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Photonic Bandgap Bragg Fibers: A New Platform for Realizing application-specific Specialty Optical Fibers and Components

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Abstract : Bragg fibers, consisting of a low index core (including air) surrounded by a series of periodic layers of alternate high and low refractive index materials, each being higher than that of the core, form a 1D photonic bandgap (PBG). In view of the multitude of individual physical parameters that characterize a Bragg fiber, they offer a wide choice of parametric avenues to tailor their propagation characteristics. Owing to their unique PBG guidance mechanism, Bragg fibers indeed exhibit unusual dispersion characteristics that are otherwise nearly impossible to achieve in conventional silica fibers. Solid core Bragg fibers, amenable to fabrication by the highly mature MCVD technology, could be designed to realize broadband supercontinuum light. This talk would review our recent works on modeling of propagation characteristics, dispersion tailoring in them for applications as metro as well as dispersion compensating fibers and also as supercontinuum light generators.

Consequent to the mind boggling progress in high-speed optical telecommunication witnessed in recent times, it appeared that it would only be a matter of time before the huge theoretical bandwidth of 53 THz, offered by low-loss transmission windows (extending from 1280 nm to 1650 nm) in OH^--free high-silica optical fibers would be tapped for telecommunication through dense wavelength division multiplexing techniques! In spite of this possibility, there has been a considerable resurgence of interest amongst researchers to develop application-specific specialty fibers, e.g. fibers in which transmission loss of the material would not be a limiting factor and in which nonlinearity and dispersion properties could be conveniently tailored to achieve transmission characteristics that are otherwise almost impossible to realize in conventional high-silica fibers. Research targeted at such fiber designs in the early 1990s gave rise to a new class of fibers, known as *Photonic Crystal Fibers* (PCF) or *microstructured optical fibers* (MOFs), characterized with wavelength scale periodic refractive index features. These structures exhibit *photonic bandgaps* i.e these forbid propagation of a band of wavelengths within them. If the frequency of incident light happens to fall within the photonic bandgap, which is characteristic of the photonic crystal, then propagation of light is forbidden inside it. Opals are naturally occurring photonic crystals consisting of a three-dimensional lattice of dielectric spheres, and *opalescence* is a direct consequence of their photonic crystal nature. The iridescent wings of some butterflies and beetles are also the result of naturally occurring photonic crystal effects that have evolved on their surface with time. In contrast to the electronic bandgap, which is a consequence of a periodic arrangement of atoms/molecules in a semiconductor crystal lattice, a photonic bandgap arises due to a *periodic distribution of refractive index* in a PCF. However by introducing a defect region to an otherwise periodic structure, light (within the bandgap) could be localized in the defect region thereby mimicking a fiber core. The defect region could be a medium of refractive index lower (e.g. air) than the surrounding. Such PCFs are known as *photonic bandgap* fibers (PBGFs). In contrast to a conventional optical fiber, in which light is guided by total internal reflection, Bragg scattering is responsible for effective wave guidance in such fibers, which led to the christening of these fibers as photonic bandgap guided optical fibers. In 1987, Yablonovitch first proposed the possibility of controlling properties of light through the photonic bandgap effect in man-made photonic crystals.

Bragg fiber is an example of a 1D-PBGF, which offers two major benefits − namely, much lower transmission loss and reduced sensitivity to nonlinear optical impairments like four wave mixing, cross phase modulation etc. Following the same reasoning, power-handling capability of these fibers would be much better and material dispersion would be much reduced. In addition, because of a multitude of physical parameters that can be altered independently, their propagation characteristics can be tuned with ease to control and maneuver light guidance for a variety of applications, ranging from telecommunication to sensors. Bragg fibers can also be formed around silica core through the well-known MCVD process of fiber manufacture. By configuring a dispersion managed Bragg fiber one could alternatively enhance nonlinear optical effects in it and exploit the same to achieve for example, *supercontinuum* generation in such structures. In this talk our focus will be to highlight the basic functional principle of propagation in Bragg fibers, modeling methods implemented by us, and few examples of several components and devices potentially feasible around this technology platform.

Bishnu P. Pal

Bishnu P. Pal was born in Shillong, India on 3rd December 1948. He received M.Sc. and Ph.D. degrees in Physics from Jadavpur University and IIT Delhi in 1970 and 1975, respectively. He has worked as Visiting Scholar/Visiting Professor in the area of Fiber Optics and Applications at the Norwegian Institute of Technology, Trondheim (Norway), the Fraunhofer Institute fur Physikalische Messtechnik, Freiburg (Germany), the National Institute of Standards and Technology, Boulder (USA), University of Strathclyde, Glasgow (UK), and Universities at Nice and Limoges (France). In late 1977 he joined the academic staff of IIT Delhi, where he is a Professor of Physics since 1990. He had been a member of the founding Editorial Advisory Board of the International Journal of Optoelectronics (1988-93) published by Taylor and Francis from UK and is currently a Member of the Editorial Board of Chinese Optoelectronics Letters and IETE (India) Journal for Students. He Guest Edited special issues of Journal of Optics (India) devoted to *Guided Wave Optical Components and Devices* (2004), Proc. IEE (Optoelectronics) devoted to *Guided Wave Optics on Silicon* (1996), International Journal of Optoelectronics devoted to *Optoelectronics in India* (1993) and Joint issue of JIETE and IETE Tech Review devoted to *Optoelectronics and Optical Communication* (1986). Prof. Pal has extensive teaching and research experience on various aspects of Fiber Optics and he has published and reported over 100 research papers and research reviews in international journals and conferences. He is co-author of the book entitled *Fiber Optics and Instrumentation* (in Russian, Mashinostroenie Publishing House, Leningrad, 1987) and has edited the books: *Fundamentals of Fiber Optics in Telecommunication and Sensor Systems* (Wiley Eastern, New Delhi and John Wiley, New York, 1992, 3rd reprint 2001) and *Guided wave Optical Components and Devices* (Academic/Elsevier, Burlington, 2006). He has also contributed by invitation 12 chapters in books. Prof. Pal is a Fellow of Optical Society of India and IETE and is a Member of the Optical Society of America. He has been an invited speaker at over 20 international conferences held in India and abroad. He is a co-recipient of the First Fiber Optic Person of the Year award in 1997 instituted by Lucent Technology in India and also the Gowri Memorial Award for the year 1991 of IETE. He has been recently selected as a Distinguished Lecturer of IEEE/LEOS for 2005-2006 for his significant contributions in guided wave optical components and devices. His current research interests concern components for DWDM and optical networks, dispersion compensators, photonic bandgap fibers, and fiber optic sensors for civil engineering structures.