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HIGH-PERFORMANCE GaAs/AlGaAs OPTICAL MODULATORS: THEIR PERFORMANCE AND PACKAGING FOR MICROWAVE PHOTONIC INTEGRATED CIRCUITS

S. H. Kravitz, V. M. Hietala, G. A. Vawter, M. E. Warren, G. R. Hadley, M. G. Armendariz, J. C. Word, M. B. Snipes, J. R. Wendt, R. F. Carson, R. F. Corless, B. E. Hammons, J. F. Klem, R. E. Leibenguth

Sandia National Laboratories
Albuquerque, New Mexico 87185-0603

Tel: 1-505-844-2456
Fax: 1-505-844-8985
e-mail: shkravi@somnet.sandia.gov

Introduction: The goal of this effort is to build and package photonic integrated circuits (PICs). This infers that compact device design is very important, with all building blocks of the circuit aimed toward integration, low voltage operation, and manufacturability. With such a device, it is important that optical packaging be considered in the initial design. To this end, an advanced photonic packaging concept was designed. This concept employs vertical coupling of light both in and out of the package. This package concept is aimed at hermeticity, with no fiber penetrations through the walls of the package. This paper will describe the building blocks of this package, including output gratings, binary optics, and an automatic fiber capture device, called CLASP.

Photonic Integrated Circuit: The circuit chosen for this device is designed to optically steer a phased array radar antenna. This circuit has been named COMPASS.¹ This acronym stands for Coherent Optical Monolithic Phased Array Steering System. The main circuit elements consist of: high speed Mach-Zehnder modulators, arranged to form a single-side-band circuit.; and a number of 8-bit digital phase modulators, each designed to steer an antenna element.

Mach-Zehnder interferometers consist of two y-branched splitter/combiners and one or two, high-speed modulators. The goal is to make these interferometers have at least 15 dB contrast ratio and operate at 3 volts bias, while keeping total length to mm. These results have been achieved, using a unique design called the X-Y coupler.²

High-speed phase modulators have been fabricated.³ These modulators have a 3dB bandwidth of 18 GHz. They use ion implantation for electrical and optical isolation, with a unique vertical structure designed to minimize inductance per unit length.

An 8-bit digital phase modulator has also been made.⁴ Its purpose is to make a linear conversion of voltage to optical phase shift. These devices show good linearity and operate at 3 volts.

Advanced Photonic Package: The package for this optical device is critical to good circuit performance and manufacturability. This device has many electrical and single-mode optical I/O. The goals of this package are: to align all optical I/O simultaneously; create a hermetic environment; minimize insertion loss; and minimize alignment time. The additional challenge is that the mode shape from the waveguides used for these devices is not a good match for single-mode fiber. There are three elements that form the package: vertical output grating couplers; binary optics, and the micro-machined fiber capture device, called CLASP.

Vertical output grating couplers have been made to shape and collimate the optical beam, prevent back-reflections, and efficiently turn it towards the package lid.⁵ The gratings are detuned second-order, so that back reflections are minimized. They are made on a waveguide that has been adiabatically expanded from 2 to 50 micrometers.⁶ The output beam is tilted backwards 10 degrees.

The divergence parallel to the waveguide is 4 degrees, while the perpendicular divergence is less than 1 degree.

Binary optics on silicon have been fabricated. These unique $f/3.1$ - $f/1.75$ elements are both anamorphic and off-axis in design. The elements are designed to accept the output of the above gratings and focus it into single mode fiber. Since the grating output is tipped back 10 degrees, the lens is designed to accommodate this angle, permitting easy package assembly. Because of the differing divergence of the two directions of the grating, the lens has an anamorphic design, to allow efficient capture of beams with differing axial divergence. These devices are patterned by direct e-beam lithography, which provides critical size control and alignment for the three lithographic levels.

CLASP, which stands for Capture and Locking Alignment Spring Positioner is a micro-machined nickel spring, that captures and locks arrays of single mode fibers into position, using pick-and-place techniques.⁷ The design consists of a movable nickel leaf spring and a fixed pocket where fibers are held. The fiber is slid between the leaf spring and a fixed block, which tensions the leaf spring. When the fiber reaches the pocket, it automatically falls into the pocket and is held by the pressure of the leaf spring. A demonstration has been made which shows that the 4 fibers have been captured simultaneously, from distances as far out of alignment as 13 micrometers.

Conclusion: An integrated scheme for a PIC and specialized photonic packaging has been presented. This technology uses a number of unique components to achieve high performance.

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