Photonic Crystal Fibres as the Transmission Medium for Future Optical Communication Systems

During this Ph.D. work, air-silica photonic crystal fibres (PCFs) have been investigated for telecommunication applications. PCFs have a complicated cladding structure, where air holes, running along the entire fibre length, ensure light guidance. Photonic crystal fibres can be classified into two major groups: index guiding PCFs and photonic bandgap fibres (PBGFs). Several aspects of index guiding PCFs are similar to conventional fibres. On the contrary, PBGFs form a fundamentally new class of fibres and their properties differ considerably from those observed for both conventional fibres and index guiding PCFs. Nevertheless, both PCF types exhibit numerous novel properties not obtainable by standard fibre technology that are very attractive for optical communication systems. Even though PCFs have now existed already for a decade, their exploitation for telecommunication applications has begun only recently. This thesis follows the evolution of PCFs as transmission media from the beginning up to now and presents state-of-the-art results of their various possible system applications. Index guiding PCFs have been investigated for transmission purposes. In this thesis, some of the initial transmission experiments comprising PCFs are presented. Among others, the first reported 10 Gbit/s transmission over 5.6 km PCF is described. The total transmission distance over index guiding PCF is increased to 57.6 km, more than four times longer than the achievable lengths of the date. The total capacity carried on a single wavelength is increased to 80 Gbit/s, the highest capacity transmitted on a single wavelength over PCF today, by polarisation multiplexed differential phase shift keying signal transmission. Index guiding PCFs have also been studied for signal processing applications as well, and exploited for building fully functional, entirely PCF based optical transmission links and networks. The first 40 Gbit/s transmission over 5.6 km PCF with mid-span spectral inversion dispersion compensation realised in a highly nonlinear photonic crystal fibre is demonstrated. The first optical network with broadcast, transmission and wavelength conversion functionalities, all realised in PCFs is presented. Furthermore, index guiding PCFs have been investigated for dispersion compensation. A novel dispersion compensating photonic crystal fibre (DC-PCF) design, which exhibits a large dispersion coefficient of $\pm 1353 \text{ps/(nm}\cdot\text{km})$ at 1550 nm, while relative dispersion slope matching with standard single mode fibre is ensured, has been presented. The proposed design is compared with other reported DC-PCF designs. Advantages and limitations of the presented design are discussed. Thereby, the great potential of index guiding PCFs as transmission media, as nonlinear media for signal processing or as dispersion compensating fibre for future high capacity long-haul transmission systems is demonstrated. Finally, the telecommunication applications of photonic bandgap fibres are investigated. This work focusses on air-guiding photonic bandgap fibres (AG-PBGFs) and their system applications. The first and currently only reported data transmission over AG-PBGF is described. The potentials and current limitations of AG-PBGFs as transmission fibres are discussed. A polarisation delay interferometer, exploiting the large birefringence of AG-PBGFs, realised in only 2.4 m AG PBGF for demodulation of 9.95 and 39.8 Gbit/s differential phase shift keying modulated signals is demonstrated, thereby demonstrating the feasibility of AG-PBGF for realising stable and compact fibre birefringence based optical devices.

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