AIIM

**Association for Information and Image Management**

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 mm

1 2 3 4 5

Inches

1.0 2.8 2.5 3.2 2.2 3.6 4.0 2.0 1.1 1.8 1.25 1.4 1.6

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

Conf-941006--1

SAND94-...

# Cut-off-mesa isolated rib optical waveguide for III-V heterostructure PICs


G. Allen Vawter and Robert E. Smith

Mail Stop 0603
P.O. Box 5800
Sandia National Laboratories
Albuquerque, NM 87185-0603
USA

Phone: (505)844-9004
Fax: (505)844-8985
E-mail: gavawte@sandia.gov



## Abstract

A new waveguide is designed using a cut-off slab waveguide for fabrication of single-mode rib optical waveguides with mesa isolation. These waveguides are easy to fabricate and offer crosstalk performance perhaps better than BH waveguides.

# Cut-off-mesa isolated rib optical waveguide for III-V heterostructure PICs

G. Allen Vawter and Robert E. Smith

Sandia National Laboratories
Albuquerque, NM 87185-0603

Photonic integrated circuits (PICs) fabricated using III-V compound heterostructure materials offer many benefits including high optical modulation efficiency and potential integration of optical sources and detectors on the same chip as optical and electronic signal processing circuitry. However, design and fabrication of single-mode optical waveguides for PICs continues to be a challenge due to requirements for low optical crosstalk and electrical isolation between waveguide modulators, sources, and detectors. Epitaxial regrowth to form buried-heterostructure (BH) waveguides has proven to be an effective, but costly, solution for the InP-based material system but is much more problematic in the GaAs-based materials. The most simple isolation technique is to use mesa-isolated rib waveguides (Fig. 1) where the rib etch depth and width are designed to create a waveguide supporting only the fundamental optical mode while the wider mesa etch prevents light from scattering to neighboring waveguides and provides electrical isolation. However, the mesa etch forms a large lateral refractive-index discontinuity which can lead to the rib and mesa combination supporting many higher-order optical modes even though the rib itself supports only the fundamental mode. We present a new mesa-isolated rib waveguide design where the single-mode rib is centered in an etched mesa that does not support or generate any higher-order optical modes. This new design is applicable to both GaAs and InP-based systems where it is desirable to eliminate complex and costly epitaxial regrowth procedures.

Figure (2) illustrates the difficulty of mesa-isolated waveguide design for single mode systems. Here a single-mode (Al)GaAs rib waveguide (Fig. 2a), embedded between two etched trenches for isolation, is simulated. The mesa-isolated waveguide is multimoded (Fig. 2b) due to the refractive-index discontinuity. The two-dimensional optical mode profiles were simulated on a personal computer by using a new iterative finite element technique to solve the 2D vector Helmholtz equation.

In order to eliminate the higher-order modes the concept of cut-off slab waveguides[1] is used to first design a mesa that does not support guided modes. Figure (3) shows the maximum thickness of a GaAs layer on $Al_xGa_{1-x}As$ which will not support any guided modes at 1.3 µm. Using this curve, we determine that for $Al_{0.2}Ga_{0.8}As$ lower cladding any remaining GaAs layer on top of the mesa less than 0.27 µm thick after the rib etch will not support guided modes in the limit of an infinitely wide mesa.

Having designed a cut-off slab waveguide we now have free reign to place any single-mode rib on top and etch to form a mesa-isolated rib waveguide without generating the higher-order modes seen in Figure (2b). Figure (4) shows simulation of one such design using $Al_{0.2}Ga_{0.8}As$ upper and lower cladding, a 0.2 µm thick GaAs waveguide layer, and 0.1 µm thick graded layers ( 5% to 20%) between the $Al_{0.2}Ga_{0.8}As$ cladding and the GaAs guide layer. The rib is 2 µm wide etched to the top of the GaAs layer while the mesa etch is 10 µm wide. This structure supports only the fundamental $TE_{00}$ and $TM_{00}$ modes at 1.3 µm wavelength even though the deeply-etched mesa is only 10 µm wide. Reducing the rib-etch depth in the design of Figure (4) by 0.2 µm moves the mesa out of cut-off such that the rib-mesa combination supports higher-order optical modes.

In conclusion, we have developed a new waveguide design using a cut-off slab waveguide for fabrication of single-mode rib optical waveguides with mesa isolation. While offering crosstalk performance perhaps better than that of BH waveguides, these mesa isolated waveguides are much easier to fabricate. This technique has applications in single-mode PICs where a high degree of optical and electrical isolation is required.

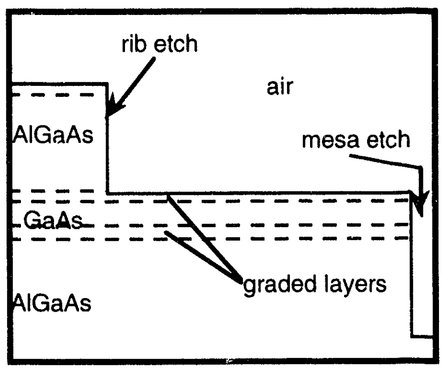


Figure 1: Cross-section diagram of mesa-isolated rib waveguide. Structure is generic to simulations in Figs. (2) and (4).

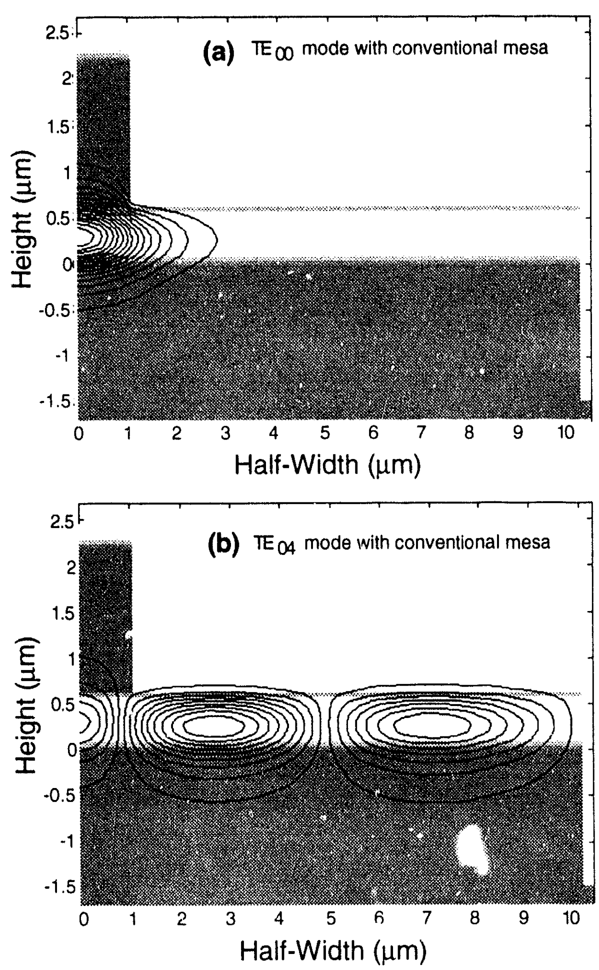


Figure 2: Simulated optical electric field contours of a mesa-isolated rib waveguide. (a) $TE_{00}$ mode of rib. ( b) $TE_{04}$ mode generated by mesa-isolation. Although the rib is single-moded, the mesa-rib combination supports many modes.

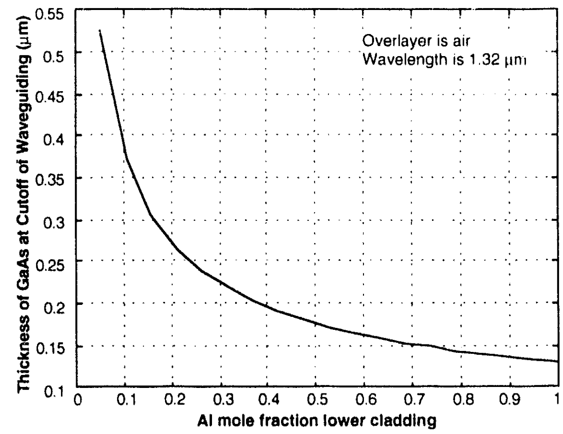


Figure 3: Plot of cut-off thickness of one-dimensional GaAs guide layer on AlGaAs at 1.3 μm wavelength. Medium above the GaAs is air. GaAs thicknesses below the curve do not support guided modes.

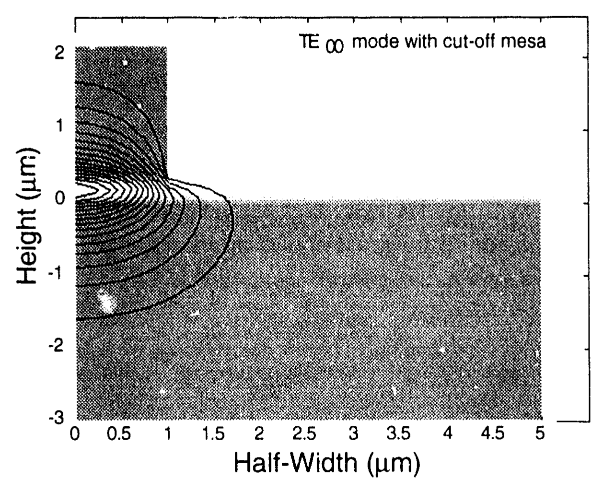


Figure 4: Simulated electric field contours of a rib waveguide using the cut-off mesa design. $TE_{00}$ mode is shown. $TM_{00}$ is the only other guided mode.

**Acknowledgments:** We would like to thank Ron Hadley for valuable discussions. This work was supported by United States Department of Energy under Contract DE-AC04-94AL85000.

**References:**

1) R. G. Hunsperger, *Integrated Optics: Theory and Technology*, pg.37, Springer Series in Optical Sciences, vol. 33, Springer-Verlag Berlin Heidelberg New York (1982).

DATE
FILMED
9/9/94

END