New focusing and dispersive planar component based on an optical phased array

Citation for published version (APA):

Document status and date:
Published: 01/01/1988

Document Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
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NEW FOCUSING AND DISPERSIVE PLANAR COMPONENT BASED ON AN OPTICAL PHASED ARRAY

Indexing terms: Optics, Optical waveguide components, Optical multi/demultiplexers, Integrated optics

A novel focusing and dispersive component is presented which is based on a phased array of bent optical waveguides. It combines good optical properties with small dimensions and can be realised with (high-quality) optical lithography. Applications are (demultiplexers, wavelength filters and polarisation splitters.

Introduction: Focusing and dispersive elements play an important role in integrated optical circuits. Components which combine both functions are of special interest for the spatial separation of signals with different wavelengths, as may occur in wavelength demultiplexers or wavelength filters. Plane lenses are conceived and executed in many kinds and dimensions. Mode-index lenses are easily fabricated but are of poor quality and require high index contrasts to obtain subcentimetre focal lengths. Planar Luneberg lenses and geometrical lenses are of better quality but require a technology which is not suited for the mass production of integrated circuits. In addition, it is difficult to miniaturise them to any extent. Fresnel lenses combine small dimensions (millimetre-order) with reasonable quality. However, they require high index contrasts. All lenses of the above type are, in principle, nondispersive. The only small sized component combining focusing and dispersive properties which can be realised with low optical contrast, is the curved planar grating. A disadvantage of the grating is that it cannot be realised with conventional optical lithography but requires submicron lithography (holographic or electron beam).

In the following, a novel component is proposed and demonstrated with properties comparable to a grating, which is realised, however, with conventional optical lithography.

Basic principle: If a broad parallel beam is impinging on an array of concentric planar optical waveguides, as shown in Fig. 1, part of the incident power will couple into the waveguides and the other part will propagate straight forward or be scattered.

The light coupled into the waveguides will propagate to the output plane and arrive there with phase distribution

\[
\phi_i = \beta R_i + \phi_0
\]

in which \(\beta\) is the propagation constant of the waveguide and \(\phi_0\) is the phase at the input plane and is not relevant for the following.

References

1 For an updated overview see for example 'Proceedings of the International Conference on Science and Technology of Synthetic Metals ICSM '86', Synth. Met., 1987, 17-18


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mental configuration. The substrate comprises five identical arrays (the white areas). We chose a number of 31 concentric waveguides with a width of 3 μm at an average distance ΔR of 6 μm. Each array has a different order and multiple foci will occur without additional measures. The photograph shows a number of focused beams emerging from the second array, which is excited by a broad Gaussian He–Ne beam (λ = 0.6320 μm). The dashed line represents the design position for the focal plane (f = 1 mm). The spatial separation of the orders in the focal plane compares well with the theoretically expected value (66 μm).

Fig. 3 Focusing phased array showing multiple orders

To avoid the occurrence of multiple orders, and simultaneously reduce coupling losses, the array should be provided with fan-in and fan-out coupling sections. The dispersion of this component can be utilized for spatially separating a number of wavebands by positioning a set of receiver waveguides next to each other in the focal plane. We realized a small size (1.3 × 4 mm) five-channel demultiplexer prototype working at He–Ne wavelength with a wavelength channel spacing of 0.5%, exhibiting good focusing properties and a channel separation better than 20 dB.

Conclusions: A novel focusing and dispersive element is introduced and demonstrated which has properties and dimensions comparable to a curved planar grating, but can be realized with conventional (high quality) optical lithography. Applications are small wavelength (de)multiplexers, polarisation splitters and wavelength filters.

M. K. SMIT
2nd February 1988
Laboratory of Telecommunication & Remote Sensing Technology
Faculty of Electrical Engineering
Delft University of Technology
PO Box 5031, 2600 GA Delft, The Netherlands

References

ACCUARATE PATTERN SYNTHESIS OF PARALLEL DIPOLE ARRAYS AND ITS APPLICATION TO UNEQUAL ELEMENTS

Indexing terms: Antennas, Dipole antennas, Antenna radiation patterns, Antenna arrays

A new simple method for accurate radiation pattern synthesis of parallel dipole arrays is described and its applications to low-sidelobe arrays with equal and unequal elements are presented.

Introduction: In antenna arrays, the distributions of field sources on elements are different, and this can cause significant errors in the resulting radiation patterns if the classical synthesis theory of point sources is used. Some authors have proposed methods based on the method of moments and obtained good results, but all these methods must make use of the δ-excitation model to approximate the fields produced by the driving voltages. However, they are all confined to relatively small arrays by computer capacity, so the problem of precise pattern synthesis remains.

The method proposed in this letter does not follow the procedure of the method of moments directly. By some assumptions based on physical considerations about mutual coupling, Pocklington's integral equation is transformed into equations involving the current flowing in only one element in an array. One can obtain the required driving voltages and the input impedances of all the dipoles by solving the equations numerically element by element. As an example, a linear array of parallel dipoles with equal length is synthesised and we show that the lengths of dipoles can be modified easily in this method to satisfy some requirements of input power distributions.

Method: Consider an N-element linear array of parallel dipoles in free space. The elements are of the same size and the axes of dipoles are perpendicular to that of the array. Obviously, the contribution of the nth element to the H-plane pattern is

\[ I_n = \int_0^L i(x_n) \, dx_n \quad n = 1, 2, \ldots, N \]  

where \( x_n \) is the coordinate along element \( n \) and \( i_n \) is the current distribution on an element. \( V_n \) is the required driving voltage of dipole \( n \) and \( I \) can be any distribution resulting from the classical point source theory.

For this array, Pocklington's integral equation for the current distributions of the \( N \) elements is

\[ -g \sum_{m=1}^{N} \int_{x_m}^{x_{m+1}} \left[ x_n \left( \frac{1}{k^2} \frac{d^2}{dx_n^2} \right) g \, dx_n \right] = \frac{-f(x_n)}{V_m} \quad m = 1, 2, \ldots, N \]

where \( f \) is the impressed field at points on element \( m \) produced by a unit driving voltage terminated at the dipole. \( g \) is Green's function between \( x_m \) and \( x_m' \).

To obtain a tractable formulation, certain assumptions are made on the basis of mutual coupling:

(a) The laws of current distribution of nearby elements are similar in an array. The amplitude and phase vary.

(b) The effect of one element on another is mainly determined by its current integral. A small change in current distribution does not change the effect if the integral is definite.

(c) Strong mutual coupling exists only between nearby elements.

Consider now the NCth element which is near the centre of the array. Following the assumptions above

\[ i(x_n) = \left( I_n / I_{NC} \right) \cdot i_{NC}(x_{NC}) \quad n = 1, 2, \ldots, N \]