A. Reed, Fullerene-Porphyrin Constructs. Accounts of Chemical Research, 2005. 38: p. 235-242.
3. Boyd, P.D.W., et al., J. Am. Chem. Soc., 1999. 121: p. 10487-10495.
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14. Vanholsbeeck, F., et al., Optics Express, 2005. 13,17: p. 6615-6625.

Talk 6 (Invited Speaker)

Optical coherence tomography in cancer

David D. Sampson^{1,2}, Andrea Curatolo¹, Timothy R. Hillman¹, Brendan F. Kennedy¹, Rodney Kirk¹, Blake R. Klyen¹, Robert A. McLaughlin¹, Bryden C. Quirk¹ and Loretta Scolaro¹

¹*Optical+Biomedical Engineering Laboratory, School of Electrical, Electronic, & Computer Engineering*

²*Centre for Microscopy, Characterisation & Analysis, The University of Western Australia, Australia*

Optical coherence tomography is a medical imaging modality that enables high-resolution, three-dimensional imaging of epithelial tissues using coherence-gated reflections of light. It is conceptually similar to ultrasound, but uses near-infrared light instead of sound, resulting in a lower penetration depth in tissue but much higher resolution. Optical coherence tomography has an advantage over ultrasound in that it can readily image through air, because light is attenuated far less strongly than ultrasound. Its application is most advanced in ophthalmology (primarily the retina) and in cardiology. Many other areas are beginning to emerge as the clinical investigations into its use and utility progress. We are particularly interested in the application of optical coherence tomography to cancer diagnosis and staging. Cancer is the second most common cause of death in the developed world, accounting for around 26% of all mortalities. Optical coherence tomography may be used to image body structure at both a microscopic and macroscopic scale. In this talk, the application of optical coherence tomography to imaging cancer in humans at both spatial scales will be considered. We feature three areas in which we are actively engaged. One of these is the microscopic imaging of lymph nodes to aid

in the detection of cancer metastasis and the avoidance of unnecessary surgical removal of lymph nodes. Another area is three-dimensional macroscopic anatomical imaging of the lower airway, performed endoscopically, with the potential to guide surgical interventions such as stent insertion and laser resection of tumours. Finally, we will preview the emerging technology of interstitial optical coherence tomography – microscopic imaging in a needle.

Talk 7

All-fiber source for multiplex CARS applications

P. Mehta, M. Walbran, J. Jang and S. G. Murdoch
Physics Department, University of Auckland

We report on an all-fiber source suitable for use in coherent anti-Stokes Raman scattering (CARS) applications. The pump laser used is a high power pulsed microchip laser operating at 1064 nm. This pump is launched into a fiber system comprised of a nonlinear arm to generate a red-detuned supercontinuum (for use as the multiplexed seed) and a linear arm designed to transmit an undistorted delayed version of the pump pulse. These two signals are then recombined by a fiber WDM. The output of the WDM contains both the CARS pump and a multiplexed seed set to the correct temporal delay. Experimentally measured CARS spectra of several common molecules are presented with single shot acquisition times <10 ms demonstrated.

Talk 8

Development of vanishing ‘tattoo’ sensor as a tool for non-invasive diagnostics

I. V. Meglinski
University of Otago

A development of system capable of measuring and analysing molecular processes in the living body is one of the most important areas in clinical analysis. Although the recent progress in physics, biochemistry and microelectronics resulted in the successful development of variety of miniature biosensor devices capable of accurate monitoring biochemical parameters, their application for in vivo monitoring remains limited. The reason for this is twofold: (i) difficult integration of artificial sensor elements with a living tissue which often results in undesirable immunochemical response and/or fouling of the sensor surface; and (ii) the existing problems in communication between the implanted detector and sensor. We develop a non-invasive optical-based technique for express diagnostics and therapeutic monitoring of human skin. The technique is based on a scanning ‘tattoo’ pattern transferred into the skin similar to the kids temporal washing ‘tattoos’. ‘Smart tattoo’ generates a fluorescence signal with optical parameters which reflect the state of the tissue and are responsive to changes in physical-chemical characteristics of the skin (temperature, concentration of metabolites and presence of drugs). An overview of current progress describing selection and testing of fluorescent dyes and the results of computer simulations of reading conditions and development of instrumental prototypes for signal scanning is presented.

Talk 9

Robust Quantum Superpositions of Mesoscopic Atomic Flow

David W. Hallwood, Thomas Ernst and Joachim Brand

*Centre for Theoretical Chemistry and Physics and Institute of Natural Sciences, Massey University
(Albany Campus), Auckland, NZ*

Large strides have been made in understanding ultra-cold atoms at a mean field level. However, in certain regimes the assumption of a macroscopically occupied state is no longer valid due to strong interactions or a small separation between the ground and excited states. Here we investigate the full quantum behaviour of several interacting ultra-cold atoms. The atoms are trapped in a quasi-1D loop with a delta-function barrier that moves around the loop at a velocity equal to half a quantum of angular momentum. We show that above a characteristic interaction strength the system is in a superposition of zero and N quanta of total momentum. Furthermore, in the strongly correlated regime the system becomes robust to loss of atoms and excitations to higher excited states. This has allowed us to understand superpositions of macroscopic currents created in superconducting loops.

Talk 10

Atom Interferometers and Optical Micro-Traps

M. F. Andersen

Jack Dodd Centre for Quantum Technology, University of Otago

We have two main areas of research: Atom interferometers and optical micro-traps for neutral atoms. Atom interferometers can serve as sensitive probes for precision measurements of quantities such as the local gravitational field and fundamental constants such as the fine structure constant α . We will present our recent results on development of novel ultra sensitive atom interferometers, and atom "beam-splitters". Through our use of high numerical aperture optics we can trap neutral atoms in optical traps with dimensions of one micron or less. We will present our results on preparation and detection of high density samples in such optical micro-traps.

Poster Presentations

Poster 1

Progress in THz waveguide

J. Anthony¹, A. Argyros², Y. H. Lo¹, R. Leonhardt¹ and M. C. J. Large²

¹*Department of Physics, University of Auckland, Auckland 1010, New Zealand;*

²*School of Physics, University of Sydney, Sydney, NSW 2060, Australia*

Terahertz (THz) radiation has stimulated much attention in research ranging from generation and detection of THz to wider practical applications such as THz spectroscopy and imaging. Transmission through waveguides however, remains a difficult barrier that needs to be overcome in order to fully exploit the novel THz technology. This is the motivation for the fabrication of the THz micro-structured polymer optical fibre (mPOF), combined with designing an optical setup that optimizes the transmission through the waveguide. We present a micro-structured Zeonex ($n=1.52$, $\alpha=0.018$ mm) fiber with a core diameter of 0.60 mm (about 1 wavelength) which in combination with specially designed lenses, the symmetric-pass lenses lead to a high transmission. The experimental investigations of both the fiber samples and lenses performances are performed using THz-time domain spectroscopy, where the electric field of the THz radiation is measured. We demonstrate a high coupling efficiency of 68% can be achieved for the micro-structured fiber using the special lenses, with an average attenuation of 0.034 mm and therefore the waveguide loss is 0.016 mm. From the extracted phase details of the measurements, the fiber is found to have a low dispersion from 0.35 THz to 1.0 THz. This may lead to a possible mean of material sensing in particular for gases and liquid forms. As the waveguide loss is comparable to the material loss, there is still room for improvement in the fibers fabrications. The future outlook for reduced losses in THz fibers is to implement hollow core fibers.

Poster 2

Experiments on calorimetry of a bose-einstein condensate

A. Ullah, S. Ruddell and M. D. Hoogerland

Department of Physics, University of Auckland, New Zealand

A Bose-Einstein Condensate (BEC), trapped in a harmonic trap, can be characterized by the total atom number (N), the internal energy (U) and the trap frequency ($\bar{\omega}$). The internal energy has been difficult to measure experimentally with any accuracy. However, when a discernible condensate fraction is present, the temperature can be measured using time-of-flight. Recently, ways to impart a precisely defined amount of energy on a BEC has been proposed by Blakie *et. al.*[*J. Phys. B: At. Mol. Opt. Phys.* **40**, 3273 (2007)]. We are presenting a series of precision calorimetry measurements, finding the internal energy of a Bose-Einstein Condensate as a function of temperature, based on their proposal.

Poster 3

The Dipolar Degenerate Bose Gas

R. N. Bisset

Department of Physics, University of Otago.

Since the first production of a Bose-Einstein condensate (BEC) in 1995 there has been massive progress in our understanding of the weakly interacting degenerate Bose gas. An important feature of the alkali atoms typically used in these BECs is that their interactions are short-ranged and can be well-approximated by a contact interaction. In 2005 Griesmaier et al. (Stuttgart) obtained the first BEC in chromium (Cr), a system which has an important new feature: Ground state chromium atoms have a large magnetic dipole moment leading to an appreciable dipole-dipole (long-range and anisotropic) interaction. A range of new physics is expected to arise from these interactions and many of the traditional theoretical tools used to describe BEC with short range interactions are inapplicable. In this poster we describe progress towards the development of Hartree-Fock meanfield theory and c-field methods for describing the dipolar Bose gas.

Poster 4

Full quantum behaviour of ultracold atoms

Thomas Ernst, Jake Guliksen, David W. Hallwood and Joachim Brand

Centre for Theoretical Chemistry and Physics and Institute of Natural Sciences, Massey University (Albany Campus), Auckland, NZ

Solving the Schroedinger equation for multiple particles is very difficult! Already for the three body problem it is not possible to derive an analytical solution. Approximate solutions are often restricted to specific situations (i.e. lattices) or parameter regimes (i.e. weak interaction). Here, we pursue a versatile and general approach employing a multi-configurational Hartree ansatz in a time-dependent variational framework. This allows us to study the full quantum behaviour of few ultracold bosonic atoms. We carefully study the convergence of the method on a 1D ring and in double-well potentials and compare them against exact solutions and approximate models. We demonstrate how rescaling of the contact interaction can compensate for errors introduced by a finite single-particle basis and dramatically improve the accuracy of our calculations.

Poster 5

Critical Velocities for Roton and Super-Flow Quantum Turbulence in Liquid He

V. I. Kruglov

Department of Physics, University of Auckland.

The understanding of the existence of critical velocity in superfluid He and its microscopic nature is a long-standing problem which also closely related to superfluid turbulence. Two new mechanisms of transition of the superfluid He to quantum turbulence regimes are proposed for the case when the influence of the normal fluid on superfluid flow is suppressed. In the roton mechanism the critical velocity depends on channel size as $v_c \propto d^{-1/4}$, matching the experiments for the first time. For the second, super-flow mechanism, equations of motion for the superfluid component are developed. From these equations it can be inferred that turbulence begins when a “quantum Reynolds number” exceeds a critical value which is about for 1D geometry. In this case the critical velocity depends on d as $v_c \propto 1/d$.

Poster 6

Non-Classically Correlated Photon Streams using Rephased Amplified Spontaneous Emission

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The ability to store and recall quantum states of light with high fidelity is essential for the implementation of long distance quantum communication, in particular, quantum repeater technology. Photon echo phenomena, such as the two pulse photon echo (2PE), have this store and recall ability. The 2PE involves an input data pulse which is written onto an ensemble of atoms, and a strong read pulse which reads out the data as an echo. An excellent candidate for implementing these are Rare Earth ion doped crystals at cryogenic temperatures, due to their narrow linewidths and long coherence times. It has been shown that using Rare Earths the 2PE has high recall efficiencies, is temporally multimode, and has high bandwidths of storage. Here we investigate the 2PE as a quantum memory for light. We present theory to show that the 2PE quantum memory is noisy due to amplified spontaneous emission (ASE). We go on to show that this amplified spontaneous emission can be rephased (RASE) to lead to temporally multimode, wide bandwidth photon streams with non-classical correlations in time. Experimental progress towards detecting RASE will be presented.

Poster 7

Traveling Solitons across the BEC-BCS Crossover

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Moving dark solitons in Fermionic superfluid across the BEC-BCS crossover have been studied for the first time within the framework of time-dependent Bogoliubov-de Gennes equations. We map out the critical velocity below which a soliton can propagate. Based on the soliton energy calculated as a function of propagating velocity, we discuss the effect of a harmonic trap on the soliton dynamics. We predict the possibilities of soliton oscillations and stability in various regimes of the coupling parameter.

Poster 8

The power dynamics of a Fiber Optical Parametric Oscillator

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We investigate the power dynamics of a Fiber Optical Parametric Oscillator (FOPO). We find that both the parametric gain and the stimulated Raman scattering play an important role in the transfer of energy between waves of different frequencies. We are able to demonstrate a pump depletion of 80% at a detuning of 5 THz, which is beyond the 58% maximum predicted for a pure parametric interaction. Good agreement is found between these theoretical predictions and the experimentally measured conversion efficiency of the oscillator.

Poster 9

Raman Heterodyne Spectroscopy of Praseodymium doped YAG

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Praseodymium doped YAG (Pr:YAG) is a material that is a good candidate for use in cavity QED quantum computing due to its (relatively) large oscillator strength and long population lifetime. The disadvantage of Pr:YAG as a cavity QED material is that the coherence time (T_2) is short compared to population lifetime (T_1). The majority of the decoherence in this system is caused by interactions of the Pr atoms with the nuclear magnetic moments of the Al atoms in the lattice. We wish to apply an appropriate magnetic field to the sample such that the frequency of the hyperfine levels is insensitive to small changes in magnetic field. This should decrease the effect of the Al nuclei thereby lengthening T_2 . In this poster I will describe recent experiments that have been done to measure the hyperfine structure parameters for the D excited state of Pr:YAG. Knowledge of these parameters should allow us to calculate a magnetic field to apply to the sample that will lengthen T_2 .

Poster 10

Frequency Stabilized Diode Laser System For Atom Trapping Using Acousto-Optic Modulation

P. D. McDowall and M. F. Andersen

The Jack Dodd Centre for Quantum Technology, University of Otago.

We report on an inexpensive commercial laser diode stabilized to the D_2 -line in Rubidium using a simple scheme. The line-width was reduced to 1.3 MHz without an external cavity, making it suitable for laser cooling and trapping. The system is very robust and the laser frequency can be changed rapidly (within 51 μ s) while the laser remains in lock. The frequency of the locked laser drifts less than 850 kHz peak-to-peak over 25 hours. We demonstrate laser cooling and trapping using our system.

Poster 11

Fidelity of single-photon teleportation

C. Noh and H. J. Carmichael

University of Auckland

It is possible to capture photons decaying out of a cavity by placing a second cavity in their path with time-dependent decay rate. By placing such a capture cavity in the path of a beam of teleported photons we calculate the fidelity of single-photon teleportation, i.e., the probability that the capture cavity contains a single photon. An analytical calculation is carried out treating the added noise due to teleportation classically. We investigate the effects of various bandwidths on the fidelity.

Poster 12

Quantum gates based on laser cooled Rubidium atoms

Muhammad Rashid and Maarten Hoogerland

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The Rydberg states of neutral atoms possess long lifetimes and are strongly polarisable due to their high energies. This leads to strong and long-range dipole-dipole interactions. Energy levels are shifted due to these interactions which can be used to block transitions of more than one excitation in the Rydberg states. This so-called dipole blockade is obtained when the excitation is shifted out of resonance by the interactions. We investigate a novel scheme based on electromagnetically induced transparency (EIT), which is very sensitive to a small detuning. Even at large distances, up to several micrometres, the interactions can disrupt the EIT effect. We performed a simulation of a CNOT quantum gate based on EIT and dipole blockade schemes which is an important step towards the quantum computation using neutral atoms.

Poster 13

Vortex decay from a high temperature Bose-Einstein condensate

S. J. Rooney, A. S. Bradley and P. B. Blakie

Jack Dodd Center for Photonics and Ultra-Cold atoms

The decay of a vortex from a non-rotating high temperature Bose-Einstein condensate (BEC) is modeled using the stochastic projected Gross-Pitaevskii equation (SPGPE). To be useful as a practical tool for describing experiments it is vital to be able to choose appropriate reservoir parameters in the SPGPE. We develop a simple and fast method to generate parameters that keep the total particle number fixed over the temperature range where the SPGPE is valid. We compare the predictions for the lifetime of a vortex in a high temperature BEC using three related classical field methods: PGPE, where vortex decay can occur only through interactions with classical fluctuations; damped PGPE, where interactions with above cutoff atoms are included via a phenomenological damping term; and SPGPE, where in addition to classical fluctuations, interactions with the above cutoff atoms introduce both damping and noise. The SPGPE theory predicts a decay rate of at least twice that of the alternative methods. The theory is used to simulate vortex decay for Rb atoms in a 4:1 oblate geometry with $\lambda = 800$ nm. We predict a vortex lifetime decreasing linearly with temperature, and lying in the range $20\text{s} \ll \tau \ll 2\text{s}$. The dynamics of angular momentum indicate regimes of dissipative and diffusive decay.

Poster 14

Dynamic effects of a Feshbach resonance on Bragg scattering

C. E. Sahlberg, R. J. Ballagh and C. W. Gardiner

The Jack Dodd Centre for Quantum Technology, University of Otago.

Feshbach resonances have been used in a number of experiments to manipulate the inter-atomic interaction strength of bosonic atoms, and to partially convert atomic condensates into molecular condensates. In a recent experiment, Papp *et al.* have used Bragg spectroscopy to probe the behaviour of a strongly interacting Bose-Einstein condensate of Rubidium-85, near the Feshbach resonance at 155 G. Close to the resonance, the resulting Bragg spectra from this experiment show a significant deviation from theoretical predictions based on a simple GPE model.

We present a theoretical model for Bragg scattering from a Bose-Einstein condensate in the vicinity of a magnetic Feshbach resonance, using a classical field projected Gross-Pitaevskii formalism. We model the Feshbach resonance by explicitly including the formation of bound pairs close to resonance, corresponding to an added molecular field in our formalism. The binding energy of the molecules can be tuned to model resonance behaviour and the associated increase in the s-wave scattering length. We model the experiment of Papp *et al.* and compare the Bragg resonance line shift from our simulations with that of simulations using a single GPE. Our treatment shows a deviation from GPE for large scattering lengths, similar to that observed in the experiment.

Poster 15

Optical detection of Ultrasound using dispersion due to spectral holes

Jian Wei Tay, Patrick Ledingham and Jevon J. Longdell

Jack-Dodd Centre, University of Otago

The detection of ultrasound waves and pulses is of great interest in non destructive imaging techniques. Remote detection can be achieved using optical means, however commonly used detection methods involving interferometry are disadvantaged by small collection angles (low etendue). Photorefractive crystal based detection overcomes this but is limited by slow response times. We present a novel method for detecting ultrasound by imposing a phase-shift on light using a spectral hole burnt in a rare-earth ion doped crystal.

Poster 16

Precession of Vortices in Dilute Bose-Einstein Condensates at Finite Temperature

Bryan Wild

Jack Dodd Centre for Quantum Technology

We demonstrate that the precessional frequencies of vortices in Bose Einstein condensates (BECs) are determined by a conservation law, and not by the lowest lying excitation energy mode. We determine the precessional frequency for a single off-axis vortex and vortex lattices in BECs using the continuity equation, and solve this self-consistently with the time-independent Hartree-Fock-Bogoliubov (HFB) equations in the rotating frame. We find agreement with zero temperature calculations (Bogoliubov approximation), and a smooth variation in the precession frequency as the temperature is increased. Time-dependent solutions confirm the validity of these predictions.

Poster 17

Finite temperature dynamics and decay of a single vortex in a Bose-Einstein condensate

T. M. Wright, A. S. Bradley and R. J. Ballagh
Jack Dodd Centre for Quantum Technology

We present a beyond-mean-field model of a finite-temperature Bose-Einstein condensate containing a single vortex in a quasi-2D trap. In our approach the condensate and excited modes are described by a conserving classical-field method which includes the effects of thermal excitations on the vortex motion nonperturbatively. We find that in an isotropic trap precessing vortex configurations arise naturally as ergodic equilibria of a classical field with finite conserved angular momentum. Introducing an inertial-frame trap anisotropy leads to the loss of angular momentum from the system, slowing the rotation of the thermal cloud which, through its frictional effect on the vortex, dissipates the angular momentum of the condensate. We identify the condensate and the complementary thermal component of the nonequilibrium field, and study the evolution of their angular momenta and angular velocities. By varying the trap anisotropy we alter the relative efficiencies of the vortex-cloud and cloud-trap coupling, and distinguish qualitatively different regimes of relaxation dynamics.

Poster 18

Optical parametric amplifier pumped with a temporally-incoherent wave

Y. Q. Xu and S. G. Murdoch
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We report on a theoretical and experimental investigation of a four-wave mixing process in an optical fiber pumped with a temporally incoherent wave which has amplitude and phase fluctuations. We also present a simple theory to calculate the parametric gain of the incoherent pump. The theoretical results agree with numerical simulations of nonlinear Schrodinger equation and the experimentally measured parametric gain.

Poster 19

Atom interferometry in magnetic waveguides

J. Squire and R. J. Ballagh
Jack Dodd Center for Photonics and Ultra-Cold atoms, University of Otago

Atom chips have promise as a robust and integrated platform on which to perform atom interferometry with Bose condensates. Versatile magnetic waveguides and potential configurations can be created from currents flowing in microscopically featured conductors, or from permanent magnets. The basic elements required for interferometry are beamsplitters and beam-mixers, and a commonly proposed design is to simply merge and then divide two waveguides. We have made a detailed theoretical analysis of the beamsplitting and beam-mixing properties of this arrangement, within the framework of the Gross-Pitaevskii equation. We have quantified the performance over a large region of parameter space, and identified the regime in which the behaviour usefully mimics that familiar from normal optical elements. An analysis of the effects of thermal magnetic near-field noise on the interferometer performance is also presented.

Poster 20

The Photon Factory Status Update

Charles Rohde, Cather Simpson, Julie Kho and Sarah Thompson

Departments of Chemistry and Physics, The Photon Factory and the Dan Walls Centre for Pure and Applied Spectroscopy, The University of Auckland

The Photon Factory (PF), a state-of-the-art, multi-user laser facility, is coming to the end of its first year of operation. Starting with the arrival of the centerpiece, Coherent Legend Elite-HP amplified ultrafast laser system in January of 2009, and finishing with the installation of the JPSA micromachining platform in July of 2009, we have completed the process of bringing the PF to operational status. In the past year we have focused upon installation of our basic instruments and the construction and testing of downstream experimental stations. In addition, we have begun to actively support the research of both internal and external (commercial and CRI) scientists and engineers. These projects already cover a broad range of areas, from the machining of micro-structured stamp prototypes for use in reel-to-reel manufacturing processes to direct patterning in polymers along which neurons pattern and communicate. We also have held two modular courses for postgraduate students: Using Lasers to Watch Chemical Reactions and Micro- and Nanomachining at the University of Auckland. The PF has been designed as a multiuser facility. In this capacity we provide the tools and expertise needed to conduct a range of spectroscopic measurements to non-experts as well as providing access to the raw laser components. Our equipment provides a wide variety of pulse durations (35 fs to 10 ns) wavelengths (450nm to 3.0 μm) and energies (up to 3.5mJ/pulse at 800nm), basic science research stations, and nano/femto-second laser micromachining capability. Through our continued interaction with our current core users we are working towards building a nationally recognized facility. A facility utilized by academic, industrial and governmental researchers from around New Zealand. In this presentation we will outline the milestone achievements we have passed, compare them with our timeline for full user access, and highlight some of the projects begun at the facility.

Poster 21

Poling and testing of nonlinear polymers

M. A. Taylor and J. J. Longdell

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The refractive index of materials which have a large nonlinearity can be modulated with an applied electric field. Organic chromophores can have large nonlinear polarizability. These chromophores can be doped into polymer films. In order for these films to have a large nonlinearity, the symmetry of the chromophore orientation must be broken. This is done by aligning the molecules, in a process called poling. In the poling process the polymer film is heated while an electric field is applied across it. The heating gives the chromophore molecules freedom to rotate, while the electric field gives a preferred direction. A simple setup was designed and built whereby the polymers could be poled and the electro-optic coefficient could simultaneously be measured. This experiment can provide information about the state of the polymers during the poling process, which may allow the poling process to be optimized. Production of materials with large nonlinearity is of interest for the construction of photonic devices, which are used in the telecommunications industry.

Poster 22

An optical Kerr Shutter for Supercontinuum Pulse Characterization.

Amy Lin, Charles Rohde and Cather Simpson

Departments of Chemistry and Physics, The Photon Factory and the Dan Walls Centre for Pure and Applied Spectroscopy, The University of Auckland

Supercontinuum (SC) generation pulses are a convenient tool utilized extensively in ultrafast spectroscopy. The large spectral content (400-750 nm here) and short pulse duration (<1 ps) allow the rapid, multispectral interrogation of molecular excited states. To effectively use SC as the probe pulse in a pump-probe transient spectroscopy experiment, the dispersion of the pulse must be well characterized. Based on the works of Nakamura et al.¹, Schmidt et al.², and Takeda et al.³ we have designed an optically gated Kerr shutter (OGKS) for our use in the Photon Factory. We report on our construction of an OGKS with sub picosecond resolution. An OGKS introduces a temporary birefringence in a thin material placed between two crossed polarizers. This birefringence is induced by a strong short (<100 fs) gating pulse. The OGKS resolution is dictated by the interaction of the gating pulse with the material. We have sampled the dispersion of SC pulses with three Kerr gate materials (quartz, fused silica, and benzene) to determine the highest temporal resolution. The resulting optimal shutter resolution was used to characterize the spectral chirp of SC pulses generated with two different techniques (water and a calcium fluoride.) We report on our progress towards incorporating this system into a new transient fluorescence experiment.

1. Nakamura, R, and Y Kanematsu. "Femtosecond spectral snapshots based on electronic optical Kerr effect." Review of Scientific Instruments, Jan 2004.
2. Schmidt, B, S Laimgruber, W Zinth, and P Gilch. "A broadband Kerr shutter for femtosecond fluorescence spectroscopy." Applied Physics B: Lasers and Optics, Jan 2003.
3. Takeda, J, K Nakajima, S Kurita, and S Tomimoto. "Time-resolved luminescence spectroscopy by the optical Kerr-gate method applicable to" Physical Review B, Jan 2000.

Poster 23

Time and Spectral domain all-fiber Optical Coherence Tomography systems with variable dispersion compensators

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We use variable dispersion compensators to build time (TD-OCT) and spectral (SD-OCT) domain all-fiber optical coherence tomography systems operating in the 800 nm wavelength range. The all-fiber tunable dispersion compensator is based on a pair of fiber stretchers made with different fiber types in which the group delay and the 2nd-order dispersion can be tuned independently. Their abilities are demonstrated in biological tissues with the TD-OCT system reaching a significant sensitivity of 86 dB.