Low Noise Narrow Linewidth Semiconductor Planar External Cavity Lasers for Optical Sensing

Mazin Alalusi, Vladimir Kupershmidt, Sanggeon Lee, Peter Mols, Lew Stolpner
Redfern Integrated Optics Inc., 3350 Scott Blvd, #62, Santa Clara, CA 95054, USA
+1 (408) 970-3500, Email: lew.stolpner@rio-inc.com

Abstract

Cost effective 1550 nm DWDM planar external cavity (PLANEX) lasers are optimal for interferometric, Brillouin, LIDAR and other optical sensing applications. Performance characteristics show linewidth < 3 kHz, low phase/frequency noise and very low RIN.

Introduction

High performance fiber optic distributed sensing technologies were developed over the past years, but only now are moving into the large-scale deployment. New applications are more cost sensitive than early applications for military, security or oil and gas. High performance, reliable and cost effective optical sources are key enablers of the optical sensing.

External Cavity Laser (ECL) is a compact and robust solution for wide variety of optical sensing applications. It offers lower linewidth, phase noise and significantly lower sensitivity to temperature and current variations than DFB lasers diodes. Compared with fiber lasers, ECLs offer lower cost, small form-factor, high reliability and environmental stability and wide bandwidth frequency tuning. Hybrid ECLs based on Bragg Gratings have been studied and compared with other low noise lasers [1].

Narrow linewidth, low frequency noise, low RIN 1550 nm DWDM planar external cavity laser (PLANEX) is based on silica-on-silicon planar lightwave circuit (PLC) waveguide Bragg gratings. This cavity structure offers low phase noise and narrow linewidth, comparable to long cavity fiber lasers over wide range of environmental conditions. PLANEX lasers are qualified for high reliability, and suitable for interferometric, Brillouin fiber optic sensing, coherent Doppler LIDAR and microwave photonics applications. Lasers are available in several product platforms allowing for plug-in-play operation.

PLANEX laser design

A diagram of a PLANEX laser cavity is shown on Fig.1. The cavity is formed by coupling light between the low anti-reflection (AR) coated facet of an InP gain chip (GC) with waveguide Bragg grating on a PLC.

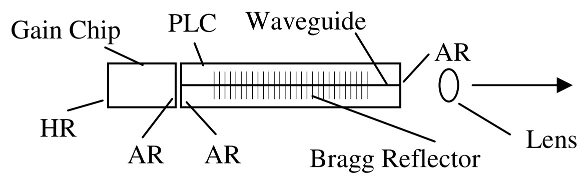

Fig 1. Schematic of PLANEX laser cavity

The PLANEX laser packaged in a standard 14-pin butterfly package on top of a thermoelectric cooler (TEC). Design insures operation over a wide case temperature range from -10 to 75ºC. The optical output includes isolator and either standard or polarization-maintaining single mode fiber. The PLANEX laser is designed and assembled using proven methods, commonly used in production of commercial semiconductor lasers. The ORION module includes low noise bias current source, TEC controller and standard digital interface for simple setup, control and integration. The high power RIO GRANDE module includes a PLANEX laser and low noise EDFA to provide output power up to 2W without degradation of coherence and noise characteristics.

Performance

Laser cavity is optimized for low phase noise by optimization of the GC, PLC Bragg grating spectrum design and coupling between GC and PLC waveguide to ensure low intra-cavity loss. Phase noise is shown on the Fig. 2. in comparison with best semiconductor DFB and commersial fiber lasers.

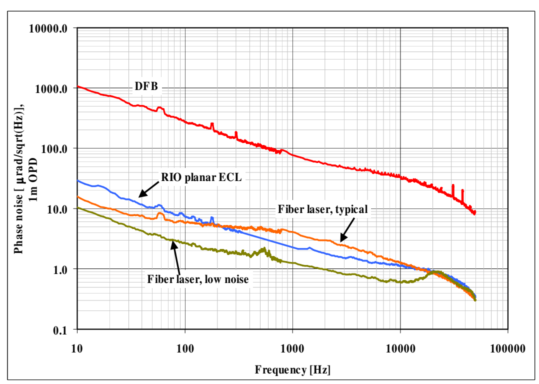

Fig. 2. Phase noise characteristics

FWHM Lorentzian linewidth of ~2 kHz has been measured using self-delayed heterodyne method with 50 km of fiber.
RIN is < -145 dB/Hz at frequency > 1 kHz and shot noise limited at >500 kHz. RIN peak, typical for fiber lasers, is absent, giving additional advantages for interferometric acoustic and seismic sensing.
The PLANEX cavity is robust and intrinsically stable, compared to FBG based lasers, both ECL and fiber lasers. Laser reliability has been proven through Telcordia qualification. The ORION and RIO GRANDE integrated modules are designed to operate in harsh environmental conditions and under vibration.

PLANEX laser applications

PLANEX lasers are tested and implemented into various distributed fiber and free space optical sensing systems, including interferometric, Brillouin temperature/stress testing, and coherent Doppler LIDARs.

Phase noise is sufficient for most interferometric fiber optic sensing applications, including TDM/DWDM and Coherent Rayleigh. Low RIN offers additional effective phase noise reduction by avoiding noise aliasing from high frequency RIN into acoustic frequency range [2]. Cost effectiveness, small form factor, high environmental stability and reliability make it the optimal optical source for complex acoustic/seismic sensing systems, including multi-channel systems for offshore and down well sensing systems in Oil and Gas, and others dynamic sensing, including hydrophones, perimeter and pipelines intrusion detection, infrastructure structural health monitoring.

Brillouin BOTDA/R, based on Optical Phase Lock Loop (OPLL), is promising technology for long reach and high resolution distributed temperature and stress systems (DTSS). Previous attempts to develop OPLL were limited by laser performance. Semiconductor DFBs are limited by low coherence and high sensitivity of the wavelength to current and cavity temperature deviations. Environmental sensitivity of fiber lasers parameters also limit performance and long term stability of OPLL.

PLANEX lasers are uniquely suitable for cost effective, commercially producible and field deployable OPLL system solution. We developed packaged OPLL, containing two PLANEX lasers, high frequency photo detector and PLL circuit. OPLL performance is sufficient for distributed sensing requirements, and shows following characteristics:

- tunable wavelength offset between two optical outputs up to 15 GHz
- tuning range up to 5 GHz
- continuous tuning range up to 1 GHz
- tuning steps from 100 kHz to 10 MHz.
- step tuning speed 0.2-0.5 msec
- linewidth of locked lasers < 1 kHz

Long term beat frequency stability was better than 10 kHz.

Coherent Doppler LIDAR emerged as rapidly developing technology for various applications, including metrology for wind energy turbines. PLANEX lasers demonstrate optimal cost/performance for wind LIDAR due to frequency stability over wide range of harsh environmental condition, including shock and vibration. Low power consumption and small form factor of the PLANEX and ORION modules make them an ideal seed lasers for MOPA, implemented in high power GRANDE module.

Conclusion.

PLANEX lasers combine high performance of fiber/solid state lasers, and small size, stability, reliability and cost effectiveness of diode lasers. Lasers have been proven in wide variety of optical sensing applications, including interferometric, Brillouin temperature/strain sensing, and coherent Doppler LIDAR. PLANEX-based OPLL shows high performance, combined with long term stability and can be integrated in the compact package. OPLL as commercially available sub-system can enable expedient development and adaption of new generation of optical sensing technologies, like Brillouin distributed sensing, coherent Doppler sensing and RF photonics.

References

[1] . Mazin Alalusi et al. “Low noise planar external cavity laser for interferometric fiber optic sensors”. Proc. of SPIE Vol. 7316, 73160X (2009)
[2]. C. K. Kirkendall et al, “Sensitivity Limitations Due to Aliased High Frequency Phase Noise in High Channel-Count TDM Interferometric Arrays”, 11th OFS Conference, Japan Soc. App. Phys., p. 678 (1996)