UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCES
DEPARTMENT OF ELECTRONICS AND COMPUTER SCIENCE

Doctor of Philosophy

A STUDY IN BIOMIMETICS: NANOMETER-SCALE, HIGH-EFFICIENCY, DIELECTRIC DIFFRACTIVE STRUCTURES ON THE WINGS OF BUTTERFLIES AND IN THE SILICON CHIP FACTORY

by Luca Plattner

Nature is an invaluable source of inspiration for engineers, who draw upon the solutions evolved by species over millions of years, to design new devices or perfect existing ones. The process of transferring nature's designs into man-made devices is called *biomimetics*.

This thesis reports on a biomimetic study in quantum optics. The microstructure found on the wings of a tropical butterfly holds the secret of its famous structural coloration. The intricate arrangement of low-index dielectric material achieves, in the short wavelength regime of the visible spectrum, an extremely high reflection with a very large angular spread of the back-scattered light and acts as a very efficient low-pass filter. Devices exhibiting these properties may be desirable for applications in a range of fields of optical engineering.

An experimental investigation of the scattering of light was performed on the butterfly microstructure. This revealed a more complex phenomenology than previously thought. In order to carry out the measurements, a novel experimental method for the spectroscopical analysis of the scattering from nanostructures surfaces was developed. This method required the construction of an experimental setup involving supercontinuum generation by means of a photonic crystal fibre and alignment tools with submicron accuracy.

To explain the optical phenomenology of the butterfly microstructure, modelling techniques, which are at the forefront of research in the field of photonic crystals, were used. A theoretical investigation of the band structure of previously unreported crystal lattices occurring in the microstructure was carried out using the plane wave method. A novel numerical method was developed, which enabled computation of the diffraction efficiencies of two-dimensional periodic arrangements of low-index dielectrics. The theoretical investigation accounted correctly for the experimental results.

Using common microelectronic processing techniques, two- and three-dimensional photonic crystals were fabricated, which were inspired by the butterfly microstructure and which shared some of its optical properties.