Novel high-performance lasers in InP

(Invited paper)

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ABSTRACT

In this paper, we provide an overview of a variety of novel, high-performance lasers and PICs in InP that Freedom Photonics has developed and commercialized over the past several years. Those include lasers in several different wavelength ranges: 1300nm, 1550nm and 1650nm. The applications for these devices span high-performance sources for Datacom systems, integrated optical transmitters for telecom applications, lasers for optical sensing as well as lasers for free-space optical communications.

Keywords: lasers, tunable lasers, photonic integrated circuits, Indium Phosphide.

1. INTRODUCTION

New and existing applications drive the demand for innovation in the area of monolithic laser technology in InP. In this paper, we are describing a number of different advanced monolithic semiconductor lasers and related PICs in InP, developed for a variety of markets and applications in the 1270nm – 1680nm wavelength range.

2. High-Performance Lasers at 1300nm

At Freedom Photonics, we have developed widely tunable monolithic semiconductor lasers operating in the O-band wavelength range, and these devices, described in [1] are available as standard products, with 3 different central wavelengths.

More recently, a new DFB laser technology at 1300nm has been developed for high output power and high wall-plug efficiency. Figure 1 left shows the output power and efficiency for one particular laser implementation, where the back facet is high-reflectivity (HR) coated for improved front-facet efficiency. Peak wall plug efficiency around 36% is observed at ~4x threshold current, and peak power >200mW. Figure 1 (right) shows lasing spectral obtained at room temperature at different laser bias. Stable and highly single-mode emission is demonstrated.

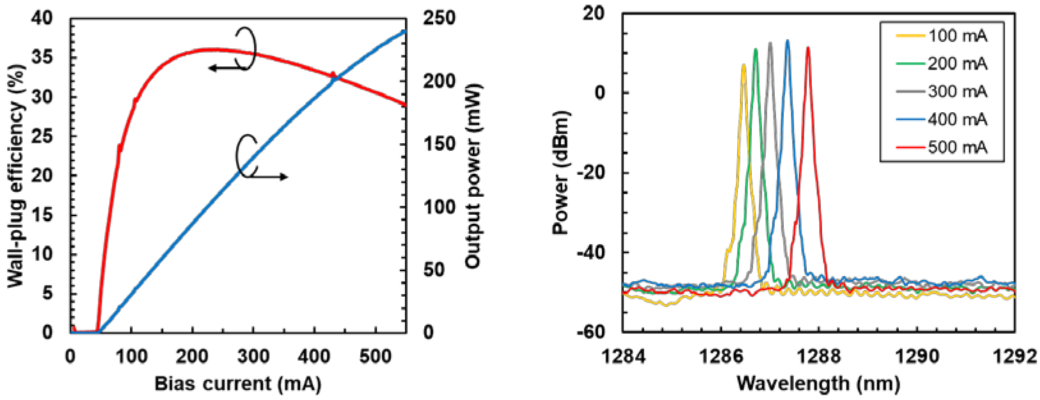

Figure 1 – Left - Output power and efficiency of a DFB laser. Back facet is HR coated such that the light primarily exits from the front facet and is detected. Right - Single-mode operation with laser bias. Data taken with temperature-controlled stage at 20ºC.

3. Integrated Optical Transmitters at 1550nm

Tunable chip-scale optical transmitter devices have revolutionized the pluggable module telecom market, by enabling excellent performance with great cost and size reduction. We have developed a novel, patented tunable transmitter device, based on a dual output tunable laser, and a pair of modulators which are interferometrically combined (Tunable Interferometric Transmitter, TunIT) [2]. This unique device architecture allows for improved performance in terms of the side-mode suppression ratio, and tuning current needed for laser tuning. TunIT image is shown in Figure 2 (left), and results of transmission experiments, are shown in Figure 2 (right).

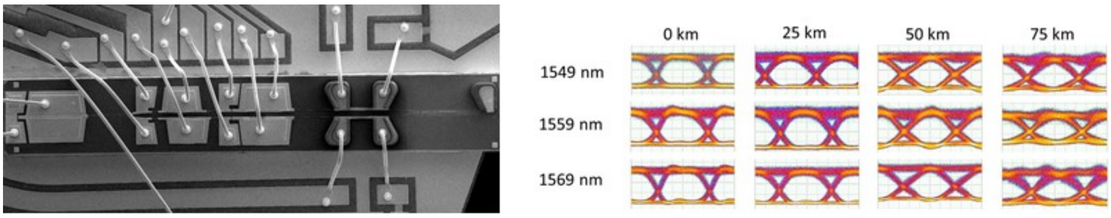

Figure 2 – (left) Scanning Electron Microscope (SEM) image of a TunIT laser chip mounted on an AlN carrier, with wirebonds connecting the contact pads on the chip to metal traces on the carrier. Sections include an HR coating rear mirror, gain section, and two output arms, each with phase control, Vernier mirrors, SOAs, and high speed modulators. In this implementation, the device has a common phase control electrode inside the laser cavity, as well as phase electrodes that control the phase of the interferometer. (right) Eye diagrams for a single TunIT device, measured over a 20 nm wide wavelength range. Eye diagrams are shown for operation at 1549 nm (top), 1559 nm (middle), and 1569 nm (bottom).

We have also developed a novel, 4-channel, monolithic widely tunable transmitter device (QUAD) in Indium Phosphide [3]. This device is based on monolithic integration of 4 widely tunable externally modulated lasers, with a single output waveguide. The QUAD device is designed to operate at 55 ˚C, in order to reduce the power consumption of the cooler. A completed, wire-bonded QUAD is shown in Figure 3 (left), with eye diagrams (middle) from a module (right).

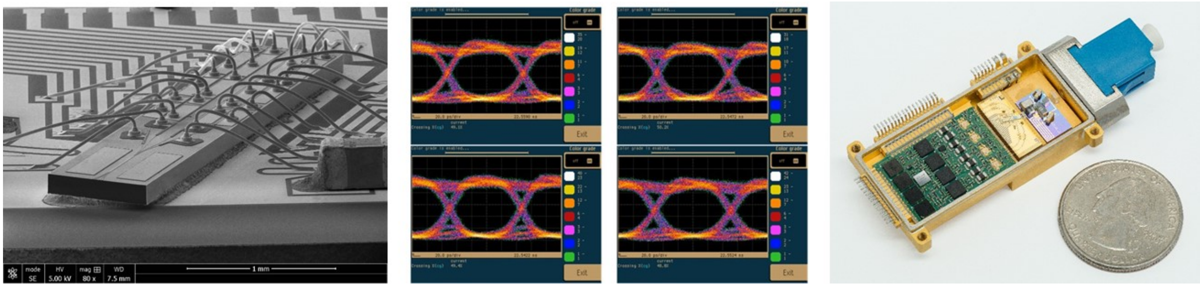

Figure 3 – (left) Scanning Electron Microscope (SEM) image of a QUAD transmitter chip mounted on an AlN carrier, with wirebonds connecting the contact pads on the chip to metal traces on the carrier. The device consists of 4 functionally equivalent widely tunable optical transmitters, connected to a single output multimode interference coupler (middle) Representative eye diagrams, at 10 Gbps, for all 4 transmitters working simultaneously. (right) QUAD module.

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4. Lasers and PIC for gas sensing at 1650nm

Methane is about 23 times more potent at trapping infrared radiation than carbon dioxide. The development of low-cost, accurate remote methane sensing technologies is becoming increasingly critical in order to analyze methane concentrations and distributions throughout the atmosphere.

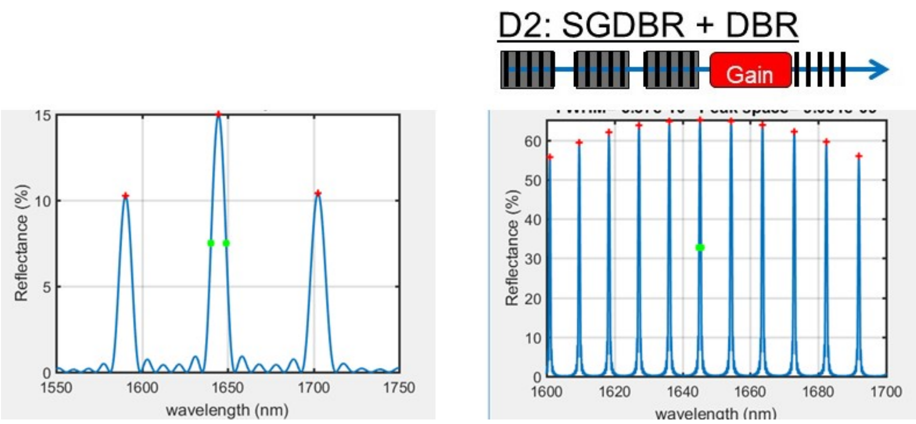

Figure 4 – Patent-pending, Comb-Optimized DBR concept: a DBR laser that uses two different DBR mirrors, one broad-band DBR mirror, and a sampled grating mirror, where sampling is used to control the shape of the DBR peaks, and allow for narrow filter response, and long DBR cavity.

LIDAR based methane spectroscopy at 1651nm presents an opportunity to perform these measurements remotely over localized areas without the need to sample the atmosphere. Majority of these techniques require tunable lasers.

Some of the key requirements for a tunable laser used in spectroscopy applications are fast tuning speed, and laser linewidths less than 10 MHz. The simplest way to realize a semiconductor tunable laser is using a Distributed Bragg Reflector laser architecture [4]. To achieve further control over design space, and decouple the dependence between the DBR laser gain section length and laser modal purity, a DBR laser can be realized using 2 different DBR mirrors, at both sides of the cavity, which allow for more precise cavity mode filtering. We have used one such novel approach, a proprietary Comb-optimized (COMBO) DBR design, to design and implement 1650nm COMBO-DBR lasers for gas sensing. An example COMBO design is shown in Figure 4, where one broad-band DBR mirror, and a sampled grating mirror are used, and where sampling is used to control the shape of the DBR peaks and allow for narrow filter response [5]. This approach allows for tuning ranges on the order of 8nm. For wider tuning ranges, more complex dual mirror DBR laser designs can be used, including varieties using Vernier tuning, as described in [4].

At Freedom Photonics, we have developed and commercialized one such laser implementation at 1650nm, which shows more than 70nm of continuous tuning range, and is now available in butterfly packaging, Figure 5.

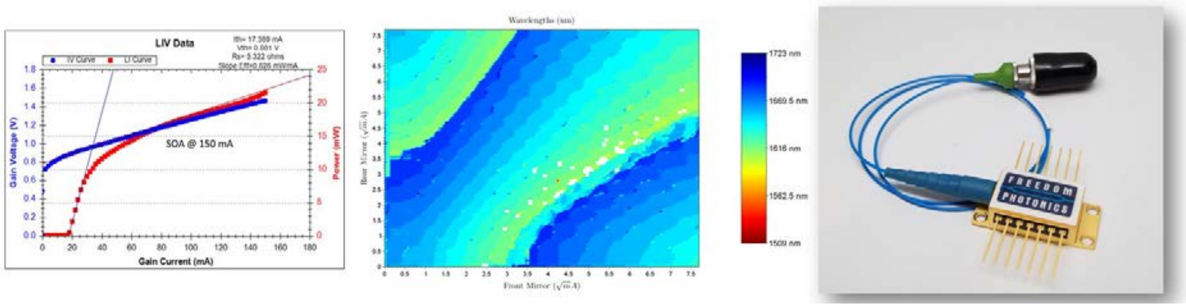

Figure 5 – (left) Light-current-voltage characteristic of a widely-tunable 1650nm laser (right) Laser tuning map, showing >70nm of laser tuning range

CONCLUSIONS

New and existing applications drive the demand for innovation in the area of monolithic laser technology in InP. In this paper, we have provided an overview of a variety of novel, high-performance lasers and PICs in InP that we at Freedom Photonics have developed and commercialized in the past couple of years. Those include lasers at several different wavelength ranges: 1300nm, 1550nm and 1650nm. The applications for these devices span high-performance sources for Datacom systems, integrated optical transmitters for telecom applications, lasers for optical sensing as well as lasers for free-space optical communications.

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