Physical sciences/Optics and photonics/Optical physics/Quantum optics [URI 639/624/400/482]

Scientific community and society [URI 706]

Jonathan Patrick Dowling in memoriam

Jonathan P. Dowling, who died in June, was a pioneer in quantum optics and one of the founders of the US Government's research program in quantum information.

James Franson and Mark M. Wilde

Jonathan P. Dowling, a theoretical physicist at Louisiana State University (LSU), passed away unexpectedly on June 5. Jon was a well-known leader in quantum optics and its application to computing, sensing, metrology and imaging. His outgoing personality and gregarious sense of humour endeared him to everyone in the international quantum science and technology community.

Jon was born in 1955 in Smithtown, NY, USA. His parents were Irish immigrants and Jon automatically became a dual citizen of Ireland and the United States. He conducted his undergraduate work at the University of Texas at Austin and completed his Master's and Ph.D. degrees at the University of Colorado, Boulder, where his advisor was the renowned theoretical physicist Asim Orhan Barut. During his Ph.D., Jon worked on the foundations of quantum mechanics and later often joked how he was told at the time by other professors that "you will never get a job" doing this "crackpot stuff." [1]. Of course, they were wrong and much later Jon found great success as a leader in quantum science and technologies. Jon's Ph.D. studies were followed by post-docs at the International Center for Theoretical Physics in Trieste, Italy, the Max Planck Institute for Quantum Optics in Munich, Germany and the Redstone Arsenal in Huntsville, US. Jon went on to become a senior scientist and group supervisor at the Jet Propulsion Laboratory, after which he became the Hearne Professor of Theoretical Physics at LSU.

Jon was one of the pioneers of the linear optics approach to quantum computing [2,3]. Quantum logic operations using photonic qubits require a nonlinear interaction between single photons, which is ordinarily very weak. But the collapse of the wave function after a quantum measurement is inherently nonlinear (it depends on the square of the wave function) and this can be engineered to produce the desired output from a quantum logic gate. Jon and his colleagues showed that linear optics techniques could be used to produce any desired unitary operation [4], such as a Kerr phase shift controlled by a single photon. These techniques are expected to be of practical use in quantum repeaters and quantum communications, as well as quantum computing. In addition to his early theoretical work on quantum technologies, Jon organized the first conferences in the US on quantum computing and quantum key distribution. One

of the main goals of these conferences was to introduce sponsors from government funding agencies, such as NSA [National Security Agency], DARPA [Defense Advanced Research Projects Agency] and ARL [Army Research Laboratory], to the extraordinary potential of quantum technologies. Despite the serious nature of these meetings, Jon entertained everyone there with his cartoon depictions of the government sponsors as characters from the Wizard of Oz. Due to his early roles and activities Jon is widely considered to be one of the founders of the U.S. government program in quantum information.

Jon was also one of the pioneers of the fields of quantum lithography, sensing, and metrology. He and his colleagues showed that non-classical states of light could be used in an interferometer to measure an unknown phase shift with a precision that would be impossible to achieve in classical optics. They considered a quantum state of the form $|\psi\rangle = |N\rangle|0\rangle + |0\rangle|N\rangle$, where $|N\rangle|0\rangle$ corresponds to N photons in one input to an interferometer and zero photons in the other input, while $|0\rangle|N\rangle$ corresponds to the opposite situation [5]. Jon and his colleagues referred to these states as "N00N" states based on the form of the equation, and in his sometimes particularly persnickety ways, Jon often emphasized the importance of spelling the technical term "N00N" as it has been done here with zeros rather than the letter O. The non-classical properties of N00N states have been the subject of much interest and many subsequent investigations. Dowling and his colleagues also developed other quantum sensor techniques, such as increased sensitivity to magnetic fields.

A physicist by heart, Jon had remarkably diverse scientific interests beyond the research areas mentioned above, and he was always introducing, developing, or learning about emerging topics, which included, e.g., cavity QED, photonic band-gap materials, matter-wave interferometry, light-wave atom mirrors, clock synchronization, relativistic quantum information, and most recently, boson sampling and quantum networks. Boson sampling is a scaled down method of quantum computing intended to demonstrate its advantage over classical methods. Jon and his colleagues devised a method to make boson sampling more practical by using a fibre-loop-based architecture [6] and later they showed how concepts from boson sampling are useful in the different area of quantum metrology [7]. He repeatedly joked and laughed about how the first initials of the author last names of the latter paper [7] spelled out "MORDOR," the mythical evil kingdom in J.R.R Tolkien's novel *"The Lord of the Rings"*. The same paper also introduced the "ordinal resource counter" (abbreviated as ORC, a fictional breed of monster that also appears in the book) as a resource-counting method to go hand in hand with the author list joke. In some of his boson sampling papers, Dowling enjoyed playing jokes on journal editors by thanking a fictitious "Dr. Schmämpling" for helpful discussions and sharing his intellectual insights.

In 2013, Jon published a popular science book on quantum technologies entitled "*Schrödinger's Killer App: Race to build the World's First Quantum Computer*, [8]. A second book in a similar vein called "*Schrödinger's Web: Race to Build the Quantum Internet"* will be published posthumously [1]. After reading his first book, Lawrence Gasman, President of *Inside Quantum Technology*, wrote that it "was informative and deep in its assessment of quantum computing" but also "funny!" and "Jon should be credited as the inventor of quantum humour." Jon and his colleagues

coined the terms “quantum technology” and “second quantum revolution” in a widely cited article [9], and Jon often joked how he should have trademarked the latter term because it only started being widely used after his paper was published. Jon and Hartmut Neven, the director of Google’s Quantum Artificial Intelligence lab, independently proposed the Dowling-Neven law, [8,10] which was subsequently described by John Preskill of the California Institute of Technology as follows: “For the largest quantum circuit that can be executed with fixed fidelity, the classical cost of the simulation is increasing doubly exponentially with time. That’s really fast.” The observation here is that the number of useful qubits that experimentalists are capable of etching on a chip appears to be growing exponentially with time, and the overhead of the best-known simulation of a quantum computer by a classical one is exponential. The combination of these two observations leads to the double exponential behaviour in the Dowling-Neven law. More generally, Jon’s popular descriptions of quantum computing have helped to provide a broader appreciation for the potential of the field.

Due to his captivating sense of humour and extensive knowledge of physics, Jon was a lauded teacher in the Department of Physics and Astronomy at LSU. His teaching was celebrated with a number of awards including the Department of Physics and Astronomy Outstanding Graduate Faculty Teaching Award (2017), the Louisiana State University Undergraduate Physics & Astronomy Majors Teaching Award (2013), and the Louisiana State University Foundation Distinguished Faculty Teaching Award (2012).

Jon was widely considered at LSU to be an excellent research mentor, and he welcomed many into his research group, including not only postdocs and Ph.D. students, but also undergraduate and high-school students. He held his famous pizza parties at the end of each semester to celebrate the arrival of new students and the departure of graduating students.

Jon had collaborators all around the world, and in the 2010s, he took frequent trips to China, Japan, and Australia. He worked closely with the group of Jian-Wei Pan of the University of Science and Technology of China, where he was Distinguished Visiting Professor. He advised Pan’s group on their experimental work on the Chinese quantum satellite Mozi and also collaborated on experiments on boson sampling and multi-photon interference. Jon was also a Distinguished Visiting Professor at New York University Shanghai and a Distinguished Visiting Member of the Chinese Academy of Sciences.

Jon’s research contributions were recognized by leading professional societies: he was elected a fellow of the American Association for the Advancement of Science (2009), the American Physical Society (2008), the Institute of Physics, and the Optical Society of America (2005). He also received the 2017 US Army Defense Intelligence “Mad Scientist” Award and the 2002 Willis E. Lamb Medal for Laser Science and Quantum Optics.

Jon was well known for his highly-developed sense of humour and a laugh that could be heard across a crowded room. One of our favourite anecdotes describes the time that Jon attended a lecture by the famous theoretical physicist Paul

Dirac. It was supposed to be a lecture for the general public, and many people from the local community came to hear the famous physicist. But the lecture was totally incomprehensible, and the audience was dismayed, until Dirac said that he was going to discuss Einstein's famous relation between energy and mass. Jon said that everyone in the audience leaned forward in anticipation of hearing something that they could finally understand. But instead of discussing the famous equation $E = mc^2$, Dirac showed another equation that would only be familiar to an expert. Jon laughed out loud, and we are sure that it was loud enough that Dirac must have heard it.

Jon was known for his colourful and flamboyant presentations, which contained many funny cartoons and illustrations [11]. At the same time, he had a deep disdain for "boring" Powerpoint presentations featuring only text and jargon delimited by bullet points. These preferences of his were perfectly encapsulated by one of his most frequently told jokes, told at the start of his 2018 lecture at the National Academy of Sciences, Engineering, and Medicine [11]: "Two theoretical physicists are on death row and have been in the same cell for ten years. One night, the warden comes and says, 'You're going to be executed tomorrow. Any last wishes?' The first theoretical physicist says, 'Well, I've been in this cell working on a new theory for the last ten years, and I would like to present it to all of the populace of the prison, so my final last good idea doesn't die with me.' And the warden says, 'Sure, we'll set up a Powerpoint for you, you can make some slides, and present your results.' He turns to the second theoretical physicist and says, 'What is your last dying wish?' The second theoretical physicist says, 'I would like to be taken out and shot before the other guy's talk!'"

Jon was a great physicist and a wonderful person. He will be greatly missed by his sisters Trisha and Ellen and his brother Michael, as well as everyone in the quantum technology community.

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FIGURE:

Figure caption:
Jonathan Dowling was a leader in the development of quantum technology.
Credit: Dr. Chenglong You