Chapter 5

EVOLVING MICROSTRUCTURED OPTICAL FIBRES

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Abstract
Optical fibres are not only one of the major components of modern optical communications systems, but are also used in other areas such as sensing, medicine and optical filtering. Silica microstructured optical fibres are a type of optical fibre where microscopic holes within the fibre result in highly tailorable optical properties, which are not possible in traditional fibres. Microstructured fibres manufactured from polymer, instead of silica, are a relatively recent development in optical fibre technology, and support a wide variety of microstructure fibre geometries, when compared to the more commonly used silica. In order to meet the automated design requirements for such complex fibres, a representation was developed which can describe radially symmetric microstructured fibres of different complexities; from simple hexagonal designs with very few holes, to large arrays of hundreds of holes. This chapter presents a genetic algorithm which uses an embryogeny representation, or a growth phase, to convert a design from its genetic encoding (genotype) to the microstructured fibre (phenotype). The work demonstrates the application of variable-complexity, evolutionary design approaches to photonic design. The inclusion of real-world constraints within the embryogeny aids in the manufacture of designs, resulting in the physical construction and experimental characterisation of both single-mode and high-bandwidth multi-mode microstructured fibres, where some GA-designed fibres are currently being patented.

Keywords: microstructured optical fibres, evolutionary design, genetic algorithm, embryogeny
1. INTRODUCTION

Whether used for telecommunications, cable television or in the operating theatre, optical fibres are one of the major components used in modern optical communications systems. Conventional optical fibres are typically made of silica, and have a refractive index profile that varies across the fibre but is constant along the fibre. In solid-core silica fibres, the refractive index profile is altered by the inclusion of chemicals, such as fluoride, germanium and boron, into the silica preform, which is several centimeters in diameter. This preform is then heated and stretched down to an optical fibre, typically 100–200 μm in diameter.

The development of silica microstructured optical fibres has expanded the application areas of optical fibres. The inclusion of air holes results in highly tailorable optical properties not possible in traditional silica fibres. Silica microstructured fibres primarily have hexagonal arrays of holes, a result of the capillary stacking approach used to manufacture preforms. Microstructured polymer optical fibres (MPOF) are a more recent advance which allows almost arbitrary symmetry and positioning of holes, opening up the design space considerably. To reflect this, new search and optimisation algorithms need to be developed which can generate the required diversity of designs and, in parallel, deal with manufacturing constraints.

This chapter presents a genetic algorithm which uses an embryogeny, or a growth phase to convert a design from its genetic encoding (genotype) to the microstructured fibre (phenotype). The result is a compact binary representation which can generate microstructured fibre designs, where the number of holes and the overall complexity of the designs is not predetermined, but can evolve over time. A brief overview of MPOFs and their manufacture is presented in Section 1.1, followed by a discussion of previous representations for microstructured fibre optimisation in 1.2, and motivating the need for more sophisticated design algorithms. Representations and embryogenies in genetic algorithms are then introduced in Section 1.3. Details of the new representation and embryogeny for microstructured fibres are given in Sections 2.1 and 2.2, with a discussion of symmetry in Section 2.3. The genetic operators mutation and recombination are discussed in Section 2.4, followed by an overview of