

Juan Rafael ALVAREZ VELASQUEZ

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Place of Birth: Medellín, Colombia

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I completed my PhD at the University of Oxford in January 2023, in the Atom-Photon Connection group led by Prof. Axel Kuhn. In March 2023, I joined the Quantum Dots group led by Prof. Pascale Senellart as a postdoctoral fellow (C2N-CNRS, France), where I have been studying the generation of photon number superpositions using single-photon sources in the solid state.

I have an excellent track record of seven publications, of which two are first-author and four are second-author. I have worked within and collaborated with diverse research groups in Colombia (Experimental quantum optics group, Universidad de los Andes, Bogotá, led by prof. Alejandra Valencia), Spain (Quantum Engineering of light group, ICFO, Barcelona, led by prof. Juan P. Torres), France (Interactions and Quantum Control, led by prof. Stephane Guerin) and the United States (Materials science group at Cornell University led by prof. Jin Suntivich). Since 2015, I have presented 6 contributed talks, one invited talk and more than ten posters in diverse international conferences and meetings. I have also given a contributed seminar in the Atomic and Laser Physics subdepartment at the University of Oxford, and was in charge of organizing the final LIMQUET 2021 Conference in Christ Church, Oxford.

I have been the beneficiary of several awards, including the Zuegel family scholarship for the Siegman School on Lasers, an awardee of the LIMQUET MSCA ITN from 2018-2022, held an Europhotonics Erasmus-Mundus scholarship to perform my master studies in France and Spain, was selected at the Universidad de los Andes Colombia to do a fully paid research internship at Cornell University in the USA, and won (but turned down) a scholarship to do my undergraduate studies in the city of Medellín, Colombia, ending fourth among 80 000 contestants in the “*Olimpiadas del Conocimiento Medellín*”, a city-wide high-school academic competition.

I have also been involved with several institutional responsibilities, including the reviewing of more than 20 papers in publishing groups such as IoP, Nature and Optica, being a Residential Junior dean in Mansfield College, Oxford (taking care of the welfare of students in said college), being the president and secretary of GOA, an Optica student chapter at the Universidad de los Andes, and an instructor at Clubes de Ciencia Colombia, an outreach event for low-income students in the city of Medellín, Colombia.

EDUCATION

01/10/2018– 25/01/2023 *PhD in Atomic and Laser Physics*. Physics subdepartment, University of Oxford (United Kingdom).

Thesis title: “*Pushing cavity-based single photon sources to the limit: Photon feedback, coherent repumping and multilayer cavities*”. Advisor: Prof. A. Kuhn.

12/09/2016– 27/08/2018 *Master in Photonics, Europhotonics POESII*.

Year 1: Aix-Marseille Université, Marseille, France. (GPA 17.097/20.00 – *Mention très bien*).

Year 2: Photonics BCN (UAB-UB-UPC-ICFO), Barcelona, Spain. (GPA 9.21/10.00).

Thesis: *Coherence-based quantum random number generator*. Advisor: Prof. J. P. Torres.

23/01/2012– 30/11/2016 Bachelor of Mathematics, Universidad de los Andes, Bogotá, Colombia.

Monograph: *Stokes phenomena in classical special functions: Bessel and Weber functions with applications*. (GPA 4.47/5.00). Advisor: Prof. A. Getmanenko

17/01/2011– 20/03/2015 Bachelor of Physics, Universidad de los Andes, Bogotá, Colombia.

Monograph: *Coupling the spatial and polarization degrees of freedom of light: Applications in measurement theory and open quantum systems*. (GPA 4.52/5.00) Advisor: Prof. A. Valencia

• CURRENT AND PREVIOUS POSITIONS

- 01/03/2023-present **Postdoctoral Fellowship.** C2N-CNRS (France).
Research topic: “*Quantum optics with semiconductor quantum dots*”.
Advisors: Dr. Nadia Belabas & Prof. Pascale Senellart.
- 01/10/2018-25/01/2023 **Graduate Student.** University of Oxford (UK). Research topic: “*Cavity-based single atom- single photon interfaces*”. Advisor: Prof. Axel Kuhn.
- 10/01/2020-31/03/2020 **PhD Secondment.** Université de Bourgogne (France). Research topic: “*Light-Matter interfaces in open cavities with dielectric stacks*”. Advisor: Prof. Stephane Guerin.
- 07/01/2018-27/08/2018 **Master Thesis.** ICFO (Spain). Research topic: “*Random number generation by coherent detection of quantum phase noise*”. Advisor: Prof. Juan P. Torres.
- 01/06/2018-31/08/2018 **Summer Fellow.** ICFO (Spain). Research topic: “*Random number generation by coherent detection of quantum phase noise*”. Advisor: Prof. Juan P. Torres.
- 01/05/2017-30/09/2017 **Intern.** IQOQI (Austria). Research topic: “*QPOINTS: Quantum POLarization based mINIaturized phoTon pair Source*”. Advisors: Siddarth K. Joshi, Rupert Ursin.
- 01/06/2015-01/08/2015 **Summer Undergraduate Research Fellow.** Cornell University (USA). Research topic: “*Design of a ring resonator for strong light-matter coupling*”. Advisors: Christopher Evans, Jin Suntivich.

• FELLOWSHIPS AND AWARDS

- 25/06/2022-02/07/2022 The Optica foundation – Zuegel family scholarship – (\$800). **Scholarship** to support my attendance to the 2022 Siegman International School on Lasers.
- 01/10/2018-30/09/2021 Marie Skłodowska-Curie Actions – LIMQUET ITN. (€156,287.88). **Grant** to support the **PhD research** at the University of Oxford (UK). Advisor: Prof. Axel Kuhn.
- 01/06/2018-30/08/2018 **ICFO Summer Fellowship** Programme 2018. Fellowship for accomplishing research training in the Quantum Engineering of Light research group led by Prof. Juan. P. Torres.
- 12/09/2016-27/08/2018 Erasmus Mundus Joint Master Degree. Europhotonics-POESII. **Erasmus+ Scholarship** holder. (€30,000.00). Scholarship to perform master’s degree in Aix-Marseille Université and in the Photonics BCN Master.
- 01/06/2015-01/08/2015 Fully funded **Summer Undergraduate Research Fellow** at Cornell University. Sponsored by the Vicerrectoría de Investigaciones (Research vice-deanship) at the Universidad de los Andes, Colombia. 25 awarded undergraduate students. Grant in aid for research of “*Design of a ring resonator for strong light-matter coupling*”.
- 01/10/2010 Finalist of the Olimpiadas del Conocimiento Medellín 2010. Awarded **full scholarship** and monetary stipend (7’210.000 COP) for performing undergraduate studies in Medellín. Third runner up in a municipal competition, out of 80 000 students. I declined this scholarship to move to Bogotá.

• TEACHING ACTIVITIES

- 01/10/2022–28/02/2023 “*Physics Computing Laboratory*” (1st and 2nd-year course on the Physics Degree), University of Oxford. Senior demonstrator. 60 hours.
- 01/10/2021–28/06/2022 “*Physics Computing Laboratory*” (1st and 2nd-year course on the Physics Degree), University of Oxford. Demonstrator. 45 hours.
- 16/01/2021-01/06/2022 “*Physics Computing Laboratory*” (1st and 2nd-year course on the Physics Degree), University of Oxford. Demonstrator. 30 hours.
- 20/01/2016-30/06/2016 “*Linear Algebra I*” (1st year course on the Universidad de los Andes Mathematics department). Complementary teacher. 30 hours.
- 01/08/2015-30/11/2015 “*Integral Calculus*” (1st year course on the Universidad de los Andes Mathematics department). Complementary teacher. 30 hours.
- 01/08/2013-30/11/2013 “*Prephysics*” (1st year course on the Universidad de los Andes Physics department). Complementary teacher. 30 hours.

- **ORGANISATION OF SCIENTIFIC MEETINGS**

19/09/2021- **Student organizer** in the *LIMQUET Conference and Workshop* - Christ Church, University of Oxford (UK). Scientific organizers of the conference: Profs. Axel Kuhn, Stephane Guerin.

- **INSTITUTIONAL RESPONSIBILITIES**

01/07/2021-12/09/2022 **Residential Junior Dean**, *Mansfield College, University of Oxford*. – Support of students, fire safety and Welfare for the Ablethorpe/Rhodes Wolfson student residence.

16/01/2015-17/01/2016 **President**, *Grupo de Óptica de los Andes (GOA) – OSA Student Chapter*.

15/01/2014-16/01/2015 **Secretary**, *Grupo de Óptica de los Andes (GOA) – OSA Student Chapter*.

15/01/2010-01/12/2010 **Student Representative on the school board**, *Colegio Montessori, Medellín, Colombia*.

- **COMMISSIONS OF TRUST**

From 01/07/2023 Referee for the nature journal npj Quantum Information. (1 paper reviewed)

From 01/03/2022 Referee for IoP's Journal of Optics. (1 paper reviewed)

From 01/03/2020 Referee for the Optica journals Applied Optics, Optics Express, JOSA B and Optics Letters. (21 papers reviewed)

- **MEMBERSHIPS OF SCIENTIFIC SOCIETIES**

Optica student member from 2013 to 2023.

- **SUPERVISING AND MENTORING ACTIVITIES**

Master students – Jiawang Li (Oxford)

PhD students – Etienne Bargel, George Crisan, Hubert Lam (C2N), Jan Ole Ernst (Oxford)

- **PEER REVIEWED JOURNAL ARTICLES**

1. J.O. Ernst, **J.R. Álvarez**, T.D. Barrett and A. Kuhn. "*Bursts of polarized single photons from atom-cavity sources*". J. Phys. B. **56** 205003 (2023).
2. **J.-R. Álvarez**, M. IJspeert, O. Barter, B. Yuen, T.D. Barrett, D. Stuart, J. Dilley, A. Holleczek, and A. Kuhn. "*How to administer an antidote to Schrödinger's cat*", J. Phys. B. **55** 054001. (2022)
3. O. Cordero-Boronat, A. Villegas, **J.-R. Álvarez**, R. J. León-Montiel, M. Passos, and J.P. Torres, "*Equivalence regimes for geometric quantum discord and local quantum uncertainty*", Phys. Rev. A **104**, 042401 (2021)
4. A. Saharyan, **J.-R. Álvarez**, T. Doherty, A. Kuhn, and S. Guérin. "Light-matter interaction in open cavities with dielectric stacks" Appl. Phys. Lett. **118**, 154002 (2021).
5. **J.-R. Álvarez**, S. Sarmiento, J. A. Lázaro, J. M. Gené and J. P. Torres. "Random number generation by coherent detection of quantum phase noise", Opt. Express **28**, 4, 5538 (2020)
6. D.F. Urrego, **J.-R. Álvarez**, O. Calderón-Losada, J. Svozilík, M. Nuñez and A. Valencia. "*Implementation and characterization of a controllable dephasing channel based on coupling polarization and spatial degrees of freedom of light*", Opt. Express **26**, 9, 11940 (2018).
7. J. Flórez, **J.R. Álvarez**, O. Calderón-Losada, L.J. Salazar-Serrano and A. Valencia. "*Interference of two pulse-like spatial beams with arbitrary transverse separation*", J. Opt., **18**, 125201 (2016).

- **ORAL CONTRIBUTIONS**

1. **Álvarez, J. R.**, Martinez, A., & Valencia, A. (2023). "*Measuring Wigner functions of quantum states of light in the undergraduate lab*", ETOP 2023 Conference.
2. Ernst, J. O., **Álvarez, J.-R.**, Barrett, T. D., & Kuhn, A. (2022). "Polarized single photons from a cavity-enhanced atom-light interface with coherent re-preparation." In Quantum 2.0 Conference and Exhibition, Session QTh4C.
3. **Álvarez, J.-R.**, IJspeert, M., Barter, O., Yuen, B., Barrett, T. D., Stuart, D., Dilley, J., Holleczek, A., & Kuhn, A. (2022). "*Administering an antidote to Schrödinger's cat*" Quantum 2.0 Conference and Exhibition, session QTh3C. – Upgraded to Invited talk.
4. **Álvarez, J.-R.**, Urrego, D. F., Nuñez Portela, M., & Valencia, A. (2016). Synthesizer of arbitrary polarization states. In Latin America Optics and Photonics (LAOP) Conference OSA. Session LTh2B.

5. **Álvarez, J. R.**, Barbosa, N., Cotrino, S., Guzmán, D. A., Mahecha, V., Medina, C., Navarrete, M. C., Uribe, L., & Valencia, A. (2015). “*Making optics appealing in Colombia through low-cost experiments with lasers*”. ETOP 2015 Conference.

• RESEARCH RESULTS

During my academic career, I have investigated several aspects of quantum optics, including single-photon production with deterministic sources, random number generation and quantum coherence and decoherence.

I. Feedback on time-resolved Hong-Ou-Mandel interference

In the publication “*How to administer an antidote to Schrödinger’s cat*”, me and my PhD research group used atoms in freefall inside a high-finesse cavity to produce single photons of controllable amplitude, frequency and phase with extremely long coherence times, on the order of several hundreds of nanoseconds. In this experiment, we performed a Hong-Ou-Mandel experiment on two photons emitted from the same source by using a delay loop and a polarizing beam splitter.

We demonstrated that the coherence times of photons produced with neutral atoms in high-finesse cavities is long enough to use the detection of a photon as a feedback loop to change the phase of the next photon under production. We showed that no further loss of coherence was incurred when doing so. This established that the wavepacket of a single photon can span several systems, some under full classical control.

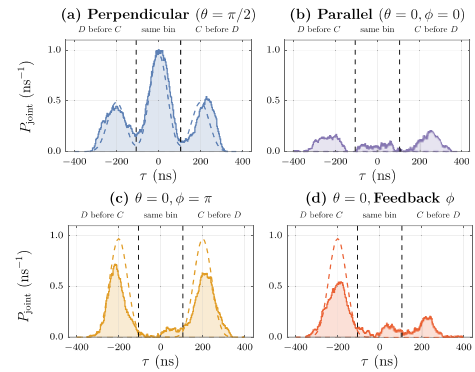


Figure B1. Different HOM behaviour for the interference of two photons whose relative phase is changed. J. Phys. B. **55** 054001. (2022)

II. Light-matter interaction in open cavities with dielectric stacks

The publication “*Light-matter interaction in open cavities with dielectric stacks*” I theoretically analyzed the propagation modes of the light of a cavity composed of a stack of dielectric mirrors coupled to a single emitter, in a design similar to that of a QD in a micropillar cavity. While varying the resonance frequency of the cavity, I observed that the peaks obtained using a free spectral range analysis of the cavity did not necessarily correspond with the geometric length of the cavity for very short cavities, as shown in Fig. B2. The model considered in this project was extensive in its theoretical and numerical analysis and has been useful for further simulating the dynamics of a single photon within a cavity with a Bragg mirror.

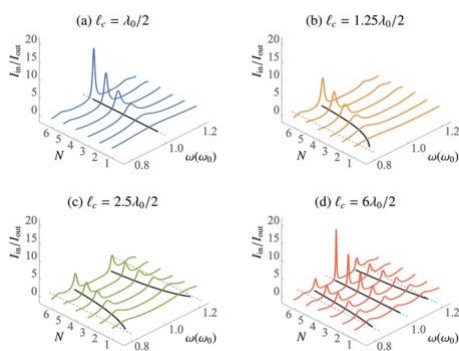


Figure B2 Cavity transmission peaks dependent on the cavity length for dielectric mirror stacks of increasing size. This figure shows a cavity transmission analysis using the continuity conditions of the dielectric stack.

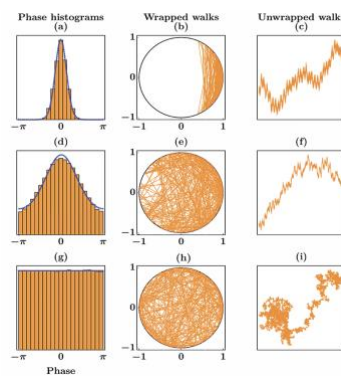


Figure B2 Random number generation phase histograms. As the phase from the laser drifts, the measurements of random numbers become more uniform.

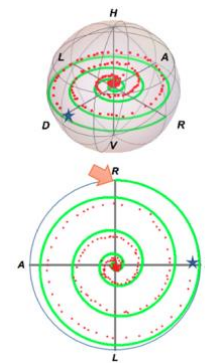


Figure B3 Polarization measurements in the Bloch sphere after having passed through a tuneable beam displacer, constituting a dephasing channel.

III. Random number generation using coherent detection of quantum phase noise

In this project, which constituted my master’s thesis, I demonstrated a fast physical random number generator based on the usage of balanced homodyne detection in two complementary quadratures. With this system, we were able to generate an intrinsically uniform probability distribution in which the phase noise of a laser was measured using standard telecom equipment. This method enabled the measurement of the coherence time of a laser, enabling a visualization of the arising of uniformity in the phase noise of a laser, as it is shown in Figure B2. I performed double-

homodyne tomography for the measurement of the phase noise of a laser, based on a thorough study of the behavior of the balanced homodyne detectors, and the characterization of coherent states in phase space with them.

IV. Implementation of a controllable dephasing channel

This experiment paved the way for the development of dephasing assisted models in the Quantum Optics laboratory at the Universidad de los Andes by coupling the polarization and spatial degrees of freedom of light of a Gaussian beam (Fig. B4) using a tunable beam displacer: a device which separated spatially the two polarizations of a light beam, in a similar way to a birefringent crystal. Several works from their group have used the mathematical models and experiments written in this work, and which I pioneered in the lab. I also helped gather some of the experimental data and built and characterized the first tunable beam displacer in this laboratory. This phase is responsible for the spiraling behavior in the dephasing channel shown in the Poincaré sphere of the generated states.