Image formation in the scanning optical microscope

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Contents

Abstract

A complete, scalar diffraction based, mathematical analysis is presented for evaluating the response of the ordinary reflectance, single detector MO and differential detector MO, Type 1 and Type 2 (confocal), scanning optical microscopes. Expressions are developed that represent the signal generated when imaging both one-dimensional and two-dimensional, reflectance and MO, samples. Two modelling approaches are described and applied, these are called the ‘direct calculation’ and ‘transfer function’ approaches which produce theoretical responses that agree exactly. In the direct calculation approach the form of the optical field is calculated through the optical system, as the sample is scanned beneath the focused spot. The direct calculation approach is shown to be particularly beneficial for generating two dimensional images of samples. In the transfer function approach the signal from the scanning optical microscopes is expressed in a form where the spatial frequency properties of the optical systems are distinct from the properties of the sample, thus enabling the quantitative comparison of the imaging performance of various optical configurations. The models have been implemented in computer code. Theoretical responses generated using the ordinary reflectance scanning optical microscope models are shown to produce results which agree with the published work of others. It is also demonstrated that the single detector MO scanning microscope exhibits imaging characteristics identical to that of the reflectance case and that the differential detector MO scanning microscope exhibits imaging characteristics identical to that of the incoherent optical channel, providing the MO sample is of uniform reflectance. The role of confocal pinhole size in the imaging process is investigated. A particularly interesting result shows that the confocal differential detector MO scanning microscope does not exhibit the enhanced lateral resolution characteristics evident in the confocal reflectance system. The application of the optical models to the signal generation process in optical storage systems is presented. In particular, the readout process in CD-ROM, Phase Change and MO optical systems, as well as future generation optical storage systems, such as digital versatile disk (DVD), are discussed. The effects of super-resolution on the response of the imaging systems using optical filtering techniques is discussed. As a result a novel approach is presented for performing partial response equalisation in the optical domain, thus removing the need for electronic equalisation. Experimental studies are presented which have been generated using an existing scanning laser microscope that may be configured to image using a variety of contrast techniques. The step responses of the reflectance and differential detector MO scanning microscopes are investigated. In particular, the effect of the confocal pinhole size on the response is compared with theoretical predictions and is shown to confirm the validity of the responses generated using the mathematical models developed.

Declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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For Mum, Dad and Julie

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I note that the mathematical analysis leading to the description of the signal generation process in the differential detector MO scanning microscope, as presented in chapter 4, was developed jointly by Philip Filbrandt [1] and myself.

List of abbreviations

SLM	:	scanning laser microscope
Illum	:	incident illumination
Obj	:	objective lens
Col	:	collector lens
Det	:	photo-detector
Aux	:	auxiliary lens
Pinhole Det	:	pinhole photo-detector
a	:	radius of a circular aperture