Photonic Device Design Using Multiobjective Evolutionary Algorithms

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Abstract. The optimization and design of two different types of photonic devices - a Fibre Bragg Grating and a Microstructured Polymer Optical Fibre is presented in light of multiple conflicting objectives in both problems. The fibre grating optimization uses a fixed length real valued representation, requiring the simultaneous optimization of four objectives along with variable bounds and a single objective constraint. This led to the human selection of a Pareto-optimal design which was manufactured. The microstructured fibre design process employs a new binary encoded variable length representation. An external embryogeny, or growth process is used to guarantee the creative generation of these complex designs which are automatically valid with respect to manufacturing constraints. Some initial results are presented for the case of two objectives which relate to the bandwidth and signal loss of a design.

1 Introduction

As more demands are made on telecommunications and other applications of optical fibres such as sensing, demand for the complexity and functionality of these devices increases. Fibre Bragg gratings (FBG) for optical filters and switching are an inherent part of such systems, offering highly tailorable optical filtering. Microstructured Polymer Optical Fibres (MPOF) are a more recent advent in the field of photonics, promising ease of manufacture along with functionality customization. Both these areas of research are served well since they can be manufactured along with the capabilities to characterize both FBGs and MPOFs. The design of both these devices is a complicated task, and forms an excellent set of technologically relevant problems for powerful design algorithms such as Evolutionary Algorithms (EA).

The design of FBGs using EAs has previously been explored using single objective techniques [1]. Typically the design goals have been simple (for example, bandpass filters), and EAs have proven very successful. In these cases the objective function was defined as the minimisation of the difference between the

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target spectrum and the design spectrum, using weights to increase the relative importance of regions of interest. The FBG used here is a 1-dimensional design problem, where the FBG features vary along the optical fibre. In this paper we consider the generalized case of multiple objectives by considering particular spectral features of interest, without reducing the problem to a single objective.

In the area of microstructured fibre design, there have been few examples of optimization technique usage. One possible reason is that the computational evaluation of traits for these types of structures can be expensive and difficult. Particular types of structures, such as hexagonal arrays of holes are used in silica due to the capillary stacking techniques used in manufacture, and this has led to most applications of microstructured fibre optimization considering these hexagonal arrays. MPOF technology on the other hand does not limit us to particular arrangements of holes, requiring the application of more general *design* techniques, as opposed to optimization using a fixed representation, which will open up the technology to more application areas. The MPOF design problem is 2-dimensional in nature, where the refractive index (placement of holes) varies across the optical fibre. In this paper we present a representation which was developed to effectively design these structures in an EA setting, along with some initial results using two conflicting objectives.

Real world engineering problems generally involve multiple objectives, and to simultaneously meet these most implementors will combine these multiple objective into a single one. In these cases, an a-priori decision is made about the relative importance of the objectives, emphasizing a particular type of solution. These techniques often require some problem-specific information, such as the total range each objective covers. In complex design problems such as those presented here, this information is rarely known in advance, making the selection of single objective weighting parameters difficult.

Instead of producing a single perfect design, multiobjective techniques consider all objectives simultaneously, resulting in a range of designs where the objectives are expressed to varying degrees (the non-dominated or *Pareto* set). Evolutionary techniques naturally lend themselves to multiobjective optimization, since they are inherently population based. Further if all the objectives can be simultaneously optimized, the whole non-dominated set converges to a single point, effectively achieving the same end results as single objective optimization.

FBGs are introduced in Section 2, along with the problem of interest and EA results in the two objective and full four objective cases. Section 3 introduces microstructured optical fibres, along with the representation used and MPOF design results.

2 Fibre Bragg Gratings

Permanent gratings in optical fibres were first demonstrated experimentally in the late 1970's. Since then, the theoretical and experimental aspects of FBG's have flourished, resulting in a multitude of applications. FBG's have been used as stand alone devices, for example, sensing applications for strain, temperature