

Experimental techniques for the study of natural photonic  
structures.

Joseph Noyes

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# Experimental techniques for the study of natural photonic structures.

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A handwritten signature in blue ink that reads "Joseph Noyes". The signature is written in a cursive style with a large initial 'J'.

Joseph Noyes, December 19, 2008

## Abstract

This thesis presents a study into structural colours that exist in natural samples, the principle aim of which is to produce experimental methods by which these colours may be examined and evaluated. In order to achieve this, previously observed structures are described, electromagnetic theory is summarised and a series of samples are examined constituting examples of the structures present in nature.

The first sample discussed is the multilayer in the epicuticle of the buprestid beetle, *C. raja*. In order to evaluate the refractive indices of the layers contained within this structure, existing optical techniques are used to establish absolute reflection spectra for a number of angles of incidence in both linear polarisations. The approximate design for the structure is obtained by electron microscopy and modelled using Fresnel's equations. This model is then refined by a recursive least squares fitting routine to obtain the refractive indices.

The second sample is the diffuse white scattering structure in the scales of two white beetles, *Lepidiota stigma* and *Cyphochilus spp.*. The reflection from these scales is measured and found to be brilliantly white due to the irregular internal structure of the scales. Comparison of the Fast Fourier Transforms of TEM images of the internal structure with the diffraction pattern obtained from monochromatic laser light diffracting through a single scale demonstrate a link between this structure and photonic effects.

The third sample type are found in the scales of the large true weevils, *Eupholus schoenherrii pettiti* and *E. magnificus*. These scales are shown to have a domained structure in which the domains were oriented differently to each other. Single domains are shown to exhibit different colours at different orientation.

The final sample is the highly regular 2-dimensional diffraction grating observed in a marine diatom, *Coscinodiscus wailesii*. Diffraction is demonstrated by measuring the in-plane diffraction from a single frustule for both monochromatic laser light and white light, showing an enhanced transmission for red wavelengths. Subsequent imaging of the transmitted diffraction pattern allows for the calculation of the transmitted power in each diffracted order.

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*"What does a Ph.D thesis signify? Is it the culmination of a piece of research by an individual? I think not. More it is simply an account of completed work due to the efforts of many for the benefit of one."*

**Kevin Roy Welford**

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