Elliptic waveguide beam focusing and collimating elements in InP: analysis and experiment
Wei, Cailin; Haes, J.; Moerman, I.; Baets, R.; Smit, M.K.

Published in: Electronics Letters

Published: 01/01/1995

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:
• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.
• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.
Elliptic waveguide beam focusing and collimating elements in InP: analysis and experiment

C. Wei, J. Haes, I. Moerman, R. Baets and M.K. Smit

A new waveguide focusing and collimating element which uses an elliptically shaped beam converter has been analyzed and experimentally tested. The experimental results show good agreement with the designed values. These elements are index contrast insensitive and compact and only need simple waveguide technology.

Introduction: Waveguide beam focusing and collimating elements have been found useful in many applications in photonic integrated circuits. In wavelength division multiplexing (WDM) systems for example, a channel drop/add filter could be realised by using a collimated beam incident on a Bragg reflecting grating, and using focusing elements to collect the reflected and the transmitted beams. In this case a collimated beam realised in a planar mirror. However, each of these structures has its drawbacks. If the waveguide lateral index contrast is low, a planar lens has a large focal distance and therefore requires a lot of space. If, conversely, the lateral index contrast is high, the diffraction losses at the lens boundary may be high. Adiabatic tapers have been widely used, but tend to be long [2, 3]. The curved mirrors require a perfectly vertical etch profile and therefore depend on sophisticated technology.

In this Letter we describe an elliptic beam converter which functions as a beam focusing or collimating element. It consists of an input waveguide followed by an elliptically shaped section and then a wide slab waveguide section, in which the wave can diffract freely in the lateral direction. The working principle of the device is based on total internal reflection at the boundary of the elliptic region, and can be understood by a three-Gaussian-beam model [4]. The input beam can be seen as a superposition of three approximately Gaussian beams: an axial beam, an upper and a lower beam. The upper and lower beam reflect off the upper and lower part of the elliptic converter, respectively, and are collimated or focused by it. The axial beam propagates with little impact from the elliptic coupler. In the slab region behind the couplers, the three beams form an interference pattern, the shape of which can be controlled by the dimensions of the device.
The influence of the half axes lengths \( a \) and \( b \) of the ellipse on the FWHM of the output field at the output facet is analysed with the slab terminated structure of figure 1b. The \( a \) values were 150, 190 and 230\( \mu \)m and the \( b \) values range from 4.5 to 8.5\( \mu \)m with a 0.5\( \mu \)m step. The camera line-scanned intensity distributions show that the combinations \(( a, b )\) \((150\mu m, 6.5\mu m), (190\mu m, 7.5\mu m)\) and \((230\mu m, 8.0\mu m)\) have good focusing properties and small field side lobes at the output facets. The focusing ability degrades for smaller \( b \) values. Instead the element starts to act as a collimating device. In Fig. 2 measurement results are shown for \( a = 150\mu m \) and for three different \( b \) values, 5.5, 6.5 and 7.0\( \mu \)m.

![Fig. 2 Measurement results for different \( b \) values](image)

**Conclusion:** A new waveguide focusing and collimating element has been analysed and experimentally tested. The experimental results show good agreement with the simulated values. The structure is lateral contrast insensitive and compact and can be made with simple waveguide technology. Those elements can be used in acousto-optic waveguide to fibre coupling and in WDM elements where the optical field needs to be focussed or collimated.

**Acknowledgements:** Part of this work was supported by the RACE-069 UFOs project and by the Flemish IWT (J. Haes). E.G. Metaal from Dutch KPN Research is gratefully acknowledged for skilful etching of the devices.

---

**References**


---

**Fabrication of single-mode polymeric optical waveguides by laser-beam writing**

R. Yoshimura, H. Nakagome, S. Tomaru and S. Imamura

**Indexing terms:** Optical waveguides, Optical polymers

A laser-beam writing system is developed for large-area optical waveguide fabrication. Single-mode embedded channel optical waveguides are successfully fabricated on both 4 and 8 in silicon substrates using deuterated fluoromethacrylate polymers by laser-beam writing in photoresist and dry etching. The propagation loss of the waveguides is as low as 0.10dB/cm at 1.3\( \mu \)m.

Recently, polymeric optical waveguides have attracted a lot of attention owing to their useful application in optical interconnections [1, 2]. Many kinds of board-level optical interconnections have been proposed [3–8]. Of these, one of the most attractive approaches is the fabrication of optical waveguides on printed circuit boards. This will require large-area optical waveguides with various patterns, because printed circuit boards are typically 20–30cm in length and have a variety of customised arrangements. However, conventional waveguide fabrication methods, in which channel waveguides are patterned using photomasks, cannot satisfy these requirements, because it is difficult to form such large photomasks with sufficiently high accuracy. For this sort of waveguide patterning, laser-beam writing [9, 10] is more suitable than conventional photolithographic techniques with photomasks. However, there have been few reports on singlemode polymeric waveguides fabricated by laser-beam writing, which would enhance the potential for the application of polymeric waveguides to optical interconnections. In this Letter, we describe a laser-beam writing system for large-area optical waveguide patterning and the fabrication of singlemode polymeric waveguides by laser-beam writing in photoresist and dry etching using deuterated fluoromethacrylate polymers [11].

The laser-beam writing system consists of a krypton ion laser (\( \lambda = 413\)nm), beam-shaping optics, an acousto-optic modulator (AOM) and an air-lubricated X-Y translation stage, as shown in Fig. 1. The AOM, which is synchronised with the movement of the stage, is used for switching the laser-beam on and off, and modulating its intensity. The air-lubricated X-Y translation stage, with a stroke of 300 \( \times \) 300\( \mu \)m, is driven by DC motors and controlled in a closed loop by attaching laser interferometers to it so that its position can be detected instantaneously. The stage translation speed is continuously variable below 10mm/s. The position-