INTEGRATED MICRO-PHOTONICS FOR REMOTE EARTH SCIENCE SENSING (IMPRESS) LIDAR

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ABSTRACT

We present recent progress on a wavelength tunable, pulsed laser source for laser spectroscopy of CO₂ at 1572 nm. An integrated photonics design in indium phosphide (InP) is presented and compared to a fiber-component-based implementation. Significant improvement in size, weight and complexity is demonstrated.

Index Terms— Lasers, photonics, environmental monitoring, remote sensing,

1. INTRODUCTION

Photonic integrated circuit (PIC) technology has seen significant investment from the communications and data center industries. As a result, a highly functional set of photonic components exist which can find use in a much wider set of applications like automotive sensors, medical devices, defense and science instrumentation. NASA’s desire for small, lightweight, rugged, efficient and highly functional optical sensors makes PIC technology an excellent choice for the next generation of hardware. NASA is working with several partners on developing integrated photonics technology for future space missions [1-5].

Goddard Space Flight Center has spent several years developing an atmospheric carbon dioxide (CO₂) sensor based on laser absorption spectroscopy that uses a tunable laser to scan through a CO₂ gas absorption line centered at 1572 nm [6-9]. The current laser transmitter implementation uses mature technologies and meets all the optical performance requirements [10] but is relatively bulky and inefficient compared to an integrated photonic solution. UCSB and GSFC have initiated a program to replace the tunable seed laser with a PIC version to significantly improve the implementation for a resource constrained space-flight mission platform.

We expect to improve the implementation of this particular application and demonstrate the efficacy of the technology for an array of future applications.

2. DESIGN AND RESULTS

The seed laser being developed is a pulsed laser with tunable wavelength output. Consecutive pulses are emitted at different wavelengths that step across the absorption feature of interest. The wavelength of each pulse is individually locked to an exact value. This is achieved by using a master laser locked to the center of the CO₂ absorption as an absolute reference and using offset locking to tune a slave laser by means of an optical phase-locked loop (OPLL). Details on the previous wavelength tuning and locking techniques can be found in [11, 12]. The requirements for the laser seed system are tabulated below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center wavelength</td>
<td>1572.3 nm</td>
</tr>
<tr>
<td>Pulse Wdth</td>
<td>1 µs</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>7.5 KHz</td>
</tr>
<tr>
<td>Pulse modulation extinction</td>
<td>35 dB</td>
</tr>
<tr>
<td>Optical power (peak)</td>
<td>10 mW</td>
</tr>
<tr>
<td>Polarization (linear) extinction</td>
<td>20 dB</td>
</tr>
<tr>
<td>SMSR</td>
<td>40 dB</td>
</tr>
<tr>
<td>Linewidth (over 1 µs)</td>
<td>&lt;50 MHz</td>
</tr>
<tr>
<td>Center wavelength drift (over 1 s)</td>
<td>&lt; 100 MHz</td>
</tr>
<tr>
<td>Standard deviation of center wavelength</td>
<td>&lt;3 MHz</td>
</tr>
<tr>
<td>Wavelength tuning</td>
<td>± 15 GHz</td>
</tr>
</tbody>
</table>

The photonics block diagram for achieving this functionality is shown in Figure 1. The main integrated design elements include a distributed feedback (DFB) master laser diode, a phase modulator, a sampled grating distributed Bragg reflector (SG-DBR) slave laser diode, a Mach-Zehnder modulator (MZM), a semiconductor optical amplifier (SOA), and a high-speed photodiode. The DFB frequency is stabilized to a reference CO₂ gas cell using a frequency modulation technique. The frequency of the DFB is modulated using the integrated phase modulator. Closely integrated electronic circuitry will then generate a frequency discriminating error signal
which is fed back into the DFB. The DFB itself is driven with low noise bias circuitry and the temperature is controlled using a thermo-electric-cooler (TEC). The widely-tunable, integrated SG-DBR is stepped across the absorption line feature at selective wavelengths using an OPLL offset-locking scheme. This offset-locking scheme is facilitated using the integrated high-speed photodetector which detects a beat note between the master and slave lasers. OPLL circuitry feeds back an error signal to ensure the offset frequency maintains the frequency stability characteristics of the master laser. Additional circuitry will drive the SOA for lidar pulse carving and amplification. The MZM offers an alternative for pulse carving.
3. CONCLUSIONS

We have demonstrated promising results on an integrated photonic circuit implementation for wavelength-tunable, amplitude-modulated laser system. This work shows the potential for orders of magnitude improvement in volume and mass while improving efficiency, ruggedness and reliability. The technology and component performance continues to improve rapidly due to increased investment from communications and data center applications. Space flight and other remote sensing applications can benefit significantly from the application of integrated photonics technology.

ACKNOWLEDGMENTS

The authors gratefully acknowledge funding from NASA’s Earth Science Technology Office (ESTO) Advanced Component Technology (ACT) program.

6. REFERENCES


