Escuela Latinoamericana de Física 2017

From July 24th to August 4th
<table>
<thead>
<tr>
<th>Time</th>
<th>Monday July 24th</th>
<th>Tuesday July 25th</th>
<th>Wednesday July 26th</th>
<th>Thursday July 27th</th>
<th>Friday July 28th</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 – 9:00</td>
<td>Opening</td>
<td>Registration</td>
<td>Registration</td>
<td>Registration</td>
<td></td>
</tr>
<tr>
<td>9:00 – 10:00</td>
<td>E. Hinds</td>
<td>E. Hinds</td>
<td>E. Hinds</td>
<td>E. Hinds</td>
<td>E. Hinds</td>
</tr>
<tr>
<td>10:00 – 11:00</td>
<td>G. Roati</td>
<td>C. Schmiegelow</td>
<td>G. Roati</td>
<td>L. E. C. Rosales</td>
<td>G. Roati</td>
</tr>
<tr>
<td>11:00 – 11:30</td>
<td>Coffee/Registration</td>
<td>Coffee/Registration</td>
<td>Coffee/Registration</td>
<td>Coffee/Registration</td>
<td>Coffee</td>
</tr>
<tr>
<td>13:30 – 15:00</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
</tr>
<tr>
<td>15:00 – 15:30</td>
<td>M. D. Reid</td>
<td>R. Ramírez</td>
<td>M. D. Reid</td>
<td>L. A. Pachón</td>
<td>M. D. Reid</td>
</tr>
<tr>
<td>15:30 – 16:00</td>
<td></td>
<td></td>
<td></td>
<td>B. M. Rodríguez</td>
<td></td>
</tr>
<tr>
<td>16:00 – 17:00</td>
<td>A. Cerè</td>
<td>A. Cerè</td>
<td>A. Cerè</td>
<td>A. Cerè</td>
<td>E. F. Galvão</td>
</tr>
<tr>
<td>17:00 – 17:30</td>
<td>Poster Session 1</td>
<td>C. Viviescas</td>
<td>R. Paredes</td>
<td>T. H. Seligman</td>
<td>Poster Session 2</td>
</tr>
<tr>
<td>17:30 – 18:00</td>
<td></td>
<td></td>
<td>S. Lerma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Monday</td>
<td>Tuesday</td>
<td>Wednesday</td>
<td>Thursday</td>
<td>Friday</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>8:30 – 9:00</td>
<td>Registration</td>
<td>Registration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:00 – 10:00</td>
<td>M. Brune</td>
<td>M. Brune</td>
<td>M. Brune</td>
<td>M. Brune</td>
<td>M. Brune</td>
</tr>
<tr>
<td>10:00 – 11:00</td>
<td>R. G. Hulet</td>
<td>R. G. Hulet</td>
<td>L. Aolita</td>
<td>L. Aolita</td>
<td>L. Aolita</td>
</tr>
<tr>
<td>11:00 – 11:30</td>
<td>Coffee/Registration</td>
<td>Coffee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:30 – 12:00</td>
<td>Coffee</td>
<td>Coffee</td>
<td>C. Sa de Melo</td>
<td>C. Sa de Melo</td>
<td>C. Sa de Melo</td>
</tr>
<tr>
<td>12:00 – 12:30</td>
<td>H. M. Moya</td>
<td>R. J. León</td>
<td>C. Sa de Melo</td>
<td>C. Sa de Melo</td>
<td>C. Sa de Melo</td>
</tr>
<tr>
<td>13:30 – 15:00</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
</tr>
<tr>
<td>15:00 – 16:00</td>
<td>T. Gorin</td>
<td>T. Gorin</td>
<td>T. Gorin</td>
<td>T. Gorin</td>
<td>T. Gorin</td>
</tr>
<tr>
<td>16:00 – 17:00</td>
<td>P. A. Nussenzveig</td>
<td>P. A. Nussenzveig</td>
<td>P. A. Nussenzveig</td>
<td>Poster Session 3</td>
<td>F. de Melo</td>
</tr>
<tr>
<td>17:00 – 18:00</td>
<td>J. I. Jiménez</td>
<td>J. W. R. Tabosa</td>
<td>S. Hofferberth</td>
<td></td>
<td>Closing</td>
</tr>
</tbody>
</table>
Índice general

Preface

Lecture Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doing fundamental physics with ultra cold atoms and molecules</td>
<td>1</td>
</tr>
<tr>
<td>An introduction to atomic Fermi gases</td>
<td>1</td>
</tr>
<tr>
<td>Quantum correlations in twin beams of light</td>
<td>2</td>
</tr>
<tr>
<td>Open quantum systems and measurement</td>
<td>2</td>
</tr>
<tr>
<td>Einstein-Podolsky-Rosen correlations and applications</td>
<td>2</td>
</tr>
<tr>
<td>Single photon - single atom interaction in free space</td>
<td>3</td>
</tr>
<tr>
<td>From cavity QED to quantum simulations with Rydberg atoms</td>
<td>3</td>
</tr>
<tr>
<td>Quantum correlations in ultracold Lithium atoms</td>
<td>4</td>
</tr>
<tr>
<td>Quantum certification of many-body quantum simulations</td>
<td>4</td>
</tr>
<tr>
<td>Ultra-cold fermions in the presence of artificial spin-orbit coupling,</td>
<td>5</td>
</tr>
<tr>
<td>Zeeman fields and interactions: Emergence of topological superfluidity</td>
<td>5</td>
</tr>
<tr>
<td>three-dimensions.</td>
<td>5</td>
</tr>
<tr>
<td>Correlations between interacting Rydberg atoms</td>
<td>6</td>
</tr>
<tr>
<td>Information flow in open and composite quantum systems</td>
<td>6</td>
</tr>
<tr>
<td>Spectral quantum correlations of bright beams and their measurement</td>
<td>6</td>
</tr>
<tr>
<td>Exciting atoms in the dark, and other things light fields can do</td>
<td>7</td>
</tr>
<tr>
<td>beyond the dipole approximation.</td>
<td>7</td>
</tr>
<tr>
<td>New configurations for biphoton state generation based on Spontaneous</td>
<td>7</td>
</tr>
<tr>
<td>Four Wave Mixing</td>
<td>7</td>
</tr>
<tr>
<td>Entanglement distribution in random states of identical particles</td>
<td>8</td>
</tr>
<tr>
<td>Superfluid and supersolid phases of dipolar fermions in square lattices</td>
<td>8</td>
</tr>
<tr>
<td>Dynamics of observables in the regular regions of the non-integrable quantum Dicke model.</td>
<td>9</td>
</tr>
</tbody>
</table>
**Applications of EPR steering in quantum teleportation and NOON states.**
(Laura Rosales Zárate, Margaret D. Reid, Run Yan Teh, Bogdan Opanchuk, Qiongyi He and Gerardo Adesso) ........................................ 9

**Ultrafast optimal sideband cooling under non-Markovian evolution.** (Johan F. Triana, Andrés F. Estrada and Leonardo A. Pachón.) ........................................ 10

**Simulators and correlations.** (Blas Manuel Rodríguez Lara) ........................................ 10

**Protecting coherence by environmental decoherence: A paradigmatic model and some random matrix considerations** (Thomas Seligman) ......................... 10

**Quantum computation with photonic chips** (Ernesto F. Galvão) ........................................ 11

**Optical lattices, Fourier transforms and the Pegg-Barnett phase operator** (Héctor Moya Cessa) ........................................ 11

**Laser spectroscopy of the $5p_{3/2} \rightarrow 6p_j$ ($j = 3/2, 1/2$) electric dipole forbidden transitions in atomic rubidium** (F. Ponciano Ojeda, C. Mojica Casique, S. Hernández Gómez, O. López Hernández, R. Colín Rodríguez, L. M. Hoyos, J. Flores Mijangos, F. Ramírez Martínez, D. Sahagún, R. Jáuregui and J. Jiménez Mier.) ........................................ 12

**Endurance of quantum coherence in Born-Markov open quantum systems** (Roberto de J. León Montiel) ........................................ 12

**Light storage in cold and warm atomic ensembles** (José W. R. Tabosa.) ........................................ 13

**Intensity field correlations in quantum optics** (Luis A. Orozco) ........................................ 13

**Reliability of digitized quantum annealing and the decay of entanglement** (Fernando de Melo) ........................................ 14

---

**Poster Session 1: Quantum Correlations and Entanglement**

**Three-body correlations with trapped ion para-Bose states** (C. Huerta Alde-rete, B. M. Rodríguez Lara) ........................................ 15

**Entanglement in the Wigner-Weyl representation** (Miller M. Murillo Mejía and Carlos Viviescas) ........................................ 15

**Comparison techniques for optical design: case study of thin films with PT-symmetric** (Alejandro Padrón Godínez and B. M. Rodríguez Lara) ........................................ 16

**Spontaneous parametric down conversion analysis by using high efficient vectorial Bessel beams** (A. L. Aguayo Alvarado, V. Vicuña Hernández, R. Ramírez Alarcón, H. Cruz Ramírez, R. Jáuregui and A. U’Ren) ........................................ 17

**Generation of photon pairs in the telecom window with controllable spatio-temporal properties** (Pablo Daniel Yepiz Graciano, Samuel Corona, Mónica Maldonado, Elisa Tejeda, Héctor Cruz Ramírez, Alfred B. U’Ren, Jesús Garduño Mejía, Carlos Wiechers and Roberto Ramírez Alarcón) ........................................ 17

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the role of crystallographic symmetries in the generation of photon pairs by nonlinear crystals (Rocío Jáuregui)</td>
<td>18</td>
</tr>
<tr>
<td>Analysis of the spectral and spatial purity of entangled photons produced by spontaneous parametric down conversion (Anamaría García and Karen Milena Fonseca)</td>
<td>19</td>
</tr>
<tr>
<td>Quantum entanglement in inhomogeneous 1D systems (Javier Rodríguez-Laguna, Jérome Dubail, Giovanni Ramírez, Pasquale Calabrese and Germán Sierra)</td>
<td>19</td>
</tr>
<tr>
<td>Controlled transverse wavevector correlations in photon pairs generated by spontaneous parametric down conversion pumped by Bessel-Gauss beams (Verónica Viciña Hernández, Jose T. Santiago, Yasser Jerónimo Moreno, Roberto Ramírez Alarcón, Héctor Cruz Ramírez, Alfred B. U’Ren and Rocio Jáuregui Renaud)</td>
<td>20</td>
</tr>
<tr>
<td>Random numbers generated using photons without post-processing (Aldo C. Martínez, Aldo Solis, Ali M. Angulo Martínez, Héctor Cruz Ramírez, Alfred B. U’Ren and Jorge G. Hirsch.)</td>
<td>20</td>
</tr>
<tr>
<td>Time-asymmetric quantum correlations of the light from a v-type three-level atom (Héctor M. Castro Beltrén, L. Gutiérrez, R. Román Anchevta, and L. Horvath)</td>
<td>21</td>
</tr>
<tr>
<td>Optomechanical photon blockade in the steady-state (C. Ventura Velázquez and B. M. Rodríguez Lara.)</td>
<td>22</td>
</tr>
<tr>
<td>Design, manufacture and characterization of optical waveguides with femtosecond laser direct write for integrated quantum photonic circuits (J. S. Durán-Gómez, R. Ramírez-Alarcón and X. J. Sánchez Lozano)</td>
<td>23</td>
</tr>
<tr>
<td>An introduction to correlations and phase transitions: An example through the Ising model (Eduardo Ibarra García Padilla, Carlos Gerardo Malanche Flores. and Freddy Jackson Poveda Cuevas)</td>
<td>23</td>
</tr>
<tr>
<td>Competition between incoherent pumping and losses in a system of two interacting qubits (J.C.Triana and K.M. Fonseca)</td>
<td>24</td>
</tr>
<tr>
<td>Experimental violation of classicality with single quantum systems (J. Castrillón, O. Calderón Losada, D.A. Guzmán, Alejandra Valencia and B. A. Rodríguez)</td>
<td>24</td>
</tr>
<tr>
<td>Searching for entanglement: Local classical strategies versus geometrical quantum constraints (R. Restrepo, J. Castrillón and B. A. Rodríguez.)</td>
<td>25</td>
</tr>
<tr>
<td>Advances on studies of quantum correlations on light with non-Gaussian structure (Luis Alberto Mendoza López, Yaneth M. Torres García, Adrián Vallejo Martínez, Jorge G. Acosta Montes, Diego Sierra Costa, Rocio Jáuregui and Daniel Sahagún.]</td>
<td>25</td>
</tr>
<tr>
<td>Advances on studies of quantum correlations on light with non-Gaussian structure: Instrumentation (Irvin F. Angeles Aguillón, Adrián Vallejo Martínez, Diego Sierra Costa, Rodrigo Gutiérrez, Yaneth M. Torres García and Daniel Sahagún Sánchez.)</td>
<td>26</td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Multipartite qubit entanglement in a cavity-based architecture</td>
<td>26</td>
</tr>
<tr>
<td>(Carlos A. González Gutiérrez, Zhong Xiao Man and Rosario Lo Franco)</td>
<td></td>
</tr>
<tr>
<td>Coherent collective dynamics and entanglement evolution of polar</td>
<td>27</td>
</tr>
<tr>
<td>molecules on 1D lattices (Vanessa Olaya Agudelo and Karen Rodríguez)</td>
<td></td>
</tr>
<tr>
<td>Generation of robust entangled states in a non-Hermitian periodically</td>
<td>27</td>
</tr>
<tr>
<td>driven two-band Bose-Hubbard system (Manuel Muñoz Arias, C. Parra</td>
<td></td>
</tr>
<tr>
<td>Muriel, J. Madroñero and S. Wimberger)</td>
<td></td>
</tr>
<tr>
<td>Generation of non classical light with Rydberg interactions</td>
<td>28</td>
</tr>
<tr>
<td>(Dalia Ornelas Huerta, Alexander Craddock, Mary Lyon, Trey Porto and</td>
<td></td>
</tr>
<tr>
<td>Steve Rolston)</td>
<td></td>
</tr>
<tr>
<td>Quantum vacuum forces between high-Tc superconductors (Carlos Villarreal)</td>
<td>28</td>
</tr>
<tr>
<td>Rydberg quantum optics in ultracold gases (Asaf Paris Mandoki,</td>
<td></td>
</tr>
<tr>
<td>Christoph Braun, Christoph Tresp, Ivan Mirogordski, Florian</td>
<td></td>
</tr>
<tr>
<td>Christaller and Sebastian Hofferberth)</td>
<td>29</td>
</tr>
<tr>
<td>Poster Session 2: Control of Quantum Systems</td>
<td>31</td>
</tr>
<tr>
<td>Collective Lamb shift in the ultrastrong-coupling regime on Dicke</td>
<td></td>
</tr>
<tr>
<td>single-photon superradiance (J. P. Restrepo Cuartas, M. Steibeck</td>
<td></td>
</tr>
<tr>
<td>Domínguez and H. Vinck Posada)</td>
<td>31</td>
</tr>
<tr>
<td>Proposal for the quantum simulation of the CP(2) model on optical</td>
<td></td>
</tr>
<tr>
<td>lattices (Wolfgang Bietenholz, Marcello Dalmonte, Wynne Evans, Urs</td>
<td></td>
</tr>
<tr>
<td>Gerber, Catherine Lafamme, Héctor Mejía Díaz, Uwe Jens Wiese and</td>
<td></td>
</tr>
<tr>
<td>Peter Zoller)</td>
<td></td>
</tr>
<tr>
<td>Evaporative cooling through the semiclassical approximation (F. J.</td>
<td></td>
</tr>
<tr>
<td>Poveda Cuevas, I. Reyes Ayala and J. E. Carro Martínez)</td>
<td>32</td>
</tr>
<tr>
<td>On the properties of ultra-cold matter wave packet confined by square</td>
<td></td>
</tr>
<tr>
<td>well potential with impurities (Ricardo Ménendez Fragos y y y Remigio</td>
<td></td>
</tr>
<tr>
<td>Cabrera Trujillo)</td>
<td>32</td>
</tr>
<tr>
<td>Chaotic dynamics on superconducting qubits in the ultrastrong</td>
<td></td>
</tr>
<tr>
<td>coupling regime (M. Steibeck Domínguez, J. P. Restrepo Cuartas and</td>
<td></td>
</tr>
<tr>
<td>H. Vinck Posada)</td>
<td>33</td>
</tr>
<tr>
<td>Fluctuations in dissipative quantum phase transitions at finite</td>
<td></td>
</tr>
<tr>
<td>system size (R. Gutiérrez Jáuregui and H. J. Carmichael)</td>
<td>33</td>
</tr>
<tr>
<td>Developing homemade instrumentation for automation and data</td>
<td></td>
</tr>
<tr>
<td>acquisition of lithium quantum gases experiment (Cristian Mojica</td>
<td></td>
</tr>
<tr>
<td>Casique, Diego Hernández Rajkov, Manuel Mendoza López, Ibáñez</td>
<td></td>
</tr>
<tr>
<td>Cortés Pérez, Andrés Gutiérrez Valdés, Aurora Borges Sánchez,</td>
<td></td>
</tr>
<tr>
<td>Eduardo Ibarra García, Ernesto Carro Martínez, Ricardo Colín</td>
<td></td>
</tr>
<tr>
<td>Rodríguez, Freddy Poveda Cuevas and Jorge Seman Harutian)</td>
<td>34</td>
</tr>
<tr>
<td>Design of an optical ring cavity for atomic interferometry (A. López</td>
<td></td>
</tr>
<tr>
<td>Vázquez, M. S. Billión, W. M. Pimenta, M. A. González, J. A.</td>
<td></td>
</tr>
<tr>
<td>Franco Villafañe and E. Gómez)</td>
<td>35</td>
</tr>
<tr>
<td>Observation of the electric-dipole-forbidden 5p_{3/2}→6p_{3/2}</td>
<td></td>
</tr>
<tr>
<td>transition in a sample of cold 85Rb atoms (Lina M. Hoyos, F. Ponciano</td>
<td></td>
</tr>
<tr>
<td>Ojeda, E. Ruiz Martínez, J. Flores Mijangos, F. Ramírez Martínez</td>
<td></td>
</tr>
<tr>
<td>and J. Jiménez Mier)</td>
<td>35</td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Quantum correlated transport in Hamiltonian pump-ratchet hybrids</td>
<td>36</td>
</tr>
<tr>
<td>(Nicolás Medina Sánchez and Thomas Dittrich)</td>
<td></td>
</tr>
<tr>
<td>Low phase noise system for gravimetry (Mario Maldonado, Nieves Arias, Vahide Abdeiye, Saeed Hamzeloui and Eduardo Gómez)</td>
<td>38</td>
</tr>
<tr>
<td>Enhancement of light transmission through random copper thin-films near the percolation threshold (Eva Mayra Rojas Ruiz, José Luis Hernández Pozos and Luis Guillermo Mendoza Luna)</td>
<td>39</td>
</tr>
<tr>
<td>Bilayer system of dipolar bosons: Few-body bound states (Grecia Guijarró Gámez, Jordi Boronat and Gregory Astrakharchik)</td>
<td></td>
</tr>
<tr>
<td>A classical formulation for generalized optical theorem for invisibility cloaks. (Irving Rondón Ojeda and Mary Carmen Peña Gomar)</td>
<td>39</td>
</tr>
<tr>
<td>Propagation of microscopic excitations in confined ultracold atomic gases (José Ernesto Alba Arroyo and Rocio Jáuregui)</td>
<td>40</td>
</tr>
<tr>
<td>Spin dynamics of many-body quantum systems after random interaction quench (Manan Vyas)</td>
<td>40</td>
</tr>
<tr>
<td>Theoretical study of manganese-copper nitride formation using first principles (J.A. Chavarría Rubio and A.M. Garay Tapia)</td>
<td>41</td>
</tr>
<tr>
<td>Ionic spinor Bose Hubbard model (Jereson Silva Valencia, Roberto Franco and Greis Julieth Cruz Reyes)</td>
<td>41</td>
</tr>
<tr>
<td>Non-Markovianity of quantum processes (Humberto Triviño Navarro)</td>
<td>42</td>
</tr>
<tr>
<td>Bosons in optical lattices (Felipe Taha Sant’Ana, Sao Carlos Institute of Physics, University of São Paulo. Axel Pelster, Technical University of Kaiserslautern.)</td>
<td>42</td>
</tr>
<tr>
<td>Mott lobes of the $S = 1$ Bose-Hubbard model with three-body interactions (A. F. Hincapie F, R. Franco and J. Silva Valencia)</td>
<td>44</td>
</tr>
<tr>
<td>Emergence of the $\rho = 1$ Mott lobe in an anyon chain with three-body interactions (J. Arcila Forero, R. Franco and J. Silva Valencia)</td>
<td>44</td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Optimal quantum rotosensors (Chryssomalis Chryssomalakos and Héctor Hernández Coronado)</td>
<td>47</td>
</tr>
<tr>
<td>Equilibration of observables for initial coherent states in a simple atom-field model (Miguel Angel Bastarrachea Magnani, Baldemar López del Carpio Jorge Chávez Carlos, Sergio Lerma Hernández and Jorge G Hirsch)</td>
<td>47</td>
</tr>
<tr>
<td>QED cavities and Ramsey zones: Semiclassical limit, adiabatic approximation and beyond. (M. Sc. Efraín Molano Parra, Grupo de Óptica e Información Cuántica (GOIC). Director: Karen Fonseca Romero.)</td>
<td>48</td>
</tr>
<tr>
<td>Use of quantum mechanics to solve the hidden subgroup problem: Advantages and disadvantages (Santiago Marín Agudelo and Jorge Eduardo Mahecha Gómez.)</td>
<td>48</td>
</tr>
<tr>
<td>The cooperation number in the study of the quantum phase transition of a matter-radiation interaction model (Luis Fernando Quezada and Eduardo Nahmad Achar.)</td>
<td>49</td>
</tr>
<tr>
<td>Semiclassical approximation to the propagator of the Wigner function for particles in confined spaces (Oscar Eduardo Rodríguez Villalba and Thomas Dittrich.)</td>
<td>49</td>
</tr>
<tr>
<td>An experimental study on quantum random number generation: from polarizing beam splitters to time tag. (Aldo C. Martínez, Aldo Solís, Ali M. Angulo Martínez, Hector Cruz Ramírez, Alfred B. U'Ren and Jorge G. Hirsch.)</td>
<td>50</td>
</tr>
<tr>
<td>Berry phase and quantum phase transition for some models formed by individual two-level systems and many-body systems. (C. A. Estrada Guerra and J. E. Mahecha Gómez)</td>
<td>51</td>
</tr>
<tr>
<td>Flat-top beam for an optical cavity (M. S. Billión, A. López Vázquez, W.M. Pimenta, J.A. Franco Villafañe and E. Gómez)</td>
<td>51</td>
</tr>
<tr>
<td>Generation of coherent blue light via four wave mixing in rubidium (F. Ponciano Ojeda, Lina M. Hoyos, S. Hernández Gómez, E. Navarro Navarrete, J. Flores Mijangos, F. Ramírez Martínez and J. Jiménez Mier.)</td>
<td>52</td>
</tr>
<tr>
<td>Embeddings of spaces of quregisters into special linear groups (Dalia Cervantes and Guillermo Morales Luna)</td>
<td>52</td>
</tr>
<tr>
<td>Adiabatic invariants in the semiclassical Dicke model (Baldemar López del Carpio, Jorge Chávez Carlos, Miguel Bastarrachea Magnani, Sergio Lerma Hernández and Jorge G. Hirsch)</td>
<td>53</td>
</tr>
<tr>
<td>A quadrupole transition induced by a Bessel Beam: experiment and theory (S. Hernández Gómez, P. Ortega Escorza, F. Ponciano-Ojeda, C. Mojica Casique, L. M. Hoyos Campo, F. Ramírez Martínez, J. Flores-Mijangos, K. Volke Sepuleveda, R. Jaurégui Renaud and J. Jiménez Mier)</td>
<td>53</td>
</tr>
<tr>
<td>From unsharp to projective measurement of a spin component (Daniel Saavedra Martínez and Karen Fonseca Romero.)</td>
<td>54</td>
</tr>
<tr>
<td>Overlap statistics for mixed states of finite dimensional quantum systems (T. Gorin and L. Alonso)</td>
<td>55</td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Theoretical analysis of the control of populations in atomic systems using schemes based on the quantum Zenon effect (Javier Contreras Sánchez, Fray de Landa Castillo Alvarado and José Luis Hernández Pozos)</td>
<td>55</td>
</tr>
<tr>
<td>Divisibility of quantum dynamical maps versus divisibility of quantum channels (David Davalos, Mario Ziman and Carlos Pineda)</td>
<td>55</td>
</tr>
<tr>
<td>Study of quantum channels using quantum error correcting codes (Carlos Tonatiuh Hernández del Toro and Thomas Gorin)</td>
<td>56</td>
</tr>
<tr>
<td>Measurements and algorithms (Aldo Solis and Jorge Hirsch)</td>
<td>56</td>
</tr>
<tr>
<td>Quantum information metric and Berry curvature from a Lagrangian approach (Javier Alvarez Jiménez, J. David Vergara and Aldo Dector)</td>
<td>56</td>
</tr>
<tr>
<td>Semiclassical initial value propagation of Wigner functions (Carlos Viviescas and José Mauricio Sevilla)</td>
<td>56</td>
</tr>
<tr>
<td>Infinite dimensional kicked Ising model (David Amaro Alcalá and Carlos Pineda)</td>
<td>57</td>
</tr>
<tr>
<td>Fidelity witness of Bosonic Gaussian states (Renato Mello da Silva Farias and Leandro Aolita)</td>
<td>57</td>
</tr>
<tr>
<td>New solutions of quasi-exactly solvable potentials in quantum mechanics (Edgar Condori, Marco A. Reyes and Mario Ranferi Gutiérrez)</td>
<td>58</td>
</tr>
<tr>
<td>Painlevé IV solutions from systems with harmonic oscillator gapped spectrum (Mario Iván Estrada Delgado and David José Fernández Cabrera)</td>
<td>58</td>
</tr>
</tbody>
</table>

**Organizing Committee**  
59

**Sponsors**  
61

**Notes**  
63
Preface

The Latin American School of Physics “Marcos Moshinsky” (ELAF, for its acronym in Spanish) was created by three of the most significant physicists in Latin America: Juan José Giambiagi from Argentina, José Leite Lopes from Brazil and Marcos Moshinsky from Mexico. After its inauguration in 1959 in Mexico City, ELAF moved to Rio de Janeiro in 1960, next to Buenos Aires in 1961, and again to Mexico City in 1962. Since then, this school has taken place every third year in Mexico, becoming one of the most traditional schools of physics in the region. ELAF has counted with the participation of prominent scientists from all over the world presenting in courses and seminars the most recent developments in modern physics, inspiring hundreds of students and young scientists from all over Latin America.

ELAF will be held for the 20th time in Mexico City from July 24th and August 4th at El Colegio Nacional. It will consist of a series of lecture courses (3-5 hours each), seminars (50 +10 minutes), short talks (25 + 5 minutes) and poster sessions.

In its current edition, ELAF will be devoted to the topic of Quantum Correlations, a central concept in contemporary physics and whose investigation has allowed a deeper understanding of the fundamentals of quantum mechanics. ELAF will focus on both recent experimental research and theoretical developments to properly characterize and control quantum correlations in a wide range of physical systems such as quantum optical systems, isolated ultracold ions and degenerate quantum gases, among others.

We are convinced that ELAF 2017 will be an excellent opportunity for our students and young researchers to interact with leading scientists as well as to learn and delve into current fascinating lines of research.
Lecture Courses

Doing fundamental physics with ultra cold atoms and molecules

Edward Hinds
Centre for Cold Matter, Imperial College London, South Kensington Campus, London SW7 2AZ, UK.

Cold atoms and molecules are used to make some of the most delicate and sensitive measurements possible through their quantum coherences. Will discuss the the cooling of atoms and molecules and their application to a range of topics including dark energy, inertial navigation, quantum photonics, particle physics and cosmology.

An introduction to atomic Fermi gases

Giacomo Roati.
National Institute of Optics of the National Research Council and European Laboratory for Nonlinear Spectroscopy (INO-CNR & LENS), University of Florence, Italy.

In these lectures, I will discuss some peculiar aspects of ultracold atomic Fermi gases, from the non interacting, ideal case to the famous BEC-BCS crossover of strongly correlated fermions. I will describe the main and more recent experimental results, highlighting the unique and fascinating aspects of this expanding research field.
Quantum correlations in twin beams of light
Paul David Lett.
Joint Quantum Institute. Atomic Physics Division. 100 Bureau Dr., MS 8424. National
Institute of Standards and Technology. Gaithersburg, MD.

I will discuss the correlations produced in in two-mode squeezed states of light. These
states, sometimes known as "twin beams" of light are produced in nonlinear optical
processes, and can enable a number of quantum-enhanced precision measurements,
which will also be discussed. In addition, these states, when they are produced in
multiple spatial modes, can be used to enhance imaging applications. I will discuss
both the various types of correlations that can be produced and measured, as well as
the experimental techniques used to both produce the quantum-correlated states and
to make the measurements.

Open quantum systems and measurement
H. J. Carmichael
The Dodd-Walls Centre for Photonic and Quantum Technologies, Department of Physics,
University of Auckland, Private Bag 92019, Auckland, New Zealand.

This 5 hour short course covers the basics of open quantum systems theory as applied in
quantum optics, optomechanics, and circuit QED, with an emphasis on its application
to a deep (dynamical) understanding of quantum measurements. Standard introd-
tory topics covered include: Lindblad master equations, Heisenberg-Langevin equations,
input-output theory, correlations and quantum regression, phase-space representations,
and quantum trajectory theory. Following this introduction, the lectures move on to a
examples selected from current research; topics will include: dissipative quantum phase
transitions, decoherence and non-classical states of light (e.g. Schrödinger cat states),
and, finally, an investigation into the question - can the notorious quantum jump be
time-reversed?

Einstein-Podolsky-Rosen correlations and applications
Margaret D. Reid.
Centre for Quantum and Optical Science Faculty of Science, Engineering and Technology
Mailstop H38, Swinburne University of Technology PO Box 218, Hawthorn VIC 3122,
Australia.

The lecture course outlines the history of Einstein-Podolsky-Rosen (EPR) correlations,
introducing the EPR argument and Bell’s theorem and also the concepts of entangle-
ment and EPR steering. Ways to determine and quantify the different sorts of quantum
correlations are explored, as well as links to the Schrödinger cat paradox and applica-
tions to quantum key distribution and teleportation.
Single photon - single atom interaction in free space

Alessandro Cerè.

Centre for Quantum Technologies, National University of Singapore, Science Drive 2, Singapore 117543, Singapore.

In this course I will discuss the interaction between two fundamental quantum systems: traveling single photons and single hydrogen-like atom in free space. After the introducing the Weisskopf-Wigner theory of spontaneous emission, I will extend it to predict the effect of the time envelope of an incident single photon. Some notable cases will be solved analytically. In the last part of the course I will present some recent experimental demonstrations.

From cavity QED to quantum simulations with Rydberg atoms

M. Brune.

Laboratoire Kastler Brossel, Collège de France, CNRS, ENS-PSL Research University, UPMC-Sorbonne Universités, 11 Place M. Bertellot, 75005 Paris, France.

Rydberg atoms and microwave photons stored in a high Q cavity constitutes a nearly ideal system for realizing a "photon box" in the spirit of gedanken experiments introduced by Einstein and Bohr for emphasizing the unbelievable strangeness of quantum theory. In the first part of the course, we will show how the experiment illustrates fundamental features of quantum measurement theory, like state projection and decoherence. On the basis on a quantum non-demolition (QND) photon counting method, we will present methods for reconstructing the quantum state stored in the cavity and to follow its quantum trajectory. Application to Schrödinger cat state preparation, to quantum feedback state stabilization and to the past quantum state reconstruction methods will be discussed. The second part of the lecture, will present new perspectives for building a quantum simulator of a 1D XXZ spin Hamiltonian. The simulator is based on the strong dipole-dipole van der Walls interaction between Rydberg atoms trapped in a 1D chain. We will show that a single circular Rydberg atom can be trapped over time scales larger than a minute. We will discuss the potential of this system for quantum simulations involving several tenths of atoms for exploring the phase diagram of the XXZ Hamiltonian, and the physics of quench, transport and localization.
Quantum correlations in ultracold Lithium atoms

Randall G. Hulet

Department of Physics and Astronomy, Rice University, Houston TX, 77005, USA.

In these lectures, I will discuss experiments employing ultracold atomic gases of the lithium isotopes. Lithium-6 is a composite fermion which we use to explore pairing, magnetism, and exotic forms of superconductivity, while we use the boson, lithium-7, to study matter-wave solitons made from Bose-Einstein condensates with an attractive non-linearity.

Quantum certification of many-body quantum simulations

Leandro Aolita

Instituto de Física, Universidade Federal do Rio de Janeiro, P.O. Box 68528, Rio de Janeiro, RJ 21941-972, Brazil.

A major roadblock for large-scale quantum technologies is the lack of experimentally-friendly certification tools. The ultimate challenge consists of making sure that quantum machines with the declared goal or solving classically intractable problems do actually work correctly. The area of many-body quantum certification aims to solving this problem. Lecture I: In the first lecture, I will provide a general motivation, review the notions of weak versus strong quantum simulations, as well as quantum and classical sampling problems, and discuss basic tools for quantum state characterisation — from brute-force quantum state tomography to direct (i.e., without tomography) fidelity estimation techniques. The latter may involve a short technical discussion on large-deviation (Chernoff) bounds. Lecture II: Here, I will focus on the certification of (non-universal) quantum simulations. I will start the with the formal definition of certification tests. I will discuss fidelity witnesses (for multi-mode photonic states, fermionic and spin-1/2 chains, and local gapped systems) as well as MPS tomography. The latter may involve a short discussion about frustration-free Hamiltonians, state nullifiers and stabilisers, and the Jordan-Wigner transform. Lecture III: In the last lecture, I will focus on the certification of universal quantum computing. I will first review the notions of measurement-based quantum computing and stabiliser states. Then, I will discuss the seminal interactive-proof schemes as well as the more recent development on non-interactive schemes, where the certifier possesses only single-particle quantum measurement capabilities. I will end up with a list of general open question in the field.
Ultra-cold fermions in the presence of artificial spin-orbit coupling, Zeeman fields and interactions: Emergence of topological superfluidity in two and three-dimensions.

Carlos A. R. Sa de Melo
Georgia Institute of Technology

In these lectures, I discuss the effects of artificial spin-orbit coupling, Zeeman fields and interactions on systems of ultra-cold fermions consisting of Lithium, Potassium or Ytterbium atoms. In the first lecture, I show how artificial spin-orbit coupling is created in the laboratory, and describe only non-interacting systems through an analysis of their excitation spectrum, momentum distribution and thermodynamic properties. In the second lecture, I discuss the case of interacting fermions in three-dimensions in the presence of spin-orbit coupling and Zeeman fields, where topological superfluid phases emerge when interactions are tuned using Fano-Feshbach resonances. In particular, I show that the crossover from Bardeen-Cooper-Schrieffer (BCS) to Bose-Einstein-Condensation (BEC) superfluidity is transformed into a sequence of quantum phase transitions of topological nature, when spin-orbit and Zeeman fields are present. In the last lecture, I turn my attention to interacting two-dimensional fermions. In special, I explain how the Berezinski-Kosterlitz-Thouless transition is modified by spin-orbit coupling and Zeeman fields, and I describe topological phases that emerge in its phase diagram. In addition, I show that sound velocities can identify the transitions between different phases and that the vortex structure is strongly modified by spin-orbit and Zeeman fields leading to the emergence of textures.

Correlations between interacting Rydberg atoms

Sebastian Hofferberth
University of Southern Denmark, Department of Physics, Chemistry and Pharmacy
Campusvej 55 5230 Odense M Dänemark.

Interacting Rydberg atoms have attracted immense attention over the last 10-15 years as a novel approach to realize strongly correlated many-body dynamics in ultracold gases. Spectacular results from recent years include the demonstration of Rydberg atom quantum gates, the direct observation of the Rydberg blockade, and the development of Rydberg quantum optics. After reviewing the basic properties of Rydberg atoms, this class will discuss in detail how the interaction potential between Rydberg atom pairs is calculated and how the Rydberg blockade mechanism emerges from this interaction. With this knowledge, we will study recent hallmark experiments in the various emerging subfields and outline future perspectives in cold and hot atomic gases and beyond.
We will start from the approach of Breuer, Lane and Piilo to the characterization of non-Markovianity in open quantum systems. To this end, we describe the reduced dynamics in terms of a communication channel. This allows to give a precise procedural definition of information flow, as the amount of classical information which can be transferred reliably under the repeated usage of a given channel. We will then be studying different types of communication channels (private classical information, entanglement assisted communication, quantum information), as well as composite quantum systems, where communication between different nodes must be taken into account: (i) information flow between system and environment; (ii) information flow between two different systems, in the presence of a common or separate environment; (iii) information flow in the presence of an entangled spectator system.

Optical parametric oscillators (OPOs) are among the most widely used tools in Quantum Optics to generate and study nonclassical features of light. They have enabled the generation of quantum light for over 30 years now. In these lectures, we will review the basic physics of these systems and the nature of the quantum correlations they generate, including Einstein-Podolsky-Rosen type entanglement of two or more modes of light. The techniques used to measure quantum properties of light in the spectral domain will be analyzed. We will see that the most widely employed technique, spectral homodyne detection, is inherently unable to allow for a complete reconstruction of the quantum state of a beam of light. This can be done with an alternative technique, resonator detection, which we have been studying in our lab. As a perspective, we will briefly describe the extension of many of these ideas to a more applied platform: cavities and waveguides on silicon chips, which are CMOS-compatible.
Seminars and Short Talks

Exciting atoms in the dark, and other things light fields can do beyond the dipole approximation.

Christian Schmiegelow
Departamento de Física e Instituto de Física de Buenos Aires, UBA-CONICET.

I will discuss experimental results where orbital angular momentum from a photon was transferred to the internal electronic degrees of freedom of a single atom. We observed strongly modified selection rules showing that an atom can absorb two quanta of angular momentum from a single photon: one from the spin and another from the spatial structure of the beam. Moreover, the results show in some cases, the longitudinal component of the field in a vortex beam plays a crucial role in determining the interaction characteristics. Furthermore, I’ll show that parasitic ac-Stark shifts from off-resonant transitions are suppressed in the center of the vortex beam. The experiments were done probing a quadrupole transition in a single trapped Calcium ion. Future applications of the use of structured beams as well as near field gradients to drive higher order transitions will be discussed.

New configurations for biphoton state generation based on Spontaneous Four Wave Mixing

Roberto Ramírez Alarcón.
Centro de Investigaciones en Óptica, CIO, Lomas del Bosque 115, Lomas del Campestre, 37150 León, Gto., Mexico.

We present a novel configuration for photon pair generation based on the spontaneous four wave mixing (SFWM) process in a birefringent and few-mode optical fiber, where multiple SFWM processes are present, each associated with a particular combination of transverse modes for the four participating waves. We have seen that in the weakly guiding regime, for which the propagation modes are described by linearly polarized modes, the departure from circular symmetry due to the fiber birefringence translates into conservation rules, which retain elements from azimuthal and rectangular symmetries: both OAM and parity must be conserved for a process to be viable. In our source: i) each process is group-velocity-matched so that it is, by design, nearly-factorable, and
ii) the spectral separation between neighboring processes is greater than the marginal spectral width of each process. Consequently, there is a direct correspondence between the joint amplitude of each process and each of the Schmidt mode pairs of the overall two-photon state.

---

**Entanglement distribution in random states of identical particles**

Carlos Viviescas and Natalia Herrera  
Departamento de Física, Universidad Nacional de Colombia, Bogotá D.C., Colombia.

In contrast to the well developed and stablished theory of entanglement for distinguishable particles, and despite the numerous attempts and significant effort invested in it, an entanglement theory for states of indistinguishable particles still remains in a precarious condition. At this point, the main hurdles faced by the theory derive from the subtleties of the quantum correlations inherent to the statistical properties of states of indistinguishable particles. In an attempt to illustrate basic differences between the nature of entanglement in systems of distinguishable and indistinguishable particles, we propose a measure for the entanglement of bipartite systems of indistinguishable particles which emerges as a natural extension of the G-concurrence; an existing monotone for NxN systems of distinguishable particles. As a first application of this measure we use it to characterize the entanglement distribution on particular ensembles of random states of high-dimensional bipartite systems of bosons and fermions, and compare it with known results for systems of distinguishable particles.

---

**Superfluid and supersolid phases of dipolar fermions in square lattices in two dimensions.**

Rosario Paredes  
Instituto de Física, Universidad Nacional Autónoma de México, México.

We investigate the superfluid and supersolid phases in ultracold Fermi molecules confined in a bilayer array of two-dimensional square optical lattices. We show that these phases appear by either, tuning the interlayer separation distance at a fixed value of the chemical potential or by varying the effective interaction between molecules at a fixed interlayer separation. We demonstrate the existence of ordered checkerboard and superfluid phases within the inhomogeneous mean-field approach, together with the Ginzburg-Landau approximation. Coexistence of density ordered phases and superfluid regimes are used as a signature of supersolidity.
**Dynamics of observables in the regular regions of the non-integrable quantum Dicke model.**

S. Lerma Hernández\(^1\), J. Chávez Carlos\(^2\), B López del Carpio\(^1\) and J. G. Hirsch\(^2\)

\(^1\)Facultad de Física, Universidad Veracruzana. \(^2\) ICN-UNAM.

The Dicke model describes the interaction between a set of two-level identical systems and a bosonic mode. This model is not integrable and its classical version shows regions of hard chaos for large enough excitation energy, in extended regions of the model parameter space. The low energy region is regular and it can be described by an adiabatic approximation, where fast and slow variables decouple dynamically. The quantum version of the adiabatic approximation, the so called Born-Oppenheimer approximation, produces a quantum spectrum organized in bands where each band is labelled by the quantum number associated to the adiabatic invariant operator. The dynamical consequences of this band structure is explored by calculating the temporal evolution of the Survival Probability of initial coherent states and other observables as the number of bosons and the population’s difference of the two levels.

**Applications of EPR steering in quantum teleportation and NOON states.**

Laura Rosales Zárate \(^1\), Margaret D. Reid\(^2\), Run Yan Teh\(^2\), Bogdan Opanchuk\(^2\), Qiongyi He\(^3\) and Gerardo Adesso \(^4\)

\(^1\)Centro de Investigaciones en Óptica, CIO; \(^2\)Centre for Quantum and Optical Science, Swinburne University of Technology, Melbourne, VIC 3122, Australia; \(^3\)State Key Laboratory of Mesoscopic Physics. School of Physics, Peking University, Beijing 100871, China; \(^4\)School of Mathematical Sciences, University of Nottingham, Nottingham NG7 2RD, United Kingdom.

EPR steering refers to the type of correlations described in the EPR paradox, where one observer seems to affect (‘steer?’) the state of the other observer by using local measurements. There have been several works regarding characterization and quantification of EPR steering. One characteristic of this non-locality is that it can be asymmetrical, which is different to entanglement. This is relevant for potential applications of EPR steering to quantum information and quantum optics, which include quantum cryptography and quantum teleportation. This latter refers to the process where one observer sends an unknown quantum state to Bob, who is in a different location. They communicate by classical means. Here we will show that EPR steering is a necessary resource to obtain secure continuous variable teleportation. We will also consider NOON states, which is an entangled state. For this state, we will present a criterion that verify a nonzero quantum coherence between states with quantum number different by n. We will also provide with a steering signature for the NOON states.
Ultrafast optimal sideband cooling under non-Markovian evolution

Johan F. Triana, Andrés F. Estrada and Leonardo A. Pachón.
Universidad de Antioquia, Medellín, Colombia.

A sideband cooling strategy that incorporates (i) the dynamics induced by structured (non-Markovian) environments in the target and auxiliary systems and (ii) the optimally time-modulated interaction between them is developed. For the context of cavity optomechanics, when non-Markovian dynamics are considered in the target system, ground state cooling is reached at much faster rates and at a much lower phonon occupation number than previously reported. In contrast to similar current strategies, ground state cooling is reached here for coupling-strength rates that are experimentally accessible for the state-of-the-art implementations. After the ultrafast optimal-ground-state-cooling protocol is accomplished, an additional optimal control strategy is considered to maintain the phonon number as close as possible to the one obtained in the cooling procedure. Contrary to the conventional expectation, when non-Markovian dynamics are considered in the auxiliary system, the efficiency of the cooling protocol is undermined.

Simulators and correlations

Blas Manuel Rodríguez Lara
Instituto Nacional de Astrofísica Óptica y Electrónica and Instituto de Estudios Superiores de Monterrey, México.

Simulators, quantum and classical, have become an important element of contemporary scientific work. The ability to reproduce exotic physics in highly controllable systems has allowed us to develop the study of physical phenomena that may have been unreachable in nature. Such systems have also allowed us to design devices such as coherent transfer systems, generation of complex light states, information coding, among others. In many of these examples, correlations play an important role. In this talk we will discuss a series of photonic and trapped ions devices that allow us to do state engineering where correlations play an important role.

Protecting coherence by environmental decoherence: A paradigmatic model and some random matrix considerations

Thomas Seligman
Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México, México
Quantum computation with photonic chips

Ernesto F. Galvão.

Instituto de Física, Universidade Federal Fluminense, Brasil.


Optical lattices, Fourier transforms and the Pegg-Barnett phase operator

Héctor Moya Cessa

Instituto Nacional de Astrofísica, Óptica y Electrónica, México.

I will show how classical light might be propagated through waveguide arrays in order to produce special outputs that have quantum analogies. In particular, I will show how to produce classical and quantum Fourier transforms and their relation to the Pegg-Barnett phase operator.
Laser spectroscopy of the $5p_{3/2} \rightarrow 6p_j \ (j = 3/2, 1/2)$ electric dipole forbidden transitions in atomic rubidium

F. Ponciano Ojeda$^1$, C. Mojica Casique$^1$, S. Hernández Gómez$^1$, O. López Hernández$^1$, R. Colín Rodríguez$^1$, L. M. Hoyos$^1$, J. Flores Mijangos$^1$, F. Ramírez Martínez$^1$, D. Sahagún$^2$, R. Jáuregui$^2$ and J. Jiménez Mier$^1$.

$^1$Instituto de Ciencias Nucleares, UNAM, Ciudad de México 04510, Mexico; $^2$Instituto de Física, UNAM, 04510, Ciudad de México, Mexico.

Doppler-free optical double-resonance spectroscopy is used to study the $5s_{1/2} \rightarrow 5p_{3/2} \rightarrow 6p_j \ (j = 3/2, 1/2)$ excitation sequence in room-temperature rubidium atoms. This involves a $5s_{1/2} \rightarrow 5p_{3/2}$ electric dipole preparation step followed by the $5p_{3/2} \rightarrow 6p_j$ electric quadrupole excitation. The electric dipole forbidden transitions occur at 911.0 nm ($j = 3/2$) and 917.5 nm ($j = 1/2$). Production of atoms in the $6p_j$ states is detected by observing their direct decay to the ground state through emission of blue photons ($\lambda = 420$ nm). A detailed experimental and theoretical study of the dependence on the relative linear polarizations of excitation beams is made. It is shown that specific electric quadrupole selection rules over magnetic quantum numbers are directly related to the relative orientation of the linear polarization of the excitation beams.

Endurance of quantum coherence in Born-Markov open quantum systems

Roberto de J. León Montiel.

Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, 70-543, 04510 Cd. Mx., México.

Controllable devices provide novel ways for the simulation of complex quantum open systems. In this talk, I will present different experimental platforms, developed in our group, where the dynamics of Born-Markov open quantum systems can be successfully simulated. In particular, I will discuss the survival of quantum coherence between two indistinguishable particles that co-propagate through quantum networks affected by dynamical disorder or noise. Furthermore, I will show, both theoretically and experimentally, that the same steady state of the system, with surviving quantum coherences, is reached irrespectively of the configuration in which the indistinguishable particles are prepared.
Light storage in cold and warm atomic ensembles  
José W. R. Tabosa.  
Departamento de Física, Universidade Federal de Pernambuco, Cidade Universitária  
50670-901 Recife, PE, Brasil.  

I will present an overview on different nonlinear optical phenomena in coherently driven  
cold and warm atomic ensembles and discuss their applications for the reversible storage  
of light. Optical memories based on the phenomena of electromagnetically induced  
transparency (EIT), coherent population oscillation (CPO), as well as memories associated  
with nonlinear higher order processes will be discussed. I also will present and discuss  
optical memories based on the atomic external degrees of freedom, specifically  
the ones based on recoil-induced resonance (RIR) and on the quantized atomic motion  
in an optical lattice. In particular, I will specially consider the case where the interacting  
light fields carry orbital angular momentum (OAM). The possibility of employing  
nonlinear higher order processes to the generation of multiphoton quantum correlation  
will be discussed.

Intensity field correlations in quantum optics  
Luis A. Orozco  
Joint Quantum Institute Department of Physics, University of Maryland and NIST, College  
Park, MD 20742  

The nature of light is a topic that has animated discussions in physics since the time  
of Isaac Newton. The argument of wave versus particle is resolved in quantum  
electrodynamics by a formalism that combines both of these aspects. The formalism is  
fundamentally statistical, and as with quantum phenomena in general, it is through  
the statistical uncertainty, fluctuations, that the wave and particle natures of light  
sit self-consistently side by side. Two lines of experiments have been followed: those  
measuring the particle aspect of light (correlations between pairs of photon detection  
using the Hanbury Brown and Twiss technique) and those studying the wave aspect of  
light (squeezing experiments that measure the fluctuation variance of the wave amplitude).  
No attempt has previously been made to draw on the particle and wave aspects  
together by correlating a photon detection with fluctuations of the electromagnetic wa-  
ve amplitude. I will present the formalism of the field-intensity correlation, third order  
on the field, and show how we have managed to measure this correlation, using as a  
source a cavity QED system. The source is known to emit non classical light; this has  
been demonstrated in both photon correlation and squeezing measurements. We now  
have a way to observe the fluctuation of the wave amplitude of light underlying these  
measurements by exploiting the conditioning on a photon detection to catch it as it  
occurs. This correlation function in its relations to the field (wave)–intensity (particle)  
opens interesting possibilities in quantum information and quantum feedback.
Reliability of digitized quantum annealing and the decay of entanglement

Fernando de Melo
Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil.

Among the models for quantum computation, quantum annealing arises as one of the front runners that may first establish the quantum computational supremacy – the stage at which implementations of quantum computers will start solving problems deemed intractable for their classical counterparts. For instance, it is the model adopted by D-Wave – the first company commercially producing and selling devices advertised as quantum computers. This first private venture was recently followed by an initiative from Google/UCSB. In this talk I will present experimental results of a banged-digital-analog simulation of a quantum annealing protocol in a two-qubit Nuclear Magnetic Resonance (NMR) quantum computer. Our experimental simulation employed up to 235 Trotter steps, with more than 2000 gates (pulses), and we obtained a protocol success above 80%. Given the exquisite control of the NMR quantum computer, we performed the simulation with different noise levels. We could then analyze the reliability of the quantum annealing process, and relate it to the level of entanglement produced during the protocol. Although the presence of entanglement is not a sufficient signature for a better-than-classical simulation, the level of entanglement achieved relates to the fidelity of the protocol.
Poster Session 1: Quantum Correlations and Entanglement

Three-body correlations with trapped ion para-Bose states

C. Huerta Alderete\textsuperscript{1}, B. M. Rodríguez Lara\textsuperscript{2,3}

\textsuperscript{1}Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México; \textsuperscript{2}Photonics and Mathematical Optics Group, Tecnológico de Monterrey; \textsuperscript{3}Instituto Nacional de Astrofísica, Óptica y Electrónica.

The modern theory of coherence is based on correlation functions. In that sense, we propose a trapped ion experimental scheme to simulate a para-Bose oscillator of even order which provides us to study the statistical properties with a three-body correlation function within the frame of cross-cavity quantum Rabi Model.

Entanglement in the Wigner-Weyl representation

Miller M. Murillo Mejía and Carlos Viviescas

Universidad Nacional de Colombia, Facultad de Ciencias, Colombia

Despite being the first, among the fascinating set of quantum correlations that a quantum state of a composite system can display, to be identified, entanglement remains as the most intriguing one due to its central role in quantum information protocols. Even though it has being studied for the last three decades, the identification and quantification of entanglement remains an area of research. Recently, questions regarding the generation of entanglement under a classical dynamics have rise that can be better address in a phase space representation of quantum mechanics. In this work we present a review of the entanglement criteria and measures that can be formulated in the Weyl-Wigner representation, and discuss the advantages of the use of this representation for the study of entanglement in some quantum systems.
Comparison techniques for optical design: case study of thin films with PT-symmetric

Alejandro Padrón Godínez\textsuperscript{1} and B. M. Rodríguez Lara\textsuperscript{2,3}

\textsuperscript{1}Instituto Nacional de Astrofísica, Óptica y Electrónica, Puebla- México; \textsuperscript{2}Grupo de Fotónica y Óptica Matemática, Tecnológico de Monterrey, México

The anomalous behavior of materials when they are used to build thin films has been established as a modern physical phenomenon. Once the anomalies are under control this has been exploited in basic research for the study of the physical and chemical properties of materials for industrial applications. A traditional option to design optical devices with reflection and transmission controlled are thin films. Although in optics historically appeared naturally as a first breach that confront physics with anomalies of thin films that were shown in the reflection of soap bubbles, trap air between two surfaces of glass or drops of grease on water. In this paper we will show how two techniques for optical design can help us to carry out an analysis of the behavior of transmission and reflection coefficients of Fresnel for doped dielectric thin films which have parity time symmetry (PT-Symmetric). In quantum mechanics the Symmetry-PT, refers to invariance to spatial and temporal reflection provided by potential complexes that obey the property $V(x) = -V(x)$, break the bidirectionality of quantum systems as sources and sinks. In particular, we make a comparison between the methods of multiple reflections and transmissions at style of the Fabry-Perot in the Etalon and the method transfer matrixes that are used in optical design devices. The graph results were obtained in notebook of Mathematica through modeling and simulated and then compared with a third technique, COMSOL with finite element, of reflectance and transmittance of one and two layers of doped thin films. In this type of devices based on doped thin films we want to design a crystal glass with high transmittance at wavelength of 1550 [nm] and have low reflectance to be part of a source where takes place a spontaneous parametric down conversion (SPDC). In the SPDC where impacts a photon, called pumping Photon, is probabilistically speaking converted into two photons known as signal and idler.
Spontaneous parametric down conversion analysis by using high efficient vectorial Bessel beams

A. L. Aguayo Alvarado¹, V. Vicuña Hernández, R. Ramírez Alarcón, H. Cruz Ramírez, R. Jáuregui and A. U'Ren

¹Laboratorio de Fotónica Cuántica, Centro de Investigaciones en Óptica, León, Gto. 37150, Mexico; ²Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, 04510 Ciudad de México, Mexico; ³Instituto de Física, Universidad Nacional Autónoma de México, 04510 Ciudad de México, Mexico.

The construction of vectorial Bessel beams is presented for use as pumping in the process of Spontaneous Parametric Down Conversion (SPDC) and the analysis of the Angular Spectrum (AS) of such a process. Is presented as well the same analysis with Laguerre-Gauss beams. The generation of vector beams is of great interest for many applications such as optical tweezers, propagation through turbulent mediums, and processes that require a strong focus of the beams; its efficient generation is achieved by superimposing two beams with orthogonal polarizations, opposite circular polarization in this case, and an opposite topological charge. It have been generated Laguerre-Gaussian and Bessel-Gauss beams that own OAM and SAM by using a Sagnac interferometer, the polarization is given by a Quarter Wave Plate and the optical vortex by using a vortex phase plate that gives to the beams the opposite topological charge of ±1. Is presented the analysis of the orbital angular momentum (OAM) and the spin angular momentum (SAM), the OAM of the beams is analyzed with a triangular aperture by observing the diffraction pattern in the far field; the SAM is analyzed by using a linear polarizer. After the process of SPDC is achieved in a second order nonlinear crystal, the angular spectrum is observed and analyzed by using an iCCD camera. The comparison in the properties of such AS in between the mentioned beams is also presented and analyzed.

Generation of photon pairs in the telecom window with controllable spatio-temporal properties

Pablo Daniel Yepiz Graciano, Samuel Corona, Mónica Maldonado, Elisa Tejeda, Héctor Cruz Ramírez, Alfred B. U'Ren, Jesús Garduño Mejía, Carlos Wiechers, and Roberto Ramírez Alarcón

¹Instituto de Ciencias Nucleares, UNAM, Ciudad de México 04510, Mexico; ²Centro de Ciencias Aplicadas y Desarrollo Tecnológico, UNAM, Ciudad de México 04510, Mexico; ³Centro de Investigaciones en Óptica, León Guanajuato, Mexico.

We demonstrate a source of photon pairs centered at 1550nm, based on the spontaneous parametric downconversion (SPDC) process, with controllable spatial and spectral properties. Our experimental work here follows our earlier theoretical analysis of the spatio-temporal character of SPDC photon pairs coupled into single-mode fibers. In particular, we show that using a single experimental adjustment, we are able to control
the resulting photon-pair spectral correlations ranging in our experiments from strongly negative to positive, with a factorable joint spectrum as a special case. We likewise demonstrate controllable spatial correlations with a single experimental adjustment, also obtaining resulting correlations ranging from negative to positive. In addition, we have characterized the mixed spectral-spatial correlations.

**Engineering the spectrum-spatial response of a photon-pair source based on optical fiber**

D. Cruz Delgado¹, R. Ramírez Alarcón², E. Ortíz Ricardo¹, J. Moroy Ruz¹, F. Domínguez Serna³, J. C. Alvarado Zacarías⁴, J. E. Antonio López⁴, H. Cruz Ramírez¹, K. Garay Palmett³, S. G. León Saval⁵, R. Amezcua Correa² and A. B. U'Ren¹

¹Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apartado Postal 70-543, 04510 D.F., Mexico; ²Centro de Investigaciones en Óptica A.C., León, Guanajuato 37150, Mexico; ³Departamento de Óptica, Centro de Investigación Científica y de Educación Superior de Ensenada, Apartado Postal 360 Ensenada, BC 22860, Mexico; ⁴The College of Optics and Photonics, the University of Central Florida, Orlando, Florida 32816, USA; ⁵Sydney Astrophotonic Instrumentation Laboratory, School of Physics, University of Sydney, NSW 2006, Australia.

We have designed and implemented a photon pair source based on the spontaneous four wave mixing (SFWM) process in a birefringent fiber, such that multiple processes occur simultaneously. This kind of source permits hybrid entanglement in frequency and transverse mode. We also demonstrate a novel technique, based on the use of photonic lanterns, for the deterministic conversion of the transverse mode structure of heralded single photons.

**On the role of crystallographic symmetries in the generation of photon pairs by nonlinear crystals**

Rocío Jáuregui

Instituto de Física, Universidad Nacional Autónoma de México, Apartado Postal 20-364, 01000 Ciudad de México., México.

We put forward a method to extract information about the symmetry group to which certain nonlinear crystals belong using a single illuminating beam. It provides such information by considering the outcome of a nonlinear optics process characterized by the electric nonlinear susceptibility tensor, whose structure is dictated by such symmetry group. Explicit results are given for the process of spontaneous parametric down-conversion, when it is pumped with a special type of Bessel beam. The observation of the spatial angular dependence of the lower-frequency generated photons provides direct information about the symmetry group of the crystal.
Analysis of the spectral and spatial purity of entangled photons produced by spontaneous parametric down conversion

Anamaría García¹ and Karen Milena Fonseca²

¹Grupo de Óptica e Información Cuántica (GOIC), Departamento de Física, Universidad Nacional de Colombia; ²Grupo de Óptica e Información Cuántica (GOIC), Departamento de Física, Universidad Nacional de Colombia.

The state of an entangled pair of photons obtained by SPDC is described using the modal function. If Gaussian approximations are applied over this function, the biphotonic state, density matrix and reduced density matrices will have Gaussian shape. Using the method reported in [1,2] a simple formula for the spatial and spectral biphotonic purity is analyzed using the characteristics of the entangled photons.

Quantum entanglement in inhomogeneous 1D systems

Javier Rodríguez-Laguna¹, Jérôme Dubail², Giovanni Ramírez³, Pasquale Calabrese⁴ and Germán Sierra⁵

¹Dto. Física Fundamental, Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain; ²CNRS and Université de Lorraine, IJL-UMR 7198, F-54506 Vandoeuvre-les-Nancy, France; ³Instituto de Investigación, Escuela de Ciencias Físicas y Matemáticas, Universidad de San Carlos de Guatemala, Guatemala; ⁴SISSA and INFN, Via Bonomea 265, 34136 Trieste, Italy; ⁵Instituto de Física Teórica (IFT), UAM-CSIC, Madrid, Spain.

The ground state of a lattice model with local interactions usually satisfies an Area Law which states that the entanglement entropy of a system’s block is proportional to the size of its boundary. However, some violations of the Area Law may appear in 1D systems with non-local interactions or in gapless systems. Furthermore, other violations may appear in inhomogeneous systems or random systems. We will show how to engineer an inhomogeneous system with local interactions which allows us to obtain a maximal violation to the area law, i.e. maximally entangled state. We use a parametrization of the inhomogeneity of the system in order to analyze the system in two regimes: the strong inhomogeneity limit where we use a Renormalization Group method to explain the linear behaviour of the entanglement entropy of the ground state, and the weak inhomogeneity limit where we use an analytic continuation in order to describe the ground state as a Thermo-Field state of a Conformal Field Theory with an effective temperature which is proportional to the inhomogeneity parameter. Finally, we obtained the entanglement entropies using a formalism of quantum field theories on a space-time with negative scalar curvature. This talk is based in the work by Rodríguez-Laguna et al. (including Giovanni Ramírez) ”More on the rainbow chain: entanglement, space-time geometry and thermal states”, J. Phys. A: Math. Theor. 50 (2017) 164001.

19
Controlled transverse wavevector correlations in photon pairs generated by spontaneous parametric down conversion pumped by Bessel-Gauss beams

Verónica Vicuña Hernández¹, Jose T. Santiago¹, Yasser Jerónimo Moreno², Roberto Ramírez Alarcón³, Héctor Cruz Ramírez¹, Alfred B. U’Ren¹ and Rocío Jáuregui Renaud²

¹Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apdo. Postal 70-543, 04510 Cd. de México, México; ²Instituto de Física, Universidad Nacional Autónoma de México, Apdo. Postal 20-364, 01000 Cd. de México, México; ³Centro de Investigaciones en Óptica A.C., Loma del Bosque 115, Colonia Lomas del Campestre, 37150 León Guanajuato, México.

We present an experimental and theoretical study of type I, frequency-degenerate spontaneous parametric downconversion (SPDC) with a Bessel-Gauss pump with a non-paraxial configuration. We present measurements of the SPDC angular spectrum (AS), of the conditional angular spectrum (CAS) of signal-mode single photons as heralded by the detection of an idler photon, and of the transverse wavevector signal-idler correlations. We show that as the pump is made increasingly non-paraxial the AS acquires a non-concentric double-cone structure, with the CAS shape depending on the azimuthal location of the heralding detector, while the signal-idler wavevector correlation region splits into characteristic doublet stripes, representing as yet unexplored non-trivial, non-local quantum correlations between the signal and idler photons.

Our work provides further understanding of SPDC with a particular class of structured pump beams and proposes an interesting new resource for photon-pair quantum state engineering.

Random numbers generated using photons without post-processing

Aldo C. Martínez, Aldo Solis, Alí M. Angulo Martínez, Héctor Cruz Ramírez, Alfred B. U’Ren and Jorge G. Hirsch.

Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apdo. Postal 70-543, Cd. Mx., Mexico, C.P. 04510.

Is the randomness of quantum phenomena a physical assumption that is testable? Many attempts have been made to answer this question. Single-photon polarization measurement outcomes pass the NIST suit of tests as well as computer-based random number generators. Has quantum randomness been experimentally proved? There are deep differences between quantum-generated random sequences and computer-generated ones. Quantum randomness can be proven incomputable; that is, it is not exactly reproducible by any algorithm, while software-generated random numbers, known as pseudo-random, can be reproduced if the computer code and the seed are known. Is it possible to distinguish between them? Algorithmic randomness provides a quantitative method to assess
the Borel normality of a given sequence of numbers, a necessary condition for it to be considered random. Performing finite tests of randomness on large pseudo-random strings (finite sequences) generated with software (Mathematica, Maple), which are cyclic (so, strongly computable), the bits of pi, which are computable, but not cyclic, and strings produced by quantum measurements (with the commercial device Quantis and by the Vienna IQOQI group), failures of quantum sources in randomness probes were reported. In our previous work, we have used ten sequences of $10^6$ bits generated from the differences between detection times of photon pairs generated by spontaneous parametric downconversion (SPDC). These sequences fulfill the Borel normality randomness criteria without difficulties. To understand these diverging observations, we extended our study, analyzing longer ($4 \times 10^9$) photon-derived random sequences, obtained both with an attenuated laser and SPDC light, and with a beamsplitter introduced both in one arm of an SPDC source and on the path of an attenuated laser. The random sequences were generated both employing the beamsplitter outputs, assigning detections in each channel the symbols 0 or 1 or, alternatively, employing the distribution of arrival times at the detectors divided in two blocks. The sequences built using the difference in arrival time are shown to be validated as random employing the Borel normality criteria, and also the stronger Bayesian inference procedure, which can characterize not only the bit strings but the source itself. In this contribution we report the challenges found in generating chains which pass the Borel normality test without post-processing. Many different sources of correlations are analyzed: time modulations, differences in detector efficiencies, which composed with the dead time and afterpulsing give rise to not obvious correlations in a delicately balanced beam splitter. Afterpulsing in the photodiodes can be modeled efficiently, but the generation of high quality random series is strongly affected. Obtaining good random chains without post-processing employing a beamsplitter exhibits many technical difficulties, while employing the detection time seems to be more robust.

**Time-asymmetric quantum correlations of the light from a v-type three-level atom**

Héctor M. Castro Beltrén¹, L. Gutiérrez¹, R. Román Ancheyta², and L. Horvath³

¹Centro de Investigación en Ingeniería y Ciencias Aplicadas, Universidad Autónoma del Estado de Morelos, Av. Universidad 1001, 62209 Cuernavaca, Morelos, México; ²Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México, Apdo. Postal 48-3, 62251 Cuernavaca, Morelos, México; ³Department of Physics and Astronomy, Macquarie University, North Ryde, NSW, 2109, Sydney, Australia.

The correlation among amplitude and intensity of the light emitted by a source is gaining importance in studies of phase-dependent quantum fluctuations of light, for the spectroscopic and field coherence information that provides, going beyond studies of squeezing. Since the amplitude and intensity operators do not commute, there is room for time-asymmetric fluctuations, which would reveal non-Gaussian fluctuations and
breakdown of detailed balance. For this asymmetry to be observed it is necessary a competition between two transitions, such as those of a bichromatically driven V-type three-level atom. The light from the weak transition (the one with smaller decay rate) shows a large and asymmetric amplitude-intensity correlation (AIC) due to its larger fluctuations due to low fluorescence rate). The AIC, of third-order in the field amplitude, thus contains fluctuations of both second order, associated to squeezing, and of third order, responsible for the non-Gaussian character of the light. The latter dominate for excitation of the transition on and above saturation. It is a regime where squeezing is absent, but the fluorescence is nonclassical nonetheless by violating two classical inequalities. The spectra of the AIC, as well as the integrated spectrum (variance), provide a better connection and departure from squeezed fluctuations. The quadrature spectra have to be obtained separately from both the positive and negative time intervals of the AIC, so the spectra reveal similar but observable differences in atom-field coupling and decay rates. The weak transition, which acts as a probe of the strong one, operates in the Autler-Townes regime (a doublet spectrum), but the spectrum from the negative time intervals contains a sharp peak that indicates a slow decay component, absent in the spectrum from the other side of the correlation.

---

**Optomechanical photon blockade in the steady-state**

C. Ventura Velázquez and B. M. Rodríguez Lara.

1Instituto Nacional de Astrofísica, Óptica y Electrónica, Calle Luis Enrique Erro No. 1, Sta. Ma. Tonantzintla. Pue. C.P. 72840, México; Photonics and Mathematical Optics Group, Tecnológico de Monterrey, Monterrey 64849, México.

We study an optomechanical cavity with weak driving. We derive approximated analytic expressions for the average photon number and the photon second order correlation function using the Langevin formalism. We find non-classical photon correlations, which can be interpreted as photon blockade, when the optomechanical coupling exceeds the cavity decay rate and a particular configuration of the external driving is selected for initial states where the mechanical resonator is in a thermal state and the cavity is in the vacuum state.
Design, manufacture and characterization of optical waveguides with femtosecond laser direct write for integrated quantum photonic circuits

J. S. S. Durán-Gómez\textsuperscript{1,2}, R. Ramírez-Alarcón\textsuperscript{2} and X. J. Sánchez Lozano\textsuperscript{1}

\textsuperscript{1}División de Ciencias e Ingeniería, Universidad de Guanajuato, León C.P. 37150, México; \textsuperscript{2}Centro de Investigaciones en Óptica, León C.P. 37150, México.

We present the advances in the fabrication of optical buried waveguides in water white glass slide using the method of Femtosecond Laser Direct-Write (FLDW) and the characterization of size, refractive index and efficiency of the waveguides. We also present the manufacture and characterization of two waveguides coupled by evanescent fields. We measure the coupling coefficient for different distance between pairs of waveguides by End Fire Coupling Method and we fabricate Power Splitters and Directional Couplers. With this technique we can create quantum integrated optical devices in three dimensions that we will implement with photons produced by Spontaneous Parametric Down Conversion.

An introduction to correlations and phase transitions: An example through the Ising model

Eduardo Ibarra García Padilla\textsuperscript{1}, Carlos Gerardo Malanche Flores\textsuperscript{2} and Freddy Jackson Poveda Cuevas\textsuperscript{3}

\textsuperscript{1}Department of Physics and Astronomy, Rice University, Houston, Texas 77005, USA; \textsuperscript{2}École Polytechnique Fédérale de Lausanne, Lausanne, VD, Switzerland; \textsuperscript{3}Instituto de Física, Universidad Nacional Autónoma de México, Apartado Postal 20-364, México D.F. 01000, México.

The two-dimensional Ising model is a useful and resourceful platform for learning about phase transitions and correlations. In this work we will present a detailed numerical study of the second-order phase transition in the two-dimensional Ising model and discuss the finite-size scaling technique for determining the critical exponents. Likewise the correlation function is calculated for different temperatures and the importance of the correlation length as the relevant parameter in phase transitions is emphasized through all the work.
Competition between incoherent pumping and losses in a system of two interacting qubits

J.C. Triana and K.M. Fonseca

Universidad Nacional de Colombia, Sede Bogotá, Facultad de Ciencias, Departamento de Física, Grupo de Óptica e Información Cuántica, Cra 30 45-03, Bogotá, CP 111321, Colombia.

We consider a model of two qubits, which interact through a Rotating Wave Approximation (RWA) potential; while the first qubit is incoherently pumped to its excited state, the second qubit loses its excitations by contact to a zero-temperature bath. We show that purely dissipative effects (and the help of the qubit-qubit interaction) can produce entangled stationary states. The steady state entanglement is significant when the interaction constant, and the pumping and dissipation rates are of the same order of magnitude. We find an analytical form for the conditions for which the qubit-qubit entanglement attains its maximum value $C_{ss}$. We show that, starting from the ground state for each qubit, transient values of concurrence larger than $C_{ss}$ can be found.

Experimental violation of classicality with single quantum systems

J. Castrillón$^1$, O. Calderón Losada$^2$, D.A. Guzmán$^2$, Alejandra Valencia$^2$ and B. A. Rodríguez$^3$

$^1$Instituto de Física, Universidad de Antioquia, Medellín, Colombia; $^2$Quantum Optics Laboratory, Universidad de los Andes, Bogotá D.C., Colombia; $^3$Instituto de Física, Universidad de Antioquia, Medellín, Colombia.

This talk is about how quantum physics, even in the single system regime, does not respect the rooted classical intuition of “realism”. First, it is described a classical inequality which set a bound on how different properties of systems are distributed in an ensemble of such classical systems. This inequality is also a consequence of the classical assumption of realism i.e., the system properties can be jointly determinable regardless of the preparation and measurement procedures for determining them. Second, it is shown that the inequality is violated when the ensemble are single two level systems, described by superposition states and the properties which characterize them are quantum operators. This is a clue that the classicality given by realism is challenged in the quantum realm. Then, it is summarized the realization of the foregoing violation, which was done in an all-optical experimental setup with heralded single photons generated via spontaneous parametric down conversion, using exclusively projective preparations and projective measurements. Finally, it is discussed the role of superposition as the quantum feature which does not allow a realistic description of quantum systems, and it is argued that what experiments testing violations of Bell inequality do for entanglement, the experiment here presented does for superposition: It indicates that superposition is quantum.
Searching for entanglement: Local classical strategies versus geometrical quantum constraints

Grupo de Física Atómica y Molecular (GFAM), Instituto de Física, Facultad de Ciencias
Exactas y Naturales, Universidad de Antioquia UdeA, Calle 70 No. 52-21, Medellín,
Colombia.

Entanglement is a quantum phenomenon without classical analog. In the literature, it is usually considered to be the quantum characteristic. In this work, we show that quantum entanglement-like correlations cannot be reproduced for any classical protocol. We build a computational simulation of the well known scheme of non-communicating students. In this scheme, the students cannot manipulate the quantum systems but they may have set up in advance a common strategy and have shared some common classical data in order to reproduce given quantum correlations of such systems. By thoroughly searching in the whole space of classical strategies we conclude that Local Operations and Classical Communications (LOCC) does not satisfy the geometrical constraints imposed by quantum entanglement.

Advances on studies of quantum correlations on light with non-Gaussian structure

Luis Alberto Mendoza López, Yaneth M. Torres García, Adrián Vallejo Martínez,
Jorge G. Acosta Montes, Diego Sierra Costa, Rocío Jáuregui and Daniel Sahagún.
Instituto de Física, Universidad Nacional Autónoma de México, Circuito de la Investigación
Científica Ciudad Universitaria CP 04510 Ciudad de México.

We present progress towards generating quantum-correlated photons resonant with atomic Rubidium. Our plan is to generate quantum light via four wave mixing in Rubidium itself. We are preparing experiments to excite the ladder system $5S_{1/2} \rightarrow 5P_{3/2} \rightarrow 5D_{n/2}$ in both hot and cold atomic gases to detect correlations amongst the doubly coloured light produced by the induced cascade decay. At first instance we will study temporal correlations using atomic ensembles at microkelvin temperatures to withdraw thermal noise; we will study spatial correlations by exciting atoms at temperatures around 100 C with no-Gaussian pumping light. Our long term goal is to generate structured photon pairs.
Advances on studies of quantum correlations on light with non-Gaussian structure: Instrumentation

Irvin F. Ángeles Aguillón, Adrián Vallejo Martínez, Diego Sierra Costa, Rodrigo Gutiérrez, Yaneth M. Torres García and Daniel Sahagún Sánchez.

Instituto de Física, Universidad Nacional Autónoma de México, Circuito de la Investigación Científica Ciudad Universitaria CP 04510 Ciudad de México.

We present the instrumentation that has been developed in our Laboratory for generating correlated photons resonant with atomic Rubidium. As non-linear media to produce quantum light we will use separately atomic samples of laser cooled and heated Rubidium gases. The instrumentation showed in this work is (1) a slave laser that can generate frequency comb modulated by a microwave source which is useful to excite multiple atomic transitions, (2) the development of a standard Rubidium magneto-optical trap and (3) home built oven that can stabilise a spectroscopy cell with ±0,3°C precision.

Multipartite qubit entanglement in a cavity-based architecture

Carlos A. González Gutiérrez¹, Zhong Xiao Man² and Rosario Lo Franco³

¹Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México, Avenida Universidad s/n, 62210 Cuernavaca, Morelos, México; ²Shandong Provincial Key Laboratory of Laser Polarization and Information Technology, Department of Physics, Qufu Normal University, Qufu 273165, China; ³Dipartimento di Energia, Ingegneria dell’Informazione e Modelli Matematici, Università di Palermo, Viale delle Scienze, Ed. 9, 90128 Palermo, Italy. Extending the cavity-based architecture studied in (Z.-X. Man, Y.-J. Xia, and R. L. Franco, Sci.Rep. 5, 2015.) in which coherence and entanglement can be preserved despite the interaction with the environment, we analyse genuine multipartite entanglement of non-interacting N qubits, each of them inside a leaky cavity, which are in turn coupled to another empty leaky cavity. Closed mathematical expressions for generalized concurrence are given and the scaling of the system is analyzed.
Coherent collective dynamics and entanglement evolution of polar molecules on 1D lattices

Vanessa Olaya Agudelo¹ and Karen Rodríguez¹,²

¹Departamento de Física, Universidad del Valle, A.A. 25360, Cali, Colombia; ²Centre for Bioinformatics and Photonics-CiBioFi, Calle 13 No. 100-00, Edificio 320 No. 1069, Cali, Colombia

We study a LiCs strongly-interacting molecular gas loaded into an one-dimensional optical lattice at quarter filling. The molecules are in the lowest electronic and vibrational state, $X_{1\Sigma}(\nu = 0)$. Due to the large intermolecular distance and low filling, dipole-dipole interaction in the nearest-neighbor approximation governs the dynamics of the rotational excitations. For low DC electric field strengths, the full set of rotational levels $N = 0, 1$ must be taken into account, nevertheless, our calculations show that very weak fields act as field-selectors disclosing two- and three-level systems out of the original four-level one. The dynamics and the generated von Neumann entanglement entropy among the internal rotational states throughout the evolution are presented for low, moderate and strong fields. We observe a sharp and monotonous growth of the entanglement as the dynamics take place showing the potential of these molecular systems to be used in quantum information protocols. The numerical simulations are performed by means of the Time-Evolving Block Decimation algorithm based on the Matrix Product State formalism and the Susuki-Trotter decomposition.

Generation of robust entangled states in a non-Hermitian periodically driven two-band Bose-Hubbard system

Manuel Muñoz Arias¹, C. Parra Murillo², J. Madroñero²,³ and S. Wimberger⁴,⁵

¹Department of Physics and Astronomy, University of New Mexico, Albuquerque NM 87131; ²Departamento de Física, universidad del Valle, Cali, Colombia; ³Center for Bioinformatics and Photonics-CiBioFi, Cali, Colombia; ⁴Complex Dynamics in Quantum Systems, Institut fur Theoretische Physik, Universität Heidelberg; ⁵DiFeST, Università degli Studi di Parma, Parco Area delle Scienze 7/a, 43124 Parma, Italy.

During the last decade the Bose-Hubbard model has proven to be an excellent tool to explore the many-body physics of ultracold atoms in optical lattices. In its simpler version, one considers only the ground energy band of the periodic potential. It is then a natural extension to explore physical phenomena beyond the ground energy band. For instance, one can think of a system composed of the ground and first energy bands, the so called two-band Bose-Hubbard model. By tilting the system one can establish the known Wannier-Stark system, where interband transport can be study. However, this tilt may also couple the excited energy band to the continuum of energy bands. If we treat the continuum of energy bands as a reservoir, the system can be described by an effective non-Hermitian Hamiltonian.
In this work the aforementioned system is addressed. In particular, we show how the interplay of dissipation and driving dynamically induces a subspace of states which are very robust against dissipation. We numerically probe the structure of these asymptotic states and their robustness to imperfections in the initial-state preparation and to the size of the system. Moreover, the asymptotic states are found to be strongly entangled making them interesting for further applications.

---

### Generation of non classical light with Rydberg interactions

Dalia Ornelas Huerta, Alexander Craddock, Mary Lyon, Trey Porto and Steve Rolston  
University of Maryland, College Park, USA.

The combination of Rydberg interactions with electromagnetically induced transparency (EIT) is a promising candidate for a wide range of applications for quantum information protocols and the study of photon many body physics. We map strong Rydberg interactions into optical fields via EIT resulting in strong quantum nonlinearities at the single photon level. In this scheme, atomic interactions mediate photon-photon interactions that enable the generation of single photons, the realization of quantum logic phase gates and the exploration of novel quantum many body phenomena with photons.

---

### Quantum vacuum forces between high-Tc superconductors

Carlos Villarreal  
Instituto de Fisica, UNAM, Ciudad Universitaria, Mexico City, Mexico.

Quantum correlations of vacuum electromagnetic fields lead to a number of manifestations on the quantum realm, such as the Lamb shift (according to Welton and Feynman), spontaneous atomic decay, Van der Waals interactions between molecules, or Casimir forces between material surfaces. This latter effect, predicted by Casimir in 1948 for perfectly-reflecting parallel surfaces, was later studied by Lifshitz in 1956 for materials with dispersive and absorptive properties. Central to his approach is the consideration of thermodynamic equilibrium between atomic radiators and electromagnetic fluctuations through the fluctuation-dissipation mechanism. It has been shown that this mechanism is necessary for the formal consistency of the quantum theory, particularly for the preservation of the commutation relations of quantum radiators interacting with a vacuum field. With the advent of microelectromechanical devices, the experimental verification of Lifshitz’s theory with a reasonable degree of accuracy was only possible until 1997. Further investigations by different experimental groups have provided, in principle, greater accuracy, while thermal contributions to the Casimir force have been also successfully tested. However, these measurements have generated sour controversies, since they rely upon different models for the materials dielectric response with no
relative consistency. For example, the most accepted approach employed in the description of experimental data, the plasma model, involves no energy dissipation of quantum radiators and thus violates the fluctuation-dissipation mechanism. With the purpose of partially elucidating these controversies, we have considered the fluctuation-dissipation mechanism to characterize the dielectric response of materials subject to vacuum fields. This leads to a correct description of Casimir forces for materials under different experimental conditions, length scales, and temperature regimes. In this work we extend this approach to study Casimir forces between high-Tc superconductors (YBCO ceramics) above and below the critical temperature, so that the materials transit from a normal dielectric behavior to a superconductive state. We observe a non-monotonic dependence of the Casimir force with the relative plate distance. This odd behavior is similar to predictions arising in previous studies of thermal contributions to Casimir forces in closed cavities.

Rydberg quantum optics in ultracold gases

Asaf Paris Mandoki¹², Christoph Braun¹², Christoph Tresp¹², Ivan Mirgorodskiy¹, Florian Christaller ¹² and Sebastian Hofferberth¹²

¹ 5. Phys. Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Stuttgart, Germany; ² Department of Physics, Chemistry and Pharmacy, Syddansk Universitet, Odense, Denmark; ³ Instituto de Física, Universidad Nacional Autónoma de México, Mexico City, Mexico.

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level of individual photons. We present the realization of a free-space single-photon transistor, where a single gate photon controls the transmission of many source photons. We also show that using an electrically tuned Förster-resonance the Rydberg-mediated interaction between single-photons is enhanced. The strong interaction in the vicinity of a Förster-resonance allows performing fine-structure-resolving spectroscopy of the involved Rydberg pair-states. We also show that an atomic medium smaller than the blockade radius can be utilized to substract exactly one photon from an input pulse over a wide range of input photon-numbers, thus the absorption of a single photon renders the medium from opaque to transparent. Reduced dephasing enables the observation of coherent Rabi-Oscillations of a single “super-atom” interacting with a light field close to the single-photon level.

29
Collective Lamb shift in the ultrastrong-coupling regime on Dicke single-photon superradiance

J. P. Restrepo Cuartas, M. Steibeck Dominguez and H. Vinck Posada
Universidad Nacional de Colombia, Bogotá, Facultad de Ciencias, Departamento de Física, Grupo de Superconductividad y Nanotecnología, Carrera 30 Calle 45-03, C.P. 111321, Bogotá, Colombia.

Ultrastrong coupling in circuit quantum electrodynamics (cQED) has become the cornerstone of the light-matter interaction beyond Jaynes-Cummings model (JCM). Single-photon superradiance, the cooperative spontaneous emission from an assembly of identical quantum emitters, when a single photon is shared between them, exhibits all the good properties of quantum many-body systems in atomic physics and quantum optics. Here we present a theoretical scheme where an assembly of resonant superconducting emitters, much larger than the radiation wavelength in a coplanar cavity, can be collectively excited into a superradiant state and allow us to assess the collective Lamb shift in the ultrastrong-coupling regime on single-photon Dicke collective phenomena.

Proposal for the quantum simulation of the CP(2) model on optical lattices

Wolfgang Bietenholz\textsuperscript{1}, Marcello Dalmonte\textsuperscript{2}, Wynne Evans\textsuperscript{3}, Urs Gerber\textsuperscript{1,4}, Catherine Laflamme\textsuperscript{5}, Héctor Mejía Díaz\textsuperscript{1}, Uwe Jens Wiese\textsuperscript{3} and Peter Zoller\textsuperscript{5}

\textsuperscript{1}Instituto de Ciencias Nucleares, U. N. A. M., México; \textsuperscript{2}ICTP, Trieste, Italy; \textsuperscript{3}University of Bern, Switzerland; \textsuperscript{4}UMSNH Morelia, Mexico; \textsuperscript{5}Innsbruck University.

The 2d CP(N-1) models share a number of features with QCD, like asymptotic freedom, a dynamically generated mass gap, and topological sectors. They have been formulated and analyzed successfully in the formalism of the so-called D-theory. In that framework, we propose an experimental set-up for the quantum simulation of the CP(2) model. It is based on ultracold alkaline-earth-atoms located on the sites of an optical lattice, where the nuclear spins represent the relevant fields. We present results for the correlation
length and for tunneling transitions, to be compared with such a future experiment. The latter would also enable the exploration of theta vacua and the phase diagram at finite chemical potential, since it does not suffer from the sign problem.

---

3 Evaporative cooling through the semiclassical approximation

F. J. Poveda Cuevas, I. Reyes Ayala and J. E. Carro Martínez.

Instituto de Física, Universidad Nacional Autónoma de México, Circuito de la Investigación Científica Ciudad Universitaria CP 04510, CDMX.

Evaporative cooling is the most effective technique for achieving quantum degenerated gases from an experimental point of view. We propose a simple model for the evaporative cooling of a gas, in order to we intend to study the classical and quantum statistical effects comparing their differences. Our objective is to understand this technique more intuitively to optimize the experimental setups. On the other hand, in this model, moreover of introduce quantum statistical mechanics, we consider the presence of the external potential through the semi-classical distribution.

---

4 On the properties of ultra-cold matter wave packet confined by square well potential with impurities

Ricardo Méndez Fragoso\textsuperscript{1} and Remigio Cabrera Trujillo\textsuperscript{2}

\textsuperscript{1}Facultad de Ciencias, UNAM; \textsuperscript{2}Instituto de Ciencias Físicas, UNAM.

In this contribution, we are considering the behavior of a ultra-cold matter wave-packet confined by a waveguide. For this, analytical solutions are presented to the nonlinear Schrödinger equation (NLS) as a model of the density profile of the wave-packet confined by an attractive square well potential of width $2R_0$ and depth $V_0$. Additionally, we introduce a distribution of delta potentials to incorporate impurities into the confinement. In consequence, the structure of the energy spectrum is modified in terms of confinement geometry and the distribution of the impurities. The main goal of this treatment is to emulate potentials like Kroning-Penney but in the regime of nonlinear coupling. By this way, we can obtain the behavior of the energy gaps as a function of the nonlinear constant, $g$, in the NLS equation. This allows to quantify the number of particles with different excitations in terms of the confinement parameters and the distribution of impurities in the square well. Finally, analytical and numerical results are presented in order to motivate future experimental work.
Chaotic dynamics on superconducting qubits in the ultrastrong coupling regime

M. Steibeck Dominguez, J.P. Restrepo Cuartas and H. Vinck Posada
Universidad Nacional de Colombia – Bogotá, Facultad de Ciencias, Departamento de Física, Grupo de Superconductividad y Nanotecnología, Carrera 30 Calle 45-03, C.P. 111321, Bogotá, Colombia.

Superconducting quantum circuits interacting with the microwave radiation confined into a cavity, operating in the ultrastrong coupling regime (USC), are promising candidates for the future of quantum applications on a chip. In this regime, the coupling strength reaches the order of radiation field energies; therefore, the rotating wave approximation (RWA) is no longer valid and the vacuum produces photons which will get bound to the qubit. In this work, we describe the distinctive features of the nonlinear regime, through the dynamics of the expectation values in the mean field approximation, taking into account an assembly of qubits embedded in a coplanar cavity, without RWA. Additionally, we characterize the underlying chaotic behavior, subject to time-dependent coherent and incoherent pumping, in order to analyze the regions of stability and chaos by means of quantifiers such as Lyapunov exponents, Poincare sections and bifurcation diagrams.

Fluctuations in dissipative quantum phase transitions at finite system size

R. Gutiérrez Jáuregui and H. J. Carmichael
The Dodd-Walls Centre for Photonic and Quantum Technologies, Department of Physics, University of Auckland, Private Bag 92019, Auckland, New Zealand

Traditionally, quantum phase transitions in driven optical systems are characterized by a sharp increase in photon number of the system, as exemplified by the laser, parametric amplifier and spontaneous dressed state polarization. However, as modern physics transition into the strong coupling regime, where the change of a single photon can induce non-linear effects on a system, phase transitions can be reached with a small change in photon number. This departure from a thermodynamical limit leads to a diminishing driving threshold and a new manner of characterizing the phase transitions is necessary.

In this work we characterize the phases two coupled non-linear oscillators can acquire. Dissipation is considered through the interaction with an external environment and a coherent field is added to drive the system out of the ground state. The system is seen to present three phases. Two of this phases present high-correlation between each cavity and are differentiated by the photon statistics, transitioning from classical to quantum. The third phase is characterized by a highly localized field in one of the cavities.

In order to characterize the phases of the system we begin with a mean-field approach.
Under this approach the effect of fluctuations is neglected and a thermodynamic limit defined. The long time dynamics of the system are determined and both population imbalance and total photon number used to define the phase of the system. The mean-field results are then complemented by a fully quantum approach where the density matrix evolves under a Lindblad-type master equation. The departure from mean-field results is highlighted and a new way to characterize the possible phases of the system is proposed. A comparison between weak and strong coupling regimes is presented and used to revisit the thermodynamic limit outside of the mean-field approximation. Finally, the crucial role of quantum fluctuations is quantified and used to define the phases at hand.

Developing homemade instrumentation for automation and data acquisition of lithium quantum gases experiment

Cristian Mojica Casique, Diego Hernández Rajkov, Manuel Mendoza López, Iliana Cortés Pérez, Andrés Gutiérrez Valdés, Aurora Borges Sánchez, Eduardo Ibarra García, Ernesto Carro Martínez, Ricardo Colín Rodríguez, Freddy Poveda Cuevas and Jorge Seman Harutinian

Instituto de Física, Universidad Nacional Autónoma de México

In this work, we present the design of several apparatus for the automation and data acquisition of the quantum gases experiments that will be performed in the emerging Ultracold Matter Laboratory in the Physics Institute at UNAM. The instrumentation is developed with free license hardware and software, this is an advantage because of the flexibility of improve, specific application design and relative low-cost. Particularly, we present a temperature control oven to produce and maintain the lithium vapor pressure in the experiment. Furthermore, a multiplexer-based temperature monitor device allows to measure the temperature in all parts in the vacuum system. In other hand, the theory and design of a homemade polarimeter is presented. The design was made to measure the Stockes parameters and then an algorithm allows the visualization of polarization states in a Poincare Sphere. Finally, we present the automation electronic system that allows the generation of digital and analog signals to control temporal sequences in the experiment execution. This system is an adaptation of the system developed at the European Laboratory for Non-linear Spectroscopy at University of Florence, in Italy.
In this work we show the design, construction and characterization of a bow-tie optical cavity to be used in collective atomic interferometry experiments. The design of this cavity match several restrictions and requirements imposed by the atomic interferometry experiments, which led us to have restrictions mainly on the cavity geometry, the waist size and the transverse electromagnetic modes (TEM) of the cavity. We based the design on the paraxial approximation, using the ABCD matrices, which gave us the equations that relate the parameters of interest, such as the waist mode (inside the cavity), the distance between the mirrors and it’s curvature radius. With the resulting equations we perform a simulation of the beam profile to establish the stability zones of the cavity. Finally, the designed cavity was implemented on an aluminum plate, that helped us to hold the mirrors in specific positions. We characterize the assembled cavity, after a rigorously alignment procedure, to obtain a Gaussian cross profile. In addition we proposed a model to obtain a flat-top transversal profile.

Evidence of the electric quadrupolar transition 5p3/2-6p3/2 was obtained in 87Rb using cold atoms confined in a magneto-optical trap (MOT). This was carried out using an external cavity diode laser with a wavelength of 911 nm incident directly on the cloud of cold atoms. The quadrupole transition is detected by the 420 nm photons that are emitted following the spontaneous decay of the 6p3/2 level towards the 5s1/2 ground state. These photons are collected using a photon detection system, which consists of a photon counter and a software for recording and storing the counts. The spectra obtained show the hyperfine structure of the 6p3/2 level, as well as the variations of the spectra by changing the detuning and the power of the trapping laser of the MOT. Evidence of this transition in cold atoms is an additional step in the observation of quadrupole transitions in alkaline atoms that complements the previous results, obtained by the group, in atoms at room temperature using a Rb cell (Ponciano-Ojeda, et al., Phys. Rev. A, 92, 4, 042511, 2015).
Quantum correlated transport in Hamiltonian pump-ratchet hybrids

Nicolás Medina Sánchez and Thomas Dittrich
Universidad Nacional de Colombia

The pump-ratchet hybrids emerge combining a spatially periodic static potential, typically asymmetric under space inversion, with a local driving that breaks time-reversal invariance. They are intended to model metal or semiconductor surfaces irradiated by a collimated laser beam. Their crucial feature is irregular driven scattering between asymptotic regions of periodic (as opposed to free) motion. We here study the underlying nonlinear transport mechanisms, from chaotic scattering in the classical case to the parameter dependence of the currents and the band structure, in three types of Hamiltonian models, (i) with spatially periodic potentials where only in the driven scattering region, spatial and temporal symmetries are broken, and (ii), spatially asymmetric (ratchet) potentials with a driving that only breaks time-reversal invariance. As more realistic models of laser-irradiated surfaces, we consider (iii), a driving in the form of a running wave confined to a compact region by a static envelope. The correlations between sites in the asymptotic region and the driven region where classical chaos is evidenced, show the existence of coherent control of tunneling between the chaotic and stability regions of phase space, even when they are far apart.

Coherent electron-nuclear spin flip-flop in GaAsN at room temperature: Master equation approach

J. C. Sandoval Santana¹, V. G. Ibarra Sierra¹, S. Azaizia², H. Carrere², L. A. Bakaleinikov³, V. K. Kalevich³, E. L. Ivchenko³, T. Amand², A. Balocchi² and A. Kunold⁴

¹Departamento de Física, Universidad Autónoma Metropolitana Iztapalapa, Av. San Rafael Atlixco 186, Col. Vicentina, 09340 Cuidad de México, México. ²Université de Toulouse, INSA-CNRS-UPS, LPCNO, 135 avenue de Rangueil, 31077 Toulouse, France. ³Ioffe Physical-Technical Institute, 194021 St. Petersburg, Russia. ⁴Área de Física Teórica y Materia Condensada, Universidad Autónoma Metropolitana Azcapotzalco, Av. San Pablo 180, Col. Reynosa-Tamaulipas, 02200 Cuidad de México, México.

As well as nitrogen-vacancy centers in diamond and impurity atoms in silicon, gallium deep paramagnetic centers in GaAsN alloys are excellent candidates to harness spintronics applications. Among other interesting properties, they allow the optical manipulation of its nuclear spin polarization. Recent results suggest that the gallium defects nuclear spin polarization can be tuned through the optically induced spin polarization of conduction band electrons. In this work, we propose a model based on the master equation approach to describe the evolution of electronic and nuclear spin polarization of gallium centers in the pulsed excitation regime. In this model the hyperfine interaction and nuclear spin relaxation mechanisms play key roles in the spin polarization...
of conduction band electrons. To show the influence of the hyperfine interaction we have proposed an experimental setup based on a pump-probe scheme that would allow to detect and trace the coherent electron-nucleus flip-flops through time resolved PL measurements.

Quantum master equation for electron-nucleus spin dynamics in GaAsN

V. G. Ibarra Sierra¹, J. C. Sandoval Santana¹, A. Kunold², S. Azaizia³, H. Carrere³, X. Marie³, T. Amand³, A. Balocchi³, L.A. Bakaleinikov⁴, V. K. Kalevich⁴ and E. L. Ivchenko⁴

¹Departamento de Física, Universidad Autónoma Metropolitana Iztapalapa, Av. San Rafael Atlixco 186, Col. Vicentina, 09340 Cuidad de México, Mexico. ²Área de Física Teórica y Materia Condensada, Universidad Autónoma Metropolitana Azcapotzalco, Av. San Pablo 180, Col. Reynosa-Tamaulipas, 02200 Cuidad de México, Mexico. ³Université de Toulouse, INSA-CNRS-UPS, LPCNO, 135 avenue de Rangueil, 31077 Toulouse, France. ⁴Ioffe Physical-Technical Institute, 194021 St. Petersburg, Russia.

We present a theoretical study of the mechanism of dynamic electronic and nuclear spin polarization in Ga deep paramagnetic centers in GaAsN. To this end, we develop a master equation model for the density matrix based on the theory of open quantum systems. It includes the Hyperfine and Zeeman interactions between the quantum correlations of electronic and nuclear spin of the Ga interstitial spin filtering defects. This approach allows us to identify the main mechanisms of spin relaxation for electrons and nuclei based on the Wangsness-Bloch-Redfield relaxation theory. The current model correctly reproduces the main features of the experimental results such as PL intensity and degree of conduction band electrons spin polarization as functions of the magnetic field and excitation power. The study of this kind of systems is important to design spintronic devices that could operate at room temperature.
Low phase noise system for gravimetry

Mario Maldonado, Nieves Arias, Vahide Abediye, Saeed Hamzeloui and Eduardo Gómez
Instituto de Física, Universidad Autónoma de San Luis Potosí.

The Raman beams required for atomic gravimetry involve two phase locked beams with different frequency. The traditional method uses two independent lasers with an optical phase lock loop to keep a fixed phase relation between them. Alternatively one can use a phase modulator to produce the required beams that are automatically phase locked. This method gives a simple system with a phase noise limited by the quality of the microwave synthesizer. Here, two Raman pairs are produced and they interfere with each other. We show that by using a calcite crystal we can change the relative polarization of the carrier and the sidebands. The destructive interference that appears in co-propagating Raman transitions is transformed into constructive interference with this method. We split the carrier and sidebands taking advantage of their different polarization and we send them in opposite directions to excite counter-propagating Raman transitions. By dialing the correct frequency we can select a particular direction for the momentum transfer.

Advances in the construction of a new experiment on lithium quantum gases

Instituto de Física, Universidad Nacional Autónoma de México, México.

In the Ultracold Matter Laboratory of the Institute of Physics of UNAM we are building a new experiment to produce ultracold quantum samples composed by atomic lithium. Our setup will be able to produce Bose-Einstein condensates of $^7\text{Li}$ and degenerate Fermi gases of $^6\text{Li}$. Both species present broad Feshbach resonances, allowing the generation of samples in different interaction regimes. In particular, will be able to produce strongly correlated systems across the BEC-BCS crossover.
In this work we present the state of our experiment and provide details on three important components of our setup, namely: (i) the laser system used to generate the optical frequencies needed to cool down the samples; (ii) the different coil arrays to produce the magnetic fields employed for trapping and manipulating the atoms, and (iii) the developed instrumentation for automation and data acquisition of the experiment. We finally present the future perspectives of our laboratory.
Enhancement of light transmission through random copper thin-films near the percolation threshold

Eva Mayra Rojas Ruiz, José Luis Hernández Pozos and Luis Guillermo Mendoza Luna
Departamento de Física, Universidad Autónoma Metropolitana Iztapalapa, Av. San Rafael Atlixco No. 186 Col. Vicentina, C.P. 09340 México D.F., México.

In this work, we investigate the optical properties of thin-films deposited on glass via laser ablation of copper. It has been found that for films lying below the percolation limit, copper is deposited in a random fashion and upon approaching the percolation threshold the light transmission experiences an enhancement; this finding is at odds with the transmission of light in related TiO2/Cu/TiO2 multilayer systems, in which such enhancement does not happen. To the best of our knowledge, this is the first example of enhanced light transmission in random media. Light transmission simulations of the systems of interest are performed using open-source software DDSCAT.

Bilayer system of dipolar bosons: Few-body bound states

Grecia Guijarro Gámez, Jordi Boronat and Gregory Astrakharchik
Department of Physics, Universitat Politècnica de Catalunya. Campus Nord B4-B5, E-08034 Barcelona, Spain.

Quantum Monte Carlo methods provide a powerful tool for predicting quantitatively the properties of many-body quantum system. At the level of few-body physics, existence of bound-states (dimers, trimers, tetramers, etc.) for dipoles in a bilayer is an open question. Anisotropy of the dipolar interaction (which can be attractive or repulsive) complicates the study but leads to rich physics. The problem of two and three dipoles can be solved analytically, the last one with more effort. However, as the number of particles is increased, the problem becomes essentially intractable using standard approaches. At this point Monte Carlo methods become highly competitive. We analyze the ground state of a bilayer system of dipolar bosons, where dipoles are oriented perpendicularly to the parallel planes. We use Variational Monte Carlo (VMC) and Diffusion Monte Carlo (DMC) methods to obtain the ground state energy and pair distribution function of the system. Results for the few-body problem are presented. A dimer exists for arbitrary separation between layers. In case of three particles, the bound state does not exist for small separation between the two layers. However, the trimer exists for distances greater than a critical separation between layers. We also study the angular and spatial distributions functions, which give information about the structure of the bound states. We have found that the dominant structure close to the critical separation is halo state, where two dipoles are close to each other while the third is far away.
A classical formulation for generalized optical theorem for invisibility cloaks.

Irving Rondón Ojeda and Mary Carmen Peña Gomar
Facultad de Ciencias Físico-Matemáticas, Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, México.

Recently it has been published in [Optik 137 (2017) 17–24], where we have reported that many practical applications require the analysis of electromagnetic scattering properties of local structures using different sources of illumination. The Optical Theorem (OT) is a useful result in scattering theory, relating the extinction of a structure to the scattering amplitude in the forward direction. Invisibility cloaks have attracted considerable interests in both science and technologies due to their great potential applications in wide fields. In this work we deal by first principles to extended a OT for invisible cloaking.

Propagation of microscopic excitations in confined ultracold atomic gases

José Ernesto Alba Arroyo and Rocío Jáuregui
Instituto de Física, Universidad Nacional Autónoma de México, México.

We propose a description of the evolution of a macroscopic excitation in a degenerate bose or fermi atomic gas confined in an external harmonic potential using the two body time propagator acting on the fully symmetric (antisymmetric) bosonic (fermionic) many body function. The strong interacting regime is expected to give insight to the BEC-BCS crossover.

Spin dynamics of many-body quantum systems after random interaction quench

Manan Vyas
Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México, México.

We analyze relaxation dynamics of fidelity decay and information entropy of a many-particle fermionic(bosonic) system in a mean-field, quenched by a random two-body interaction (preserving many-particle spin) as a function of spin degree of freedom. The system Hamiltonian is represented by embedded Gaussian orthogonal ensemble (EGOE) of random matrices (for time-reversal and rotationally invariant systems) with one plus two-body interactions for fermions/bosons. Both fermion and boson systems show significant spin dependence on the relaxation dynamics of the fidelity and entropy. A simple general picture, in which the variances play a central role, is also achieved for describing the short-time spin dynamics of fidelity decay and entropy production.
Copper nitride Cu3N is a semiconductor that has been studied for potential applications in optical storage devices such as high-speed integrated circuits, spin barrier tunnel junctions, resistive random access memories and magnetic nanostructures. Due to its metastable character, the thermal stability is a factor that must be considered for the manufacture and/or application of this material. Low-temperature decomposition restricts its use to certain applications where thermal degradation is minimal. Regarding this issue, it has been proposed the use of different elements to manipulate magnetic and electronic properties or increase stability. In this work, we performed a complete theoretical study on the Cu-Mn-N system. The calculations were performed using Density Functional Theory (DFT) implemented in VASP software with a plane wave basis (PAW) technique and kinetic energy cutoffs of 600 eV. Exchange and correlation potential energies were treated according to the generalized gradient approximation (GGA) with the gradient corrected Perdew, Burke, and Ernzerhof (PBE) functional. The irreducible part of the Brillouin zone was established with Monkhorst-Pack for a mesh of $13 \times 13 \times 13$ k-points. The lattice parameter calculated for Cu3N and Mn4N were 3.8342 Å and 3.7469 Å respectively, these are consistent with reported data. The formation enthalpy shows the tendency to form perovskite instead of anti-ReO3 structure. The $\text{Mn}_{3.5}\text{Cu}_{0.5}\text{N}$ composition shows to be energetically more favorable than meta-stable Cu3N and magnetic moment of 0.6377 µB per unit cell, the Mn3CuN composition display an increment in the magnetic moment (7.1596 µB) above Mn4N (1.1247 µB). The information obtained in the calculations will be used to validate future experimental studies of the electronic, magnetic and thermodynamic properties of Cu3N structures modified with manganese in different concentrations.

**Ionic spinor Bose Hubbard model**

Jereson Silva Valencia$^1$, Roberto Franco$^1$ and Greis Julieth Cruz Reyes$^2$

$^1$Universidad Nacional de Colombia. $^2$Universidad Santo Tomás.

We study bosons with spin 1 loaded on superlattices, these formed with unit cells of two sites. As an initial analysis, we explore the system behavior at the atomic limit, where the chemical potential as a function of the spin-dependent term and the energy difference between the sites, reveal a variety of insulators and phase transitions between Mott insulators and Charge Density Wave phases. By Density Matrix Renormalization Group calculations, we develop the ground state phase diagram in the thermodynamic limit. We observe a significant influence of the exchange interaction in the creation of Mott insulator because the energetic expenditure is less for creating singlets than
coupling an extra boson. In that way, the critical points, which determine the size of the insulator regions, depend on the spin-interaction strength. We get to generalize the role of the Coulomb and spin interactions for different relations between the structure parameter and the interaction.

Non-Markovianity of quantum processes
Humberto Triviño Navarro
Universidad de Antioquia, Medellín, Colombia.

In recent years non-Markovian quantum systems have been enjoying much attention due to both fundamental reasons and foreseeable applications as shown by the rapid growth in the related literature. Indeed, the potential relevance of memory effects in the field of complex quantum systems and quantum information has led to an intense study. However, there are numerous open question yet to be studied. The latter include fundamental questions such as the mathematical structure of the space of non-Markovian quantum dynamical maps, the role of complexity in the emergence of memory effects or the relevance of non-Markovianity in the study of the border between classical and quantum aspects of nature, as well as more applied issues such as the identification of the environmental features or system-environment correlation which can indeed be detected by means of local observation on the system. A further fruitful line of research could be to examine the role of quantum non-Markovianity and optimal state pair in quantum control and dynamical decoupling schemes. Therefore, We have already incorporated sufficient and necessary criteria for the composition "divisibility" onto discrete or continuous systems, we have used super operators in the partition of Liouville’s spaces and the principles of linear response theory.

Bosons in optical lattices
Felipe Taha Sant’Ana, Sao Carlos Institute of Physics, University of São Paulo. Axel Pelster, Technical University of Kaiserslautern.
Francisco Ednilson Alves dos Santos, Federal Univeristy of São Carlos.

Bose-Einstein condensation is a common phenomenon occurring in physics on all scales, from condensed matter to nuclear physics, elementary particle and astrophysics, with ideas flowing across boundaries between fields. The systems range from gases, liquids and solids, including semiconductors and metals, to atomic nuclei, elementary particles and matter in neutron stars and supernova explosions. Generally, the bosonic degrees of freedom are composite, originating from underlying fermionic degrees of freedom. Confining cold atoms in optical lattices, play an important role in the scenario of trapping ultracold atoms. These lattices are produced by using electromagnetic standing waves generated by orthogonally aligned laser beams, with their intersection point positioned
to the center of the BEC. The oscillating electric field produced by the laser induces an oscillating dipole moment in the atom while at the same time interacts with this oscillating dipole, creating a trapping potential. An important demonstration of the role of interparticle interactions in the strongly correlated regime is the transition between the superfluid state and the insulator state, called Mott phase. Bosonic gases in optical lattices can exist in these two different phases, which can be chosen by tuning the depth of the potential wells generated by the optical waves. This model is characterized by two energies: the tunneling energy, which determines the probability of an atom to tunnel from a lattice site to one of its neighboring sites, and the on-site interaction energy which is the energy between the interaction of two atoms located in the same lattice site. When the on-site interaction is small compared to the hopping amplitude, the bosons are delocalized and the system is in the superfluid state. In the opposite scenario, where the on-site interaction dominates over the hopping energy, the ground state of the system is a Mott insulator, which is characterized by an integer number of bosons trapped in each potential minimum. Interacting bosons in the presence of a disordered potential can present interesting and, sometimes, unexpected behavior. It is known that a system as described exhibit a phase called Bose-glass, characterized as an insulating phase with no gap and finite compressibility. Its importance is due to the fact that any transition from the Mott-insulator phase to the superfluid phase in the presence of disorder should follow through the Bose-glass phase. By treating the kinetic energy, i.e., hopping term, as a perturbation, the phase diagram in the hopping strength and chemical potential, can be worked out. For the pure, nonrandom, system it is found two types of phases: a set of incompressible Mott insulating phases in which the density is fixed commensurately at a positive integer per site; and a superfluid phase with the usual off-diagonal long-range order. In the random case, it is argued that a gapless, insulating Bose-glass phase with nonzero compressibility must intervene between the Mott and superfluid phases, and that, in fact, the Mott phase can be completely destroyed if the randomness is sufficiently strong. Considering that there is until now no accepted theory for calculating the zero-temperature phase diagram for the lattice boson with weak bounded disorder and that a perturbative approach dealing with the homogeneous Bose gas has been largely studied, the first objective of this project will be the study of such an approach to the problem of disordered bosons in optical lattices. Within Gizburg-Landau theory, where the order parameter is site-dependent but time-independent, one can eliminate the quantum fluctuations and determine an effective potential, whose extremization determines the order parameter, which fluctuates due to the disorder from site to site. This perturbative approach allows then to determine the respective phase boundaries for the superfluid, the Bose-glass, and the Mott phase. Regarding the Ginzburg-Landau theory, where the order parameter is site and time-dependent, we can determine the corresponding effective action by eliminating the quantum fluctuations. When taking the disorder average, its zeroth order can be interpreted as a background wave and the second order term can be expressed as a dispersion term which was impacted by disorder, resulting in a further plane wave, whose excitation spectra can be studied perturbatively and nonperturbatively together with
numerical approaches. Finally, we will conduct a study that approaches the elimination of the disorder fluctuations. Thus we determine an effective potential whose extremization yields self-consistency equations for the superfluid and the Bose-glass phase order parameters without any disorder term. With this in hands, it is possible to determine again the respective phase boundaries.

Mott lobes of the $S = 1$ Bose-Hubbard model with three-body interactions

A. F. Hincapie F, R. Franco and J. Silva Valencia
Departamento de Física, Universidad Nacional de Colombia, A. A. 5997 Bogotá, Colombia

Using the density-matrix renormalization-group method, we studied the ground state of the one-dimensional $S = 1$ Bose-Hubbard model with local three-body interactions, which can be a superfluid or a Mott insulator state. We drew the phase diagram of this model for both ferromagnetic and antiferromagnetic interaction. Regardless of the sign of the spin-dependent coupling, we obtained that the Mott lobes area decreases as the spin-dependent strength increases, which means that the even-odd asymmetry of the two-body antiferromagnetic chain is absent for local three-body interactions. For antiferromagnetic coupling, we found that the density drives first-order superfluid-Mott insulator transitions for even and odd lobes. Ferromagnetic Mott insulator and superfluid states were obtained with a ferromagnetic coupling, and a tendency to a “long-range” order was observed.

Emergence of the $\rho = 1$ Mott lobe in an anyon chain with three-body interactions

Departamento de Física, Universidad Nacional de Colombia, A. A. 5997 Bogotá, Colombia.

A quantum phase transition driven by the statistics was observed in an anyon-Hubbard model with local three-body interactions. Using a fractional Jordan-Wigner transformation, we arrived at a modified Bose-Hubbard model, which exhibits Mott insulator and superfluid phases. The absence of a Mott insulator state with one particle per site depends on the anyonic angle, and a quantum phase transition from a superfluid to a Mott insulator state is obtained for a fixed value of the hopping. The critical points were estimated with the von Neumann block entropy and increase as the hopping grows. The statistics modify the ground state, and three different superfluid regions were observed for larger values of the anyonic angle. Using the density-matrix renormalization-group method, we studied the ground state of the one-dimensional $S = 1$ Bose-Hubbard model with local three-body interactions, which can be a superfluid or a Mott insulator state.
We drew the phase diagram of this model for both ferromagnetic and antiferromagnetic interaction. Regardless of the sign of the spin-dependent coupling, we obtained that the Mott lobes area decreases as the spin-dependent strength increases, which means that the even-odd asymmetry of the two-body antiferromagnetic chain is absent for local three-body interactions. For antiferromagnetic coupling, we found that the density drives first-order superfluid-Mott insulator transitions for even and odd lobes. Ferromagnetic Mott insulator and superfluid states were obtained with a ferromagnetic coupling, and a tendency to a “long-range” order was observed.
Poster Session 3: Quantum Information and Optics

Optimal quantum rotosensors

Chryssomalis Chryssomalakos\textsuperscript{1} and Héctor Hernández Coronado\textsuperscript{2}

\textsuperscript{1}Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, México, México. \textsuperscript{2}Facultad de Ciencias, Universidad Nacional Autónoma de México, México, México.

We look for optimal quantum rotosensors, ie, quantum spin states that are optimal in detecting rotations by a given angle. The exact quantity to be minimized is the probability that the rotated state projects onto the original one, averaged uniformly over all rotation axes. We show analytically that, for small rotation angles, the solution is given by anticoherent states, that maximize entanglement. Numerical analysis shows that, for spin $s = 1$ and $3/2$, there exists, in each case, a critical rotation angle beyond which the minimum is instead achieved by the coherent states, of zero entanglement, the transition between the two being discontinuous. For $s = 2$, a third, degenerate minimum appears, in between the above two, consisting of pairs of antipodal points, regardless of the angle between their axes. We also determine the worst rotosensors, ie, those states that maximize the above quantity — interestingly, the same set of states shows up, but for different ranges of the rotation angle.

Equilibration of observables for initial coherent states in a simple atom-field model

Miguel Ángel Bastarrachea Magnani\textsuperscript{1,2}, Baldemar López del Carpio\textsuperscript{3} Jorge Chávez Carlos\textsuperscript{2}, Sergio Lerma Hernández\textsuperscript{2,3} and Jorge G Hirsch \textsuperscript{1}

\textsuperscript{1}Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apdo. Postal 70-543, Cd. Mx., C.P. 04510, Mexico; \textsuperscript{2}Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, Freiburg D-79104, Germany; \textsuperscript{3}Facultad de Física, Universidad Veracruzana, Circuito Aguirre Beltrán s/n, Xalapa, Veracruz, C.P. 91000, Mexico.

In this job we present a study on the dynamics of initial coherent states for the Dicke model with a number of atoms $N \sim 200$. This number of atoms allows interpreting
the quantum results in the light of the corresponding semi-classical limit. We explore
the long time behavior of different observables, like the survival probability. Emphasis
is placed on identifying quantum signatures of regularity and chaos in the temporal
evolution of observables. In particular, the long-time temporal average of the survival
probability (the Inverse Participation Ratio or IPR) is shown to decay as $1/N^C$ with
$C > 0$. The value of $C$ depends on the regular or chaotic nature of the region where
the initial coherent state is located. For coherent states in the regular region of the
underlying semi-classical phase space $C$ is smaller than one and close to $1/2$, whereas
for chaotic ones the decay is faster and $C > 1$.

QED cavities and Ramsey zones: Semiclassical limit, adiabatic
approximation and beyond.

M. Sc. Efraín Molano Parra, Grupo de Óptica e Información Cuántica (GOIC).
Director: Karen Fonseca Romero.

A beam of Rydberg atoms crossing a Ramsey zone is simulated numerically. While
the atoms are modeled as two-level systems whose center of mass moves classically
with constant velocity, the Ramsey zone is described by a driven single electromagnetic
mode almost resonant with the atomic transition, with large energy losses (low quality
factor). Since the atoms are prepared in Rydberg states with large principal quantum
number (of the order of $n = 50$), whose average lifetimes are much larger than the
average lifetime of the cavity photons, atomic decoherence is neglected. The global time
evolution of atoms and photons is simulated by quantum trajectories. Three regimes
(quantum, intermediate and semiclassical) are found. We show that in the semiclassical
regime, corresponding to large values of the dissipation rate, the global system can be
approximated by two interacting qubits.

Use of quantum mechanics to solve the hidden subgroup
problem: Advantages and disadvantages

Santiago Marín Agudelo and Jorge Eduardo Mahecha Gómez.
Instituto de Física, Universidad de Antioquia, Medellín, Colombia.

The mathematical hidden subgroup problem (HSP) provides a way to generalize diffe-
rent computational problems, which allows to test the power of the hypothetical quan-
tum computers. Some problems which are solved with exponential-time algorithms in
classical computation, and whose solution is accelerated by using quantum algorithms,
can be viewed like particular cases of the HSP. Some of these are Simon’s problem,
Shor’s factoring algorithm and search database problem. The statement of the HSP is:
Let any group $G$ finitely generated, $X$ a finite set, $K$ a subgroup of $G$ and $f$ a function
from G to X such that \( f(a) = f(b) \) if only if \( b \in aK \) (left coset) then we say that \( f \) hides \( K \). The mission is, given G, X, and \( f \) with these characteristics find a set of generators for \( K \). We will present the tools to approach the problem and construct quantum algorithms with speed-up with respect to their classical counterparts. Next with this machinery, we show some instances of the HSP, that classically are hard problems but in quantum computation have speed-up, including an exponential speed-up, like the Shor's factoring algorithm. But, contrary to an intuitive belief, not all HSP instances have speed-up with quantum algorithms. There are several examples of the HSP whose solution cannot be accelerated using quantum algorithms. We will illustrate this through a non-abelian group and explain why the quantum procedure doesn’t work.

---

**The cooperation number in the study of the quantum phase transition of a matter-radiation interaction model**

Luis Fernando Quezada and Eduardo Nahmad Achar.
Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, 04510 Ciudad de México, México.

We show how the use of variational states to approximate the ground state of a system can be applied to study a matter-radiation interaction model. One of the main contributions of this work is the introduction of a not very commonly used quantity (the cooperation number) and the study of its influence over the behavior of the system, paying particular attention to the phase transitions and the accuracy of the used approximations. We also show how these phase transitions affect the dependence of the expectation values of some of the observables relevant to the system and the entropy of entanglement.

---

**Semiclassical approximation to the propagator of the Wigner function for particles in confined spaces**

Óscar Eduardo Rodríguez Villalba and Thomas Dittrich.
Universidad Nacional de Colombia, Departamento de Física, Colombia

Particles restricted by infinitely high potential walls on one or two sides, were studied since the beginning of quantum mechanics. Despite their simplicity, they constitute highly nonlinear systems with a rich dynamical behaviour. For the classical system, it is known that trajectories of particles interacting with one or two walls can be thought of in terms of the mirror image method, that is, the reflected trajectory is seen as a free-particle trajectory between the starting point and a mirror image of the final point in a replica of the original confined region. Both approaches, namely, the periodic and confined approach, assume a different nature of the walls. While the periodic approach considers thin walls (delta functions) between each replica of the original region, in
the confined approach the walls are assumed thick (theta functions), which means that
wavefunctions cannot go through the walls. The existing symmetry in the repetitions
of the original box facilitates the analysis of the box with thin walls. Without this sym-
metry, the box with thick walls imposes big technical challenges. Despite this difficulties,
big walls are closer to nonlinear classic systems (as a limit of potentials of the form $q^2$). These systems constitute an important research topic owing to their behaviour.
This work construct the exact propagator of the Wigner function in the case of thick
walls, a novel result with a huge potential for both theory and applications. Although
semiclassical approximation does not apply in this case, this work takes advantage of
the limit of polynomial potentials so as to obtain the semiclassical approximation of
smooth potentials close to the box with thick walls. With this approach, we want to
confirm the closeness of this smooth potential approximation to the exact propagator
of the infinitely deep potential well.

An experimental study on quantum random number
generation: from polarizing beam splitters to time tag.

Aldo C. Martínez, Aldo Solis, Alí M. Angulo Martínez, Hector Cruz Ramírez, Alfred
B. U'Ren and Jorge G. Hirsch.


Measurements in individual quantum systems are random. This fact has been exploited
to develop random number generators based on quantum phenomena that, in contrast
to pseudo-random numbers generated by software, are not deterministic. Shocked by
the results that the chains obtained from the path split of photons in a polarizing beam
splitter (PBS), by the Vienna Quantum Optics group, fail Borel Normality test, we
decided to study the experimental challenges of this kind of random number generator.
Our implementation uses an attenuated laser, a motorized half wave plate, a PBS, and
single photon detectors. Our system remains balanced along the measurement by a
feedback program. To asses the quality of our generated binary chains, we use Borel
Normality and NIST test suite. Our binary chains are well balanced, but, as shown by
the histograms of the events in every channel, they are biased by afterpulsing effect and
differences in detectors. Looking for a more robust method to generate random chains,
we use the distribution of arrival time of photons and we retake, with some extensions
that allow a greater generation rate, a method from radioactive decay based on the time
tag of every event [4]. The last method is robust, easy to implement, produces more
than one bit per photon and requires no post-processing. So it is a good candidate to
be considered for a practical application. In this contribution, I will focus on several
details of our experiment and results.
Berry phase and quantum phase transition for some models formed by individual two-level systems and many-body systems.

C. A. Estrada Guerra\textsuperscript{1} and J. E. Mahecha Gómez\textsuperscript{2}

\textsuperscript{1}Instituto de Física, Universidad de Antioquia, Medellín-Colombia. \textsuperscript{2}Instituto de Física, Universidad de Antioquia, Medellín-Colombia.

Some studies of many-body models have shown a criticality of the ground state geometric phase. Therefore, said phase may reveal critical phenomena in a many-body system, not necessarily connected to quantum phase transitions. We study the Berry phase and Berry curvature for some models formed by individual two-level systems and many-body systems. Different forms of the interaction between atoms and modes of the quantized electromagnetic field are considered, using the rotating wave approximation (RWA). When a gauge transformation is performed on the Hamiltonian, a cyclic and adiabatic evolution gives place to a Berry phase. When varying parameters, for example those of radiation-matter coupling, it is possible to control quantum phase transitions. This is possible by the non-analyticity of the ground state, which can be observed in mean field models.

---

Flat-top beam for an optical cavity

M. S. Billión\textsuperscript{1}, A. López Vázquez\textsuperscript{2}, W.M. Pimenta\textsuperscript{1}, J.A. Franco Villafañe\textsuperscript{3} and E. Gómez\textsuperscript{1}

\textsuperscript{1}Instituto de Física, UASLP, San Luis Potosí 78290, México; \textsuperscript{2}Facultad de Ciencias Físico-Matemáticas, BUAP, Puebla, Puebla 72000, México; \textsuperscript{3}CONACYT - Instituto de Física, UASLP, San Luis Potosí 78290, México.

Resonators for experiments with cold gases enhance the quality of a laser beam that will hit an atomic cloud. Our team works on a type of interferometry in which atoms are excited collectively inside a “Bow-tie” cavity to perform precision measurements of accelerations. In this work we present the characteristics of the cavity with a maximum beam waist for an homogeneous lighting, based on exciting 2 independent transverse modes on a “flat top” profile, through an incoherent superposition of LG00 and LG01 modes; never used before for this type of cavity. Our “Bow-tie” configuration allows a traveling wave and a cooperativity factor higher than one to improve the interferometer sensibility by increasing his relative phase; all together to reach the ultimate goal of reduce uncertainty.
Generation of coherent blue light via four wave mixing in rubidium

Instituto de Ciencias Nucleares, UNAM.

We study the generation of a beam of coherent blue (∼ 420 nm) light in thermal rubidium atoms by means of a four-wave mixing (4WM) process. To do so two counter-propagating lasers were used in a three level ladder excitation scheme, $5s_{1/2} \rightarrow 5p_{3/2} \rightarrow 5d_{5/2}$. From the excited $5d_{5/2}$ state the decay is carried out through a two photon cascade, one of the photons being infrared at $5.2 \mu m$ and the other being visible at 420 nm, which satisfies the energy and momentum conservation in the 4WM process. Fluorescence signals of the 420 nm photon in the atoms were observed, as well as the generation of a collimated blue beam as a function of the rubidium vapor density. These changes were realized using an oven, and the detection was done using a photomultiplier tube and band-pass filter centered at $420 \pm 2$ nm. Several tests were carried out to verify the coherent nature of the blue beam generated in this experiment.

Embeddings of spaces of quregisters into special linear groups

Dalia Cervantes and Guillermo Morales Luna

We study embeddings of the unit sphere of complex Hilbert spaces of dimension a power $2^n$ into the corresponding groups of non-singular linear transformations. For the case of $n = 1$, the sphere $S_1(C)$ of qubits is identified with SU(2) and the algebraic structure of this last group is carried into $S_1(C)$. Hence it is natural to analyse whether it is possible, for $n \geq 2$, to carry the structure of the symmetry group SU($2^n$) into the unit sphere $S_{2^n-1}(C)$. For $n = 2$ the embeddings of $S_3(C)$ into GL($2^2$), obtained as tensor products of the above embedding, fails to determine a bijection between $S_3(C)$ and SU($2^2$), but they determine entanglement measures consistent with von Neumann entropy. Until now, we have extended the above embeddings for $n > 2$. We can assert that for $n$ an even number, the images of these maps form a subset of GL($2^n$) and for $n$ an even number, these are in SU($2^n$). On this last case the algebraic structure is carried into $S_{2^n-1}(C)$. 
Adiabatic invariants in the semiclassical Dicke model

Baldemar López del Carpio1, Jorge Chávez Carlos1, Miguel Bastarrachea Magnani2, Sergio Lerma Hernández1,3 and Jorge G. Hirsch1

1Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apdo. Postal 70-543, Ciudad de México, México, C.P. 04510; 2Physikalisches Institut, Albert-Ludwigs-Universitat Freiburg, Hermann-Herder-Str. 3, Freiburg, Germany, D-79104; 3Facultad de Física, Universidad Veracruzana, Circuito Aguirre Beltrán s/n, Xalapa, Veracruz, México, C.P. 91000.

In this work it is found an integrable limit, different from the usual ones, for the Dicke Hamiltonian using the adiabatic approximation. In this approach it is considered that a system with fast dynamics is coupled to another with slow dynamics. The Dicke model has a one bosonic and one fermionic degree of freedom, and one can choose which will have rapid dynamics. In this work is studied the adiabatic approximation of fast pseudo-spin in the semiclassical Dicke model. This approximation allows to obtain an effective adiabatic Hamiltonian for the slow bosonic variables and an adiabatic invariant is found. The effective adiabatic Hamiltonian is studied in detail and together with the study of the adiabatic invariant one can establish the regions of validity of the approximation in the space of parameters of the model. It is shown that the breaking of the adiabatic approximation is associated with the transition to chaos.

A quadrupole transition induced by a Bessel Beam: experiment and theory

S. Hernández Gómez1, P. Ortega Escorza1, F. Ponciano-Ojeda1, C. Mojica Casique1, L. M. Hoyos Campo1, F. Ramírez Martínez1, J. Flores-Mijangos1, K. Volke Sepúlveda2, R. Jáuregui Renaud 2 and J. Jiménez Mier1

1Instituto de Ciencias Nucleares, UNAM. Circuito Exterior, Ciudad Universitaria, 04510 Ciudad de México, México; 2Instituto de Física, UNAM. Circuito Exterior, Ciudad Universitaria, 04510 Ciudad de México, México.

This work shows the progress done in the Laboratorio de Átomos Fríos (Cold Atoms Laboratory) of the Instituto de Ciencias Nucleares - UNAM to study the transfer of orbital angular momentum from light to the internal coordinates of rubidium atoms.

During this project an experimental and theoretical analysis of the interaction between scalar Bessel beams and room-temperature rubidium atoms was performed. In the experiment the electric quadrupole transition $5P_{3/2} \rightarrow 6P_{3/2}$ was induced on atoms, using a 911 nm laser beam previously modulated in phase and intensity in order to transform it into a scalar Bessel beam (responsible of transferring the orbital angular momentum towards the atoms). In order to study the electric quadrupole transition, the atoms are first excited into the $5P_{3/2}$ ($F = 3$) state by interacting with a 780 nm laser beam. After interacting with the second radiation field, the atoms decay from the $6P_{3/2}$
state into its ground state, emitting blue photons during this process. A spectroscopy can then be performed by detecting these spontaneously emitted blue photons. Three different experiments were performed, on each of them the width and power of the excitation beams were modified, in the hope of amplifying the effects that the different topological charges of the Bessel beams may have had in the measured spectra.

The theoretical part of the project was to generalize a model, previously developed in the Laboratorio de Átomos Fríos, that predicts the probability of measuring blue emitted photons (during the excitation process mentioned above) whilst changing the excitation beams’ polarization. The previous model uses the plane wave approximation to simulate the light that induces the electric quadrupole transition. The generalization reported here simulates this radiation field as a Bessel or Gaussian beam, both of them in the paraxial regime.

A very good agreement was found between the theory and experiment. The experimental results showed that the spectroscopy was possible while using Bessel beams, meaning that it is possible for room-temperature atoms to absorb photons with orbital angular momentum. However the theoretical model shows that measuring variations in the intensity of the spectral lines, due to changes in the amount of orbital angular momentum carried by the electromagnetic radiation, is not possible under the circumstances on which the experiments were performed, which include using: room-temperature atoms, paraxial beams, 911 nm beam intensities bellow saturation, among others. This was confirmed by the experimental results.

14 From unsharp to projective measurement of a spin component

Daniel Saavedra Martínez and Karen Fonseca Romero.
Universidad Nacional de Colombia, Colombia.

The usual description of a quantum measurement is based on von Neumann’s model. We consider the problem of the measurement of a spin component of a one half spin system. A two-level apparatus, prepared in a specific initial state, is assumed to interact with this system. A decoherence process acts as a strong (projective) measurement of the apparatus. If the strength of the impulsive interaction is appropriately chosen, this scheme corresponds to a projective measurement of a system’s spin component. For any other interaction strength, it corresponds to an unsharp measurement. We write the POVMs associated to this measurement for any value of the interaction strength, and we show that, by repeating the process a suitable number of times, the average value of the chosen spin component can be estimated for any interaction strength.
Overlap statistics for mixed states of finite dimensional quantum systems

T. Gorin$^1$ and L. Alonso$^2$

$^1$Departamento de Física, Universidad de Guadalajara; $^2$Instituto de Física, Benemérita Universidad Autónoma de Puebla.

We consider the statistics of overlaps between a mixed state and its image under random unitary transformations. Choosing the transformations from the unitary group with the invariant (Haar) measure, the distribution of overlaps only depend on the eigenvalues of the mixed state. It may thus be possible to estimate its eigenvalues from measurement results for the overlap statistics. Here, we present our analytical results for the case of arbitrary mixed states of a qutrit.

Theoretical analysis of the control of populations in atomic systems using schemes based on the quantum Zenon effect

Javier Contreras Sánchez$^1$, Fray de Landa Castillo Alvarado$^2$ and José Luis Hernández Pozos$^3$

$^1$Escuela Superior de Física y Matemáticas, I. P. N.; $^2$Universidad Autónoma Metropolitana Unidad Iztapalapa; $^3$Instituto Politécnico Nacional, México

We consider the statistics of overlaps between a mixed state and its image under random unitary transformations. Choosing the transformations from the unitary group with the invariant (Haar) measure, the distribution of overlaps only depend on the eigenvalues of the mixed state. It may thus be possible to estimate its eigenvalues from measurement results for the overlap statistics. Here, we present our analytical results for the case of arbitrary mixed states of a qutrit.

Divisibility of quantum dynamical maps versus divisibility of quantum channels

David Davalos$^1$, Mario Ziman$^2$ and Carlos Pineda$^1$

$^1$Instituto de Física Universidad Nacional Autónoma de México; $^2$Research Centern for Quantum Information, Slovak Academy of Sciences.

We present a comparative study of the divisibility properties of qubit dynamical maps and the divisibility properties of the channels parametrized by such dynamical map. We first show the implementations of the conditions for Lindbladian divisibility for the qubit case and the characterization of the full Kraus rank Pauli channels. We give concrete physical examples of quantum dynamical maps, including the Spin-Boson system and a parametrization of the best approximation of the NOT gate inside the complete positive trace preserving channels, the last one shows interesting regions where the concept of non-markovianity is non trivial.
**Study of quantum channels using quantum error correcting codes**

Carlos Tonatiuh Hernández del Toro and Thomas Gorin
Departamento de Física, Universidad de Guadalajara, Guadalajara, México.

We study quantum channels related to different errors and apply Quantum Error Correcting Codes (QECC) to correct those different errors. We consider different types of errors, such as "bit flip" and "phase flip". In addition, we consider continuous errors corresponding to small random rotations in the Bloch sphere. We then analyze the performance of the different error correcting codes, not only in a theoretical setup, but also when implemented in a more realistic model of a quantum computer, based on an Ising spin-chain, where quantum gates are applied with the help of radio-frequency pulses.

**Measurements and algorithms**

Aldo Solis and Jorge Hirsch
Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México

Measurement procedures have a central role in physics. They are the only connection between physical theories and our experiences. Although physics is concerned with the result of measurements, we have no theory to talk about measurement itself. This work tries to make touch with the foundations of measurement. We explore different aspects of measurements, the development of scales and measurement theory. We relate measurement and computation theory in order to give a mathematical formalization of measurements procedures that allows us to prove some basic theorems.

**Quantum information metric and Berry curvature from a Lagrangian approach**

Javier Álvarez Jiménez, J. David Vergara and Aldo Dector

1 Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México; 2 Instituto de Física Teórica IFT UAM/CSIC.

We take as a starting point an expression for the quantum geometric tensor recently derived in the context of the gauge/gravity duality. We proceed to generalize this formalism in such way it is possible to compute the geometrical phases of quantum systems. Our scheme provides a conceptually complete description and introduces a different point of view of earlier works. Using our formalism, we show how this expression can be applied to well-known quantum mechanical systems.
Phase space representation of quantum mechanics has always been invoked when looking for a clear way to picture the correspondence between quantum mechanics and classical mechanics; its use being widespread in fields like quantum optics, molecular dynamics and quantum chaos. In the last decade, due to new challenges emerging from developments in chemical physics, both experimental and theoretical, in the direction of complex time evolution, a revival of the interest on semiclassical methods in the time domain has been witnessed, including phase approach methods. A major contribution in this respect were the formulation of semiclassical propagators in phase space, in particular those in the Weyl-Wigner representation. Recently, based on weakly numerical studies [S.-I. Koda, J. Chem. Phys. 143, 244110 (2015)], the speed convergence of these approaches has been questioned. In this work we present a careful numerical study of the semiclassical propagation of Wigner function showing that such criticisms lack justification.

Infinite dimensional kicked Ising model

David Amaro Alcalá and Carlos Pineda
I.F. UNAM.

We investigate the infinite dimensional kicked Ising model with a basis that we have developed using Young diagrams exploiting the invariance under permutations. A subspace of this model is equivalent to the quantum kicked top and we are studying properties of both systems using this basis in the corresponding chaotic regime.

Fidelity witness of Bosonic Gaussian states

Renato Mello da Silva Farias and Leandro Aolita
Instituto de Física, Universidade Federal do Rio de Janeiro, P. O. Box 68528, Rio de Janeiro, RJ 21941-972, Brazil.

Using a experimentally-friendly fidelity witnesses, we show how to certify efficiently all pure bosonic Gaussian states. We also show a lower bound for the number of state copies necessary to do so. The method is shown to be robust against finite experimental-state infidelities.
New solutions of quasi-exactly solvable potentials in quantum mechanics

Edgar Condori\textsuperscript{1}, Marco A. Reyes\textsuperscript{1} and Mario Ranferi Gutiérrez\textsuperscript{2}

\textsuperscript{1} University of Guanajuato, Mexico. \textsuperscript{2}Universidad Mariano Gálvez, Guatemala.

In the present work, results are presented on the solution of a quasi-exactly problem for a particle in a one-dimensional potential $V(x) = V_0 \text{senh}^4(x)$, which does not belong to the set of problems classified by Turbiner. To find possible analytical solutions, we use the solution techniques developed by Downing and Wen et al., which leads us to obtain symmetrical and antisymmetric solutions of the problem separately, for determined values by the parameters of the same. It is shown that the numerical solutions exactly match the eigenvalues $\lambda$ and the forms of the obtained eigenfunctions.

Painlevé IV solutions from systems with harmonic oscillator gapped spectrum

Mario Iván Estrada Delgado and David José Fernández Cabrera

CINVESTAV, Mexico City, Mexico.

Supersymmetric transformations of order $k$ are applied to the harmonic oscillator to generate potentials $V$ whose spectra have a gap of thickness $k + 1$ with respect to the initial spectrum. The system’s extremal states are identified and, since the reduction theorem conditions are satisfied, which ensures that the system has third order ladder operators and hence it is connected with the PIV equation, solutions to this equation can be found. Then, an alternative supersymmetric transformation is applied to the harmonic oscillator, by adding the levels needed to reproduce the spectrum of $V$, up to a displacement by a constant factor. The extremal states are identified and, as the reduction theorem is met again, we can get also solutions to the PIV equation. Finally, the PIV solutions found through both transformations are analyzed.
Organizing Commitee

Pablo Barberis, IIMAS - UNAM
Alejandro Frank, Member of El Colegio Nacional
Rocío Jáuregui, IF - UNAM - Chairwoman
Octavio Novaro, Member of El Colegio Nacional
Rosario Paredes, IF - UNAM
Carlos Pineda, IF - UNAM
Pedro Quinto, ICN - UNAM
Daniel Sahagún, IF - UNAM
Jorge Seman, IF - UNAM
Alfred U’Ren, ICN - UNAM

Latin American contacts:
Fabricio Toscano – Brazil.
Juan Pablo Paz – Argentina.
Carlos Leonardo Viviescas – Colombia.
Local committee e-mail: elaf2017@fisica.unam.mx
Sponsors

We gratefully acknowledge our sponsors that made this school possible.
Notes