12 Interconnects with optically thin elements

A. Kirk and T. Hall
Department of Physics, King's College London.

12.1 Introduction

Electronic architectures are typified by their flatness. Wires and active devices are laid out on boards and interconnection occurs in two dimensions only. It is difficult and expensive to manufacture integrated circuits which have more than a few simple `crossovers' - points at which one wire passes over another. In contrast to this, the ability of light to propagate through space allows optically interconnected systems to make full use of all the space available. Rather than using the planar design inherited from electronics, many of these architectures envisage the use of the `parallel optics concept'. In such schemes two dimensional arrays of electronic and optoelectronic logic and switching devices are interconnected through free-space optics. These designs are typified by a much greater parallelism and a higher degree of interconnection than in electronic circuits. A more detailed discussion of these architectures will be made later in this chapter, but initially we will concentrate upon the devices used to define the optical interconnections.

In these parallel architectures devices are required to direct light from a source - which may be a laser diode, an LED or a modulated beam of light directed from elsewhere - through free space to one or more receivers or modulating devices. This should be achieved with as little crosstalk as possible between channels and with the loss of as little light as possible. In many architectures the most suitable and flexible candidates for this task are diffractive optical elements. In this chapter we will discuss the application of thin diffractive optical elements to parallel optical interconnections. In section 12.2 we will show the way in which Fourier plane array generators can be used to perform fanout and multiple imaging operations. In section 12.3 techniques by which fixed-weight shift-variant interconnections can be obtained will be described. Shift-invariant
interconnections are also of great interest for optoelectronic information processing applications and these are considered in section 12.4. One of the most important applications for diffractive elements is in creating and multiply imaging arrays of beamlets which can then be switched by spatial light modulators. This allows reconfigurable interconnections to be obtained and is discussed in section 12.5. In section 12.6 we consider the ability of diffractive elements to allow very compact optical interconnects to be defined. Finally we will discuss some of the developments which may occur in this area in the near future.

12.2 Fourier plane array generators

In 1971 H. Dammann and K. Görtler introduced a technique for the design of binary phase diffraction gratings to split a single beam of light into several equally intense diffraction orders [1]. Such a grating is shown in Fig. 12.1

![Fig. 12.1 Separable design for a Dammann grating (from [1]).](image)

This grating has a period $P_0$ and a total width of $R$. If it is illuminated with a Gaussian beam of half-width $w_0$ at the $1/e^2$ intensity points then following McCormick [2] we may write the amplitude $I_0(x_0)$ immediately behind the grating as

$$I_0(x_0) = I_0 \left[ h(x_0) \otimes \text{comb}(\frac{x_0}{P_0}) \right] \times \left[ \text{gauss}(\frac{x_0}{w_0}) \text{rect}(\frac{x_0}{R}) \right]$$

(12.1)

where $h$ is the binary grating function, $\text{gauss}(x_0/w_0)$ is a Gaussian envelope with intensity profile $\exp(-x_0^2/w_0^2)$, $\text{rect}(x_0/R)$ is the square pupil defined by the edge of the grating, and $\text{comb}(x_0/P_0)$ is the lattice of delta functions which define the periodic replication of the grating function. The convolution operation is represented by $\otimes$ (See Fig.12.2). Assuming that the paraxial approximation is