Fabrication and Measurement of Fiber-Matched InP Rib Waveguides

Herstellung und Messung von faserangepaßten Rippenwellenleitern aus InP

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Abstract:

We report on design, fabrication and measurement of fiber-chip butt joints with fiber-matched InP rib waveguides. The waveguides are fabricated by liquid phase epitaxy and wet chemical etching. The intrinsic waveguide losses and the transmission efficiency of the butt joints are measured using the cut-back method. The results agree well with numerical calculations of the excitation efficiency of the fundamental rib waveguide mode using the finite-difference method. Transmission efficiencies of more than 70% are obtained for rib waveguides without anti-reflection coatings at the facets.

Übersicht:

Wir berichten über den Entwurf, die Herstellung und die Messung von stumpfen Faser-Chip-Verbindungen mit faserangepaßten InP Rippenwellenleitern. Die Rippenwellenleiter wurden mit Flüssigphasenepitaxie und naßchemischem Ätzen hergestellt. Die intrinsischen Wellenleiterverluste und der Transmissionswirkungsgrad der stumpfen Stoßstelle wurden durch Leistungsmessungen nach dem Rückschneideverfahren ermittelt. Die Ergebnisse stimmen mit Berechnungen des Anregungswirkungsgrades der Rippengrundwelle nach der Finite-Differenzen Methode überein. Transmissionswirkungsgrade von mehr als 70% wurden erreicht, ohne die Wellenleiterstirnflächen zu entspiegeln.

Für die Dokumentation:

Faser-Chip-Stoßstelle / Optische Wellenleiter / Flüssigphasenepitaxie / Rückschneideverfahren

1. Introduction

The simple, robust and low-loss connection of an optoelectronic integrated circuit with a single mode fiber appears to be of critical importance for the practical application of integrated optics. The main problem of this connection is caused by different spot sizes of the guided modes and different refractive indices of the waveguides. Thus, the incident mode is partially reflected at the butt joint and a considerable amount of power is radiated away. To decrease these Fresnel and radiation losses, microlenses [1] and fiber tapers [2] can be used, but they require difficult and expensive mounting techniques and allow only very small adjustment tolerances. Simple butt joints between the fiber and a large input waveguide on the chip (**Fig. 1**) combined with a nested integrated optical taper [3] may provide an efficient solution of the problem.

We report here on the fabrication of fiber-matched InP rib waveguides by liquid phase epitaxy and wet chemical etching. Such a waveguide can form the input section of an integrated optical taper. It is made of an undoped InP layer grown on an n-doped InP substrate, since the doping slightly reduces the refractive index. In section 2 we describe the design of the large input waveguides and the influence of some geometrical and material parameters on the excitation efficiency of the fundamental mode. Section 3 presents a description of the fabrication process and the merits of the wet chemical etching used to obtain the large ribs. Sections 4 gives an overview of the cut-back method for measuring the intrinsic waveguide loss and estimating the butt-joint transmission efficiency and compares the calculated and measured results.

2. Theory

To estimate the butt-joint losses we calculate the two-dimensional field distributions of the guided modes using the finite-difference method [4]. In this method the cross section of the waveguide is covered with a rectangular grid with mesh sizes of Δx and Δy in x and y directions. On the grid the transverse magnetic field components H_x and H_y are calculated by solving the coupled wave equations

$$\left.\frac{\partial^2 H_x}{\partial x^2}\right|_P + \left.\frac{\partial^2 H_x}{\partial y^2}\right|_P - \left.\frac{1}{n^2}\frac{\partial n^2}{\partial y}\frac{\partial H_x}{\partial y}\right|_P + \left.\frac{1}{n^2}\frac{\partial n^2}{\partial y}\frac{\partial H_y}{\partial x}\right|_P + \\ + (k^2 n^2 - \beta^2) H_{xP} = 0\,, \qquad (1)$$

$$\left.\frac{\partial^2 H_y}{\partial x^2}\right|_P + \left.\frac{\partial^2 H_y}{\partial y^2}\right|_P - \left.\frac{1}{n^2}\frac{\partial n^2}{\partial x}\frac{\partial H_y}{\partial x}\right|_P + \left.\frac{1}{n^2}\frac{\partial n^2}{\partial x}\frac{\partial H_x}{\partial y}\right|_P + \\ + (k^2 n^2 - \beta^2) H_{yP} = 0\,, \qquad (2)$$

where $k = 2\pi/\lambda$ denotes the wave number in free space and β the propagation coefficient of a mode traveling in positive z-direction. These equations are formulated in each of the four adjacent meshes of a particular grid point P. We assume constant refractive indices n in each single mesh and expand the field components into second order Taylor series around point P. These series together with the continuity conditions on the grid lines replace the partial derivatives in (1) and (2). The result is a system of coupled linear difference equations that relate the magnetic field components at point P to those of the adjacent grid points. Applying this procedure to each point of the rectangular grid sets up a system of difference equations