STUDIES ON PHOTONIC BANDGAP BRAGG FIBERS AND WAVEGUIDES

by

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Fiber - optic devices
Bragg fibers

Dedicated to my father...

CERTIFICATE

This is to certify that this thesis entitled STUDIES ON PHOTONIC BANDGAP BRAGG FIBERS AND WAVEGUIDES, being submitted by Ms. Sonali Dasgupta to the Indian Institute of Technology Delhi, is a record of bonafide research work carried out by her. She has worked under our guidance and supervision, and has fulfilled the requirements, which to our knowledge, have reached the requisite standard for the submission of this thesis. The results contained in this thesis have not been submitted in part or full to any other university or institute for the award of any degree or diploma.

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Abstract

Optical fibers have revolutionized the field of telecommunications. High-speed optical networks have penetrated domains ranging from long-haul trans-oceanic networks to local access networks. Conventional optical fibers used in telecommunications comprise of a high-index doped silica core surrounded by a low-index silica cladding. Light is guided through the core by the phenomenon of total internal reflection. Photonic bandgap fibers are a special variety of optical fibers, which confine and guide light through the *photonic bandgap effect.* Bragg fibers belong to the category of one-dimensional photonic bandgap fibers. These fibers have lately attracted a great deal of interest owing to their potential to outperform the conventional silica fibers. This thesis deals with the design and analysis of Bragg fibers/waveguides and presents some novel designs for realizing high-performance components based on them for various applications.

In spite of the tremendous growth in data communication/Internet traffic, the last decade has witnessed a glut in the long-haul networks sector. This was a fallout of the over-capacity of installed fiber base under the ground than the actual requirement. However, the demand and bandwidth usage in metropolitan networks has been increasing significantly in the recent past. We propose for the first time in this thesis that Bragg fibers could prove to be an attractive transmission medium for the metro networks. Cost is one of the driving factors for these networks, which in turn necessitates the use of minimum number of components used in the network. The commercially available metro fibers typically provide a span length of $\sim$ 100 km, without the need for a dispersion compensator. However, they still require an amplifier to compensate for the propagation loss. We exploit the low-loss feature of air-core Bragg fibers to overcome the need for amplifiers as well. We propose a Bragg fiber design that is optimized for metro applications and is capable of providing a span length of $\sim$ 100 km at 10 Gb/s, without the need for any dispersion compensator and amplifier.

Besides the fiber as the transmission medium, optical fiber networks comprise of a number of optical components, many of which are fiber-based, thereby enabling easy integration through splicing. Dispersion compensating fibers (DCFs) are one such integral component of any long-haul network. In this thesis, we propose the use of Bragg fibers for realizing ultra low-loss dispersion compensators. We present a novel Bragg fiber design for achieving highly efficient dispersion compensation. The figure of merit (which is a measure of efficiency) of the proposed dispersion compensator is almost two orders of magnitude higher than that of commercially available DCFs.

Apart from the air-core Bragg fibers, solid-core Bragg fibers also form an attractive alternative technology platform for realizing certain interesting optical devices. In this thesis, we propose for the first time, the use of solid-core Bragg fibers for nonlinear optical applications. We carry out a detailed theoretical study of nonlinear spectral broadening of a pulse propagating through solid-core Bragg fibers. Subsequently, we also propose generation of supercontinuum pulses, centered at the Nd-YAG wavelength (1064 nm), through the novel design of a dispersion-decreasing solid-core Bragg fiber.

The photonic bandgap effect has also been widely exploited to design planar low-loss waveguide-based devices, which are commonly referred to as Bragg reflection waveguides (BRWs). In all practical applications, these waveguides are of finite extent. However, the Bloch-wave formulation that is extensively used to study these waveguides inherently assumes an infinitely extended structure. In this thesis, we examine the validity and applicability of the Bloch-wave formulation to study some of the propagation characteristics (e.g. effective index and leakage loss) of the BRWs as obtained by the Bloch-wave formulation and those yielded by a matrix method based on leaky mode analysis. We show that the structural finiteness of the BRWs spawns a difference in the values of the effective indices as compared to that of the infinitely-extended BRWs. We also show that the proposed method can be applied to analyze all symmetric BRW designs as well as chirped BRWs.

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