MIRO
Millennium Institute for Research in Optics

WM

WORKSHOP MIRO 2023

BOOK OF ABSTRACTS

ORGANIZERS:

Felipe Herrera
Birger Seifert

OCTOBER **10 - 13, 2023** | SANTIAGO, **CHILE**

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Host: Pontificia Universidad Católica de Chile

Participate: Universidad de Concepción; Universidad de Santiago de Chile; Universidad de Chile; Universidad de los Andes

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WELCOME NOTE

The MIRO Workshop is the annual scientific meeting of the Millennium Institute for Research in Optics. The goal of the event is to bring together researchers and students from the universities that compose the Institute and discuss research breakthroughs and ongoing projects that further advance the position of MIRO as a leading center for experimental and theoretical physics in Chile.

This year's event builds on the success of previous editions in 2019, 2020 and 2022 which have contributed to the strengthening of collaborations between universities. Our community benefits immensely from the participation in the MIRO Workshops of a selected group of invited speakers from leading Chilean institutions who work on closely related areas of physics, chemistry and engineering. To promote excellence in scholarly presentations, this year there will be a student poster competition during the event.

We look forward to this year's presentations. Your participation and enthusiasm for science is most important for MIRO.

Prof. Felipe Herrera and Prof. Birger Seifert
2023 MIRO Workshop organizers

PROGRAM

MARTES 10

09:00 - 09:20	Apertura	
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10:00 - 10:20	"Emergence of disordered branching patterns in confined chiral nematic liquid crystals"	Marcel Clerc
10:20 - 10:40	"Effective detection of OAM laser modes for terrestrial wireless optical communication in strong turbulence"	Jaime Anguita
10:40 - 11:00	"Process-dependent topological transitions in thermodynamic equilibrium"	Víctor Fernández-González
11:00 - 11:40	Coffee Break	
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12:20 - 12:40	"Spectral Broadening and White Light Generation in Bulk Media"	Fernando Villanueva
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15:20 - 16:00	"Intra-cavity laser-assisted solar-energy conversión"	Sascha Wallentowitz
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16:40 - 17:00	"Terahertz (Millimeter, Submillimeter, Far Infrared) for Materials Studies"	Faustino Wahaia
17:00 - 17:20	"Mitigation of Beam Wander and Angle-Of-Arrival Fluctuations Using Tip-Tilt"	José Durandeau

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09:40 - 10:20	"Individual quantum emitters in molecules and 2D materials for quantum information applications"	Jerónimo Maze
10:20 - 10:40	"Chemical sensors based in MOFs and Fiber Optics"	Rubén Fritz
10:40 - 11:00	"Synthesis of ultra-luminescent carbon particles and graphene quantum dots for optical applications"	Dinesh Singh
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12:20 - 13:00	"From Scientist to Entrepreneur: Navigating the Path of Innovation"	Sebastián Niklitschek
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12:00 - 12:20	"Intramolecular vibrational interaction modulated by mid-infrared nanoantennas"	Johan Triana
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16:40 - 17:00	"Adaptive Measurements in Quantum Information"	Daniel Concha
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09:40 - 10:20	"Mesophases on demand: a variety of mesophases and transfer of chirality from discrete heterocycle molecules to liquid crystal mixtures"	Paulina Hidalgo
10:20 - 10:40	"Mid-IR phase control for light-matter fields using anharmonic semiconductor dipoles"	Mauricio Arias
10:40 - 11:00	"Dynamics in a liquid crystal light valve with translational Feedback"	David Pinto
11:00 - 11:40	**Coffee Break**	
11:40 - 12:00	"Optimal estimation of high-dimensional unitary transformations"	Daniel Uzcátegui
12:00 - 12:20	"Generation of TMSS via FWM in 85 Rb vapor"	Fabián Ramírez
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13:00	**Cierre**	

WORKSHOP
MIRO 2023

Oral Presentations

SPEAKERS

Melissa Maldonado-Pontificia Universidad Católica de Chile
Invited speaker

Optical nonlinearities in 2D materials

Understanding the nonlinear optical (NLO) properties of photonic materials is relevant and necessary for fundamental studies and technological developments. Among the materials with high optical nonlinearities, layered transition-metal dichalcogenides (LTMDs) have attracted considerable attention from the viewpoint of both synthesis as well as characterization and applications. In this talk, we review the NLO response of a series of 2D-LTMDs nanomaterials in suspension, using different temporal regimes, and we will try to explain the origin of the NL responses, which is very dependent on the spectra-temporal regime of the optical source employed in the studies.

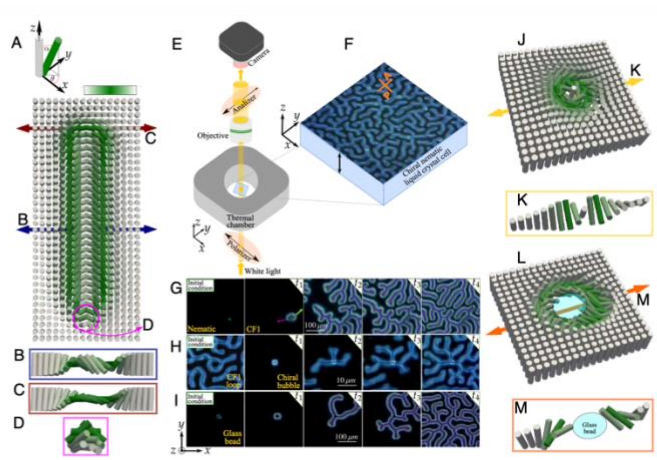
Marcel Clerc-Universidad de Chile
Associate researcher

Emergence of disordered branching patterns in confined chiral nematic liquid crystals

Marcel Clerc

Departamento de Física and Millennium Institute for Research in Optics, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Casilla 487-3, Santiago, Chile

Spatial branching processes are ubiquitous in nature, yet the mechanisms that drive their growth may vary significantly from one system to another. In soft matter physics, chiral nematic liquid crystals provide a controlled setting to study the emergence and growth dynamic of disordered branching patterns. Via an appropriate forcing, a cholesteric phase may nucleate in a chiral nematic liquid crystal, which self-organizes into an extended branching pattern. It is known that branching events take place when the rounded tips of cholesteric fingers swell, become unstable, and split into two new cholesteric tips. The origin of this interfacial instability and the mechanisms that drive the large-scale spatial organization of these cholesteric patterns remain unclear. In this work, we investigate experimentally the spatial and temporal organization of thermally driven branching patterns in chiral nematic liquid crystal cells.



We describe the observations through a mean-field model and find that chirality is responsible for the creation of fingers, regulates their interactions, and controls the tip-splitting process. Furthermore, we show that the complex dynamics of the cholesteric pattern behaves as a probabilistic process of branching and inhibition of chiral tips that drives the large-scale topological organization. Our theoretical findings are in good agreement with the experimental observations.

Figure 1. disordered branching patterns in confined chiral nematic liquid crystals

[1] Sebastián Echeverría-Alar, M.G. Clerc,and Ignacio Bordeu, Proc. Natl. Acad. Sci. U.S.A. **120**, 2221000120 (2023).

Jaime Anguita -Universidad de los Andes
Associate researcher

Effective detection of OAM laser modes for terrestrial wireless optical communication in strong turbulence

A long-term experimental campaign for the propagation of laser modes carrying orbital angular momentum (OAM) over one kilometer has been established at UANDES university campus. At the receiver, the beams are sensed using a 20-cm reflecting telescope and recorded using a high-speed video camera and a Shack-Hartmann (SH) sensor. We describe our method for extracting topological charge spectra from the recorded images and analyze the spread of the intended, transmitted OAM as seen by the receive system as a function of the path-averaged turbulence strength of the link.

Víctor Fernández- González – Universidad de Chile
Contributed

Process-dependent topological transitions in thermodynamic equilibrium

Víctor Fernández-González y Marcel G. Clerc

Departamento de Física and Millenium Institute for Research in Optics, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Casilla 487-3, Santiago, Chile

Chiral magnets, superfluidity, superconductivity, and liquid crystal blue phases are some examples of exotic forms of matter in thermodynamic equilibrium [1- 3]. This is the case of the Berezinskii-Kosterlitz-Thouless transition, where the system reaches the phase transition at a critical temperature, regardless of the process by which the system is brought to the final state [4,5].

In the case of liquid crystals, the appearance of these defects can range from vortex-like localized structures such as spherulites, skyrmions, and torons, to dislocations and convex disclinations in pattern formation [6-10]. These defects are singularities in complex fields that manifest as a discrete jump in the envelope phase, giving the structures topological protection as they can only be annihilated by interaction with opposite charges [6,7]. Under the right conditions, it is possible to form both vortex lattices and disordered patterns, which can induce novel optical phenomena and form the basis for new metamaterials [11,12]. In this talk, we present how temperature plays a role in the creation of different exotic states and how the number of topological defects in these textures can be controlled. We observe how the number of defects varies with the heating rate, indicating the presence of process-dependent topological transitions. Theoretically, we also observe similar phenomena in a Ginzburg-Landau type amplitude equation.

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Ignacio Rojas– Universidad de los Andes
Contributed

Estudio experimental de la superposición de Vórtices Ópticos para Comunicación Digital en Espacio Libre

Ignacio Rojas

Universidad de los Andes
Millenium Institute for Research in Optics

En este trabajo mostramos cómo se pueden utilizar haces con momento orbital angular (OAM) de dos modos superpuestos para transmitir información a través de espacio libre. Primero, tratamos de solucionar los problemas de figura que se producen cuando generamos haces OAM de modos desbalanceados, es decir con modos que no sean “x” y “-x”. Luego comparamos distintos métodos para detectar los OAM que se están trasmitiendo, de tal forma que puedan identificar correctamente los modos.

Finalmente, se seleccionan distintos OAM de tal forma que se pueda tener la mayor cantidad de estos con la menor posibilidad de errores al identificarlos, dándole así a cada uno de los OAM que conforman el universo de posibles símbolos para la comunicación su propio dato asociado. El alcance de este trabajo se limita a resultados experimentales de laboratorio, y no se preocupa de la tasa de transmisión de la información, sino que solamente de ampliar la cantidad de información enviada en cada símbolo transmitido, ya que creemos que es un primer paso a una alternativa para transmitir información. Se muestran resultados preliminares del trabajo, en donde solo el problema de la forma ha sido afrontado y se proponen distintos posibles métodos para la detección de los OAM.

Jorge Escandón– Universidad de Concepción
Contributed

Quantum channel to quantum state converter

Jorge Escandón-Monardes[a,b], Daniel Uzcategui[a,b], Marco Rivera-Tapia[a,b], Aldo Delgado[a,b], Stephen P. Walborn[a,b]

[a] Departamento de Física, Universidad de Concepción, casilla 160-C, Concepción, Chile.
[b] Millenium Institute for Research in Optics, Universidad de Concepción, casilla 160-C, Concepción, Chile.

We introduce a circuit (see Fig. 1) that takes an arbitrary quantum channel on a d-dimensional system and outputs its process matrix, a.k.a. χ-matrix [1]. Our circuit consists in one target qudit and two control qudits. Interestingly, at the end of the circuit the χ-matrix gets encoded in the control register, while the target qudit recovers its arbitrary initial state no matter which quantum channel was applied on it. This circuit can be used for quantum process tomography and we envisage that it could also find application for error protection, dense coding with authentication, remote sensing with validation and quantum digital signature.

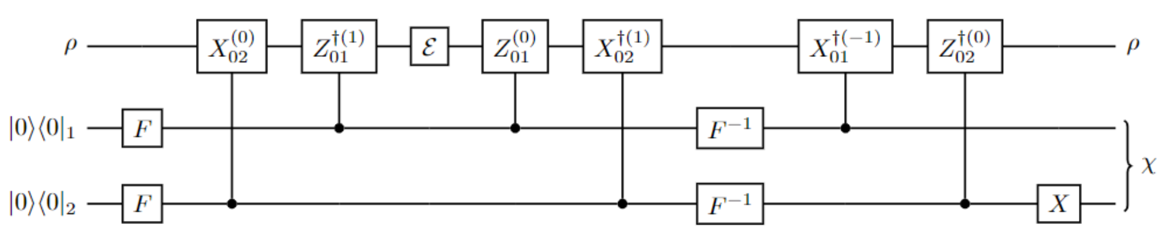

Figure 1. Quantum channel to quantum state converter. F are d-dimensional Fourier transforms acting on control qudits 1 and 2, $X_{tc}^{(i)}$ are controlled gates with shift in the control and $\mathcal{E}$ is an arbitrary quantum channel.

[1] C. H. Baldwin, A. Kalew, and I. H. Deutsch, *Phys.Rev. A* **90**, 012110 (2014).

Fernando Villanueva– Pontificia Universidad Católica de Chile
Contributed

Spectral Broadening and White Light Generation in Bulk Media

Fernando Villanueva[a,b], Diego Hidalgo[a,b], Francisco Capdeville[a,b], Birger Seifert[a,b]

[a] Pontificia Universidad Católica de Chile (PUC), Chile
[b] Millennium Institute for Research In Optics (MIRO), Chile

Although nonlinear pulse compression has been practiced for decades, this could only be carried out in optical fibers [1]. By using more powerful lasers, the distance over which spectral broadening occurs can be drastically reduced, thus allowing for the use of bulk media [2]. Although the technique has been refined over the last decade, to date almost all publications in the topic use similar parameters. The main difficulty of this technique is maintaining a stable spectrum without damaging the material either by thermal effects or photoionization due to the strong self-focusing at play [3]. Applying the multi-plate approach, a stable spectral broadening factor of 5.8 spanning over 11.5 nm was obtained. Currently, the way different materials behave under certain parameters is being researched, having obtained stable white light generation in many of them. Finally, with a white-light supercontinuum, the optical pulse compression from the hundreds into tens of femtoseconds is feasible.

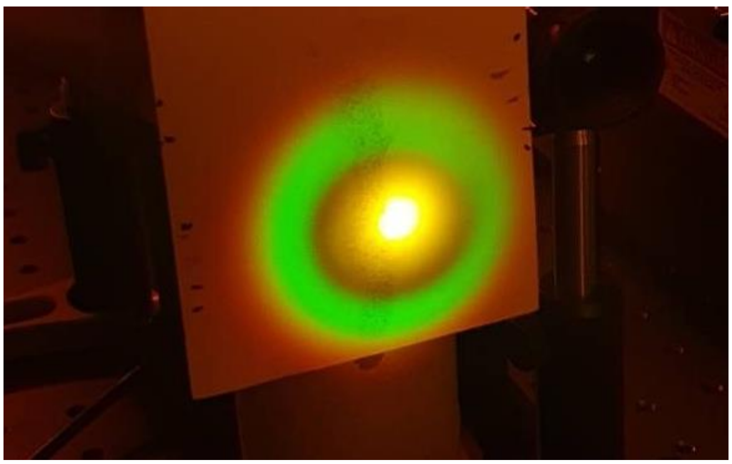

Figure 1. White light generation in sapphire.

[1] Shank, et al. 1982. "Compression of Femtosecond Optical Pulses." Applied Physics Letters 40 (9): 761–63.
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Katy Aruachan–Universidad de Santiago de Chile
Contributed

Semi-Empirical Haken-Strobl Model of Molecular Spin Qubits

Katy Aruachan[1], Yamil Colón[2], Daniel Aravena[3] and Felipe Herrera[1,4]
[1]Department of Physics, Universidad de Santiago de Chile, Santiago, Chile.
[2]Department of Chemical and Biomolecular Engineering, University of Notre Dame, IN,USA;
[3]Department of Chemistry and Biology, Universidad de Santiago de Chile, Santiago, Chile;
[4]Millennium Institute for Research in Optics (MIRO), Chile.

Understanding the mechanisms that determine relaxation times of molecular spin qubits is essential for applications in precision measurements and quantum information processing [1]. Recent spin-echo experiments on the spin relaxation times of molecular spin qubits as a function of magnetic field and temperature have stimulated the development of phenomenological and ab-initio quantum mechanical modeling techniques [1-3].

We propose an alternative semi-empirical approach for building Redfield quantum master equations using a stochastic Haken-Strobl model with fluctuating molecular gyromagnetic tensors and local magnetic fields, parametrizing the corresponding bath spectral densities using only a small number of T_1 relaxation measurements [4]. Taking a vanadium-based spin qubit as a case study, we compute relaxation (T_1) and decoherence (T_2) timescales, extrapolating over a broad range of temperatures and magnetic fields beyond the experimental conditions used to parametrized the model. The theoretical predictions agree quantitatively with experiments [3] and represent a solid foundation for the theoretical characterization of other spin qubits, which could be beneficial for designing novel molecule-based quantum magnetometers.

References:

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Ignacio Bordeu- Universidad de Chile
Invited speaker

Spatial branching dynamics: from biology to physics and back

Branching processes are ubiquitous in nature. In biology, ramified architectures allow for efficient propagation of electrical signals among neurons, optimize fluids transport and exchange in the lungs and vasculature, to name a few of the many ramified tissues and organs. More generally, in out-of-equilibrium systems such forced liquid-crystal cells and excitable systems, branching dynamics emerge as dissipation mechanisms, by which the systems may reach nontrivial stationary states, with complex spatial organizations. In this talk, I will show different systems, both biological and physical, where branching structures emerge, and will discuss how simple agent-based models provide a unified framework to describe them, providing insight into the mechanisms that drive their growth.

Sascha Wallentowitz– Pontificia Universidad Católica de Chile
Invited speaker

Intra-cavity laser-assisted solar-energy conversion

It is shown how to convert solar into electrical energy, using laser amplification and an intra-cavity low-efficiency converter. The latter may consist of a low-efficiency transparent photovoltaic cell or a thermoelectric cell integrated into a metallic laser-cavity mirror, constituting a minor intra-cavity loss for the laser operation. The overall power-conversion efficiency is derived and discussed for a variety of current solid-state laser materials. It is shown that power-conversion efficiencies comparable with commercial silicon photovoltaic cells may be obtained with suitable laser materials.

Felipe Recabal– Universidad de Santiago de Chile
Contributed

Modification of chemical reactivity via light–matter coherence

Felipe Recabal[1], Johan F. Triana[2], Felipe Herrera[1,3]

[1] Department of Physics, Universidad de Santiago de Chile, Santiago, Chile
[2] Department of Physics, Universidad Católica del Norte, Antofagasta, Chile.
[3] Millennium Institute for Research in Optics (MIRO), Concepción, Chile.

Molecular polaritons are hybrid states created by the strong light-matter coupling, and have demonstrated modification of chemistry, energy transfer and spectroscopy [1,2]. However, the development of general theories to understand and reproduce the experiments is already a challenge in the field. In this work, we propose a model that describes the reaction-rate suppression of up to 80% observed in experiments of alcoholysis of phenyl isocyanate with cyclohexanol in a Fabry-Perot cavity [3].

We implement a Lindblad quantum master equation that describes the molecular-cavity system through the NCO vibrational modes of the phenyl isocyanate molecules in strong coupling to the electromagnetic vacuum of the cavity, interacting with their respective thermal equilibrium baths. The model assumes the reaction-rate suppression is a consequence of the depopulation of the vibrational mode implicated in the reaction. The results suggest that reaction-rate suppression is associated to light-matter coherences at steady states that modifies the vibrational population distribution in the resonant condition. We predict energetic disorder of NCO mode protect light-matter coherences for an ensemble of molecules [4]. Our findings extend the understanding of cavity-modified chemistry by tunning the cavity modes with the molecular vibrational modes.

References:

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Faustino Wahaia– Pontificia Universidad Católica de Chile
Contributed

Terahertz (Millimeter, Submillimeter, Far Infrared) for Materials Studies

Faustino Wahaia[1,2], Irmantas Kašalynas[3], Danil Pashnev[3], Gintaras Valušis[3], Mindaugas Karaliunas[3], Andrzej Urbanowicz[3], Juan M. Garcia- Garfido[4], Dinesh Pratap Singh[2,4], Felipe Herrera[2,4], Birger Seifert[1,2]

[1]Facultad de Física, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22, Chile
[2]ANID – Millennium Science Initiative Program – Millennium Institute for Research in Optics (MIRO), Chile
[3]FTMC - Terahertz Photonics Laboratory, Optoelectronics Department, Center for Physical Sciences and Technology, Vilnius, Lithuania
[4]Department of Physics, Universidad de Santiago de Chile, Santiago

Terahertz radiation was until recently an almost unexplored area of research due to the hindrances in its generation and detection. Neither optical nor microwave techniques are directly applicable in the THz frequency band since optical wavelengths are too short and microwave wavelengths are too long compared to terahertz. The development of ultrafast lasers, the manufacturing of semi-insulating semiconductors with very short lifetimes and high mobility photocarriers [1], and engineered heterostructures, as well as the micromachining techniques and nanotechnology have fostered the THz frequency band-related techniques as a new area with many important applications.

This presentation constitutes an overview on what THz radiation is, techniques for its generation and detection, and Laboratory spectrometer's setup for in view spectroscopic and imaging studies. The realization of a reliable, scalable, and portable sources and detectors is one of the ambitious important objectives.

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[3] Kürner, T., & Priebe, S. (2014). Towards THz communications - Status in research, standardization and regulation. *Journal of Infrared, Millimeter, and Terahertz Waves*, *35*(1), 53–62. https://doi.org/10.1007/s10762-013-0014-3

José Durandeau– Universidad de los Andes

Contributed

Mitigation of Beam Wander and Angle-Of-Arrival Fluctuations Using Tip-Tilt

José Pablo Durandeau Verni[a], Carlos Pirela[b], Jaime Anguita[c]

[a,b,c] Universidad de Los Andes
[a,b,c] Millenium Institute for Research in Optics (MIRO)

Atmospheric turbulence causes beam wandering and angle-of-arrival fluctuations, which are undesirable in an optical wireless communication link as they degrade its quality. Tip-tilt mirrors can be employed to mitigate these errors by centering the beam on its desired position. Prior to implementing this solution, the initial step involved characterizing the system. This characterization involved determining the maximum angle of deflection, observing the maximum angle of deflection under the influence of a sinusoidal signal with various voltages and frequencies, and measuring the closed-loop response time using the optimal PID parameters and different setups. Once the characterization is complete, experiments can be conducted using two tip-tilt mirrors under the influence of real turbulence effects to measure the system's performance under such conditions.

Felipe Barra – Universidad de Chile
Invited speaker

An optical setup for a dissipative quantum battery

The interaction of a three-level atom with the electromagnetic field of a quantum cavity in the presence of a laser field presents a rich behavior that we exploit to discuss two quantum batteries.

In the first setup, we consider a single three-level atom interacting sequentially with many cavities, each in a thermal state. We show that under this process, the atom converges towards an equilibrium state that displays population inversion. In the second setup, a stream of atoms in a thermal state interacts sequentially with a single cavity initially in a thermal state at the same temperature as the atoms. We show that the cavity's energy increases continuously as the stream of atoms continues to cross, and the cavity does not reach an equilibrium state. However, if we consider the state after many atoms have traveled, the cavity is in an active state that stores energy. The charging process we propose is robust. We discuss its thermodynamics and evaluate the energy supplied by the laser, the energy stored in the battery, and, thus, the device's efficiency.

Jerónimo Maze – Pontificia Universidad Católica de Chile
Invited speaker

Individual quantum emitters in molecules and 2D materials for quantum information applications

Robust nanoscale systems on which individual degrees of freedom can be accessed and controlled are potential candidates as bricks for quantum information applications. Molecules and semi-conductors can host optically addressable degrees of freedom allowing for robust nanoscale systems with useful properties for the preparation and readout of quantum states.

In this talk, we will present our progress to identify such systems in vanadium oxide phthalocyanine (VOPc) and defects in hexagonal boron-nitride. Individual VOPc molecules can be isolated with stable optical properties. They have associated a short excited state lifetime leading to a strong fluorescence under red illumination which might be useful for large signal-to-noise measurements. We show that its internal structure can be modelled by group theoretical analyses and confirmed by optical interrogation with different optical polarisations. Similarly, we will present our results regarding color centers in hexagonal boron nitride monolayers produced by ion implantation. We will discuss about their stability under different environmental conditions and their interaction with the lattice in order to unequivocally identify their atomic configuration. Characterising the optical properties and spin degrees of freedom of these systems is a must step towards the successful implementation of quantum information applications based on single emitters.

Rubén Fritz – Universidad de Santiago de Chile
Contributed

Chemical sensors based in MOFs and Fiber Optics

Rubén A. Fritz [a], Felipe Herrera[a,b]

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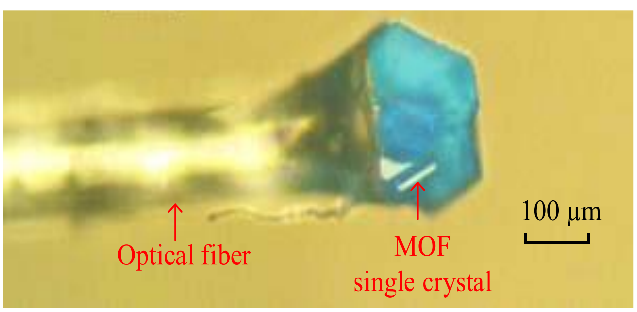
[b] Millennium Institute for Research in Optics MIRO, Chile.

Highly specific chemical sensing capable of monitoring and detecting chemical compounds of interest would require the development of non-destructive, reusable, and portable devices for mass deployment. Metal-organics frameworks (MOFs) are porous materials, their optical properties such as dielectric constant can change upon loading of different guest molecules in gas and liquid phase, enabling the use of these materials as an optical sensing platform [1-3]. Formed by two distinctive molecular blocks: a metal node and an organic ligand (linker), MOFs, display a wide range of different properties due to the combinatorial number of ensembles that are possible; creating an almost infinite chemical space. Exploring this space solely using experiments is challenging, but computational methods allowed a faster investigation in search of suitable candidates for optical applications. We develop a computational approach to study the changes in MOFs' optical and non-linear properties upon loading methane in this study. We calculate dielectric response and Second Harmonic Generation as a function of methane gas loading. Our work aims to establish the basis for a computational filter and characterization of MOFs for chemical sensing of different chemical compounds; helping selection, and design of optical sensors devices based on MOFs.

a)



b)

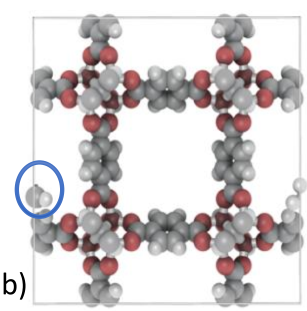


Figure 1. a) Sensor device: optical fiber with attached MOFs crystal device. b) IMOF-1 structure, a methane molecule inside the porous (blue circle).

[1] C. Zhu, R. E. Gerald, and J. Huang, *Metal-Organic Framework Materials Coupled to Optical Fibers for Chemical Sensing: A Review*, IEEE Sensors Journal **21**, 19647 (2021).
[2] C. Zhu, R. E. Gerald, Y. Chen, and J. Huang, *Metal-Organic Framework Portable Chemical Sensor*, Sensors and Actuators B: Chemical **321**, 128608 (2020).
[3] C. Zhu, J. A. Perman, I. I. Rex E. Gerald, S. Ma, and J. Huang, *Chemical Detection Using a Metal–Organic Framework Single Crystal Coupled to an Optical Fiber*, ACS Applied Materials & Interfaces (2019).

Dinesh Singh– Universidad de Santiago de Chile
Associate researcher

Synthesis of ultra-luminescent carbon particles and graphene quantum dots for optical applications

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Department of Physics and Millennium Institute for Research in Optics (MIRO), University of Santiago of Chile, Av. Victor Jara 3493, Santiago Chile

Material synthesis is a core part and state of art to explore applications of various nano/ micro / macro materials for diverse applications in the various sectors of energy conversion and storage, biosensors, biomedicine, and optics etc. Among all, recently carbon- based materials such as carbon[1,2] and graphene[3] quantum dots[4] astonished the scientific community due to their facile and controllable synthesis, ultra-high luminescent properties, easy to manipulate the structures with different functional groups, tunable electrical and optical properties etc. These properties put these materials in upfront to explore it´s applications in various desired areas of interest.[5,6] Here we report the facile synthesis and characterizations of various carbon-based structures such as graphene, carbon particles and graphene quantum dots by chemical hydrothermal method. The synthesized materials are characterized by various techniques of X-ray Diffraction, Scanning electron microscope, UV- visible spectroscopy, and photoluminescence spectrometer. The possible applications of these materials will also be discussed in detail during the presentation.

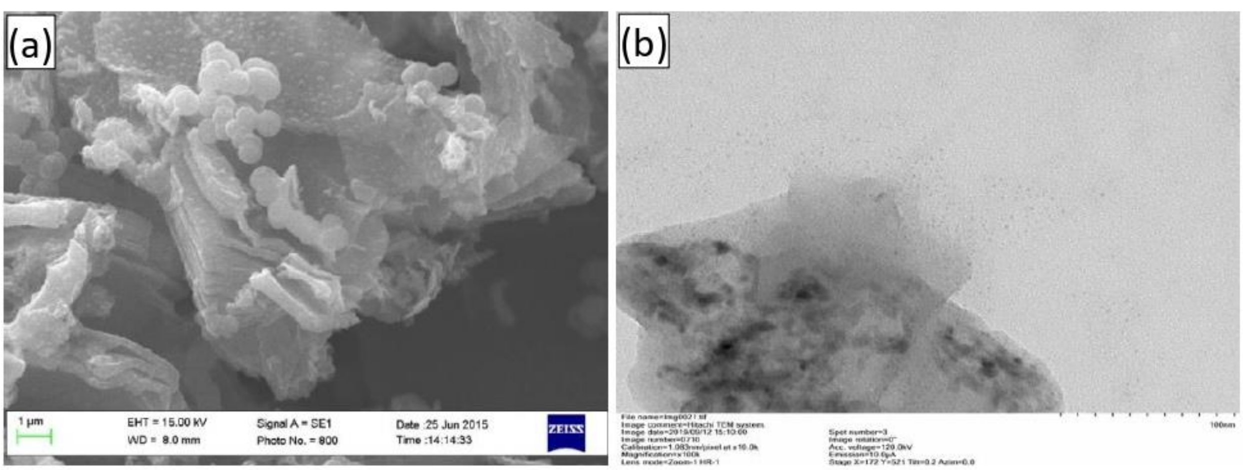

Figure: SEM images of (a) graphene and carbon particles and (b)Graphene quantum dots.

References:
1- Y. Wang et al. https://doi.org/10.1039/C4TC00988F
2- X. Guan et al. https://doi.org/10.1002/smll.202207181
3- A. S. Rasal et al. https://doi.org/10.1021/acsanm.1c01372
4- A. Abbas et al. https://www.nature.com/articles/s41598-020-78070-2 5- X. Guan et al. https://doi.org/10.1002/smll.202207181
6- A. Ghaffarkhah et al. https://doi.org/10.1002/smll.202102683

Rodrigo Vicencio – Universidad de Chile
Associate researcher

Fotónica dipolar

Rodrigo A. Vicencio

Departamento de Física, Faculrad de Ciencias Físicas y Matemáticas, Universidad de Chile
Instituto Milenio para la Investigación en Óptica – MIRO

En esta charla revisaremos nuestros últimos hallazgos teóricos y experimentales respecto a la existencia de estados orbitales no triviales en redes 1D y quasi-1D. Veremos cómo la inclusión de estos estados nos permite observar localización y transporte de energía de forma controlada. Veremos también cómo estos estados permiten generar la existencia de bandas planas, campos magnéticos efectivos y estados topológicos de superficie, constituyendo de esta forma un elemento clave en el control de excitaciones en redes en general. Mediante nuestros estudios en esta área de investigación buscamos proponer nuevos mecanismos de transporte y localización, dos de las preguntas más relevantes en física básica y aplicada.

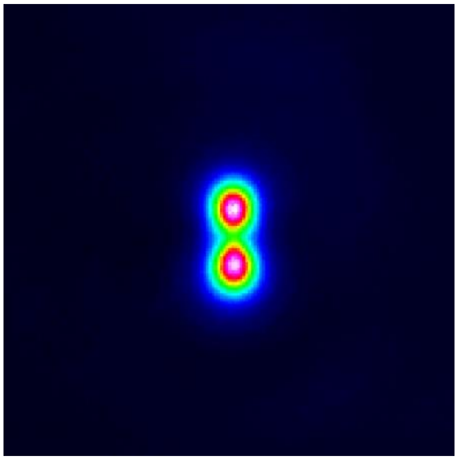

Figure 1. Estado dipolar para una molécula delgada.

[1] D. Guzmán-Silva, et al., Physical Review Letters 127, 066601 (2021).
[2] G. Cáceres-Aravena, et al., Physical Review Letters 128, 256602 (2022).
[3] M. Mazanov, et al., “Topological SP dimerized molecular ribbon photonic lattices,” to be submitted (2023).
[4] M. Nedic, et al., “Topological nontrivial fluxes on graphene ribbons,” to be submitted (2023).
[5] P. Vildoso, et al., “AB caging and optical gates in diamond lattices,” to be submitted (2023).
[6] D. Roman, et al., “The magic dipolar angle,” to be submitted (2023).
[7] D. Roman, et al., “One-dimensional SP photonic lattices,” to be submitted (2023).
[8] B. Real, et al., “Vortex-induced nontrivial magnetic fluxes,” to be submitted (2023).

Simón Paiva– Universidad de Santiago de Chile
Contributed

Giant Generation of Polarization-Entangled Photons in Metal Organic Frameworks

Simón Paiva[1], Ruben A. Fritz 2[1], Sanoj Raj 3[2], Yamil J. Colon 3[2], Felipe Herrera 3[1,3]

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[2] Department of Chemical and Biomolecular Engineering, University of Notre Dame, USA
[3] Millennium Institute for Research in Optics, Concepción, Chile

The generation of entangled light via parametric nonlinear optical processes is an enabling tool in optical quantum technology [1]. However, the variety of optical materials that can be efficiently used to produce entangled photons efficiently is severely restricted. To accelerate the development of next-generation quantum light sources, we use a multi-scale methodology to study spontaneous parametric down-conversion (SPDC) of visible light using metal-organic frameworks (MOF), an emerging family of optical materials with tunable nonlinear optical response and demonstrated chemical and optical stability [2]. For a set of experimentally relevant zinc-based MOF crystals, we theoretically explore the phase-matching conditions for the generation of polarization-entangled photons via collinear degenerate type-II SPDC. For a single-mode 1D waveguide geometry, entangled pair generation rates of $10^6 - 10^7$ $[s^{-1}mW^{-1}mm^{-1}]$ are predicted at 1064 nm, outperforming the conversion efficiency of equivalent periodically-poled KTP waveguides by orders of magnitude [3]. This work demonstrates the potential of MOF single crystals as bright sources of entangled light for quantum communication and sensing.

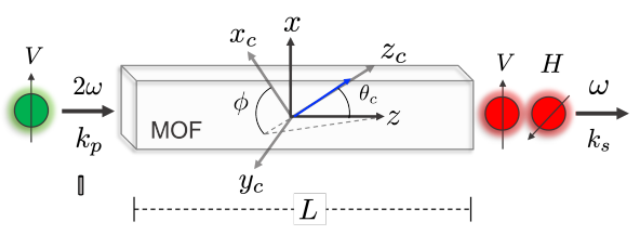

Figure 1. Illustration of degenerate collinear type-II SPDC with a single crystal MOF waveguide with length L. Pump photons with wavevector k_p and frequency 2ω enter the waveguide with lab-frame vertical polarization V and produce a pair of polarization entangled photons with orthogonal polarizations in the same input direction, each with frequency ω and wavevector k_s

[1] Jeremy L. O'Brien, Akira Furusawa, and Jelena Vuckovic. Photonic quantum technologies. *Nature Photonics*, 3(12):687–695, 2009
[2] Ruben A. Fritz, Yamil J. Colón, and Felipe Herrera. Engineering entangled photon pairs with metal–organic frameworks. *Chem. Sci.*, 12:3475–3482, 2021.
[3] James Schneeloch, Samuel H Knarr, Daniela F Bogorin, Mackenzie L Levangie, Christopher C Tison, Rebecca Frank, Gregory A Howland, Michael L Fanto, and Paul M Alsing. Introduction to the absolute brightness and number statistics in spontaneous parametric down-conversion. *Journal of Optics*, 21(4):043501, feb 2019.

Sebastián Niklitschek– Universidad de Concepción
Invited speaker

From scientist to entrepreneur: Navigating the path of innovation

Sebastian has transitioned from the world of research to become a successful entrepreneur. With a remarkable track record of founding six tech companies, he will share their journey of translating scientific breakthroughs into thriving businesses. Discover the pivotal moments, challenges, and strategies that led to their entrepreneurial success. Whether you're a scientist, aspiring entrepreneur, or simply curious about the intersection of science and business, this presentation promises valuable insights into the transformation from scientist to visionary leader.

Daniel Aravena – Universidad de Santiago de Chile
Invited speaker

Ab Initio Studies of Luminescence Properties in Inorganic Systems

Daniel Aravena

Departamento de Química de los Materiales, Facultad de Química y Biología, Universidad de Santiago de Chile (USACH), 9170002 Santiago, Chile; daniel.aravena.p@usach.cl

We present some recent research from our research group, focusing on spectroscopic properties of transition metal and lanthanide complexes. The first part of the presentation discusses key findings related with the luminesce properties of two copper(I) complexes bonded to N,N, phosphine and iodine ligands.[1] Both compounds present thermally activated delayed fluorescence with similar activation barriers (554 and 583 cm^{-1}, respectively) but constating triplet lifetimes (90.0 μs (dimer) and 46.0 μs (monomer)). CASSCF and DFT calculations permitted to assign the nature of the relevant electronic transitions and to understand the structural and electronic effects governing the observed excited state dynamics.

The final part of the talk is devoted to the magnetic and luminescent properties of a ten coordinated Dy^{III} complex featuring a belt macrocyclic ligand in the equatorial positions and nitrate axial ligands.[2] CASSCF calculations are consistent with the observed single-molecule magnet behavior of this complex and provide a sensible estimation of the yellow/blue emission ratio, which is the key parameter controlling the emission color in lanthanide phosphors.

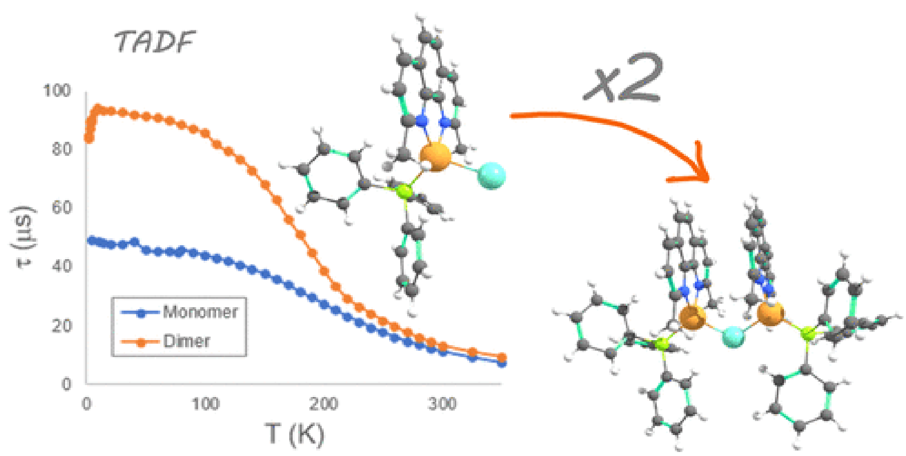

Figure 1. Temperature dependence of the lifetime for the copper(I) complexes.

References:

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[2] Gil, Y; Costa de Santana, R; Vega, A; Aravena, D; Spodine E., *Submitted.*

Dardo Goyeneche – Pontificia Universidad Católica de Chile
Invited speaker

Optimal reconstruction of quantum states with minimal resources

Quantum state reconstruction typically involves a number of incompatible observables that grows with the dimension of the Hilbert space. Within all informationally complete set of observables, those so-called tight quantum measurements are highly attractive, as they minimize the error propagation (e.g. maximal sets of mutually unbiased bases and symmetric informationally complete quantum measurements). However, experimental implementation of known solutions is typically challenging. Is it possible to implement tight quantum measurements having at hand a single unitary operation and a measurement apparatus? In this talk, we provide a positive answer to the question in any finite dimensional Hilbert space.

Birger Seifert – Pontificia Universidad Católica de Chile
Associate researcher

Properties and limitations of the single-shot d-scan technique for the characterization of femtosecond pulses

Birger Seifert [a,b], Francisco Capdeville [a,b]

[a] Facultad de Física, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22, Chile.

[b] ANID – Millennium Science Initiative Program – Millennium Institute for Research in Optics (MIRO), Chile

Even after decades of development of various measurement techniques for the temporal characterization of femtosecond pulses, this topic is still relevant. This is mainly due to the characteristics of the existing methods and the complexity of the problem. One of the most interesting measurement techniques, the dispersion-scan (d-scan) technique, was first published only in 2012 [1]. The decades before, one has always refrained from generating spectral dispersion in the setup, because this means an extra experimental effort. In addition, this changes the pulses, which should actually be measured unchanged. In 2012, the idea of using spectral dispersion returned almost automatically with d-scan, when pulses shorter than 30 femtoseconds needed to be measured. The reason for this is that such short pulses are very sensitive to chromatic dispersion. Even sub-3.5-fs pulses have already been measured with d-scan. A shortcoming of d-scan is that the chromatic dispersion added to the pulses must be precisely characterized quantitatively. For scanning d-scan this is not a significant concern, but for a single-shot implementation it is more challenging [2,3]. The latter problem is addressed and analyzed in more detail. The retrieval algorithm to reconstruct amplitudes and phases of the pulses is not the issue and is therefore only roughly outlined.

[1] M. Miranda, T. Fordell, C. Arnold, A. L'Huillier, and H. Crespo, "Simultaneous compression and characterization of ultrashort laser pulses using chirped mirrors and glass wedges," Opt. Express 20, 688–697 (2012).

[2] D. Fabris, W. Holgado, F. Silva, T. Witting, J. W. G. Tisch, and H. Crespo, "Single-shot implementation of dispersion-scan for the characterization of ultrashort laser pulses," Opt. Express 23, 32803-32808 (2015).

[3] Maïté Louisy, Chen Guo, Lana Neoričić, Shiyang Zhong, Anne L'Huillier, Cord L. Arnold, and Miguel Miranda, "Compact single-shot d-scan setup for the characterization of few-cycle laser pulses," Appl. Opt. 56, 9084-9089 (2017).

Marco Rivera– Universidad de Concepción
Contributed

Large scale quantum interferometers and weak-gravitational fields effects

M. Rivera-Tapia[a,b] , A. Delgado[a,b] and G. Rubilar[b]

[a] Millennium Institute for Research in Optics, Chile
[b] Departamento de Física, Universidad de Concepción, casilla 160-C, Concepción, Chile

In this work, we study the effects of a weak-gravitational field effect on large-scale quantum interferometers. In the first part of this talk, we consider the application of different interferometers for the estimation of two post-Newtonian parameters, gamma, and beta: we use two different configurations of a Hong-Ou-Mandel [1] array feed with photons, and a Mach-Zehnder array feed with particles with inner degrees of freedom [2] (which act as a clock and couples with the gravitational potential). Both schemes are complemented by performing Bayesian inference.

We show how Bayesian inference improves estimations on both parameters. In the second part of this talk, we use quantum state discrimination to distinguish between quantum states that propagate on two different metrics.

The protocol is the following: we consider particles with inner degrees of freedom (d.o.f) that propagate in a classical background. This classical background is given by a weak-field approximation of the Schwarzschild [3] and Ellis-Thorne [4] metrics (up to second-order corrections in Schwarzschild radius, form function, and gravitational redshift function, which are characteristics functions of a black hole and a wormhole, respectively). Then, for these metrics, we obtain a Schrodinger equation for particles with inner d.o.f. and with relativistic corrections [5]. Such equations show a coupling between the Schwarzschild radius, for a black hole, the gravitational redshift, and the form function with the inner d.o.f Hamiltonian. Next, we calculate the propagation in radial coordinates, trace out the center of mass d.o.f and apply quantum channel discrimination to obtain the probability of misidentification between both metrics. Our protocols show how to improve the classical test of General Relativity through coincidence detection probability and through performing Bayesian inference, moreover, our last method allows us to possibly detect wormholes and distinguish them from black holes, which is relevant to support the existence of exotic matter.

[1] C. K. Hong; Z. Y. Ou & L. Mandel (1987). "Measurement of subpicosecond time intervals between two photons by interference".
[2] Zych, M., Costa, F., Pikovski, I. et al. Quantum interferometric visibility as a witness of general relativistic proper time.
[3] Misner, C. W.; Thorne, K. S.; Wheeler, J. A. (1970). Gravitation. W.H. Freeman. Chapters 31 and 32.
[4] M. S. Morris; K. S. Thorne (1988). "Wormholes in spacetime and their use for interstellar travel: A tool for teaching general relativity".
[5] Philip K Schwartz and Domenico Giulini (2018). "Post-Newtonian corrections to Schrödinger equations in gravitational fields"

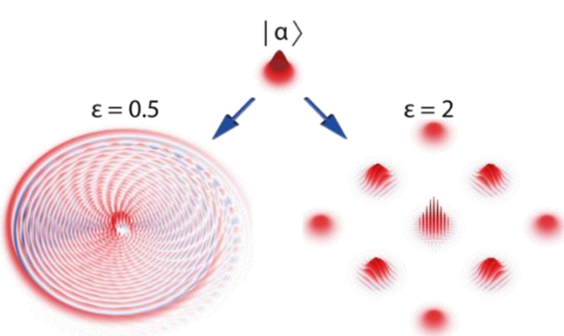
Carla Hermann – Universidad de Chile
Associate researcher

Towards macroscopic quantum light

Mariano Uría(1,2) , Ignacio Salinas(2,3) , Gerd Hartmann(2,3) , Pablo Solano(2) and Carla Hermann (2,3)

(1) Departamento de Física, Facultad de Ciencias físicas y matemáticas, Universidad de Concepción
(2) Departamento de Física, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile.
(2) ANID - Millenium Science Initiative Program - Millenium Institute for Research in Optics
Email: carla.hermann@uchile.cl

Can we harvest useful quantum properties from coherent states? Can we engineer quantum states with them, creating useful nonclassical states from mostly classical light? Our last works attempt to answer both questions with a solid yes. We show how nonlinear light-matter interactions reveal the unambiguous quantum nature of coherent states, creating macroscopic and highly nonclassical light while preserving their coherent photon statistics [1]. Figure 1 shows examples of the generation of such states, where the uncertain region of an initial coherent state in the phase space representation (Wigner Function) nonlinearly evolves into negative values, an unmistakable quantum fingerprint. The emergent non-minimal uncertainty states have a significant metrological advantage, a fundamental resource for quantum metrology. Remarkably, we also show how to deterministically generate Fock states with large photon numbers and high fidelities within the well-known Jaynes–Cummings model, which is a particular case of such nonlinear interactions [2].



Our results highlight how useful quantum features can be extracted from the seemingly most classical states of light, a relevant phenomenon for quantum optics applications. During this present year, we have intensified our efforts in exploring how to characterize this type of light in the laboratory. In addition, we have investigated other exotic quantum states that can be generated by nonlinear light matter interactions.

Figure 1: Nonlinear evolution of a coherent state into highly non-Gaussian states.

[1] Emergence of Non-Gaussian Coherent States Through Nonlinear Interactions. M. Uria, A. Maldonado-Trapp, C. Hermann-Avigliano, and P. Solano. Phys. Rev. Research 5, 013165, https://doi.org/10.1103/PhysRevResearch.5.013165
[2] Deterministic Generation of Large Fock States. M. Uria, P. Solano, and C. Hermann-Avigliano. Phys. Rev. Lett. 125, 093603 – 2020. https://doi.org/10.1103/PhysRevLett.125.093603

Johan Triana– Universidad Católica del Norte
Contributed

Intramolecular vibrational interaction modulated by mid-infrared nanoantennas

Johan F. Triana[a], Felipe Herrera[b,c]

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[b] Department of Physics, Universidad de Santiago de Chile, Av. Víctor Jara 3493, Santiago, Chile
[c] Millennium Institute for Research in Optics, Concepción, Chile

Intramolecular vibrational energy transfer is one of the fundamental processes to control chemical reactivity via light-matter interactions. However, current theoretical studies of intramolecular vibrational energy redistribution are limited to large molecular ensembles and under low dissipation rates of photonic modes. In this work, we show how mode-selective coupling of different vibrational modes to IR nanoantennas can be considered as an indicator of intramolecular vibrational energy transfer (VET), considering that VET has been only detected with 2D spectroscopy techniques. Our findings agree with recent experimental measurements, which also suggest the emergence of an anti-Purcell effect [1]. This counterintuitive anti-Purcell effect is described with our proposed model that considers intrinsic intramolecular coupling and extrinsic energy relaxation mechanisms. Our work paves the way to control intramolecular interactions via infrared nanospectroscopy at the single molecule level for applications in nanophotonics and coherent control.

[1] R. Wilcken, J. Nishida, J.F. Triana, *et.al.*, Antenna-coupled infrared nanospectroscopy of intramolecular vibrational interaction, *Proc. Natl. Acad. Sci. 120, e2220852120* (2023)

Jorge Gidi – Universidad de Concepción
Contributed

Estimation of mixed quantum states using relative entropy measurements

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[a]Instituto Milenio de Investigación en Óptica y Departamento de Física, Facultad de Ciencias Físicas y Matemáticas, Concepción, Chile
[b]ICFO-Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, Barcelona, Spain
[c]Instituto de Física Fundamental IFF-CSIC, Madrid, Spain

The estimation of unknown quantum states is essential in the characterization and control of increasingly complex quantum systems and the assessment of emerging quantum technologies.
Traditional quantum state estimation methods are based on the post-processing of data gathered from the measurement of N identically prepared instances of the state to reconstruct. This process, however, involves the solution of an optimization problem in a d^2-dimensional search space, where d represents the dimension of the quantum system, often demanding substantial memory and processing resources. A prevalent approach is the standard tomography with Maximum Likelihood Estimation (MLE), which is widely employed but becomes infeasible for large systems and manifests sensitivity to noise in the collected data.
In practice, quantum hardware and quantum experiments are susceptible to errors, potentially hindering the integrity of the data retrieved from measurements.
A robust and efficient tomographic technique in the case of pure quantum states is the self-guided quantum tomography (SGQT) [1], which iteratively follows a stochastic optimizer to maximize the overlap between a parameterized control state and the system state.
In this work, we introduce a self-guided quantum tomography algorithm for mixed quantum states conceived from a variational standpoint. We parameterize a quantum state through the complex non-zero components of a Cholesky decomposition, and use complex stochastic optimization methods [2] to minimize the relative entropy between the control and the system state. In particular, we chose relative entropy as our objective function due to its amenability to experimental realization.
Finally, we benchmark our method by simulating relative entropy measurements under various levels of experimental preparation errors, demonstrating its robustness against noise by achieving superior fidelities compared to MLE in the scenario of imperfect measurements.

[1] Phys. Rev. Lett. **113**, 190404 (2014)
[2] Phys. Rev. A **108**, 032409 (2023)

Gabriel Saavedra – Universidad de Concepción

Contributed

Spatial optical switch for multicore fibers

C. Melo[a], C. Rosado[a], L. Faundez[b], E. Sepulveda [c], S. Walborn [c], G. Lima [c], J. Cariñe[b], G. Saavedra[a]

[a] Dept of Electrical Engineering, Universidad de Concepción

[b] Dept of Electrical Engineering, Universidad Católica de la Santísima Concepción [c] Dept. of Physics, Universidad de Concepción

To satisfy the increasing demand for data transmission, optical fibers need to increase their information carrying capacity, and to do so space division multiplexing (SDM) has been acknowledged as one of the potential solutions to the impending capacity crunch of optical fiber links and networks[1,2]. In order for SDM to become a viable candidate for practical optical networking solutions, several challenges are still to be resolved, in particular related to devices and integration with current infrastructure. Among these challenges, the development of devices such as optical amplifiers, multiplexers and de-multiplexers, and optical switches can enable the next generation deployment of SDM optical networks [3]. Optical switches are one of the key elements in modern day optical networks. Depending on the property used to switch a signal in an optical node, four switching granularities have been identified in [3] to build multi-dimensional SDM nodes, namely: independent spatial mode/wavelength channel switching; spatial mode switching across all wavelength channels; wavelength switching across all spatial modes (wavelength granularity); and, wavelength switching across spatial mode subgroups. In order to design SDM nodes a combination of devices will be required to achieve one of the aforementioned switching granularities. In this work, we show the performance of a fiber-based core switch for multicore optical fibers. We evaluate insertion losses, inter-core cross talk and switching speed for the proposed device.

[1] Puttnam, B. J., Rademacher, G. & Luís, R. S. Space-division multiplexing for optical fiber communications. Optica 8, 1186–1203, DOI: 10.1364/OPTICA.427631 (2021).

[2] Winzer, P. J. & Neilson, D. T. From scaling disparities to integrated parallelism: A decathlon for a decade. J. Light. Technol. 35, 1099–1115 (2017).

[3] Marom, D. M. & Blau, M. Switching solutions for wdm-sdm optical networks. IEEE Commun. Mag. 53, 60–68, DOI: 10.1109/MCOM.2015.7045392 (2015)

Pablo Solano – Universidad de Concepción
Invited speaker

Optomechanical feedback cooling of a 5 mm long torsional mode

P. Solano[a,b], D. Su[c,d], Y. Jiang[c,d], J.D. Wack[e], L. A. Orozco[e], J. Lawall[f], Y. Zhao[c,d]

[a] Departamento de Física, Facultad de Ciencias Físicas y Matemáticas, Universidad de Concepción, Concepción, Chile.
[b] CIFAR Azrieli Global Scholars program, CIFAR, Toronto, Canada.
[c] State Key Laboratory of Quantum Optics and Quantum Optics Devices, Institute of Laser Spectroscopy, Shanxi University, Taiyuan, People's Republic of China.
[d] Collaborative Innovation Center of Extreme Optics, Shanxi University, Taiyuan, People's Republic of China.
[e] Joint Quantum Institute, Department of Physics, University of Maryland, College Park, MD, USA.
[f] National Institute of Starndards and Technology, Gaithersburg MD, USA.

Optomechanics, the study of how light interfaces with mechanical motion, has recently witnessed remarkable progress toward metrology and testing the foundations of physics [1]. A striking facet of optomechanics is its ability to cool mechanical systems using purely optical techniques. This talk introduces a novel optomechanical platform that exploits angular momentum exchange between light's spin and mechanical torsion in mesoscopic objects [2,3]. Specifically, we achieve optical feedback cooling of the fundamental torsional mode in a 5 mm long optical nanofiber [4].

Harnessing the nanofiber's intrinsic birefringence, we establish a coupling mechanism between its rotation and the polarization of guided laser fields. Real-time monitoring of microradian-scale rotations using a weak laser probe serves as feedback for an auxiliary driving laser, enabling cooling of the torsional mode by three orders of magnitude (~320 mK) within a cavityless system. Our analysis delves into the characterization of cooling effects in both frequency and time domains. We explore the prospective applications of this platform, envisioning its role as a high-precision torque sensor. We outline a vision for advancing quantum metrology and precision control by combining cryogenic and optical feedback cooling techniques.

[1] M. Aspelmeyer, T. J. Kippenberg, and F. Marquardt, "*Cavity optomechanics*," Rev. Mod. Phys. 86, 1391–1452 (2014).
[2] E. F. Fenton, A. Khan, P. Solano, L. A. Orozco, and F. K. Fatemi, "*Spin-optomechanical coupling between light and a nanofiber torsional mode*," Opt. Lett. 43, 1534–1537 (2018).
[3] D. Su, P. Solano, J. D. Wack, L. A. Orozco, and Y. Zhao, "*Torsional optomechanical cooling of a nanofiber*," Photon. Res. 10, 601–609 (2022)
[4] D. Su, Y. Jiang, P. Solano, L.A. Orozco, J. Lawall, Y. Zhao, "*Optomechanical feedback cooling of a 5 mm-long torsional mode*" arXiv:2301.10554 (2023)

Andrés Seguel – Universidad de los Andes

Contributed

Effectiveness of Spatial Diversity in Free-Space Quantum Communications

Andrés Seguel, Jaime Anguita

Universidad de los Andes
Millenium Institute for Research in Optics

Spatial diversity is a technique widely used in wireless communications to enhance the signal quality at the receiver. We make use of this technique to evaluate its effectiveness in reducing photon losses in a free-space quantum communication link. The system comprises a single receiver and two transmitters with different optical paths to exploit the random nature of atmospheric turbulence. Each transmitter consists of two collinear optical signals: a classic signal used to measure turbulence and a quantum signal. The latter is transmitted through the transmitter that is least distorted by turbulence at that moment. We present the experimental system design and the preliminary results obtained.

Adrián Rubio– Universidad de Santiago de Chile
Contributed

Casimir nanoparticle levitation in vacuum with broadband perfect magnetic conductor metamaterials

Adrián E. Rubio López [a], Vincenzo Giannini [b,c,d]

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[b] Technology Innovation Institute, P.O. Box 9639, Building B04C, Masdar City, Abu Dhabi, United Arab Emirates
[c] Instituto de Estructura de la Materia (IEM-CSIC), Consejo Superior de Investigaciones Científicas, Serrano 121, 28006 Madrid, Spain
[d] Centre of Excellence ENSEMBLE3 Sp.zo.o., Wolczynska Str. 133, 01-919, Warsaw, Poland

In this talk, first I will briefly introduce the basic physics of Casimir forces. Then, I will present a recent proposal to implement these forces for nanoparticle levitation[1]. The levitation of nanoparticles is essential in various branches of research. Casimir forces are natural candidates to tackle it but the lack of broadband metamaterials precluded repulsive forces in vacuum. We show sub-micron nanoparticle levitation in vacuum only based on the design of a broadband metamaterial perfect magnetic conductor surface, where the Casimir force is mostly given by the (quantum) zero-point contribution and compensates the nanoparticle's weight. In the harmonic regime, the volume-independent characteristic frequency depends linearly on Planck's constant $\hbar$.

[1] Adrian E. Rubio López, and Vincenzo Giannini, arXiv: 2210.12094.

Carlos Pirela– Universidad de los Andes
Contributed

Experimental results of atmospheric turbulence strength through scintillation and beam dance in the focal plane

To successfully establish a wireless laser-based communication link, correct alignment and detection between the transmission and reception systems is essential. However, due to distortions caused by atmospheric turbulence -induced, in turn, by inhomogeneities, changes in temperature and pressure- the quality of the propagated beam is greatly reduced. Effects such as intensity profile fragmentation, scintillation, and beam displacement continue to be some of the great difficulties that free space optical communications must face. In this sense, measurements of the atmospheric turbulence strength present in a given instance can be useful to estimate the quality of the results or corrective capacity of an adaptive system. Experimental measurements were made with a freely propagated beam for an effective distance of 1km after which fluctuations in the intensity of the received beam were analyzed (that is, the scintillation), together with a record of the beam's displacement in the focal plane (the beam dance). Measurements allowed the calculation of the parameter Cn2, used as a reference for the strength of atmospheric turbulence. Results showed that if turbulence strength is in the medium range, both methods of estimation lead to similar results, however there exists significant differences between them up to 2 orders of magnitude; a possible explanation is the fact that angle-of-arrival displacements are more sensitive to turbulent effects than those related to the scintillation index. Further conclusions and future improvements are presented.

Daniel Concha – Universidad de Concepción
Contributed

Adaptive Measurements in Quantum Information

D. Concha[1], F. Quinteros[1], A. Guerra[1], A. Delgado[1], E. Sepúlveda[1]

1. Instituto Milenio de Investigación en Óptica y Departamento de Física, Universidad de Concepción, casilla 160-C, Concepción, Chile

In this work, we study the problem of variational parametric measurements, with applications in different areas of quantum information. For instance, these adaptive measurements can be used to discriminate unknown non-orthogonal quantum states [1], provided a training step is implemented. We show the training method in the case of minimum-error discrimination strategy and show that it achieves error probabilities very close to the optimal one, with a similar result for larger number of states in higher dimensions. We also study the feasibility of using these adaptive measurements to implement measurement-induced evolution of states and other applications, including their potential implementation in the laboratory.

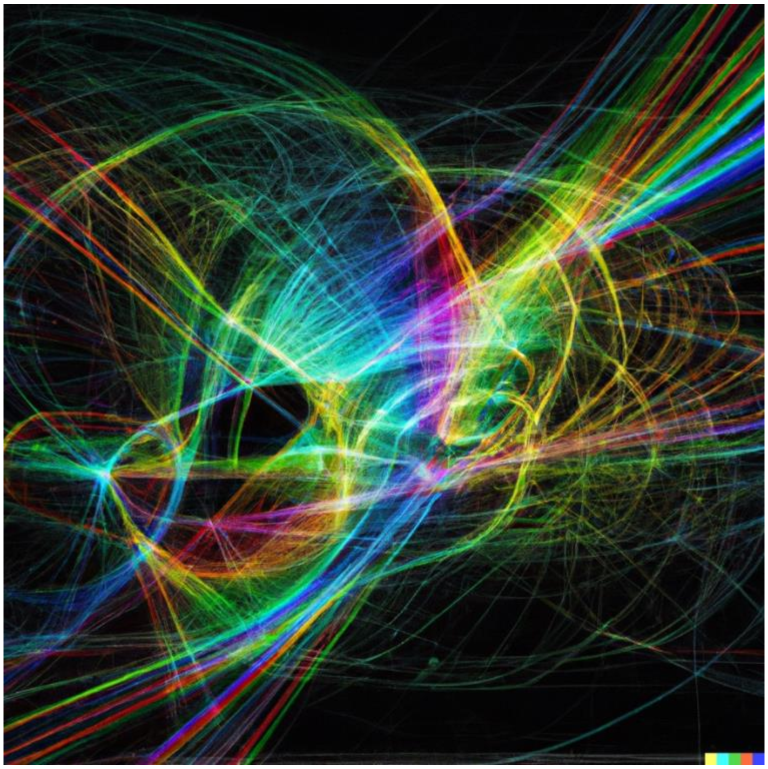

Figure 1. "Artist's rendition" of quantum entanglement made with generative AI

[1] D. Concha, L. Pereira, L. Zambrano, A. Delgado, Training a quantum measurement device to discriminate unknown non-orthogonal quantum states. Sci Rep 13, 7460 (2023).

Santiago Rojas – Universidad de Concepción
Contributed

Using Noise to Protect Information in Multicore Optical Fibers

Santiago Rojas-Rojas[a,b], Daniel Martínez[a,b,c], Kei Sawada[a,b], Luciano Pereira[d], Stephen P. Walborn[a,b], Esteban S. Gómez[a,b], Nadja K. Bernardes[e], Gustavo Lima[a,b]

[a] Departamento de Física, Universidad de Concepción

[b] Millennium Institute for Research in Optics

[c] Departamento de Física, Universidad del Bío-Bío

[d] Instituto de Física Fundamental IFF-CSIC [e]Departamento de Física, Universidade Federal de Pernambuco

The transmission of a quantum state in real-world scenarios is bounded by environmental noise, so that the quantum channel is an open quantum system. We study a high dimensional non-Markovian open quantum system in a multi-core optical fiber by characterizing the environmental interaction as quantum operations, which here correspond to phase flips between pairs of computational basis states. The experimental platform is currently state-of-the-art for space division multiplexing optical fiber communication, which can serve as a robust channel for high-dimensional quantum communication. To test the channel, we perform a quantum communication task in the prepare-and-measure scenario. The non-Markovian nature of the system is demonstrated by implementing a Quantum Vault protocol [1]. A better understanding of the phase noise in multi-core fibers could improve the stability and quality of several real-world communication protocols since they are a prime candidate to increase the telecom data transmission rate worldwide.

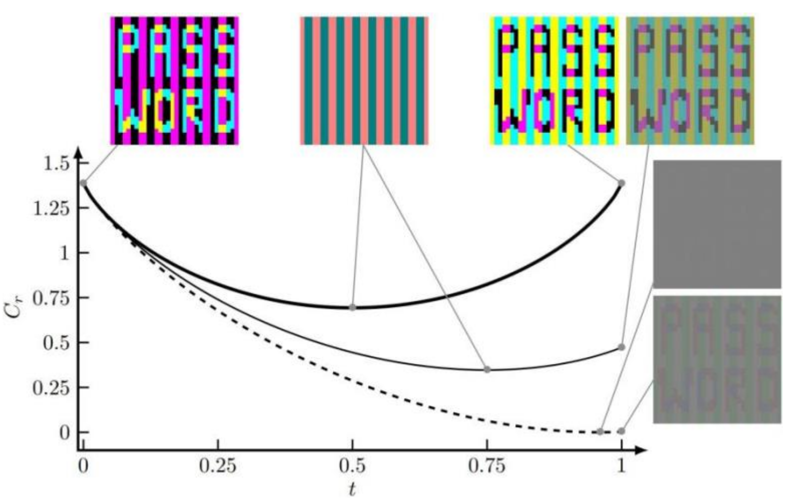

Figure 1. The non-Markovian nature of our map is reflected in a non-monotonic behavior of the channel capacities (black curves). The corresponding decay in distinguishability allow us to hide a message and recover it at the end of the evolution.

[1] C. Pineda et. al, Phys. Rev. A 93, 022117 (2016)

Nelly Cerpa – Universidad de los Andes

Contributed

Adaptive Optics optimal control and applications for horizontal beam transmission

Nelly Cerpa-Urra[ab]

[a] Universidad de los Andes

[b] Millenium Institute for Research in Optics (MIRO)

Spreading of the beam spot due to optical turbulence produces further power losses than diffraction alone, and both temporal and spatial fluctuations may lead to unacceptable fade levels. This is the same atmospheric turbulence that limits astronomical seeing where Adaptive Optics (AO) was born to compensate for the phase deformations. The integrator is the most common controller today in AO [1]. On the other hand, the linear Quadratic Gaussian (LQG) controller is a predictive controller based on a model of the AO system and the turbulent phase. It is obtained as the regulator that minimizes the residual phase variance for a given turbulent phase model ([2],[3]). The LQG controller has been implemented in two AO systems for astronomy for a single system [5] and a cascade system [6], showing performance improvements. However, for free space optics communications, the work is still ongoing [7], and laboratory corroborations and further simulations are still necessary. In this presentation, we show the results of using an LQG controller on double-stages cascade AO systems and how they are applied. We will also introduce the main challenges and how we can apply optimally controlled AO system for long-range wireless laser communication links to improve the overall robustness of the system and evaluate the implications of using different control AO schemes applied to FSO communication systems.

[1] Rousset, G. et al. (Apr. 1990). "First diffraction-limited astronomical images with adaptive optics". In: aap 230.2, pp. 129-132.

[2] Kulcsar, Caroline, Henri-Frangois Raynaud, Cyril Petit, Jean-Marc Conan, and Patrick Viaris de Lesegno (Aug. 2006). "Optimal control, observers and integrators in adaptive optics". In: Optics Express 14.17, p. 7464. DOI: 10.1364/0E.14.007464.

[3] Le Roux, Brice et al. (July 2004). "Optimal control law for classical and multi conjugate adaptive optics". en. In: Journal of the Optical Society of America A 21. 7, p. 1261. ISSN: 1084-7529, 1520-8532. DOI: 10. 1364/ JOSAA. 21. 001261.

[4] Petit, C et al. (2014). "SPHERE eXtreme AO control scheme: final performance assessment and on sky validation of the first auto-tuned LQG based operational system". In: Adaptive Optics Systems IV. Vol. 9148. International Society for Optics and Photonics, 914800.

[5] Cerpa-Urra, Nelly et al. (Jan. 2022). "Cascade adaptive optics: contrast performance analysis of a two-stage controller by numerical simulations". In: Journal of Astronomical Telescopes, Instruments, and Systems 8, 019001, p. 019001. DOI: 10.1117/1.JATIS.8.1 019001

[6] LiZhaokun and ZhaoXiaohui (June 2016). "Kalman Filter Based Optimal Controllers in Free Space Optics Communication". In: Journal of the Optical Society of Korea 20.3, pp. 368-38

Leonardo Vivas – Universidad de Santiago de Chile
Contributed

Dependence of graphene oxide (GO) concentration on the increase in dielectric losses on low-cost, biodegradable conductive gels

[a b] Leonardo Vivas , [a b] Giovani Marín , [a] Fernanda Jiménez, [a b] Dinesh Pratap Singh

[a] Department of Physics, Universidad de Santiago de Chile, , Santiago, Chile
[b] Millennium Institute for Research in Optics, Chile

The combination of optical and electrical properties that characterize conducting polymers makes relevant the role they play in light generation and control, and their use in the fabrication of optoelectronic devices, for example, as active materials in OLED displays and organic solar panels. Conductive polymers, such as optical couplings and/or waveguides, are also used in optical devices to improve the performance and efficiency of light transmission. In this study, we present low-cost and biodegradable PEDOT/agar-agar/GO-based conducting polymers. We electrically characterized these polymers by dielectric spectroscopy to study their dielectric loss behavior as a function of GO concentration. As the GO concentration increased, the dielectric loss increased significantly. We also found that the relaxation time required for polarization decreased as the GO concentration increased and gradually with temperature at all GO concentrations. This opens a gap in the use of agar as a possible candidate for optoelectronic devices.

Paulina Hidalgo – Universidad de Concepción
Invited speaker

Mesophases on demand: a variety of mesophases and transfer of chirality from discrete heterocycle molecules to liquid crystal mixtures

Paulina I. Hidalgo[a], Jorge Vergara[a], Mauricio J. Morel[b], Marcel Clerc[c]
[a] Facultad de Ciencias Químicas, Universidad de Concepción, Chile.
[b] Facultad de Ciencias Naturales, Universidad de Atacama, Copiapó, Chile.
[c] Departamento de Física and Millennium Institute for Research in Optic, FCFM, Universidad de Chile, Santiago, Chile.

The design and manufacture of molecular materials combine the versatility of chemical synthesis with the information of the materials obtained through condensed matter. These molecular materials result from the union of molecules or molecular blocks that have different properties, which depend exclusively on the individual characteristics of the molecules. Liquid crystals are a prime example of molecular materials, exhibiting properties such as selective reflection of light, anisotropy in optical, electrical, and magnetic properties, and the fluidity of liquids. An appropriate combination of these properties allows the obtaining of multifunctional materials [1]. The challenge lies in achieving these properties at room temperature, which can be addressed by using mixtures. Additionally, introducing chirality into liquid crystals can result in interesting phase properties [2]. In this work, the effect of structural in a series of chiral compounds used as chirality transfer agents in a commercial mixture was studied. The mesomorphic properties, including transition temperatures and the type of mesophase, were modified by varying the percentage of the chiral dopant in the mixtures. These properties were studied by polarized light optical microscopy (POM) and Differential Scanning Calorimetry (DSC)). The structure of the compounds was authenticated by FT-IR and 1H/13C NMR and the photophysical properties were studied using UV-Vis.

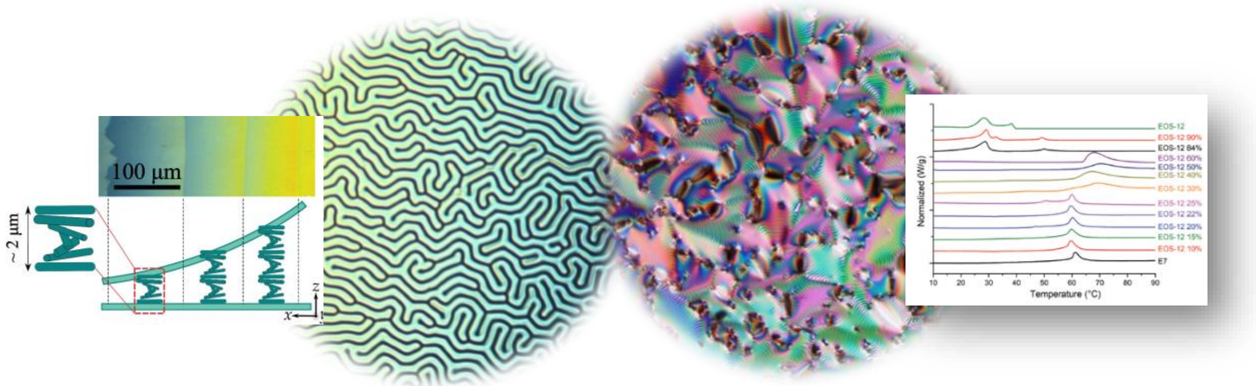

Figure 1. Left: Characterisation of the cholesteric pitch by Grandjean-Cano method; center: micrograph of typical textures of the N*. Right: Differential Scanning for the mixtures

[1] Yang DK, Wu ST. Fundamentals of liquid crystal devices.New York: Wiley; 2006. doi: 10.1002/0470032030
[2] Fitas J, Marzec M, Szymkowiak M, et al. Phase Transit. 2018;91(9–10):1017–1026. doi: 10.1080/01411594.

Mauricio Arias – Universidad de Concepción
Contributed

Coherent anharmonicity transfer from matter to THz nanoresonators

Mauricio Arias [a], Johan F. Triana [b], Aldo Delgado [a,d], Felipe Herrera [c,d]

[a] Departamento de Física, Universidad de Concepción, Concepción
[b] Departamento de Física, Universidad Católica del Norte, Antofagasta
[c] Department of Physics, Universidad de Santiago de Chile, Av. Victor Jara, 3493 Santiago
[d] ANID-Millennium Institute for Research in Optics, Concepción, Chile

In this talk I want to show the latest advances in the characterization of the nonlinear phase [1] that is transferred from a N=2 anharmonic Multi-Quantum Well (MQW) to the near field of a single mode mid-IR cavity in weak coupling. In particular, if the light-matter system presents a high decay offset between a wide cavity and narrow dipole bandwidth, we can approximate an insightful analytic expression for the nonlinear dipole coherence in amplitude and phase, that can be used to analyze the nonlinear phase response of the coupled system. We also explore the case where the individual parameters from each Quantum Well (QW) are different, which breaks the permutation symmetry, generating coherent and incoherent coupling between the single dark mode with the bright one. This changes the phase response in an observable way by increasing the phase rotation of the coherences with respect to the homogeneous case of two identical QW oscillators.

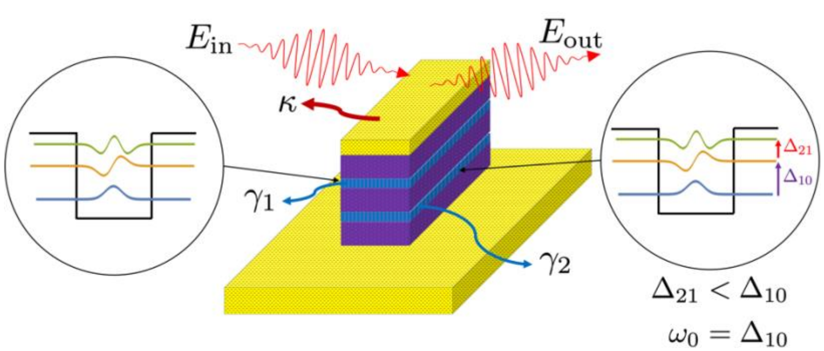

Figure 1. Prototypical design of a N=2 MQW, where each quantum well supports at least three anharmonics subbands in the mid-IR spectrum and allows for tailored material and optical parameters individually. Following the example of the experiments due by Belkin *et al* [2], this heterostructure has a metallic nanoantenna at top, which is driven by short laser pulses that are scattered and measured to infer the dynamic of the light-matter system in real time with femto-second time resolution [3].

[1] Johan F. Triana, Mauricio Arias; Jun Nishida, Eric A. Muller, Roland Wilcken, Samuel C. Johnson, Aldo Delgado, Markus B. Raschke, Felipe Herrera, "Semi-empirical quantum optics for mid-infrared molecular nanophotonics," *J. Chem. Phys*. 156, 124110 (2022)
[2] S. A. Mann, N. Nookala, S. C. Johnson, M. Cotrufo, A. Mekawy, J. F. Klem, I. Brener, M. B. Raschke, A. Alù, and M. A. Belkin, "Ultrafast optical switching"

David Pinto – Universidad de Chile
Contributed

Dynamics in a liquid crystal light valve with translational feedback

David Pinto Ramos[a]

[a] Universidad de Chile

Liquid crystal light valves allow us to analyze the spatial instabilities emerging from the light-matter interaction. An optical feedback loop enables the study of nearly-instantaneous nonlocal interactions among the liquid crystal reorientation field [1]. We speak of translational feedback for a translated input (to the feedback) with respect to the optical axis. The naturally arising patterns are subject to different instabilities, such as convective instabilities, dislocation dynamics, and even turbulent behavior. We present a model developed to describe the liquid crystal reorientation in our operating conditions. Numerical simulations of the model are carried out, showing excellent agreement. In particular, focus is made on the dynamics of pattern dislocations induced by translational feedback.

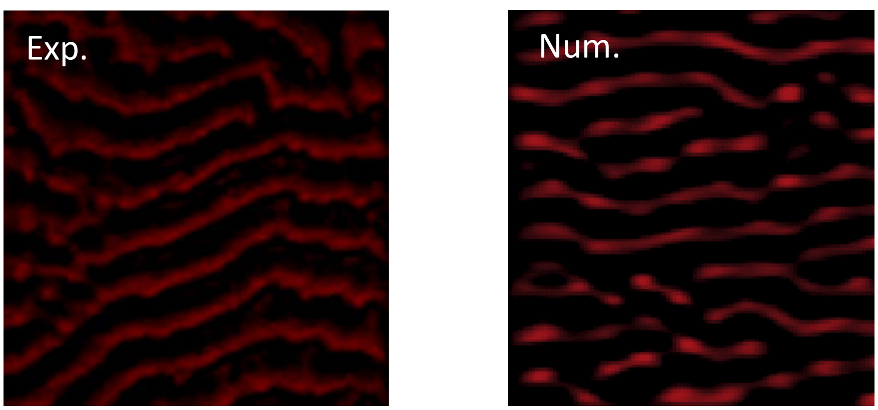

Figure 1. Snapshot of a reminiscent dynamical behavior observed in the experiment, then reproduced in the numerical simulations of the model for the liquid crystal orientation.

[1]: Residori, S. (2005). Patterns, fronts and structures in a liquid-crystal-light-valve with optical feedback. *Physics Reports*, *416*(5-6), 201-272.

Daniel Uzcátegui – Universidad de Concepción
Contributed

Optimal estimation of high-dimensional unitary transformations

J. Escandón-Monardes[12], D. Uzcátegui[12], M. Rivera-Tapia[12], S. Walborn[12] and A. Delgado[12]

[1]Departamento de Física, Universidad de Concepción
[2] Millennium Institute for research in Optics

We propose an estimation procedure for d-dimensional unitary transformations under prior in- formation. For $d > 2$, the unitary transformations close to the identity are estimated reaching the quantum Cramér-Rao limit. For $d = 2$, the estimate of all unitary transformations saturates the quantum Cramér-Rao limit. We show through numerical simulations that, even in the absence of prior information, two-dimensional unitary transformations can be estimated with greater precision than by means of quantum process tomography.

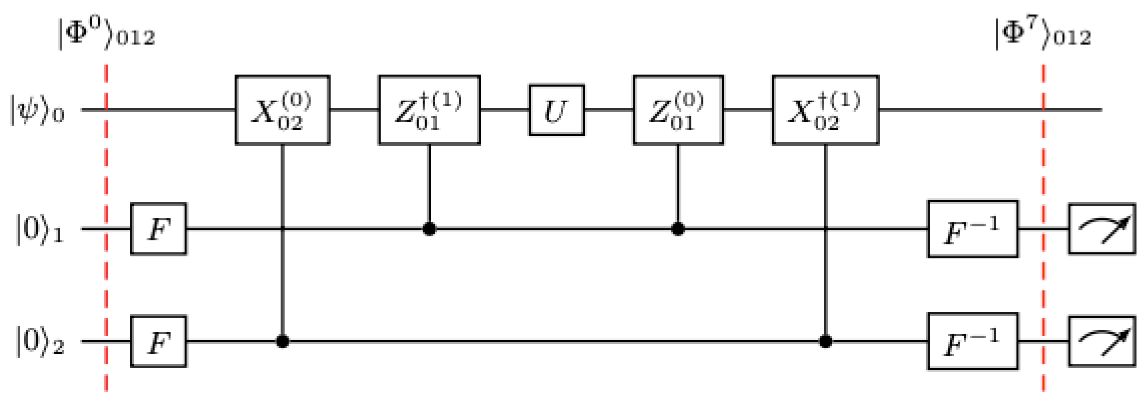

Figure 1. Quantum circuit implementation of the estimation procedure. F are d- dimensional Fourier transforms acting on control qudits 1 and 2, $X^{(\$)}$ and $Z^{(\$)}$ are controlled gates and U is the unitary transformation to be estimated.

Fabián Ramírez – Universidad de Chile
Contributed

Generation of TMSS via FWM in ^{85}Rb vapor

Fabián Ramírez[a,b], Diego Guzmán[a,b] , Carla Hermann[a,b]

[a] Depto. de Física, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile
[b] Millenium Institute for Research in Optics, MIRO

The light has been studied for a long time and has been demonstrated its quantum nature, and the amplitude and the pase of the EM-fiels, called the quadratures, are constrainted to satisfy the Heinsenberg uncertainty principle. The squeezed states of light are nonclassical states of the EM field in that its quadratures can overcome the shot noise by reducing the uncertainty of one of its quadratures at the cost of increasing the uncertainty in the other one.

The FWM is a nonlinear interaction between four modes of the field, in which a pump beam (high power) and a probe beam (low power) interact in an atomic medium, in our case rubidium vapor, and creates a new “conjugate” beam. The probe and the conjugate are correlated and exhibit a two-mode squeezed state (TMSS) [1][2].

In this talk I will explain how we stimulate the necessary transitions following a double-Λ scheme in the rubidium, taking into account its hyperfine splitting of the lowest energy level, as we can see in fig. 1.

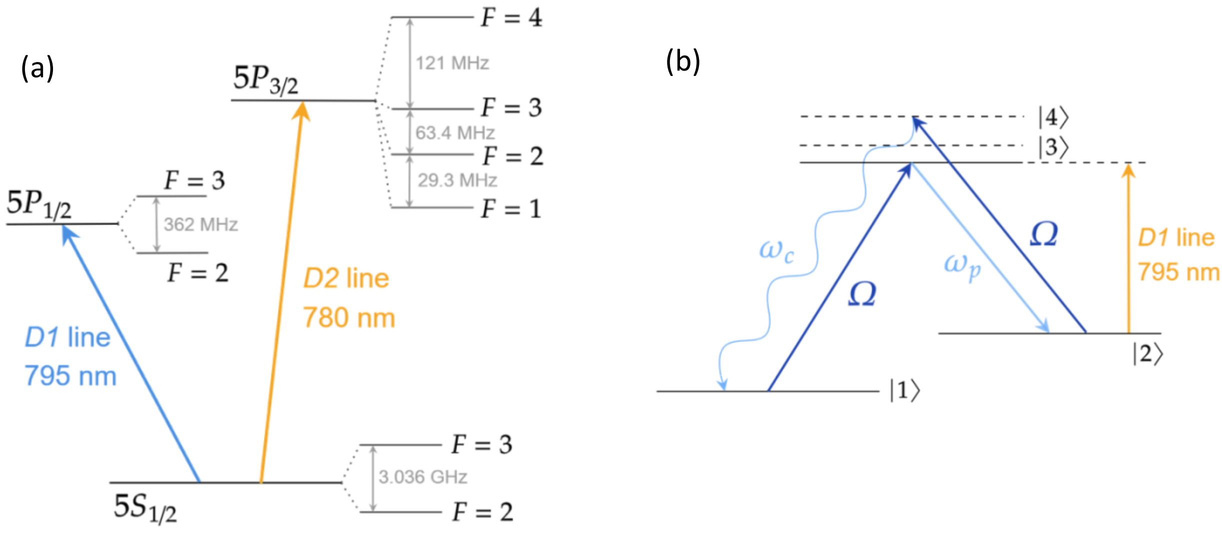

Figure 1. (a) Hyperfine structure of the lowets energy levels of ^{85}Rb. (b) Transitions following the double-Λ scheme.

[1] McCormick et al. (2006). Strong relative intensity squeezing by four-wave mixing in rubidium vapor. In Optics Letters (Vol. 32, Issue 2, p. 178). The Optical Society.
[2] Wu, M.-C. et al. (2019). Twin-beam intensity-difference squeezing below 10 Hz. In Optics Express (Vol. 27, Issue 4, p. 4769). The Optical Society.

Ítalo Machuca – Universidad de Concepción

Contributed

Multi-dimensional entanglement generation with multi-core optical fibers

E.S. Gómez,[1,2] S Gómez, [1,2] I. Machuca, [1,2] A. Cabello,[3,4] S. Pádua,[5] S. P. Walborn [1,2] and G. Lima[1,2]

[1] Departamento de Física, Universidad de Concepción

[2] Millennium Institute for research in Optics

[3] Departamento de Física Aplicada II, Universidad de Sevilla

[4] Instituto Carlos I de Física Teórica y Computacional, Universidad de Sevilla

[5] Departamento de Física, Universidad Federal de Minas Gerais, Belo Horizonte

Trends in photonic quantum information follow closely the technical progress in classical optics and telecommunications. In this regard, advances in multiplexing optical communications channels have also been pursued for the generation of multi-dimensional quantum states (qudits), since their use is advantageous for several quantum information tasks. One current path leading in this direction is through the use of space-division multiplexing multi-core optical fibers, which provides a new platform for efficiently controlling path-encoded qudit states. Here we report on a parametric down-conversion source of entangled qudits that is fully based on (and therefore compatible with) state-of- the-art multi-core fiber technology. The source design uses modern multi-core fiber beam splitters to prepare the pump laser beam as well as measure the generated entangled state, achieving high spectral brightness while providing a stable architecture. In addition, it can be readily used with any core geometry, which is crucial since widespread standards for multi-core fibers in telecommunications have yet to be established. Our source represents an important step towards the compatibility of quantum communications with the next- generation optical networks [1].

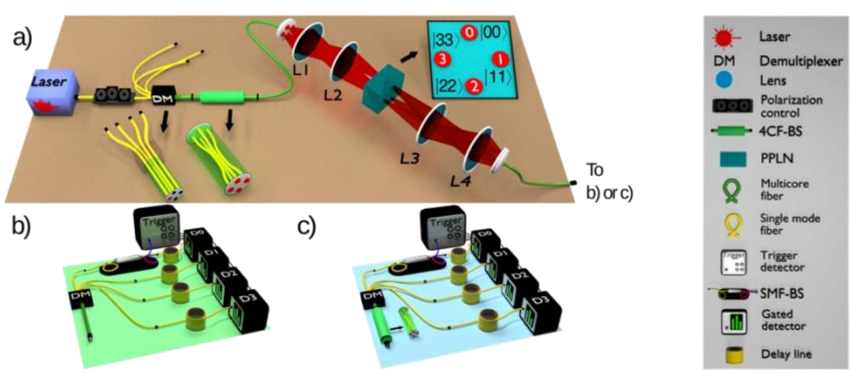

Figure 1. Schematics of the experimental setup.

[1] E. S. Gómez, S. Gómez, Machuca, A. Cabello, S. Pádua,5 S. P. Walborn, and G. Lima, *Multi-dimensional entanglement generation with multi-core optical fiber,* Physical Review A. March 2021.

Stephen Walborn – Universidad de Concepción
Associate researcher

Experimental quantum optics platforms at UdeC

In the interest of scientific collaboration, I'll present some of the experimental platforms available at UdeC, and give brief examples of what can be done with them.

WORKSHOP MIRO 2023

Poster Session

Posters

Awardees

First place

"Optimal estimation of high-dimensional quantum pure states with generalized measurements", by Kei Sawada- Universidad de Concepción.
P. 70

Second place

"Bistable optical system with controllable non-reciprocal coupling", by Manuel Díaz- Universidad de Chile.

P. 61

Third place

"Low-loss broadband multiport optical splitter", by Paloma Vildoso, Universidad de Chile. P. 76

People's choice

"Vector dark dissipative solitons in Kerr resonators", by Bilal Kostet, Université Libre de Bruxelles. P.82

Athul Sambasivan Rema – Universidad de Santiago de Chile

Strong Light-Matter Coupling with Molecules in Plasmonic Nanospheres

Athul S. Rema[a] and Felipe Herrera[a,b]

[a] Department of Physics, Universidad de Santiago de Chile, Av. Victor Jara 3493, Santiago, Chile
[b] Millennium Institute for Research in Optics, Chile

Near-resonant molecule-field interactions have attracted significant attention in chemical physics and quantum optics [1,2]. We study the quantum dynamics of a molecular dipole emitter coupled to near-field modes of an optical nanosphere using macroscopic quantum electrodynamics (QED). We use the electromagnetic dyadic Green's tensor of the nanosphere to construct frequency and position dependent interaction Hamiltonians in macroscopic QED that are used to derive and numerically solve the system of non-Markovian integro-differential equations (IDE) that describe the dynamics of molecular and photonic degrees of freedom. The material and dipole parameters are encoded in the structure of the kernel function of the IDE. We solve for photonic and molecular observables for a single dipole emitter in a resonant optical nanocavity and compare the results with recent phenomenological Markovian models developed for molecular polaritons [3], to better understand the reach and limitations of reduced Markovian quantum optics models to describe currently available experiments.

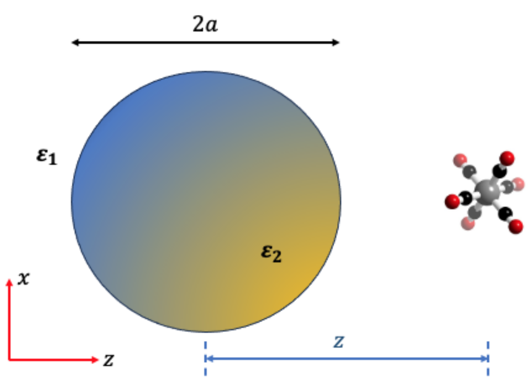

FIG 1: Schematic diagram of the molecular dipole-nanosphere system embedded in a homogeneous background medium.

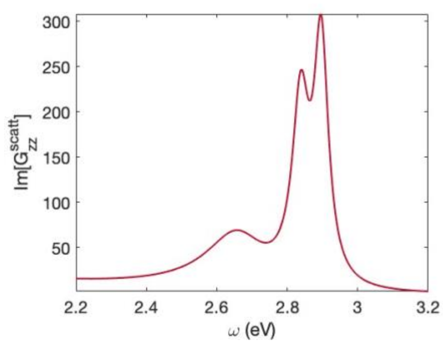

FIG 2: Dependence of Green's dyadic as a function of frequency ω when the dipole is oriented along the z axis.

[1] F. Herrera and J. Owrutsky, J. Chem. Phys. 152, 100902 (2020)
[2] T. W. Ebbesen, Acc. Chem. Res. 49, 11, 2403–2412, (2016)
[3] J. Triana, M. Arias, J. Nishida, E. Muller, R. Wilcken, S. C. Johnson, A. Delgado, M. B. Raschke, F. Herrera, Semi-empirical quantum optics for mid-infrared molecular nanophotonics, J. Chem. Phys. 156, 124110, 2022.

Belén Hidalgo Ogalde – Universidad de Chile

Patrones horizontales y oblicuos en sistemas anisótropos fuera del equilibrio

Belén Hidalgo-Ogalde[a], David Pinto-Ramos[a] , Marcel Clerc[a]

[a] Departamento de Física and Millennium Institute for Research in Optics, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile

Los patrones existen en diversos contextos, en la naturaleza los observamos en las rayas de las cebras, dunas e incluso en la vegetación [1]. En el ámbito de la ciencia, los vemos en reacciones químicas reacción-difusión, flujo de Taylor-Coutte, cristales líquidos, entre otros. Dentro de la variedad de patrones, se estudian los rollos horizontales y oblicuos en sistemas fuera de equilibrio anisótropos, como en la auto-organización de plantas en sistemas áridos y semi áridos[2], proponiendo un modelo teórico y aplicado a sistemas ópticos, como una válvula de cristal líquido con sistema de retroinyección (LCLV), estudiando la emergencia de este tipo de patrones, la universalidad de la transición entre un patrón de rayas horizontales y uno con rayas oblicuas.

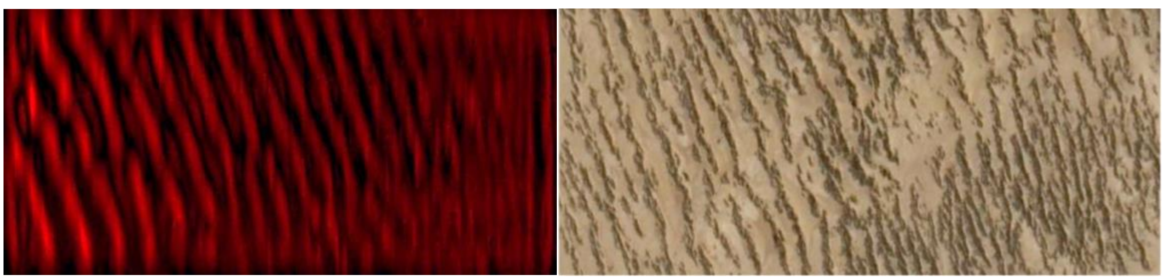

Figure 1. [Patrones oblicuos en distintos contextos. A la derecha patrón formado en LCLV y a mano izquierda, foto satelital de *tillandsia landbeckii* en el norte de Chile]

[1] M. C. Cross, P. C. Hohenberg, Pattern formation outside of equilibrium, Reviews of Modern Physics (1993).
[2] W. Macfadyen, Vegetation patterns in the semi-desert plains of british somaliland. The Geographical Journal (1950).

Martin Bataille González – Universidad de Chile

Isolas of localized structures and Raman-Kerr frequency combs in micro-resonators

M. Tlidi [a], M. Bataille-Gonzalez [b], M. G. Clerc [b], L. Bahloul [c,d], S. Coulibaly [e], B. Kostet [a], C. Castillo-Pinto [f], K. Panajotov [f,g]

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Optical frequency combs, introduced by Hänsch and Hall in the early 2000s, have become a cornerstone in modern optics, boasting remarkable applications in fields spanning from high-precision spectroscopy to photonic analog-to-digital conversion. These combs, consisting of equally spaced coherent laser lines, have been recently generated using dissipative solitons and have been harnessed for a myriad of scientific and technological advancements [1, 2]. This work delves into the theoretical exploration of dissipative solitons and their corresponding frequency comb in micro-resonators with a Kerr nonlinearity, focusing on the Lugiato-Lefever equation and a reduced model, considering the influence of Raman scattering and a fourth-order dispersion term. This study reveals that the traditional snaking bifurcation structure of both bright and dark solitons is broken by the presence of stimulated Raman scattering, giving rise to a plethora of isolated, moving stable solutions [3].

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Sebastián Ayala – Universidad de Concepción

Encoding quantum information using Perfect Vortex Beams of Light

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We prove that perfect vortex beams (PVB)[1] form basis and can be expressed in terms of Laguerre-Gauss(LG)[2] modes and vice versa.

From [1,4,5] we have:

$$\sum_{l=-\infty}^{\infty} \int_0^{2\pi} \int_0^{\infty} PVB_l \cdot PVB_l^* \cdot r dr d\theta = 1 \tag{1}$$

From [2] we have the expression of the LG modes:

$$LG_{lp}(x) = \sqrt{\frac{2}{\pi}} \sqrt{\frac{p!}{(|l|+n)!}} \frac{\exp^{-\frac{ikr^2}{2q(z)}}}{W(z)} \left[\frac{\sqrt{2}r}{W(z)}\right]^{|l|} L_p^{|l|} \left[\frac{2r^2}{W(z)^2}\right] \exp^{i(l\theta+(2p+|l|+1)\zeta(z))} \tag{2}$$

From [3] we can obtain the coefficients of expansion C_{lp} and C_l :

$$C_{lp} = \int_0^{2\pi} \int_0^{\infty} PVB_l \cdot LG_{lp}^* \cdot r dr d\theta \qquad C_l = \int_0^{2\pi} \int_0^{\infty} PVB_l^* \cdot LG_{lp} \cdot r dr d\theta \tag{3}$$

With which we can write:

$$PVB_l = \sum_{p=0}^{\infty} \sum_{l=-\infty}^{\infty} C_{lp} \cdot LG_{lp} \qquad LG_{lp} = \sum_{l=-\infty}^{\infty} \int_0^{\infty} C_l \cdot PVB_l \cdot r dr \tag{4}$$

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Manuel Díaz Zúñiga – Universidad de Chile

Bistable optical system with controllable non-reciprocal coupling

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Reciprocity is a common behavior in many physical systems where interaction symmetry exists. Non-reciprocal systems, by breaking this symmetry, generate a variety of phenomena of great interest, as well as possible technological applications [1]. Based on previous theoretical work on unidirectional propagation over coupled systems [2], we study the non-reciprocal propagation of fronts over a discrete array of coupled structures in a Liquid-Crystal-Light-Valve (LCLV) bistable system with optical feedback [3]. When displacing the optical feedback controllable input ($\alpha\alpha$) of the liquid crystal system, a non-reciprocal behavior was observed on the increase of the average propagation velocity in the direction of displacement. We propose a theoretical model that qualitatively explains very well the non- reciprocal propagation of fronts on periodic structures. Our experimental results are shown below.

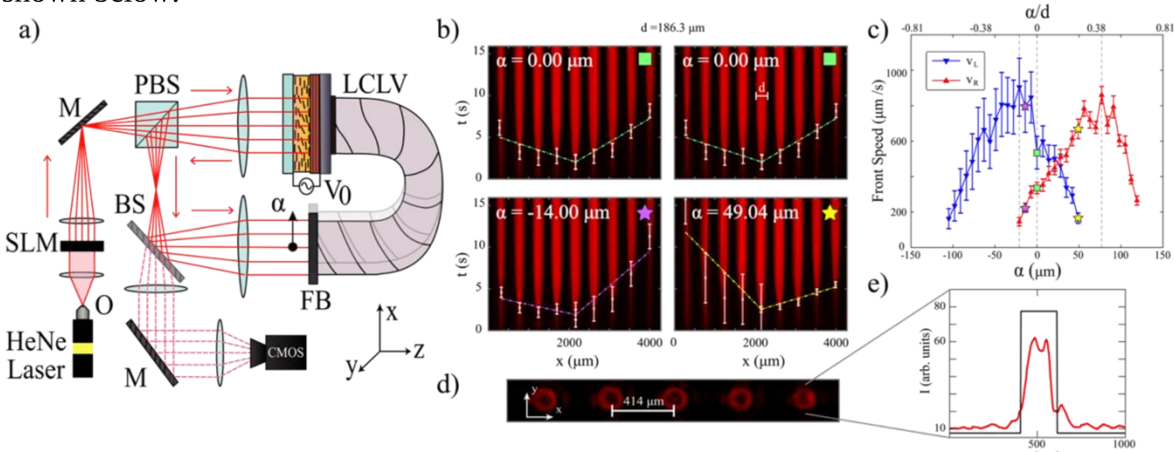

Figure 1. a) Schematical representation of experimental setup. b) Experimental spatiotemporal diagrams of front propagation over a discrete array of coupled structures in the system for different $\alpha\alpha$. c) Average propagation velocity for a displacement sweep of $\alpha\alpha$. d) Experimental snapshot of the discrete array of coupled induced over de LCLV. e) Average intensity profile for one discrete structure induced over LCLV.

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Roberto Gajardo Pizarro – Universidad de Chile

Experimental observation of particles trapped by vortices in a nematic liquid crystal cell

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By the application of an oscillatory electric field onto an homeotropic nematic liquid crystal cell it is possible to induce vortices, which are particle-type defects with topological charge. The dynamics of the vortices is such that topological charge of the system is conserved, so these defects are always induced in pairs that annihilate after a short amount of time[1]. Using a magnetic ring it is possible to induce a stable vortex triplet that allows the study of its dynamics[2], which is of an oscillatory kind when a low-frequency voltage is applied[3]. In this regime it is observed that impurities in the material are trapped by the positive vortex, in a way that particles describe different kind of trajectories around the singularity. Preliminary observations show that the size and shape of the impurities, as well as the intensity and frequency of the applied voltage, are key parameters for understanding the trajectory (ellipse, spiral, etc) that an impurity in the liquid cristal describes.

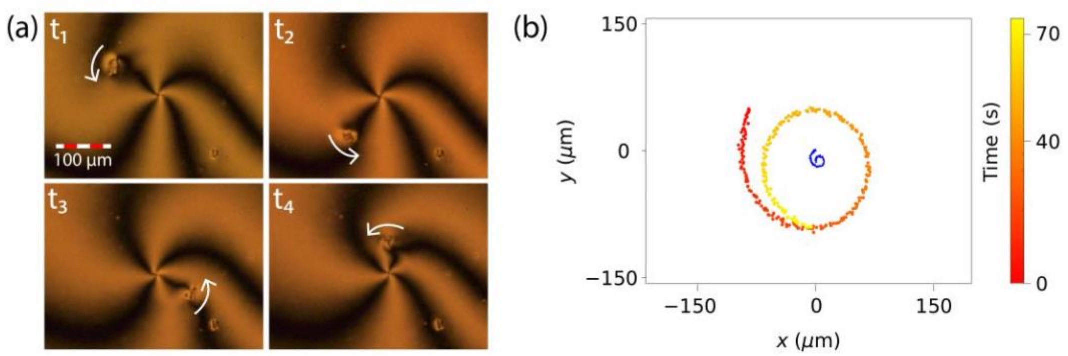

Figure 1. (a) Time sequence of snapshots of an irregular particle (presumably made of glass) describing a trajectory around a positive vortex in a nematic liquid crystal cell (t_1=0 s, t_2=16 s, t_3=32 s, t_4=48 s). It can be seen that a most regular particle (lower right corner) remains still. (b) Trajectory of the particle in the plane of the cell, where the color of each point represent the time at which the particle was in that position. It can be observed that the vortex (blue points) describes a similar trajectory.

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Nematic phase separation in a dye doped Liquid Crystal

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Near to the nematic isotropic transition, the separation of two phases is observed, the evolution, dynamics and interaction is characterized, and compared to a simple nematic Liquid crystal mixture.

Diego Román Cortés – Universidad de Chile

Redes SP unidimensionales basadas en moléculas fotónicas

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El desarrollo de la técnica de escritura por láser de femtosegundos ha revolucionado la fabricación de guías de ondas y redes fotónicas debido a su simplicidad y versatilidad [1]. Sin embargo, la elipticidad vertical propia de las guías de ondas fabricadas con este método es un gran desafío que impide estudiar interacciones más complejas. En este trabajo, utilizamos la técnica de escritura con láser de femtosegundo y estudiamos el efecto de escribir dos guías de ondas muy cercanas, de modo que puedan tratarse como una guía de ondas más ancha efectiva o "molécula fotónica" [2]. Demostramos que se pueden excitar diferentes estados de orden superior [3] dependiendo de la longitud de onda de excitación, y que los dipolos verticales de las guías de ondas individuales ahora se pueden orientar horizontalmente, lo cual tiene consecuencias muy importantes al estudiar la dinámica de la red en configuraciones no triviales. Para demostrar este efecto, fabricamos una red SP alternante unidimensional. Estudiamos la excitación de una onda gaussiana de momento nulo (utilizando un modulador espacial de luz) y observamos máximo transporte energético en la dirección transversal. Esto contrasta fuertemente con las redes 1D estándar en las que la energía tiende a la localización. Además, también encontramos que para una pequeña diferencia de constantes de propagación no nula entre los modos S y P, la red 1D se puede mapear a una red de diamante efectiva [4] que exhibe una banda plana y propiedades topológicas que afectan fuertemente la dinámica esperada de esta red que de otro modo sería trivial.

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Letícia Lira Tacca – Universidad de Concepción

Photonic High-Dimensional Entanglement Sources

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High-dimensional entangled states (qdits) are quantum states that exist in higher-dimensional spaces and offer advantages such as increased information density [1], improved security [2], and better resilience to noise [3]. They play a vital role in various quantum information tasks and are the focus of ongoing research in the field of quantum optics and quantum information. Here, we show some developments on sources of entangled qudits that are fully based on state-of-the-art multicore-fiber (MCF) technology. We use two-photon spontaneous parametric down-conversion (SPDC) source, coupled into single mode fibers, to test two-photon interference. We expect to observe quantum interference in MCF beam splitters. A direct application of this kind of interference is the realization of a Bell-state analyzer for photons propagating in MCF. We expect to realize a robust linear-optics based Bell-state analyzer in high-dimensions (N=4 or larger), which could serve in high-dimensional quantum information protocols such as quantum target detection and quantum key distribution.

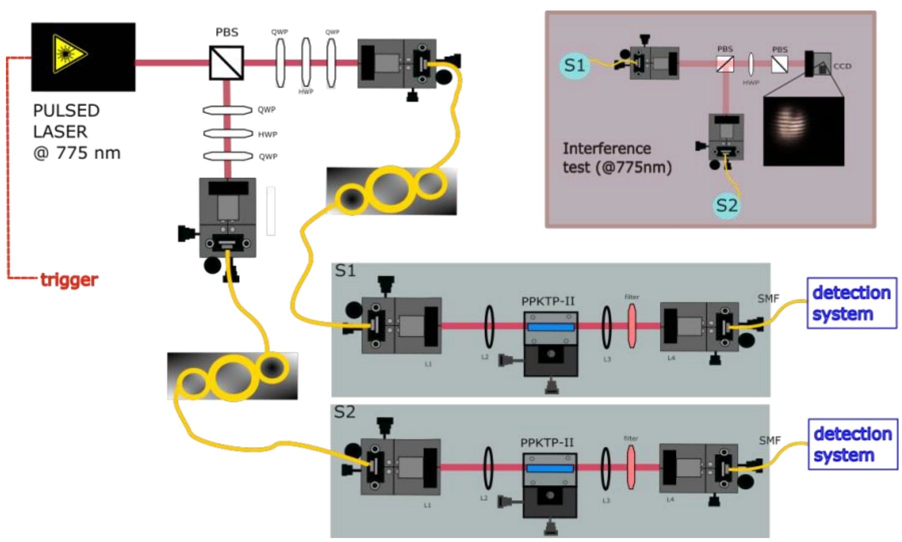

Figure 1. Preliminary experimental set up.

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Diego Guzmán Silva – Universidad de Chile

Generación experimental de luz comprimida: primeros resultados

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El uso de haces comprimidos ha adquirido gran notoriedad debido a la capacidad de mejorar la precisión en la toma de medidas de diversos sistemas. Un gran ejemplo de esto fue la utilización de estos haces para la verificación experimental de las ondas gravitatorias [1]. Es así que en la comunidad de esta área, se ha vuelto relevante tener las habilidades y equipamiento para la obtención de este tipo de haces, que permita obtener investigaciones que tienen tanto una parte teórica como una parte experimental. Es por ello que en nuestro grupo hemos tomado el desafío de generar experimentalmente este tipo de haces, cuestión que (a saber) es primera vez realizado en Chile. Es así, que en este poster, nos centraremos en los detalles experimentales de nuestro setup el cual implementa una técnica llamada *four wave mixing* (FWM) [2], y donde iremos describiendo las distintas etapas para la obtención de este tipo de haces, el cual se puede dividir en tres etapas: generación y caracterización del haz de bombeo y semilla, preparación de una celda de Rubidio 85 e inyección de los haces en esta celda y por último una fase de recolección de datos y lectura de estos. Junto a ello, mostraremos también los primeros resultados experimentales obtenidos a la fecha, los cuales muestran efectivamente la generación de un haz conjugado (debido al proceso de FWM) y las primeras lecturas del parámetro de *squeezing,* los cuales bordean los -2 dBm.

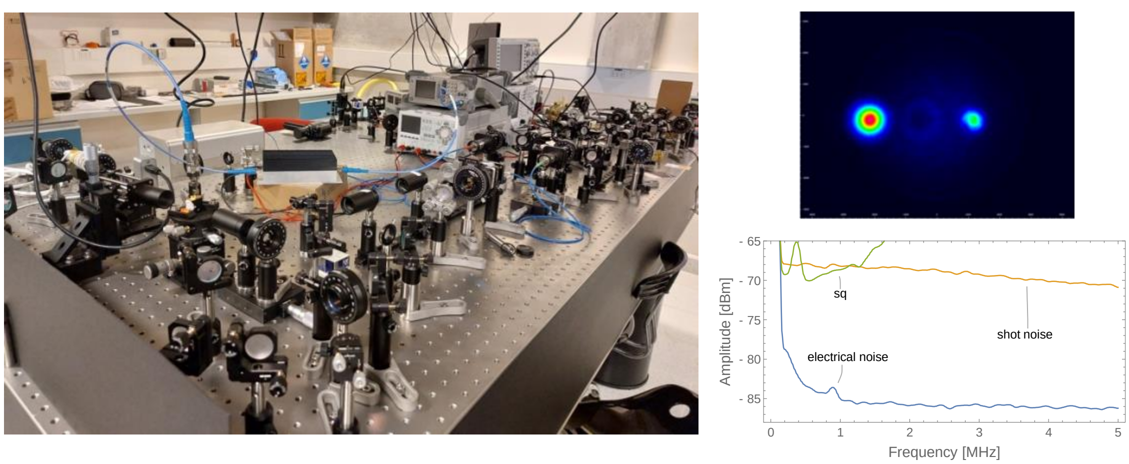

Figura 1. (izq.) Foto del setup experimental. (der. arriba) Imagen experimental del haz de prueba y conjugado generado por FWM. (der. abajo) Amplitud del ruido vs frecuencia para el estado comprimido de 2 haces (sq), el *shot-noise* y el ruido electrónico.

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Francisco Jara Lobo – Universidad de Concepción

Quantum distinguishability between Blackholes and wormholes

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In this work, we apply quantum state discrimination [1] to distinguish between different elements the metric of a black hole and a wormhole. The protocol is the following: we consider particles with inner degrees of freedom (d.o.f) that propagate in a classical background. This classical background is given by a weak-field approximation of the Schwarzschild [2] and Ellis-Thorne [3] metrics (up to second-order corrections in Schwarzschild radius, form function, and gravitational redshift function, which are characteristics functions of a black hole and a wormhole, respectively). Then, for these metrics, we obtain a Schrodinger equation for particles with inner d.o.f. and with relativistic corrections [4]. Such equations show a coupling between the Schwarzschild radius (for a black hole), the gravitational redshift, and the form function (for a worm hole) with the inner d.o.f Hamiltonian. Next, we calculate the propagation in radial coordinates, trace out the center of mass d.o.f and apply quantum channel discrimination to obtain the probability of misidentification between both metrics. We also show how this probability depends on the number of levels of the inner quantum state.

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Osmar Aravena González – Universidad de Santiago de Chile

Spectroscopic Properties of Dielectric Heterostructures using Maxwell-Garnett Effective Medium Theory

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Effective media have shown multiple technological applications in recent times, we show preliminary results for the effective permittivity of a multicomponent medium obtained from an effective medium theory based on the Maxwell-Garnett equation. This theory allows us to analyze its spectroscopic properties under typical normal incidence and dual medium conditions [4]. We explore how the volume fraction of silver inclusions [3] affects the absorption, transmission and reflectivity of a matrix medium made of PMMA [1,2]. We find that by increasing the volume fraction of the silver inclusion there is a monotonic redshift in the reflectance spectrum of the total composite film.

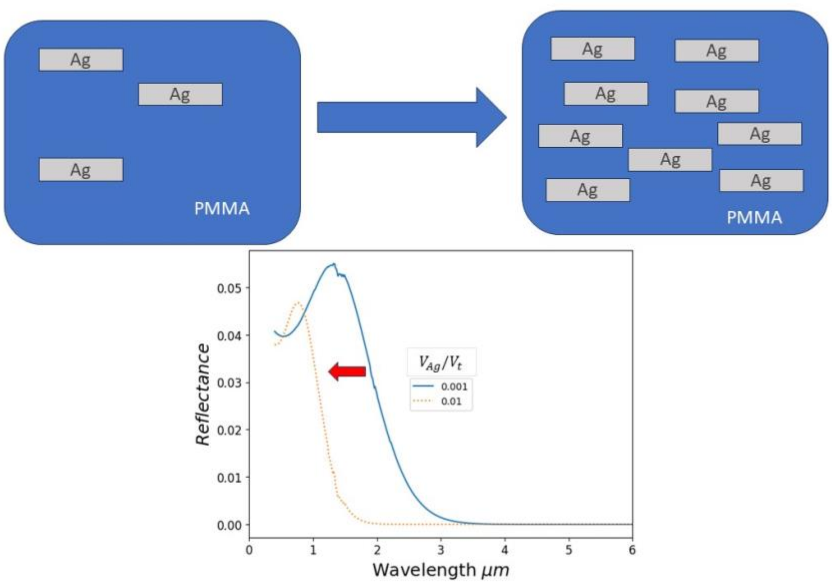

Figure 2: Difference in the peaks of the reflectance for two mediums with different concentrations of silver inclusions nanorods, expressed through the volume fraction, revealing a redshift.

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Carolina Manquián Villalobos – Universidad de Santiago de Chile

Synthesis and Optimization of Nickel-based Metal-Organic Frameworks

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Metal-Organic Frameworks (MOFs) are hybrid materials, that consist of the union of a central metal ion and an organic ligand [1]. They are an active element in energy-related devices, including devices such as rechargeable batteries, supercapacitors, and hybrid SC batteries due to their high surface area, controllable chemical composition, adaptive structure, and their periodic arrangement. However, they are limited by their low electrical conductivity, so, to resolve these limitations, some of their dimensions are reduced to improve their electrical properties [2].

In this work, the synthesis of a nickel MOF (NiMOF) was optimized using a H_2bdt ligand [3], where the effective parameters of the hydrothermal synthesis were modified such as Metal: Ligand molar ratio, agitation, and synthesis temperature. The material was characterized by X-ray diffraction, Raman Spectroscopy, Scanning Electron Microscopy, and UV-vis spectroscopy. Of the synthesized materials, it was achieved that for a ratio of 1:1, by stirring, the synthesis of the NiMOF was optimized, producing a homogeneous sample, without byproducts, and with a rectangular prism nanostructure. The electrochemical properties were studied in a 3-electrode configuration, in a potential window of [-0.4 to 0.55] V at 2M KOH, whereby means of cyclic voltammetry a specific capacitance of 296.46 F/g, 152.19 F/g and 190.74 was obtained. F/g at 5mV/s for the synthesis performed at 100°C, 150°C and 200°C, respectively.

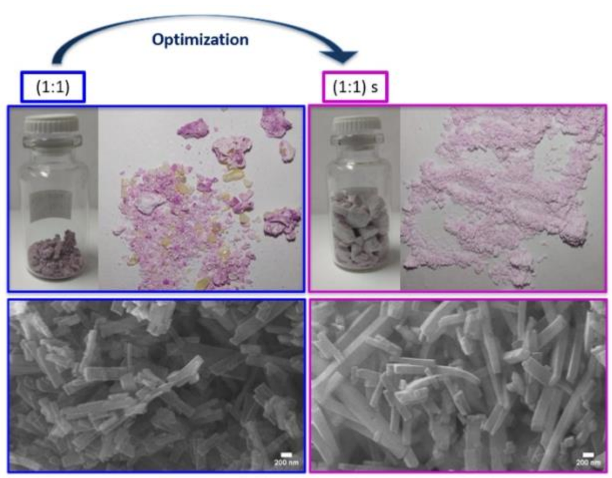

Figure 1. The synthesis was optimized obtaining a homogeneous powder.

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Kei Braz Sawada– Universidad de Concepción

Optimal estimation of high-dimensional quantum pure states with generalized measurements

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High-dimensional quantum states (qudits) are useful for tasks in quantum imaging, computing, metrology, memory, simulation, and cryptography. A practical method to estimate such states is SIC-POVM (symmetric informationally complete positive operator valued measure) tomography, in which every measurement is an informationally complete POVM, allowing the experimenter to characterize the state by measuring repeatedly with the same setting.[1] In order to characterize a d-dimensional qudit, one must embed it into a d^2-dimensional Hilbert space, which becomes difficult as the system dimension grows.[2] Here we present an approximation of SIC-POVM tomography in which we estimate a *4*-dimensional qudit close to a pure state by embedding it into a $2d - 1$-dimensional Hilbert space, providing better scalability as the dimension increases. Our method reaches the Gill-Massar limit and is achieved with an approximated FSM (Fisher-symmetric measurement).[3] We also present its experimental implementation and results, in which the FSM is implemented with a seven-core fiber multiport beam splitter followed by seven single-photon detectors.

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Simón Navia Rafide – Universidad de Chile

One and two dimension spot pattern turbulence

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Macroscopic systems in thermodynamics equilibrium are characterized by exhibiting homogeneous equilibriums that are invariant in time and space, which are controlled by the temperature and chemical potential among other parameters. When these systems are subjected to energy interchange—out of equilibria— they present new equilibria named dissipative structures [1,2]. Nature is full of these types of structures like dunes, skin of mammals and fish, snowflakes, vegetation, mountain waves and cloud patterns. In this type of system, the dynamics become complex and chaotic in time and space, being able to transition to a turbulent state. This turbulence could be understood not only in the context of fluids [3] but also like the path through two bifurcations: A primary, corresponding to Hopf bifurcation y and a secondary that gives way to turbulence, characterized by spatio-temporal chaos. In this study, we present how this turbulence emerges in the context of the spot pattern experiment in one and two dimensions at LCLV (Liquid Crystal Light Valve), giving a characterization of this phenomena through statistical and dynamical analysis. Theoretically, we propose a non variational model to explain the permanent dynamics of the experiment that has been put to the test to verify the validity of this.

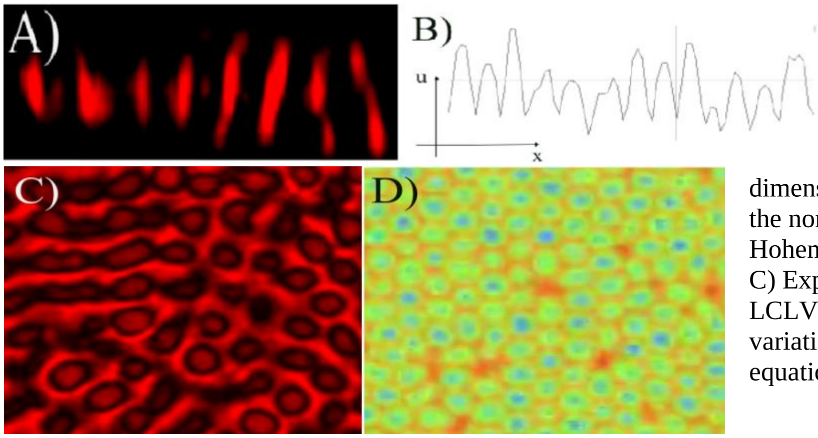

Figure 1. Images from the experiment and simulations. A) Experiment in one dimension at LCLV. B) Simulation of the non variational Turing-Swift-Hohenberg equation in one dimension. C) Experiment in two dimensions at LCLV. D) Simulation of the non variational Turing-Swift-Hohenberg equation in two dimensions.

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Tania Brito – Universidad de Santiago de Chile

Influence of Copper Doping on the Optical Properties of Carbon Quantum Dots (CQDs)

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Carbon quantum dots (CQDs) have attracted great interest among researchers due to their astounding optical properties and facile synthesis methods [1]. CQDs being a zero-dimensional structure and having particle size less than 10 nm, exhibit ideal optical and chemical properties as a luminescent nanomaterial enticing into wide range of applications in energy, catalysis, biological imaging, drug delivery, and environmental monitoring etc. [1-2]. Metallic (Fe, Co, Ni, Cu) and non-metallic (N, P, B) doping enhances photoluminescence and extend the use of CQDs [3]. Since metals are prominent electronic donors, the insertion of metal ions into CQDs (M-CQDs) expands the opportunities of electronic tuning and charge transfer with metal cations. Moreover, it also improves the physicochemical properties, including optical and catalytic [4]. In this work, a new kind of N, Cu doped carbon quantum dots (Cu/N-CQDs) is achieved via a facile one-pot hydrothermal method by using citric acid, copper(I) chloride and ethylenediamine. The effect of Cu doping can be observed in the fluorescent emission spectra with different excitation wavelengths (as shown in Figure) in terms of broadening and red shift of the emission bands of Cu/N-CDs in comparison to N-CDs.

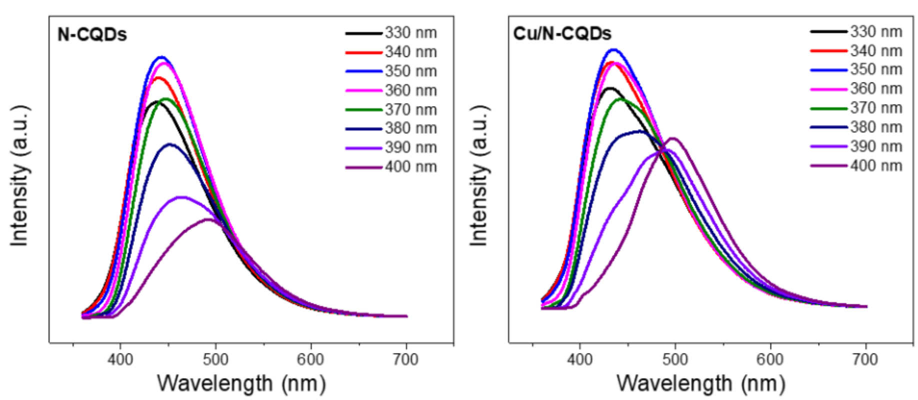

Figure. Fluorescence spectra of N-CDs and Cu/N-CDs excited from 330 to 400 nm.

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Mariano Uria Valencia – Universidad de Concepción

Generación de estados intermedios de la luz

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Es bien conocido que los estados coherentes poseen propiedades similares a campos clásicos y por ello son ampliamente estudiados en el ámbito de la óptica cuántica. Por otra parte existen estados que no tienen ninguna contraparte clásica como los estados de Fock y tienen por tanto un comportamiento altamente no clásico. Es así que se crean estados intermedios entre estados de Fock y estados coherentes, estos estados son llamados photon added coherent states (PACS) [1], por tener la característica de añadir fotones a un estado coherente y que dependiendo del tamaño del estado del sistema pasan de tener características cuánticas a características clásicas, y viceversa.

Es en este contexto que el estudio de estados intermedios es de importancia para entender el rol que cumplen los fotones en el cambio de la estadística de un estado cuántico de la luz y por ello hay tanto propuestas experimentales [2] como teóricas [3] para poder generarlos, sin embargo esto ha demostrado no ser una tarea sencilla. En este trabajo exploramos una manera de generar estos estados con una fidelidad de más de 0.99 usando un método de bombeo clásico de fotones en una cavidad QED.

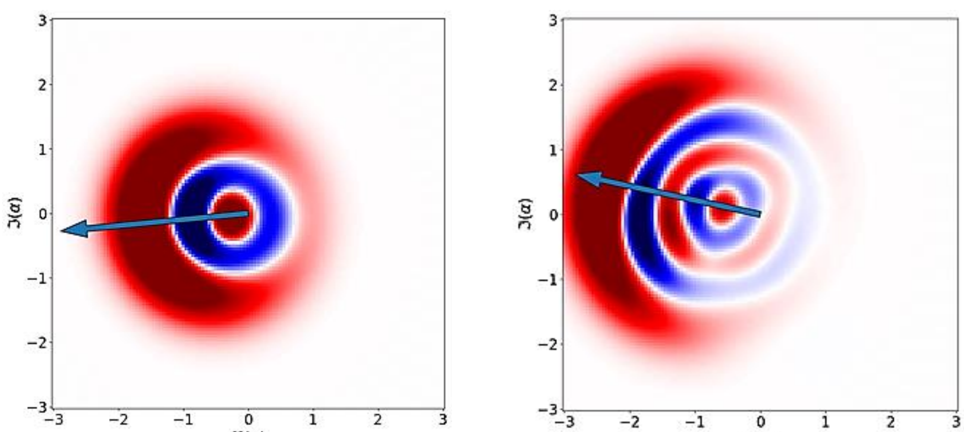

Figura 1. Funciones de Wigner de PACS con dos y cuatro fotones añadidos, generados a partir de un bombeo clásico de fotones.

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Adheris Contreras Palma – Universidad de Concepción

Characterization of a beam splitter with interference of two photons

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The implementation of quantum technologies requieres the ability to perform NxN unitary transformations. These NxN unitaries can be implemented with a beam splitter, and estimating this matrix is a key task. A characterization method will be implemented to determine the unitary matrix for 4x4 multicore-beam-splitters (MBS), with the advantage of it being independent of the input and output phases. The real and imaginary parts of this matrix are determined entirely by photon detector count statistics. The amplitude (real) components of the matrix are obtained from single-photon intensity measurements. The phase components are determined using the Hong-Ou-Mandel effect, which describes the interference of two photons when they are indistinguishable.

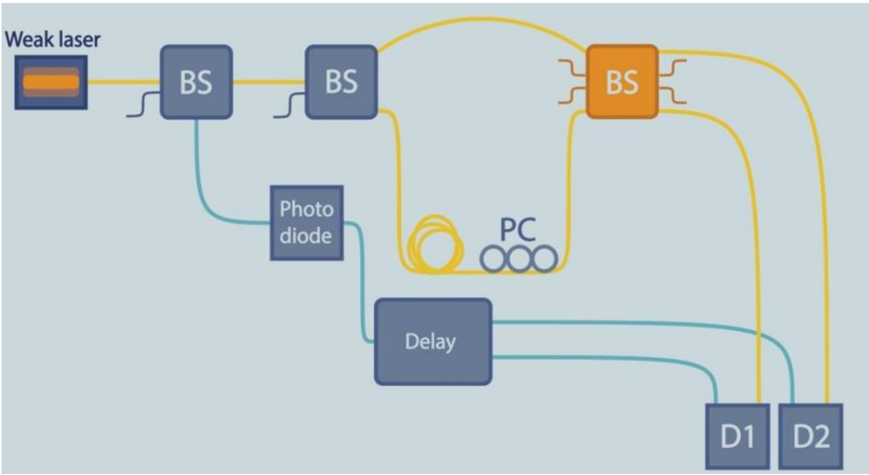

Figure 1: Experimental setup. Pulsed weak laser 5 ns, BS: multiport beam splitter, photodiode, PC: polarization controller, D: single photon detector.

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Femtosecond laser writing

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A first approach to laser writing [1][2][3][4][5] was achieved, using different laser parameters, materials and writing speeds.

For the writing, a setup was built around the *L-731.44SD Precision XY Stage* from *PI*, which has nanometric precision in its movement. Initially, one of the stage controllers malfunctioned, so only one of the axes could be used, at a time. A pulsed laser was used, with a repetition rate of $114\ kHz$, a wavelength of $515\ nm$ and a pulse duration of $340\ fs$.

The writing was successful on microscope slides (made of soda lime glass) and *PMMA* blocks. In the former, it was proved that the writing changed the refraction index of the material, by passing the light of a laser pointer through the sample and seeing the dispersion caused by the irradiated zone. In the latter, even though the effects of the writing can be seen in plain sight, the behavior of light when it goes through it is not the desired one. The material acts as if it was opaque in the irradiated zones and blocks the transmission of light.

On the other hand, it was not possible to cut through the other two materials, aluminum and mica, by using laser writing. This was attributed to poor alignment of the system, and possibly poor positioning of the focal point.

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Paloma Vildoso Pinto – Universidad de Chile

Low-loss broadband multiport optical splitter

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Conventional design of Multiport coupler (or Splitter) relies on concatenation of directional couplers or multimode interference [1-3]. However, they show a considerable insertion loss, which limits their bandwidth and footprint requirements to circuits application. Recently, nanotechnology has tabled direct inverse design of these devices by electron-beam lithography, demonstrating that they can fulfill all above requirements [4-5] but having a high cost of time and energy to design a single specific Splitter.

In this work we present an efficient inverse design algorithm and experimental implementation of Multiport couplers with low insertion loss, broad bandwidth, small footprint, arbitrary splitting ratio and low time-energy cost, showing themselves to be competitive compared to the current design. To demonstrate the capabilities of our method, we design several splitting ratios 1 N based on single mode linearly coupled waveguide arrays (WGAs)and fabricate in a borosilicate waffer by femtosecond laser writing technique [6]. Splitters show near zero insertion loss and bandwidth of 20 60 nm while maintaining low imbalance <0.5 dB. We demonstrate that one Multiport can be tuned to achieve different splitting ratios. Furthermore, the scaling of the splitter footprint follows an exponential relation in glass. Finally, we offer new possibilities for multiple applications such as quantum optics,logical operations, sensing and communications.

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Pedro Aguilera Rojas – Universidad de Chile

Turbulent labyrinthine patterns in liquid crystal light valve with optical feedback

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Systems with energy injection and dissipation self-organise by forming patterns of stripes, hexagons, squares, and superlattices at the onset of spatial instabilities. Increasing the disproportion between injection and dissipation of energy generates the emergence of disordered patterns with complex spatiotemporal behaviours. We investigate the turbulent dynamics of labyrinthine patterns far from the primary spatial instabilities in a liquid crystal light valve (LCLV) with optical feedback experiment [1]. Using statistical tolos [2,3], we reveal the turbulent and intermittent nature of the intensity field. We reveal phase and defects turbulence characterized by power law spectra with exponents -2 and -3, respectively. The pattern orientation field also presents a power law spectrum with exponent -2. The largest Lyapunov exponent is determined experimentally and shows that the observed dynamics is chaotic. We provide a phenomenological model to capture the experimental observations.

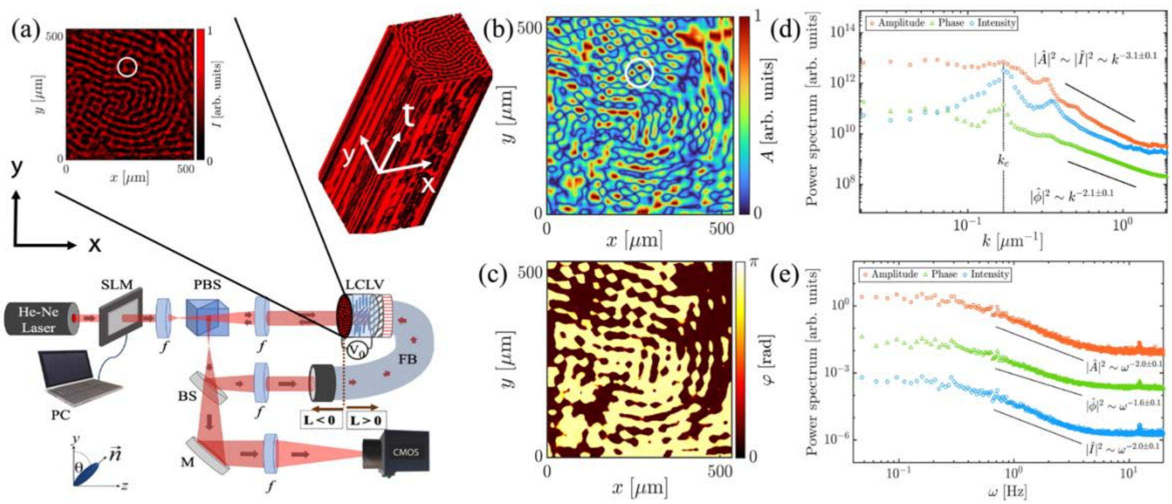

Figure 1. (a) Schematic representation of a liquid crystal light valve with optical feedback and instantaneous intensity field, and corresponding amplitude (b) and phase (c). The white rings illustrate the position of a defect in the intensity and amplitude fields. Spatial (d) and temporal (e) power spectra of intensity, phase, and amplitude.

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Giovanni de Jesús Marín Lobo – Universidad de Santiago de Chile

Influencia de la intensidad de luz sobre el efecto fotovoltaico en uniones p-n de semiconductores

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El avance tecnológico en el campo de generación de energía eléctrica, basado en el uso de energías alternativas, requiere de tiempos de respuestas inmediatas en cuanto al desarrollo de nuevos materiales semiconductores que puedan utilizarse en la fabricación de dispositivos optoelectrónicos, aprovechando al máximo su interacción con las fuentes de radiación luminosa.

En este trabajo estudiaremos la influencia de la intensidad de la radiación de luz proporcionada con un simulador solar de lámpara de tungsteno desde 500 W/m^2 hasta 2000 W/m^2 y un simulador solar de LED montado de 6500 K con irradiación mostrada en la figura.

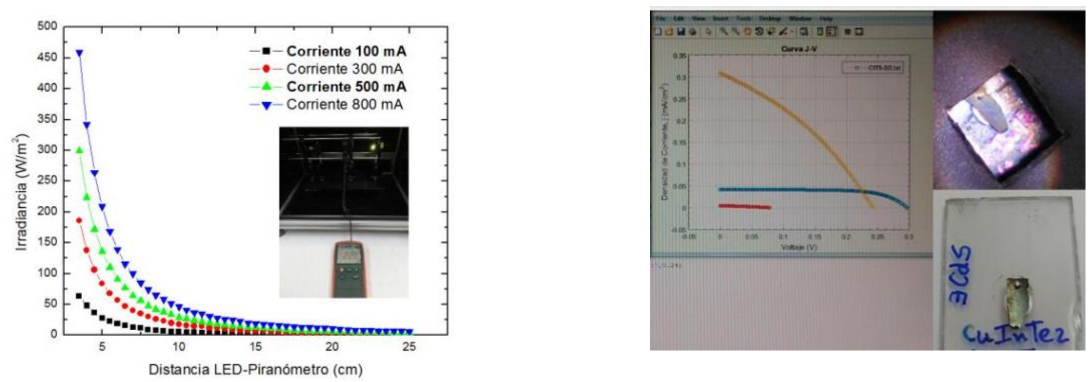

Figure 1. a) Variación del IRRADIANCIA W/m^2 LED MCWHL6 con la distancia b) Unión p-n de los semiconductores $CuInTe_2/CdS$

Se ha reportado que el uso de un concentrador de radiación solar influye directamente en el incremento de la potencia y energía de los sistemas fotovoltaicos [1], simulando una incidencia de 3000 W/m^2 se incrementaría la potencia eléctrica desde 63 W a 1000 W/m^2 hasta 190 W, por lo que este estudio podría aportar información relacionada con la variación de la intensidad de irradiancia de luz artificial sobre la unión p-n de materiales semiconductores que presentan respuesta fotovoltaica ante la incidencia de luz sobre su superficie.

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Gastón González– Universidad de Santiago de Chile

Simulation of gas and thermal transport in nanoporous media

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Using molecular dynamics (MD) simulations, we study the transport of gases and thermal conductivity of nanoporous materials. The diffusive properties of a variety of gases in porous media can be modeled using MD simulations that can be computationally demanding depending on the pore geometry, complexity, and amount of gas adsorbed [1]. We explore a dimensionality reduction scheme for estimating the self-diffusion coefficient of non-polar gases in simple nanopores using Langevin dynamics, such that the three-dimensional (3D) atomistic interactions that determine the diffusion properties of realistic systems can be reduced to an effective one-dimensional (1D) diffusion problem along the pore axis. We demonstrate the approach by modeling the transport of nitrogen molecules in single-walled carbon nanotubes (SWCNT) of different radii, showing that 1D Langevin models can be parametrized with a few single-particle 3D atomistic simulations. The reduced 1D model predicts accurate diffusion coefficients over a broad range of temperatures and gas densities [2]. We also use the Green-Kubo method for determining thermal transport with equilibrium molecular dynamics (EDM) [3] of different materials such as silicon crystals and metal-organic frameworks (MOFs), studying the influence of different Force Fields (FF) in the accuracy of the heat conductivity estimation [4]. We calculate the thermal conductivity tensor of MIRO-101 as a case study and discuss possible applications in the study of thermal management in MOF-based optical devices.

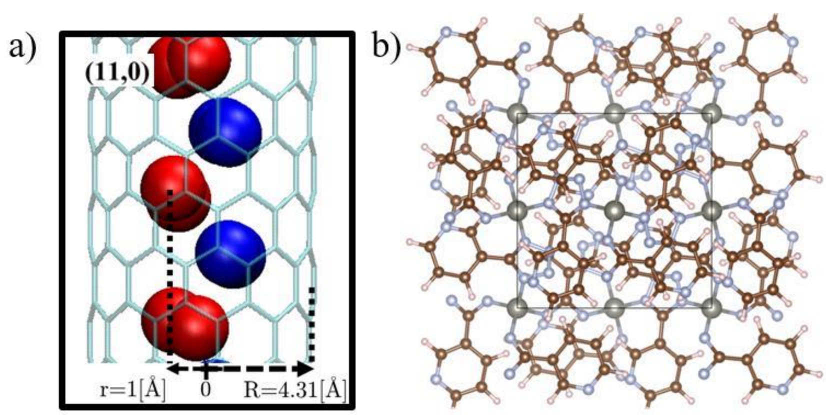

Figure 1. (a) Nitrogen molecules inside the SWCNT(11,0). (b) MIRO-101 structure.

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Gerd Hartmann Salvo – Universidad de Chile

Función de correlación de intensidad-campo para detectar estados coherentes generalizados

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La luz actúa como un revelador del universo, desde escalas astronómicas hasta las microscópicas. Especialmente cuando manifiesta propiedades cuánticas, desempeña un papel crucial en la observación de alta precisión y en tecnologías emergentes, potenciando desde microscopios hasta interferómetros como LIGO [1-3].

Un santo grial en el mundo de la cuántica es la generación de luz cuántica intensa y la detección de esta. Un avance significativo ha sido la transformación de un estado coherente de luz, considerado "clásico" e intenso, en estados coherentes generalizados (ECGs) mediante interacciones no lineales [4]. Estos ECGs son estados del campo electromagnético intensos que exhiben propiedades cuánticas notables y una ventaja metrológica cercana al límite de Heisenberg. Sin embargo, presentan una estadística de fotones Poissoniana y su función de correlación $g^{(n)}$ es constante e igual a 1 tal como cualquier estado coherente, lo que conlleva a que su detección sea compleja sin reconstruir funciones específicas, como la Función de Wigner.

En este trabajo, se propone utilizar una función de correlación entre intensidad y campo [5] para detectar los ECGs y revelar la naturaleza cuántica de estos. Nuestros resultados muestran que la función de correlación toma valores prohibidos para luz descrita clásicamente y además se propone un experimento relativamente simple con el que se pueden diferenciar los ECGs de los estados coherentes clásicos.

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Bastián Real Elgueda – Universidad de Chile

Manipulación de estados topológicos en redes fotónicas unidimensionales

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En las últimas décadas, las redes fotónicas han demostrado ser una plataforma experimental bastante versátil para la ingeniería y manipulación de estados de borde topológicos [1]. En este trabajo estudiamos y fabricamos redes unidimensionales para controlar el flujo de la luz mediante los estados de borde. Primeramente, usamos una red cuasi-unidimensional con geometría de diamante para demostrar la transferencia de luz de un borde al otro de la red gracias al acoplamiento de los estados localizados en sus terminaciones. Posteriormente, proponemos una técnica experimental para generar paquetes de ondas con momentum bien definido. Para ello, explotamos la analogía existente de un átomo decayendo en un continuo de estados en arreglos de guías de ondas [2,3]. Este paquete de ondas codifica una energía precisa y, por lo tanto, facilita la excitación pura de estados de borde topológicos cuando es utilizado como condición inicial. Esto último lo demostramos experimentalmente en una red del modelo de Su-Schrieffer-Heeger (SSH).

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Vector dark dissipative solitons in Kerr resonators

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We investigate the formation of vector solitons in weakly birefringent high-Q resonators. The presence of nonlinear polarization mode coupling in optical resonators subject to a coherent optical injection allows stabilizing up to two families of bright or dark vector dissipative solitons, depending on dispersion properties of the system. We use coupled Lugiato–Lefever equations to investigate the dynamical properties of interacting laser fields confined in Kerr optical resonators. The normal dispersion regime is considered, and it is shown that in both cases two branches of dissipative solitons coexist and exhibit different peak powers and polarization properties. In these regimes, the input-output characteristics possesses either a bistable or a tristable homogeneous response. The coexistence of two vectorial branches of localized states is not possible without taking into account the polarization degrees of freedom. The stabilization mechanism of these localized states is attributed to a front locking mechanism in the normal dispersion regime, contrary to the case of anomalous dispersion where the underlying cause was modulational instability. Their bifurcation diagrams exhibit a heteroclinic snaking type of instability.

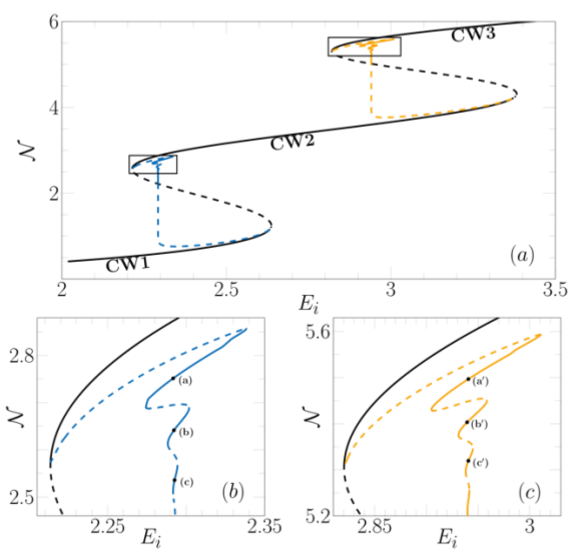

Figure 1. Bifurcation diagram of vector dark localized structure in the normal dispersion regime.

[1] B. Kostet, S. S. Gopalakrishnan, E. Averlant, Y. Soupart, K. Panajotov & M. Tlidi, OSA Continuum, 4, 1564–1570 (2021).
[2] B. Kostet, Y. Soupart, K. Panajotov & M. Tlidi, Phys. Rev. A, 104, 053530 (2021)

Timothy Woodworth– Universidad de Chile

Deep Neural Network via Four-Wave Mixing

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Machine learning allows for the classification and/or prediction of data based on a set of training data[1,2]. In physics, this is often done when fitting data to a line or other function. In this talk, we will discuss using neural networks to classify handwritten characters. We will show how we intend to generate an optical neural network using a nonlinear process, four-wave mixing, that creates a quantum state of light. This quantum state will carry the classification information in the momentum cross correlation of two spatially separated modes of light. We will discuss how multiple four-wave mixing processes can be used to create deep neural networks and relate the process to a convolution neural network layer[3]. We will also go over various ways such a network can be trained in order to correctly classify handwritten alphanumerical characters.

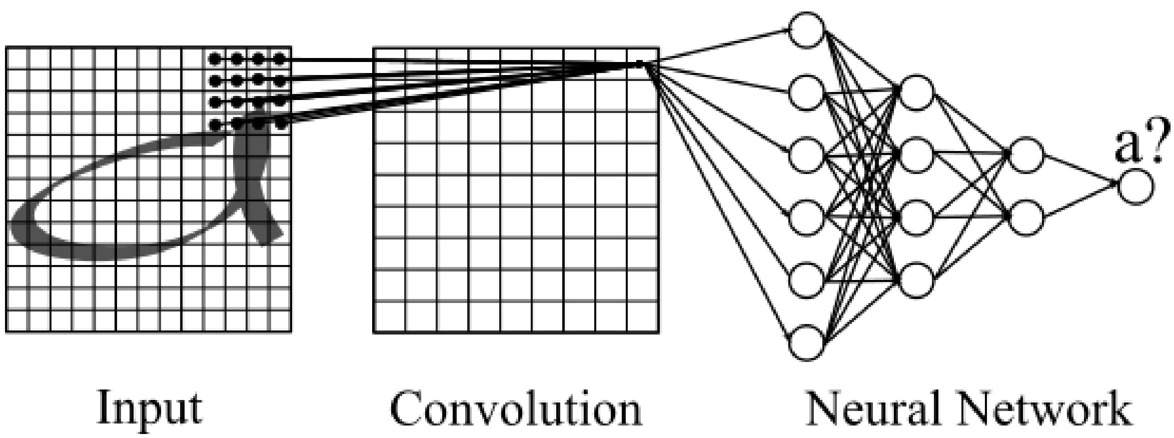

Figure 1. A model for a deep neural network with a convolution layer used to classify the letter 'a'.

[1] Martin T. Hagan, et al., Neural network design 2nd edition
[2] Michael Nielsen, Neural networks and deep learning (accessed Aug 2023)
[3] Rikiya Yamashita, *et al*., Convolutional neural networks: an overview and application in radiology, Insights Imaging **9**, 611-629 (2018)

Jaime Cariñe – Universidad Católica de la Santísima Concepción

Phase noise control strategies for high-speed optical router systems

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Phase noise in fiber optic-based interferometers affects the coherence of the optical input into the system, which reduces the quality of the optical overlap at the interferometer output [1], where mechanical disturbances and temperature variations are the most influential [2]. Although the property of interferometers to superimpose optical signals is essential for measuring path-encoded quantum states[3], superposition also enables signal switching in the optical domain to route information between multiple users, where factors such as visibility and crosstalk should be optimal for switching. In this work, we evaluate forward and backward propagation control laser[4] in a 4-arm Mach Zehnder interferometer built on multicore optical fibers to stabilize phase noise. These strategies allowed for high-speed switching and minimal crosstalk for telecommunication signals. These results contribute to new multicore fiber technologies that can be applied in quantum networks.

[1] J. Carine, G. Canas, P. Skrzypczyk, et al., Optica, vol. 7, pp. 542-550, 2020.
[2] G. Xavier y J. von der Weid, Opt. Lett., vol. 36, pp. 1764-1766, 2011.
[3] Máté Farkas, Nayda Guerrero, Jaime Cariñe, et al., Phys. Rev. Applied, vol. 15, p. 014028, 2021.
[4] B. Da Lio, D. Bacco, D. Cozzolino, et al., IEEE J Sel Top Quantum Electron, vol. 26, pp. 1-8, 2020.

Felipe Quinteros – Universidad de Concepción

Spatial qubits and multicore fibers: recovering states using minimal resources

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The characterization of quantum channels is an important task for quantum communication. Optical fibers and free-space media are the two main channels to propagate quantum information encoded on single photons. One problem is perturbations induced by channels over quantum states, producing issues in the communication process due to the lack of information. In this work, we propose a method to characterize and correct the effect of a 4-core optical fiber beam splitter acting as a quantum channel. We use the Choi-Jamiolkowski isomorphism between quantum channels and states, resorting to correlations among polarization and spatial propagated modes of single photons. We use the compressed sensing technique to implement the quantum tomography of the Choi matrix related to the state after passing through the channel. That allows us to characterize the quantum channel using fewer measurements than required by standard tomography, which enables a practical method to recover the initial state and then perform communication protocols effectively. This study is helpful for quantum information protocols implemented on networks based on the modern spatial división multiplexing optical fibers technology.

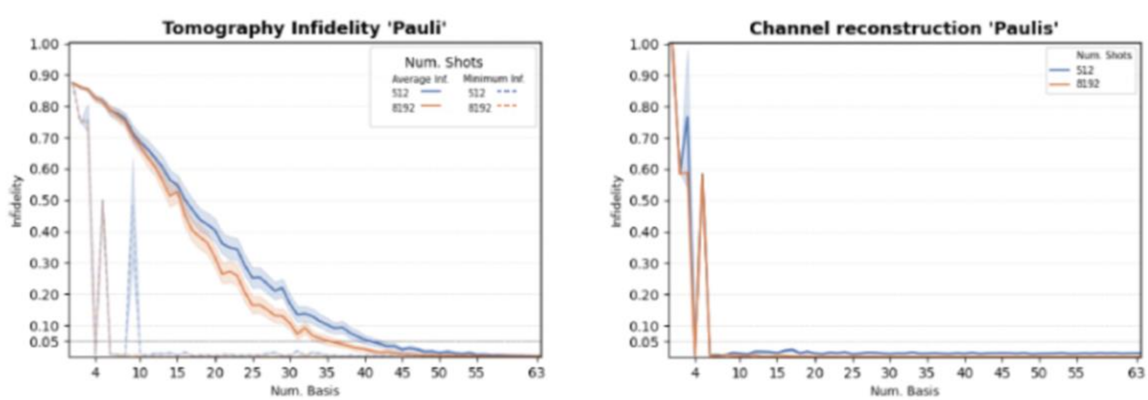

Figure 1. The left side shows the infidelity of the tomography against the number of basis. There is a subset that with 4 basis the mínimum is reached. The right side shows that with 4 basis the channel reconstruction also reaches the lower infidelity.

[1] David Gross, et al., Quantum State Tomography via Compressed Sensing, PRL 105, 2010.
[2] Jaime Cariñe et al., Multi-core fiber integrated multi-port beam splitters for quantum information processing, Optica, 2020.
[3] Chemist M. Mabena, et al., Quantum channel correction with twisted light using compressed sensing, PARA 101, 2020.
[4] Min Jiang, et al., Channel-state duality, PARA 87, 2013.

Felipe Osorio– Universidad de Santiago de Chile

Optical classifier for organic molecules and polymers

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In this work a methodology for the identification of materials is presented, using statistical learning techniques on data of the linear optical response of a transparent material in the visible region of the spectrum. Recreating the state of the art [1], a classification model based on "Random Forest" is proposed to identify the refraction curve in different materials, within the visible spectrum.

The training data is generated using the Sellmeier equation from refractive index observations of birefringent materials, reported in specialized literature [2]. The performance of this synthetic data set is tested, obtaining a validation of the proposed model of 78% average precision with data not seen by the classifier. In addition, different levels of Gaussian noise applied to the fit data are explored, evaluating the impact on the general performance of the classifier.

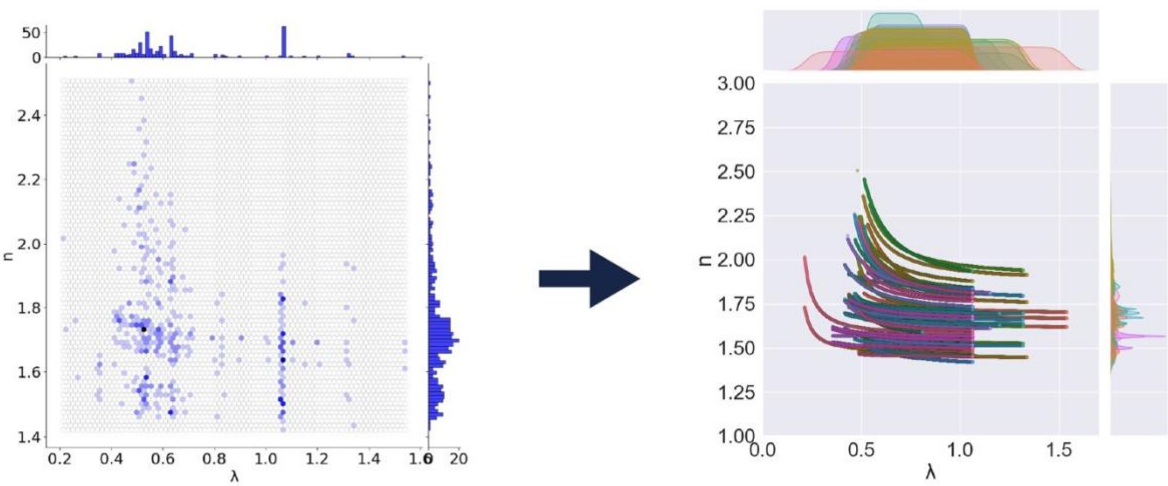

Figure 1. Join distribution of n and λ, before and after data augmentation. Left image shows observations of refractive index v/s wavelength of 25 materials, reported in *Nalwa & Miyata* [2]. Right image shows augmented data, fitted in Sellmeier dispersion formula, using Levenberg–Marquardt non-linear least squares method.

[1] Bikku, T., Fritz, R. A., Colón, Y. J. & Herrera, F. (2022). Machine learning identification of organic compounds using visible light. https://doi.org/10.48550/arxiv.2204.11832

[2] Nalwa, H. S., & Miyata, S. (Eds.). (1996). Nonlinear Optics of Organic Molecules and Polymers (1st Edition). CRC Press. https://doi.org/10.1201/9780138745493

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