Light coherence properties in
optical fibres and visual receptors

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The optical field on the end of an optical fibre can display varying
degrees of spatial coherence. The classical analyses of the excitation of
the fibre have relied on the assumptions that the coherence properties of
this field can be approximated by either perfect coherence or total
incoherence, and it has long been appreciated that the resulting
excitations are markedly different.

It is the purpose of the work presented in this thesis to investigate
the effects of differing degrees of coherence of this excitation field.
The investigation has been restricted in the main to the bound or guided
power of the fibre, and the prime consideration has been of current
practical communications fibres.

Chapter I provides some necessary background information for the
thesis and discusses the types of optical fibres to which the study is
applied.

Chapter II contains a discussion of the theory of partial coherence.
The history of optical coherence theory is summarised and then the formal
treatment of the theory is described. In the last part of the chapter, an
alternative representation of a partially coherent field by an angular
spectrum of plane waves is introduced. This is of considerable importance,
as it has been used extensively in the work presented here in the framework
of the geometric optics description of optical fibre excitation.

The need to normalise the power launched into an optical fibre by a
partially coherent source led to an investigation of the diffraction of

partially coherent light. This is contained in Chapter III. After a
discussion of the classical diffraction theory and of previous studies of
the diffraction of partially coherent light, a vector formulation is
presented, which is shown to have some advantages over the previous
analyses. The angular spectrum representation is then used to examine the
problem, and shown to give some very informative, if qualitative, results.

The central problem of the excitation of an optical fibre by a
partially coherent source is tackled in the next two chapters. In Chapter
IV the excitation mechanism is discussed in terms of both mode theory and
geometric optics. A general analysis for polychromatiç partially coherent
sources is then developed and the limiting forms of total coherence and
total incoherence·are derived. A quasimonochromatic approximation is also
obtained from this general result. A separate derivation of the quasimono-
chromatic form is then presented. These analyses are restricted to large
V fibres, but are independent of the fibre type.

In Chapter V, the quasimonochromatic analysis is applied to the step
index fibre, giving detailed results for $V \leq 20$ and asymptotic
expressions for $V \gg 1$ and for the two extremes of total coherence and
total incoherence. A geometric optics treatment of the step index fibre is
then presented, and shown to be a good approximation for $V \gtrsim 10$ and for
more incoherent excitations. The last part of the chapter examines the
excitation of both step and graded index fibres using a more general and
detailed geometric optics approach. This approach is shown to be very
powerful, and is used to examine both the bound and leaky powers associated
with the fibres.

Particular examples of excitations are considered in Chapter VI. In
the previous chapters, the source used was the optical field on the end of
the fibre, with no reference being made to specific physical sources. In
this chapter the two most important sources, the light emitting diode and
semiconductor laser, are examined with reference to the results obtained in
Chapter V, and with reference to the common approximations used. The
effect of a lens to increase the coupling efficiency of the light emitting
diode is also examined.

The lens excitation in Chapter VI prompted the investigation of the
propagation of spatial coherence that appears in Chapter VII. The
propagation of the degree of spatial coherence along an optical fibre is

investigated first, and the phenomenon of coherence enhancement is shown to occur in this situation. The effect of the temporal coherence of the source, a reflection of the finite bandwidth of any physical source, is briefly discussed. A study of the degree of coherence in the image of a partially coherent object forms the last part of this chapter. The simple rule used in Chapter VI is initially derived from intuitive ideas, then shown to be supported by a more formal approach, and finally proved by the use of Fourier theory.

The final chapter deals with the previously excluded small V fibres. These are of relevance to communications systems, in the guise of monomode fibres, and to vision research, where visual photoreceptors have been successfully modelled by small V optical waveguides. The relevance of the partially coherent excitation theories developed in this thesis is discussed with reference to these two examples of small V fibres.