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Extended Abstracts and Speaker information

Daniel Colladon and the origin of light guiding

Jeff Hecht

Abstract:

Daniel Colladon's 1841 demonstration of light guiding by total internal reflection in a water jet was a crucial early step along the road that led to the development of modern fiber optics. My talk will describe his work and put it in the context of the time and other early work on light guiding.

Colladon came upon the idea while demonstrating the flow of water jets through various sized holes in lectures at the University of Geneva. Lecture-hall lighting was dim by modern standards, and his audience could not see the flowing water, so he collected sunlight from outside and focused it through a tube to his table in the lecture hall. There he focused the sunlight through a lens through a tank of water and into a jet of water flowing from the tank. Total internal reflection at the surface of the water jet guided the sunlight along the flowing water. Colladon called it "one of the most beautiful, and most curious experiments that one can perform in a course on optics," and described his experiments in Comtes Rendus the following year.

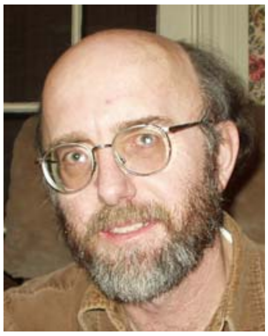
Others repeated his experiment, including John Tyndall, who heard of it through his mentor Michael Faraday. Colladon adapted his light-guiding demonstration to provide special effects for the Paris Opera in 1853. He first used it in a ballet called "Elias and Myias," then used red light to make a stream of "fire" flash from a wine barrel in Gounod's opera Faust. Later, the light-guiding principle was extended to make illuminated fountains, which became expensive household decorations, selling for up to 1000 French francs in the 1870s.

The most dramatic use of illuminated fountains came in the great Victorian-era exhibitions of the 1880s, where they entertained a public fascinated by the new age of electric lighting. The first great illuminated fountains were used at the 1884 International Health Exposition in London. Bigger and better illuminated fountains followed, culminating in the 1889 Universal Exhibition in Paris. Colladon, who visited the exhibition at age 86 from his home in Geneva, must have been delighted to see the French magazine La Nature call them "Colladon fountains."

Biography

Dr. Jeff Hecht

Contributing Editor, Laser Focus World, Author of several books on fiber optics and its history



Jeff Hecht has written about lasers, optics, and fiber optics since 1974. He is a full-time free-lance writer, a contributing editor to *Laser Focus World*, and a correspondent for *New Scientist* magazine. He is the author of 11 published books, including *City of Light: The Story of Fiber Optics* (Oxford, 1999), a book in the Sloan Technology Series funded by a grant from the Alfred P. Sloan Foundation. Researching that book led him to study the work of Daniel Colladon, who first demonstrated light guiding in water jets, a precursor to light guiding in glass fibers, at the University of Geneva in 1841.

Most of his other books cover lasers, optics, fiber optics, and the histories of those technologies. They include *Beam - The Race to Make the Laser*; *Laser Pioneers*; *Understanding Lasers: An Entry-Level Guide (3rd ed); Understanding Fiber Optics (5th ed); The Laser Guidebook (2nd ed); Beam Weapons - The Next Arms Race*; *Optics - Light for a New Age*; and *Laser - Supertool of the 80s*. He wrote the *Encyclopedia Britannica* entry for "lasers" and has given invited talks on the history of lasers at the Conference on Lasers and Electro-Optics, SPIE's Photonics West conference, and at the Massachusetts Institute of Technology.

Hecht has also written for a wide range of publications, including *Optics and Photonics News, Physics Today*, *Technology Review*, *IEEE Spectrum*, *Physics World*, *Cosmos*, *Sky & Telescope*, and *Analog Science Fiction.* Before he became an independent writer, he was managing editor of *Laser Focus* magazine for seven years; he also was a co-founder of *Lasers & Applications* magazine. He is a member of the Optical Society of America, the American Physical Society, the Institute of Electrical and Electronics Engineers, the Authors Guild, and the National Association of Science Writers. He earned a B. S. in electronic engineering from the California Institute of Technology, where he worked one summer in a holography lab.

LINKS: http://www.jeffhecht.com/ (September 2011)

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Through a Glass Brightly: Making the First Low-Loss Optical Fibers

Donald B. Keck

Abstract

Forty years ago a Corning Incorporated team invented the first low-loss optical fiber usable for telecommunications. This critical component launched a global effort that resulted in the Information Age in which we live. Some of the stories of that invention will be shared together with other thoughts concerning this technological revolution.

Biography

Dr. Donald B. Keck

Former Vice President, Research Director for Corning

Dr. Keck is currently a technology consultant and lecturer. He retired in 2002 as Vice President, Research Director for Corning Incorporated. He had served there in a number of technical and management positions for 34 years. From 2002-2004 he then served as the CTO for the Infotonics Technology Center that he helped start in upstate New York. He was a key member of the Corning (Keck, Maurer and Schultz) team that invented low-loss optical fiber in 1970. This work created the optical fiber telecommunications revolution and enabled the Internet. He has authored more than 150 papers and holds 36 patents.

Dr. Keck received his physics degrees from Michigan State University. He is a Distinguished Alumnus and currently serves on the College of Natural Science Advisory Board. He received an honorary D.Sc. degree from Rensselaer Polytechnic Institute.

Dr. Keck is an inductee of the National Inventors Hall of Fame. He is a member of the National Academy of Engineering and has served on several NRC Panels. He is a Fellow of the Optical Society of America and the IEEE, and an honorary member of the World Innovation Foundation. Among his awards are the Department of Commerce American Innovator Award and the President's National Medal of Technology.

Presently he is serving as vice-chair, Invent Now Board of Directors. He has been a member of the Congressional oversight board for the National Institute of Standards and Technology (NIST). He is a past Board Chairman of the Optoelectronics Industry Development Association (OIDA) and Past President of the National Inventor's Hall of Fame. Formerly he served on the boards of directors of PCO, Inc., a joint venture of Corning, Inc. and IBM, and the Optical Society of America. Locally he serves or has served on the American Red Cross, the Community Foundation, the Salvation Army, and the Science Center Boards. He is a Paul Harris Fellow of Rotary International.

He and his wife, Ruth, have a grown daughter, Lynne, living with husband Richard Vaia and their children, Annika and Arin in Dayton, OH, and grown son, Brian, living outside St. Paul, MN with significant other, Molly Schiltgen.

LINKS: http://en.wikipedia.org/wiki/Donald_Keck (September 2011)

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No networks without amplifiers

David N. Payne

Abstract

By the mid-1970's, optical fibre transmission technology had been developed and commercially deployed. However, as remains evident today, the new and powerful enabling technology created demand for bandwidth that soon began to outstrip its availability, despite the fact that the optical fibre theoretically offered copious capacity. Early solutions to capacity demand were achieved by increasing the bit rate, but this was never going to fill the available bandwidth window offered by the silica fibre. In the early 80's, the obvious strategy of using multiple carriers (i.e. wavelengths), referred to as wavelength division multiplexing (WDM) emerged. This would make it possible to dramatically increase the capacity by transmitting many signal channels on separate wavelengths in the same optical fibre. Unfortunately, this idea was incompatible with existing repeater technology that utilised electrical amplifiers. Channels would need to be split and each channel individually electrically amplified before being re-injected into the fibre, a costly and complex solution.

In response, a number of teams across the world began work on optical amplifiers that would be able to amplify simultaneously each of the wavelength channels. The two competitors were the semiconductor laser diode amplifier, and Raman amplification within the transmission fibre itself. While the diode approach looked very attractive, semiconductors suffer from fast gain dynamics that can cause cross talk between channels, i.e., rapid amplitude changes at one wavelength will vary the gain at another. The Raman amplifier on the other hand required a pump power that was difficult at the time, although today Raman amplification is sometimes used in tandem with the EDFA.

In 1985, a team at the University of Southampton began publishing on rare-earth-doped silica fibres for laser applications and quickly established that all the usual rare-earth ions laser ions could be incorporated into silica at the required low dopant concentration without significantly increasing the background loss. These lasers made excellent, high efficiency sources and it was noted that erbium-doped fibres operated at the telecommunications window of 1.55 microns. Today this work has given birth to a whole new and parallel industry of kW fibre lasers for material processing.

Despite 27 publications citing erbium as an interesting telecommunications fibre laser, it was not until OFC in January 1987 that the first publication emerged of an erbium-doped fibre in an amplifier configuration, (albeit pumped by a large argon laser). Interestingly, this caused a flurry of activity in the competing technologies (Raman and semiconductor diodes), but the logic of the erbium-doped fibre amplifier (EDFA) became increasingly compelling, largely because its slow gain dynamics results in minimal crosstalk between WDM channels. This today remains the single most important advantage, although many were quick to exploit the merits of an integrated fibre solution.

In 1986, Bell Laboratories had also noted the possibility of a rare-earth amplifier and had established a team led by Emmanuel Desurvire working on a very similar topic. In the years to follow, the primary research work of the University of Southampton and Bell Labs would have tremendous consequences in the conception of lightwave systems. However, it remained to develop a practical, efficient, and miniature pump source. Luckily, the same InGaAsP technology used in laser diodes for telecommunications sources could be used for EDFA pumping, as demonstrated in 1989 by an NTT team under Masataka Nakazawa.

Since then, major contributors too numerous to list from the photonics community have explored every avenue of EDFA performance and even today the EDFA remains an active research topic.

The combination of the EDFA and DWDM allowed the fibre capacity to be increased by at least two orders of magnitude and, interestingly, is now usually the limiting factor to available bandwidth. These technologies together directly led to an explosive growth in the telecoms industry. And the rest is history!

Biography

Prof. David N. Payne

Director of the Optoelectronics Research Centre, Southampton UK

David Payne obtained a PhD in 1976 from the University of Southampton, and is now a professor of photonics and Director of the Optoelectronics Research Centre (ORC). He has published over 650 Conference and Journal papers and is co-inventor on over 20 patents. Over the last forty years, he has made several key contributions in optical fibre communications and laser technology. His work in fibre fabrication in the 1970s resulted in many of the special fibres used today, including the revolutionary erbium-doped fibre amplifier (EDFA) and kilowatt-class fibre lasers for manufacturing and defence. He has received the UK Rank Prize for Optics, the 2001 Mountbatten

Medal, the 2004 Kelvin Medal for the application of science to engineering, the 2007 IEEE Photonics Award, the 1991 IEEE/LEOS Tyndall Award, the 1998 Benjamin Franklin Medal for Engineering, and is Laureate of the 2008 Millennium Technology Prize. He is also an Eduard Rhein Laureate and a foreign member of the Norwegian and the Russian Academies of Sciences. He is a Fellow of the Royal Society and of the Royal Academy of Engineering. As an entrepreneur, he founded York Technologies, (now PK Technology Inc.) and SPI Lasers plc (now part of the Trumpf Gruppe).

Links: http://www.orc.soton.ac.uk/people.html?person=dnp (September 2011)
http://en.wikipedia.org/wiki/David_N._Payne (September 2011)

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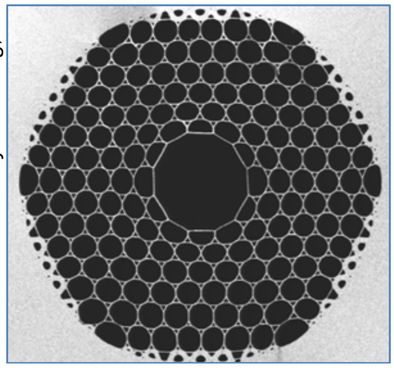
Photonic crystal fibres: New ways to guide light

Philip Russell


courtesy Xin Jiang, MPL

Mirages form above the hot surface of a sun-baked road when a layer of hot air is trapped under a mass of cooler air just above it. The hot air has a lower refractive index, which creates the condition for a phenomenon known as total internal reflection. As a result light incident at a shallow angle cannot penetrate into the hot layer, and instead is reflected away from the road surface, creating inverted images of distant mountains or the sky. In a conventional glass optical fibre light is trapped inside a cylindrical core (of slightly higher refractive index than the surrounding cladding) in exactly the same way. A trapped resonance appears when core light strikes the core-cladding boundary at a shallow enough angle, allowing formation of a single-lobed pattern of intensity that is confined to the core – a single guided mode. This mechanism cannot work for a hollow core, because no glass exists that has a refractive index less than unity – the refractive index of vacuum.

In 1991 I proposed to make an optical fibre that would guide light by a different mechanism, one that permits the core to be hollow. It is closely related to the effect that makes butterfly wings or beetle carapaces shine with brilliant colours in bright sunlight. Known as "structural colour" this phenomenon owes its origin to wavelength-scale periodic structures that have the ability to strongly Bragg reflect light of certain colours; the finer the pitch, the bluer the hue. A characteristic of such entomological colour is that reflection occurs only over a narrow range of angles, for example causing brilliant blue flashes as a Morpho butterfly wing catches the sunlight.

By careful design it turns out to be possible to create a three-dimensionally periodic "photonic crystal" of transparent material that strongly reflects light for all angles of incidence and all polarization states. Such a "photonic band gap" material would remarkably create a “dark space” within which light could not, in a fundamental sense, exist. Wrapped around so as to form an empty tube, it would permit light to be trapped in a hollow core. My idea was then to fashion a glass optical fibre with a periodic lattice of hollow channels running along its entire length. Suitably arranged, this photonic crystal fibre or PCF would create a two-dimensional photonic band gap for a range of incident angles and optical frequencies, allowing light to be trapped inside a central hollow core because it is simply *not allowed to exist in the cladding*.
The sceptics had much to say. Is it not almost impossible to make such a structure? If an under-sea cable made from such fibres was damaged (perhaps chewed by a shark or torn in two by a passing whale) wouldn’t water get into the holes and drown out the telecommunications channels?

Nevertheless—and it was far from easy to work out a way of making such structures—we succeeded in 1998 and by 2004 had achieved remarkably low loss: only half the light was lost after 3 km of propagation (in the best telecommunications fibres this occurs after 15 km). Hollow core PCF neatly overcomes a long-standing problem in optical physics: how to increase the depth of focus of a lens *in empty space* while maintaining high focal intensity. To achieve this, one must overcome the diffraction (or spreading out) of a beam of light as it travels – a fundamental property of three-dimensional space. Amongst many other advances, hollow core PCF is revolutionizing studies of nonlinear interactions between laser light and gases, as well as allowing diffraction-free laser propulsion of small dielectric particles. It may also ultimately lead to a huge increase in the capacity of optical communications fibres by permitting the inter-channel wavelength spacing to be reduced while avoiding detrimental inter-channel cross-talk introduced by nonlinear interactions in a solid glass core.

Biography

Prof. Philip St. John Russell

Director of the third division of the Max Planck Research Group at the Institute of Optics, Information and Photonics at the University of Erlangen-Nuremberg

Philip Russell is Director at the Max-Planck Institute for the Science of Light in Erlangen, Germany and holds the Krupp Chair in Experimental Physics at the University of Erlangen-Nuremberg. He obtained his M.A. (1976) and D.Phil. (1979) degrees at the University of Oxford and subsequently worked in research laboratories and universities in France, Germany and the USA. Since 1976 his interests have ranged from the behaviour of light in periodically structured materials to nonlinear optics, waveguides and optical fibres. He has over 340 journal publications and is co-inventor on 37 disclosures or patents covering many aspects of photonics. He is a Fellow of the Royal Society and the Optical Society of America (OSA) and has won several international awards for his research including the 2005 Körber Prize for European Science, the 2005 Thomas Young Prize of the Institute for Physics (UK) and the 2000 OSA Joseph Fraunhofer Award/Robert M. Burley Prize. He was a Director-At-Large of the Optical Society of America 2007-2009 and from 2005 to 2006 he was an IEEE-LEOS Distinguished Lecturer and the recipient of a Royal Society/Wolfson Research Merit Award.

Links: http://en.wikipedia.org/wiki/Philip_Russell (September 2011)
http://www.mpl.mpg.de/mpf/php/abteilung3/ (September 2011)

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