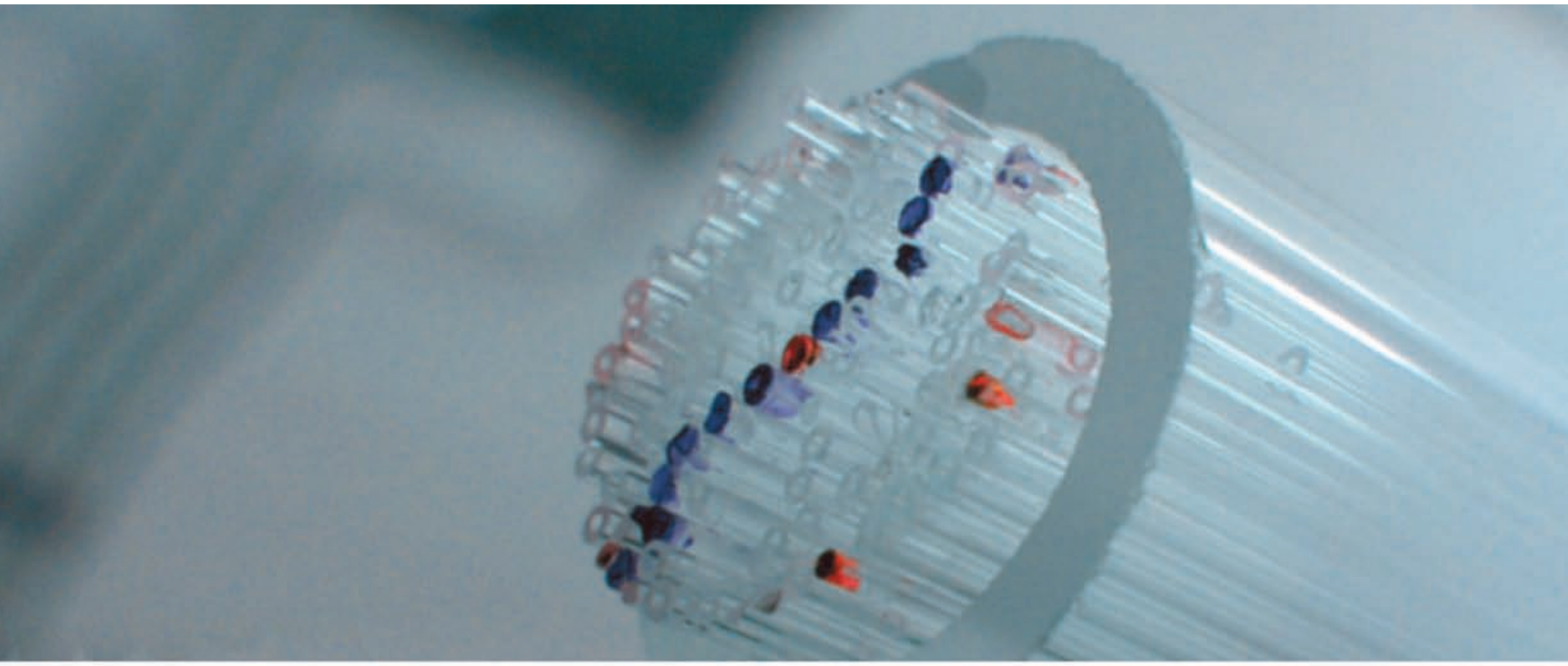

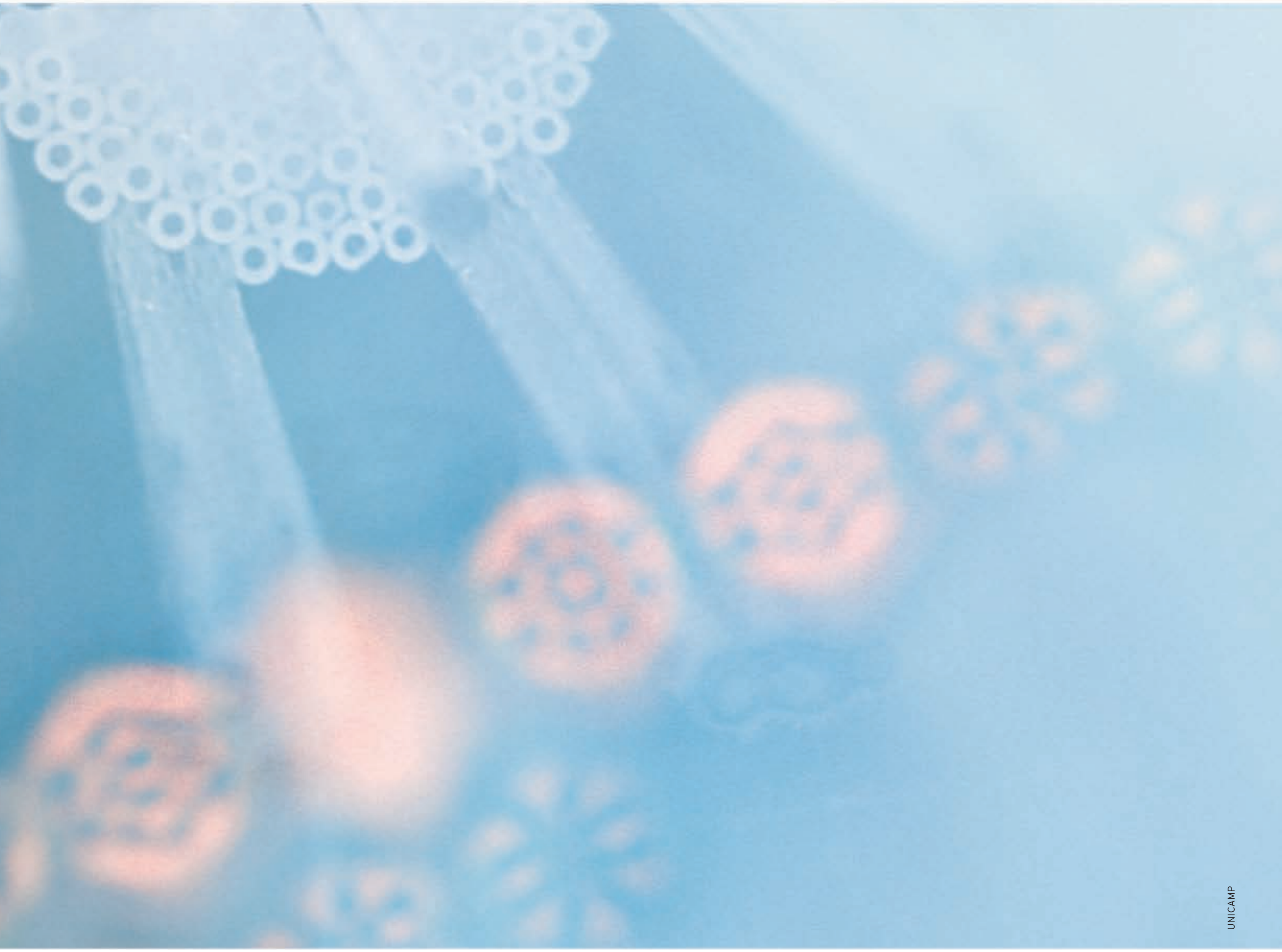

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Multiplied beams

Researcher publishes article in leading international journal on the new generation of optic fibers

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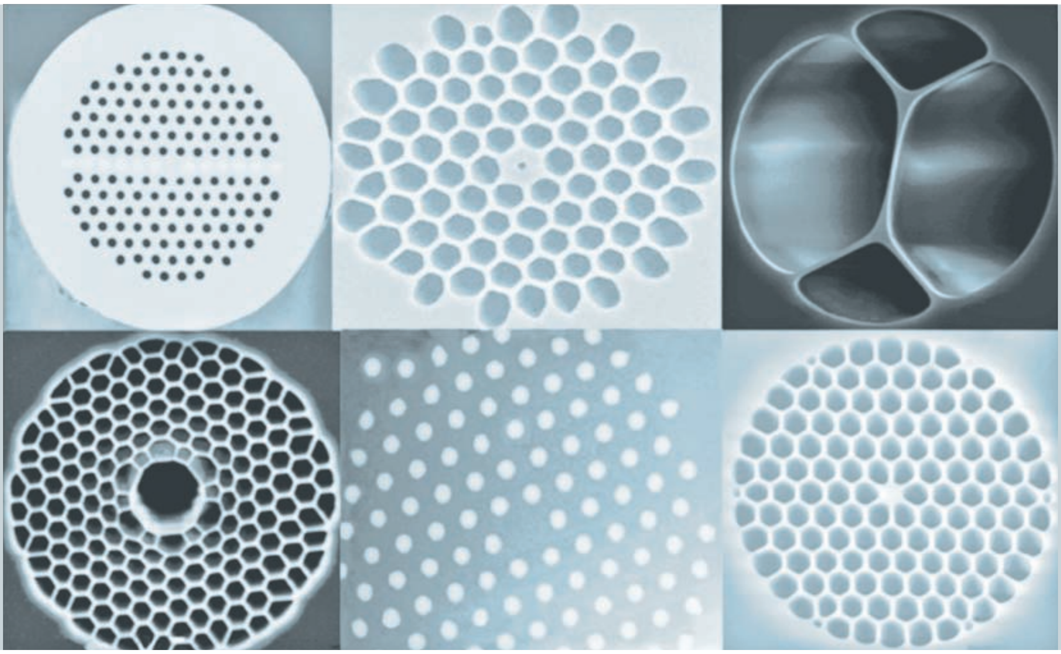
Photonic crystal fibers are a new moment in the era of optical communication

In the mid 1990s, researchers from England's University of Bath, created a new kind of optic fiber and revealed it to the world. This new optic fiber was named Photonic Crystal Fiber (PCF). According to the inventors, this innovation had several advantages over existing fibers and its properties were much more interesting than those of conventional optic fibers. Optic fibers are filaments made from silica or from polymer material; these filaments are as thin as a strand of hair. Optic fibers are capable of providing high-speed data transmission in the form of light. Nearly 15 years after their discovery, PCFs are already being used in a number of applications – ranging from signal amplifiers in data transmission networks to computerized optic tomography, laser devices, ultra-sensitive sensors and light sources. However, they have not totally substituted traditional fibers. This January, electrical engineer Arismar Cerqueira Sodré Júnior, a professor at the College of Technology (FT) at the State University of Campinas (Unicamp), Limeira campus, published an article called "Recent progress and novel applications of photonic crystal fibers", in the *Report on Progress in Physics*, journal, in which he writes about the applications and this state-of-the-art technology.

At the beginning of the article, the 31-year old Cerqueira refers to a question asked by Irish physicist Philip Russell, from Germany's University of Erlangen-Nuremberg. Russell was the inventor of this new class of optic fibers. The question was: could photonic crystal fibers be the beginning of a new era in optic communications? In the conclusion of his 21-page article, Cerqueira left another provocative question unanswered: can PCF technology make conventional optic fibers obsolete? The paper was written at the invitation of the publishers of the journal, considered one of the world's most prestigious publications in the field of photonics. The referred article's impact factor corresponded to 12.9; this factor is related to the number of times the articles published in the journal are quoted in papers written by other authors. According to the publishers of *Report on Progress in Physics*, the electronic version of the paper – technically a revised copy, because it does not contain any new discovery and merely revises everything that exists on the given topic – had more than 250 downloads in the first 11 days after the paper was published in January 2010. This goal had been achieved by only 10% of all the articles divulged in journals published by England's Institute of Physics (IOP).

The PCFs have raised many questions, but have also provided many answers. To better understand the future perspectives of this new kind of fiber, it is essential to understand how they work, their potential, what kind of equipment they are used in and how they differ from traditional technology. Conventional optic fibers, which are much more efficient than copper wires, have an outer layer and a core, usually made of silica. The functioning principle is very simple: a laser beam is launched from one end of the fiber and, according to the material's optic characteristics, travels through the fiber by means of successive reflections.



Various forms of photonic crystal fibers in images captured by electronic scanning microscope. The first fiber is a hybrid fiber, with two kinds of laser light guides

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The ability to confine light and make it travel inside the fiber is because the core's refractive index is higher than that of the outer layer. To achieve a higher refractive index, the inner silica is enriched – or doped – with atoms from another material, such as germanium. One of the differences between phonic crystal fibers and conventional fibers is that the former do not necessarily have to contain doping elements in their core. The refractive difference between the outer coating and the fiber's core is due to the existence of a regular set of small apertures in the form of tunnels that run parallel to the fiber's axis, along the entire length of the fiber. The diameter of these apertures corresponds to one micrometer, which is equivalent to one millimeter divided by one thousand.

Another specific characteristic of photonic crystal fibers – manufactured by such giant corporations as France's Alcatel-Lucent, Japan's Sumitomo, the US's, Corning, and Holland's Draka – is that they can have varied geometries and are made from several different materials, among which are pure or doped silica, polymers, liquids, metals, other kinds of glass and even air and gases. The possibility of varying geometries and raw materials is an advantage because manufacturers can design the fiber's microstructure in a way that provides the fiber with properties defined according to the specific need. Thus, it is possible to guide the light by means of different propagation mechanisms in a variety of wave lengths. "The PCFs meet the requirements of the global market, which demands small, energy-saving, lightweight devices. PCFs take better advantage of the light and this increases the performance of optic devices and the precision of such equipment as temperature and pressure sensors, biosensors, electric field detectors and gas sensors, among others," says Cerqueira.

Thousands of fibers – In the researcher's opinion, the invention of the PCF technology and its entry into the market represent a new period in the era of optic communication. But he does not believe that this new technology will make traditional optic fibers obsolete. "There are currently hundreds of thousands of kilometers of optic fibers installed all around the world. These optic fibers go across continents, across the bottom of the sea, and have many applications in telecommunications. The substitution of all these optic fibers with PCFs would be unfeasible. The new fibers represent a complementary technology and can be used in applications in a variety of fields, such as medicine, sensors, telecommunications, and metrology, among others," he says.

In the article, Cerqueira describes new kinds of photonic crystal fibers, among them the hybrid PCFs that he helped invent during his doctorate studies at Italy's Scuola Superiore Sant'Anna. Cerqueira also spent some studying at the University of Bath, where he joined the team headed by professor Jonathan Knight, who had produced the world's first PCF. The hybrid fibers combine the light guidance of two categories of existing PCFs. In the first category, the guidance is obtained in manner similar to that of traditional technology, by means of the internal reflection of the light in the core of the fiber. In the second category, the light is guided by a new effect, called photonic bandgaps, and travels through specific frequency windows specified in the design of the fiber. According to the professor from Unicamp, the hybrid PCF was the first optic wave guide to make it feasible to guide light simultaneously by means of two propagation mechanisms. The professor says that one of the most promising fields for the use of PCFs is the development of the so-called nonlinear optical devices, used in telecommunications and produced from dozens of meters of optic fibers. He adds that some of the related equipment, such as supercontinuum sources, is already being sold in the market. Supercontinuum is an effect characterized by the generation of very intense laser light and extensive wavelength. “Supercontinuum is used in computerized tomography, fiber characterization equipment, and optical devices, as well as in multiple wavelength systems for communication equipment called Dense Wavelength Division Multiplexing (DWDM), which exists in all telecommunication systems,” he says. Fianium, a British company, and RPMC Lasers, an American company, are two of the main manufacturers of supercontinuum sources with photonic crystal fibers.

This technology could also be used for the development of the so-called frequency combs, multiple length wave sources with a variety of applications, such as frequency measurements for the generation of ultra short pulses. They can also be used in metrology and high resolution optical spectroscopy equipment. None of these are commercially available yet. In addition, the PCFs can also be used as light guides in close and distant infrared regions and in sensors, to detect gas leaks in industrial processes and in terrorist attacks. “In this region, traditional fibers don’t work because of massive optical loss. Light does not travel along more than one meter with traditional technology, while the PCF can travel for dozens of meters,” says the researcher from Unicamp. NKT Photonics, a Danish company, sells products based on the PCF technology to the infrared area.

The PCFs can also guide light in the terahertz (THz) electromagnetic frequency region, a frequency which is prohibitive for traditional fibers. In Cerqueira’s opinion, the propagation of light in this band is the key technology to solve existing data transmission bottlenecks between microelectronics and optical communication. “Nowadays, the data transmission capacity of optical systems is infinite, or at least, much higher than the current traffic demands of communication systems. However, due to the limitations of electronic components, the transmission band is underused. With light guiding in the THz frequency, the data transmission limit can increase several dozen terabytes per second, which would multiply the performance of the world’s communication systems by up to one thousand times.”

Brazil’s contribution – Brazil is one of the world’s most advanced centers for research on PCFs. Important research projects on optical fibers have been conducted by professor Cerqueira and other colleagues at Gleb Wataghin Physics Institute, at Unicamp, for more than 30 years. The physics institute is part of the Centro de Pesquisa em Óptica e Fotônica (CePOF), optics and photonics research center in Campinas, which, in turn, is one of the Centros de Pesquisa, Inovação e Difusão (Cepid) research centers of FAPESP. In addition to the CePOF, Unicamp is taking part in another major project which includes PCFs as one of the lines of research. More specifically, this is the Fotonicom project being developed at one of the Institutos Nacionais de Ciência e Tecnologia (INCT) national science and technology centers supported by FAPESP and by the National Council for Scientific and Technological Development (CNPq) research foundation. One of the innovations that came from Unicamp was a photonic crystal fiber with integrated electrodes (copper wires). This makes it possible to apply voltage to the fiber or make it go through a beam of light that can be shaped with the electric current, thus opening up new possibilities to use the fiber in gas detection sensors and optical modulators used in data transmission networks. It is also important to highlight the experiments conducted under the coordination of professor Carlos Henrique de Brito Cruz, scientific director of FAPESP, at the Laboratório de Fenômenos Ultrarrápidos, laboratory on ultra rapid phenomena. An article published by Cerqueira and Brito in the *Optics Letters*, journal in 2008, explains the development of a frequency converter for the transfer of energy between photonic bandgaps. More articles on the experiments conducted with PCF fibers at Unicamp are available in issues 106 and 147 of *Pesquisa FAPESP*. ■

Scientific articles

1. CERQUEIRA S. JR., A. “Recent progress and novel applications of photonic crystal fibers.” **Reports on Progress in Physics.** v. 73. 2010. On-line.
2. CERQUEIRA S. JR., A.; CORDEIRO, C. M. B.; BIANCALANA, F.; ROBERTS, P. J.; HERNANDEZ-FIGUEROA, H. E.; BRITO CRUZ, C. H. “Nonlinear interaction between two different photonic bandgaps of a hybrid photonic crystal fiber.” **Optics Letters.** v. 33, p. 2.080-82. 2008.
3. CERQUEIRA S. JR., A; LUAN, F.; CORDEIRO, C. M. B.; GEORGE, A. K.; KNIGHT, J. C. “Hybrid photonic crystal fiber.” **Optics Express.** v. 14, p. 926-31. 2006.

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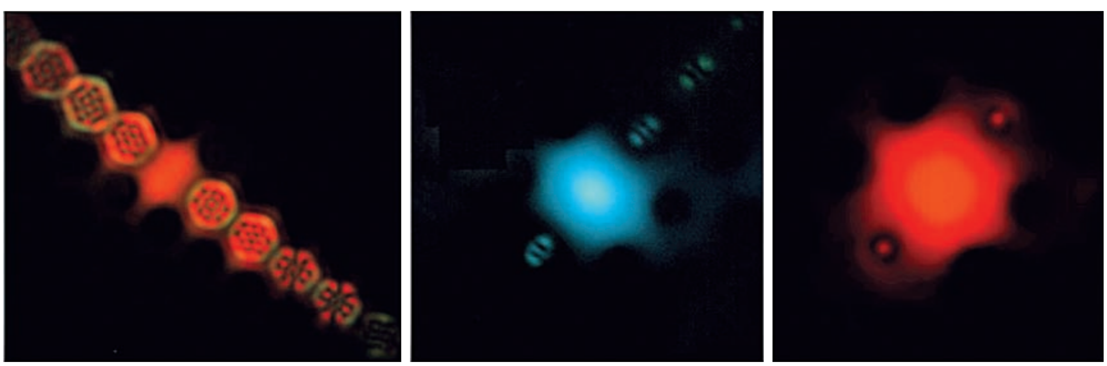

Demonstration of hybrid photonic crystal fibers: a fiber without filter and, on the left, a fiber with blue and orange filter. Multiple electromagnetic wavelengths