

Generation of High Speed, Linear Wavelength Sweeps Using Sampled Grating Distributed Bragg Reflector Lasers

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Abstract – Wavelength-tunable sampled grating distributed Bragg reflector (SG-DBR) lasers are used for telecommunications applications in which the laser is set to a communication channel and changed infrequently. SG-DBR lasers can be tuned to any wavelength over a 50 nm tuning range with fast transition times using a set of three control currents. This paper demonstrates generation of fast linear wavelength ramps covering the entire tuning range of the laser. Continuous and linear wavelength sweeps are achieved by applying three time synchronized waveforms to the front mirror, back mirror, and phase sections of the laser. Continuous wavelength coverage is achieved by appending 50 separate mode-hop-free tuning segments. The wavelength stitching transitions require a maximum of 60 ns for amplitude, wavelength, and thermal settling time to allow the laser and drive electronics to equilibrate. Full band wavelength ramps with 100 kHz repetition rates have been demonstrated. An example FMCW LIDAR application of this fast wavelength ramp is given.

Index Terms – Distributed Bragg reflector lasers, light detection and ranging.

I. INTRODUCTION

Sampled grating distributed Bragg reflector (SG-DBR) lasers demonstrate wavelength switching times that are faster than external cavity tunable diode lasers or fiber ring lasers due to their very short optical cavity length. Experimental results demonstrate stepped-wavelength switching times on the order of 10 ns for the phase section of the laser¹.

Continuous wavelength sweeps are achieved by mapping the wavelength as a function of current into the front mirror, back mirror, and phase sections of the laser. The wavelength maps are used to find tuning paths that can be concatenated together into a continuous coverage wavelength ramp. Arbitrary waveform generators are used to drive the front mirror, back mirror, and phase sections of the SGDBR laser and create the associated linear wavelength ramp.

A Mach-Zehnder Interferometer is used to experimentally test this wavelength sweep for high speed light detection and ranging (LIDAR) applications². The results reveal that short range LIDAR measurements at sweep rates between 10 and 80 kHz demonstrate a distance resolution of $\pm 45 \mu\text{m}$ or less.

II. CONSTRUCTING THE WAVELENGTH SWEEP

To create a continuous and linear wavelength sweep, the three tuning sections of the laser must be controlled with very accurate, time synchronized current waveforms. These waveforms are obtained by first analyzing the wavelength of

the laser as a function of the front and back mirror bias currents as shown in figure 1.

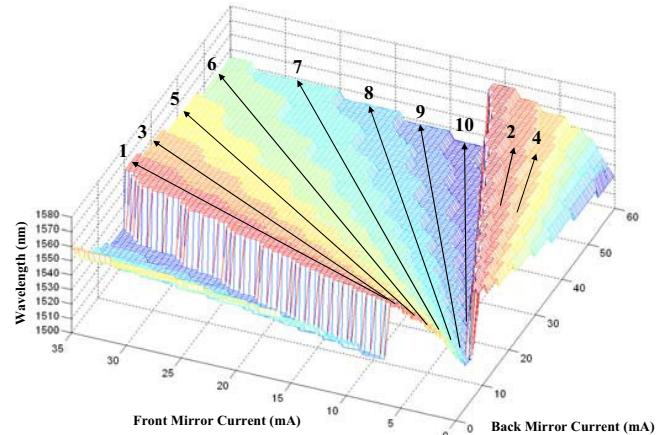


Figure 1: Mode map demonstrating wavelength as a function of front mirror and back mirror bias currents. From this mode map, a tuning strategy is obtained to generate a continuous and linear wavelength sweep from 1523.317 nm to 1570.078 nm.

Figure 1 illustrates 10 different paths that can be utilized to cover the full wavelength span of the laser. On each path the front mirror and back mirror currents are nearly proportional. The phase section tuning current is not included in the map of Fig. 1. The wavelength of the laser would jump in 0.2 nm steps if the phase section current of the laser were constant. The 0.2 nm step size corresponds to the longitudinal modal spacing of the laser. The phase section can be utilized to electrically stretch the cavity length in order to create 1.0 nm wide mode-hop free tuning segments. An example tuning segment of the laser for path 5 is given in figure 2.

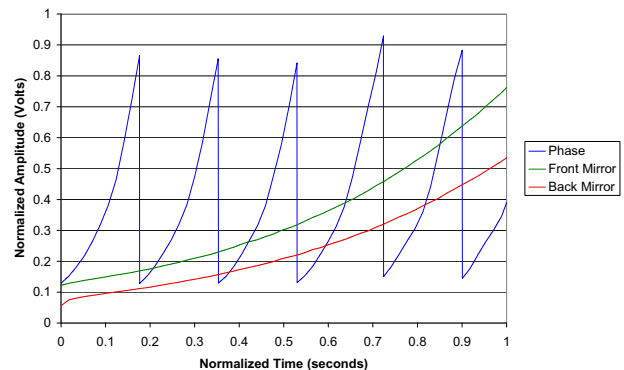


Figure 2: Front mirror, back mirror, and phase section waveforms that drive the laser along path 5.

The front and back mirror currents are proportional but parabolic current versus time function is required to get a linear wavelength versus time output. The phase section is electrically stretched and reset 6 times over the duration of this tuning path.

Each path illustrated in figure 1 has a path width. The tuning waveforms are designed to ensure that the laser is tuned along the center of each tuning path to prevent mode hops throughout the sweep. The side mode suppression ratio of the tunable laser wavelength ramp was optimized by characterizing the optimal position along the tuning path.

In order to achieve wavelength sweep linearity, the three synchronized tuning currents are mapped in 0.1 nm increments. 1 pm wavelength resolution was achieved by linear interpolation between the bias points. Finally, by concatenating tuning paths in the specific order shown in Figure 1, a continuous 47 nm wavelength sweep is achieved from 1523.317 nm to 1570.078 nm.

These three tuning waveforms are uploaded into three Agilent 33220A Arbitrary Waveform Generators. The waveform generators are time synchronized using an external trigger input. Frequency limitations and finite switching times of the waveform generators result in wavelength glitches at each tuning segment concatenation point. Thermal settling times intensify the magnitude of the wavelength glitch at these transition points. Experimental analysis demonstrated that a maximum of 60 ns is required for the laser and drive electronics to equilibrate.

III. LIDAR EXPERIMENT

Fig. 3 shows an experimental set up to observe the performance of the wavelength sweep for LIDAR applications. The swept wavelength output of the laser is split into two paths; a short reference path, and a long delay path. These two paths are then combined to create a beat signal that relates to the length difference between the two paths.

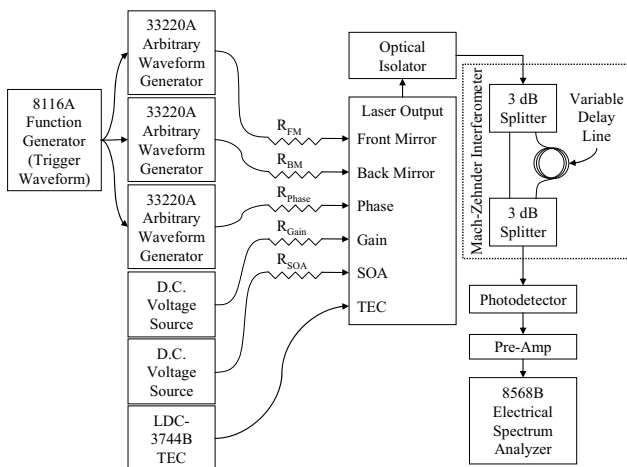


Figure 3: The laser is powered by the D.C. sources and the wavelength sweep is controlled by the arbitrary waveform generators. The Mach-Zehnder Interferometer provides a fiber based LIDAR environment. The frequency of the beat signal, which relates to the length difference between the reference path and delay path, is measured by a spectrum analyzer.

The envelope of the optical beat signal is converted to an electrical signal at the output of a photodetector. This signal is then amplified and measured using a spectrum analyzer.

Figure 4 demonstrates several spectral measurements of the beat signal as a function of the repetition rate. At the 10, 20, 50, and 80 KHz repetition rates, the beat signal demonstrates a resolution of ± 45 , 40, 35, and 25 millimeters respectively. Though the theoretical distance resolution of the 47 nm wavelength sweep is approximately $25.6 \mu\text{m}^3$, the spectral bandwidth of the beat signal dominates the distance resolution. Furthermore, the spectrum of the beat signal due to a 50 KHz and 80 KHz repetition rate demonstrates an unusual shape. This distortion is most likely attributed to both the non-linearities in the wavelength as a function of time, which is intensified by faster sweep rates, and the bandwidth limitations of the arbitrary waveform generators.

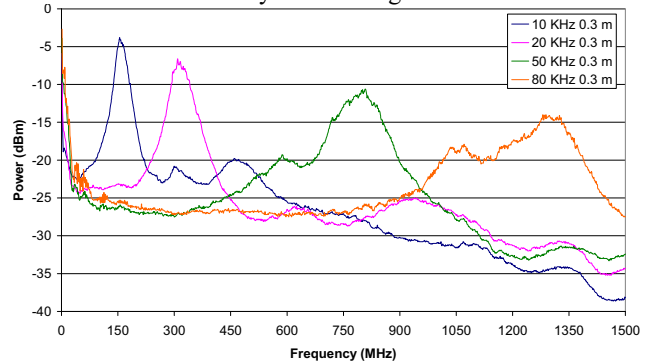


Figure 4: LIDAR measurements for a 0.3 m delay line at sweep rates ranging from 10 KHz to 80 KHz (left to right respectively). The LIDAR measurements are contained within optical fiber using an FMCW architecture.

IV. CONCLUSION

Fast wavelength sweeps with SG-DBR lasers have been demonstrated by applying three synchronized arbitrary waveforms to the respective tuning inputs of the laser. Mapping the wavelength as a function of the three tuning currents and appending the tuning segments results in a 47 nm continuous wavelength sweep. Performing LIDAR measurements using a Mach-Zehnder Interferometer demonstrates that short range distance measurements at update rates between 10 and 80 KHz provides distance resolutions between ± 45 and ± 25 micrometers.

REFERENCES

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