POSITION AND VELOCITY SENSING MEASUREMENTS USING AN INTEGRATED VCSEL AND PIN PHOTODETECTOR ASSEMBLY

BY

THOMAS MARK JEFVERT

THESIS

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Electrical and Computer Engineering in the Graduate College of the University of Illinois at Urbana-Champaign, 2011

Urbana, Illinois

Adviser:

Professor Kent D. Choquette
ABSTRACT

A position sensing optical microsystem that is low-power, non-contact and long-range was characterized. A vertical-cavity surface-emitting laser monolithically integrated with a photodetector packaged in a low profile assembly was used in conjunction with a metallic optical grating. By observing the modulated reflection of laser light off the grating collected by the detector, we can determine the speed and/or the relative position of the grating. The capability of the assembly as a sensor was investigated using a motorized stage and an air gantry motion system. On the air gantry system, the position sensing assembly measured the distance traveled to within 0.875 microns and the velocity to within 3% of the speed measured by conventional means. With the linear actuator, due to the discrete steps of operation, the measured distance was within 3.5 microns and the velocity to within 60%.
To Rachel
ACKNOWLEDGMENTS

I would like to express my gratitude to everyone who helped me make this work possible. First, thanks to my adviser Professor Kent D. Choquette for his guidance and support during my time at the University of Illinois. Also I would like to thank my fellow members of the Photonic Device Research Group for their assistance and support. Finally, I am very grateful to my parents, Mark and Lisa Jefvert, and my wife, Rachel, for their support and encouragement.
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1.1 VCSEL Background

A vertical-cavity surface-emitting laser (VCSEL) is a type of semiconductor laser diode. It was first reported in 1979 [1]. VCSELs differ from edge-emitting laser diodes in that the coherent light is emitted perpendicular to the surface of the semiconductor wafer, rather than parallel. Several advantages arise from this difference: lasers can be tested during fabrication, it is much simpler to create 2-dimensional arrays of devices, and the output beam is round and has a lower divergence. In addition, VCSELs operate at much lower operation power and can be more easily integrated monolithically with other semiconductor devices. Some disadvantages of VCSELs as compared to edge-emitting laser diodes are a lower output power and operation in multiple transverse modes.

Figure 1.1: Cross section of typical oxide VCSEL
A common VCSEL structure is an active region between two distributed Bragg reflector (DBR) mirrors. DBR mirrors have alternating layers of high and low refractive index, achieved by varying the composition of each layer. When the layers have a thickness of one quarter of the laser wavelength, and the relative difference of index between the layers is large enough, the reflectivity of the mirror can be well over 99%. This is required for VCSEL operation, since the active region is very short and with lower reflectivities the laser cannot achieve sufficient gain to reach stimulated emission threshold. The number of periods needed for the DBR to reach the necessary reflectivity ranges from 20 to 40 periods for typical VCSELs with semiconductor DBRs. In addition, the layers of the top and bottom DBRs are doped with p-type and n-type electrical impurities, respectively. This means that the mirrors also act as a diode junction and permit electrical carriers to be injected into the active region.

The active region of the VCSEL is formed from multiple quantum wells, and the DBRs are spaced so that the cavity between them is one wavelength of laser light. The use of quantum wells with high reflectivity DBR mirrors allows the cavity to be so short. Quantum wells also yield an electron density of states that has discrete steps in energy and the hole and electron effective masses are more similar. For these reasons, quantum wells are the structure of choice for the active region of many diode lasers, and the VCSEL is no exception.

Because of the one wavelength cavity, VCSELs are considered microcavity lasers, and have the advantage of operating in a single longitudinal mode. In addition, the structure must provide confinement for the driving current to keep the current threshold low. Methods to create confinement include etched air-posts [2], ion implantation [3], and oxide apertures [4]. Air-post defined VCSELs are created by etching away material between devices, which is the simplest method of confinement but thermal characteristics are poor. Ion implanted VSCELs provide confinement by damaging the crystal lattice around the device, which provides excellent current confinement but no inherent optical. Oxide aperture VCSELs are grown with one or more relatively high aluminum-content layers in the DBR, and after exposing this layer by etching it can be converted into a stable oxide layer that is electrically insulating and low index. The oxide-confined structure provides inherent index confinement with heat sinking, making it a better structure than either the
etched air post or implanted VCSEL. A cross-section view of a typical oxide aperture VCSEL is shown in Figure 1.1.

1.2 PIN Detector Background

A p-type/intrinsic/n-type (PIN) semiconductor photodiode is a photodetector that converts input light into current, and is formed by an intrinsic semiconductor layer sandwiched between heavily doped p- and n-type regions [5]. A photon incident on a photodiode with an energy greater than the bandgap of the semiconductor will excite an electron-hole pair, which transports through the junction to create a photocurrent. The simplest version of a photodiode is the PN junction, but the PIN structure was created to permit more control over the operation of the device. The intrinsic layer is depleted of carriers at low electrical bias applied across the junction, and the heavily doped outer layers cause the depletion width to be narrow. Advantages of PIN photodiodes over other types are that they can be optimized for a given wavelength (by control of the bandgap) and the modulation frequency response is improved compared to other types of photodiodes. These characteristics account for the PIN photodiode’s common deployment within optical fiber telecommunication systems.

1.3 Thesis Motivation

A position sensor that is non-contact, high-precision and long-range has many applications. One such non-contact, high-precision sensor is a capacitive displacement sensor, which is used in applications like optical lithography and other precision work. However, the capacitive displacement sensor only operates over a relatively short lateral range. Laser interferometers and optical encoders [6] are common choices for non-contact and high-precision sensors; however, they tend to be bulky and can be costly. One notable low cost position sensor is the laser mouse used for computers. VCSELs are the optimum technology choice in laser mice, due to their low power operation. Sensing is achieved by reflecting the laser emission from a surface and imaging the speckle pattern with a camera. As the mouse is moved, the changes
in the pattern indicate the direction of motion and the new position. This application requires camera imaging, and thus the resolution will be limited by its resolution. Another approach for position sensing that is studied in this work is to monitor the modulated reflection of VCSEL emission from an optical grating using a PIN photodiode. The PIN photodiode can be monolithically integrated with the VCSEL, creating a compact position system. This approach can provide long range (as long as the grating length) with high precision, and also is lower cost.

As a VCSEL-PIN assembly moves laterally relative to an optical grating, one would expect the photocurrent response of the detector to be periodic, with one period of varying output current corresponding to one period of the optical grating passing by the VCSEL beam. This operation was previously simulated to test the feasibility of a VCSEL/detector as a position sensor [7]. The simulations calculated the reflected emission of a VCSEL incident on a periodic sawtooth metallic corrugation. Three VCSEL and PIN detector geometries were considered; a chip with a VCSEL surrounded by four detectors in a cross pattern was determined to be the most promising, with the largest variation in reflected power. This geometry was designed and fabricated [7, 8], as shown in Figure 1.2. The simulated power variation over one grating period is shown in Figure 1.3.

![VCSEL in center, surrounded by PIN photodetectors](image)

Figure 1.2: VCSEL in center, surrounded by PIN photodetectors [7]
1.4 Previous Work

VCSELs and photodetectors have been monolithically integrated to create optical communication transceivers. The possibility of using a VCSEL structure as a detector was first investigated in 1991, with the quantum well layer acting as both an active and absorption layer [9]. This structure, called a resonant cavity enhanced (RCE) detector, was fabricated and investigated [10]. A resonant photodetector based on the VCSEL structure has also been monolithically integrated with a VCSEL [11]. A resonant photodetector is not suitable for sensing applications because of its spectral and angular sensitivity due to its resonant cavity design.

Another detector that has been integrated with a VCSEL is the metal-semiconductor-metal (MSM) photodetector, first demonstrated in the 1970s [12]. It is formed by a uniformly doped semiconductor with metal contacts on opposite sides. It thus operates as two Schottky barriers with opposite orientations. These devices can be designed to be very sensitive and high speed [13]. MSM photodetectors have been integrated with VCSELs for bidirectional fiber communication [14]. However for our application as a position sensor, MSM photodetectors are not desired since the actual detection area of the device is small relative to the total device size.

Non-resonant detection can be integrated with different epitaxial semiconductor layers for the VCSEL and the photodiode [15]. This allows for optimization of the VCSEL and the detector while still allowing integration with
other components. Recently this approach has been used for bidirectional data communication over optical fibers [16]. For our position sensing chip, the VCSEL and detector can be fabricated using the same semiconductor layers.

1.5 Thesis Scope

In this work, a VCSEL-PIN assembly is characterized for use as a position sensor with a metallic grating. The VCSEL-PIN is incorporated into a low profile assembly to enable the experimental testing. The optimum VCSEL-PIN layout determined by simulations is used and integrated into the assembly. The assembly is mounted onto two different positioner systems to evaluate the system. In Chapter 2, the details of the VCSEL device fabrication and testing are presented, as well as a description of how the low-profile assembly was constructed. In Chapter 3, the experiments performed are presented. The assembly was first investigated using a motorized stage, which yielded inconsistent results. Then the assembly was combined with an air gantry system with smooth motion which resulted in consistent position data. In addition to position sensing, the determination of velocity is studied and used to compare the accuracy. In Chapter 4, the results of this thesis work are summarized.
CHAPTER 2
ASSEMBLY PREPARATION

2.1 VCSEL Fabrication Review

Fabrication of a standard oxide aperture VCSEL begins with a GaAs wafer which has an epitaxially grown top DBR, a quantum well active region, and a bottom DBR. This wafer is cleaved into quarters or smaller pieces during fabrication. The bottom surface is then degreased and an ohmic contact is created by evaporating 400 Å of gold-germanium, 200 Å of nickel, and finally 1400 Å of gold. This contact on the substrate covers the entire bottom surface of the sample. A cross section of the wafer with the bottom contact is shown in Figure 2.1.

Figure 2.1: Cross section of sample with bottom contact

The next step is to pattern the top surface with photoresist and create a top contact. The process for spinning on photoresist includes a 110 °C heating step to remove any moisture from the sample, spinning on HMDS to
promote adhesion, and then spinning on AZ4330 photoresist. The edge bead of photoresist around the sample is removed by carefully swabbing away the excess. Then the sample is heated to harden the photoresist and a pattern is defined by placing a mask and exposing the sample under ultraviolet light. This process is called optical photolithography. When placed in AZ400K developer, the exposed regions of photoresist will be dissolved, and after being cleaned the surface is ready for a metal deposition. An image of the sample after it has been developed is shown in Figure 2.2.

![Figure 2.2: Sample after photoresist has been developed](image)

The design of the ohmic contacts for the top surface is a square contact with a square aperture in the center to allow laser emission. The top contact is fabricated by evaporating 150 Å of titanium followed by evaporating 1500 Å of gold. To remove the remaining photoresist and metal, the sample is placed in a bath of boiling acetone to dissolve the remaining photoresist, and the metal on the photoresist will float off of the sample. This process is called metal liftoff. An image of the sample after evaporation is shown in Figure 2.3 and an image after liftoff is shown in Figure 2.4.

Silicon dioxide is used to define the areas of the DBR to be etched into the mesas, but it must first be patterned itself. The SiO$_2$ is deposited on the sample by a plasma-enhanced chemical vapor deposition (PECVD) process to a total thickness of 4000 Å. As before, photolithography is used to define the areas of SiO$_2$ to be etched, but this time a thicker AZ5214 photoresist is used. The photoresist is spun on, exposed, and developed. The sample
is then placed in a reactive ion etching chamber, where the exposed SiO$_2$ is completely removed and the portions under the photoresist are unaffected. An image of the sample after the photoresist is developed is shown in Figure 2.5 and an image of the sample after the reactive ion etch is shown in Figure 2.6. Following the etch, the remaining photoresist is removed by spraying the sample with acetone.

The next step is to etch through the top DBR to create the mesas. This is done by placing the sample in an inductively coupled plasma reactive ion etching chamber. The SiO$_2$ etches much more slowly than the GaAs material
of the DBRs and protects the mesas. The target etch depth is about four DBR periods into the bottom DBR. This etch depth exposes the higher Al-containing layers in the DBR to create the oxide aperture. An image of the sample after the mesas have been defined is shown in Figure 2.7.

The sample is then steam oxidized so the high aluminum content layer(s) become aluminum oxide and create the necessary electrical and photonic confinement. The length of the oxidation process determines the size of the aperture within the VCSEL. The oxidation is performed at 400 °C, which results in an oxidation rate of about 0.75 µm/min. Once the oxidization is
Figure 2.7: VCSEL after etching mesas

complete, the layer of SiO$_2$ on the surface can be removed by a reactive ion etch as before, and the VCSEL is ready for testing. An image of a finished oxide VCSEL is shown in Figure 2.8. Photos of a completed VCSEL and a completed VCSEL in operation are shown in Figures 2.9 and 2.10.

Figure 2.8: Completed VCSEL

The oxide VCSEL shown in Figure 2.10 has an oxide aperture of 9×9 microns. A light and voltage versus current curve was recorded for the device, shown in Figure 2.11. These curves are typical for an oxide aperture VCSEL: there is a relatively low threshold current, then a linear rise in output power
Figure 2.9: Photo of completed VCSEL

Figure 2.10: Photo of completed VCSEL while lasing

Figure 2.11: Light and voltage versus current characteristic for 9 micron aperture VCSEL
above threshold. At high currents the output saturates and begins to decline. This rollover in output power occurs when the heating in the VCSEL causes the cavity resonance and gain spectrum to shift apart. The current-voltage characteristics are typical of a diode.

Many characteristics of the VCSEL vary with the oxide aperture size, such as threshold current and maximum output power. Figure 2.12 shows how the threshold current changes as the aperture size is increased for VCSELs that emit at 850 nm. Except for very small apertures, the threshold current generally increases with size, meaning that higher powers are necessary for laser operation. However, large aperture devices have greater output powers. An aperture of $9 \times 9$ microns was chosen for the position sensor VCSEL as a combination of low threshold current and high output power.

![Threshold Current vs. Aperture Size](image)

Figure 2.12: Plot showing how threshold current varies with aperture size

### 2.2 VCSEL/PIN Fabrication

For the integrated VCSEL/PIN for the assembly [7, 8], a wafer was epitaxially grown that included all the semiconductor layers for both VCSELs and the detectors. On the substrate there was a 35-period $\text{Al}_x\text{Ga}_{1-x}\text{As}$ n-type bottom DBR, then a cavity containing three quantum wells designed for emission at 850 nm, and then a 20-period $\text{Al}_x\text{Ga}_{1-x}\text{As}$ p-type top DBR. These are typical for a wafer used in standard VCSELs that emit at 850 nm. Grown on the top DBR was a 100 nm thick $\text{In}_{0.49}\text{Ga}_{0.51}\text{P}$ layer, which is later used as an etch stop layer. The epitaxy for the detectors consists of a 270 nm
Al$_x$Ga$_{1-x}$As p-type layer, then a 2 $\mu$m intrinsic GaAs layer, and finally a 300 nm Al$_x$Ga$_{1-x}$As n-type layer [7].

To fabricate the devices, first a contact was deposited onto the substrate as described in Section 2.1. Then the detector mesas were created using reactive ion etching. The composition used for the etch was a 50:1 mixture of BCl$_3$ to Cl$_2$. The etch was chosen to etch through the AlGaAs and the GaAs but to stop at the In$_{0.49}$Ga$_{0.51}$P layer. The use of the etch stop layer created a uniform 2.7 $\mu$m deep etch across the wafer. Then the etch stop layer was removed with an etch of HCl:H$_3$PO$_4$. The top VCSEL facets were then exposed and procession was continued as detailed in Section 2.1: the top contacts were deposited, mesas were defined using an inductively coupled plasma reactive ion etch with an SiO$_2$ etch mask, and the apertures were oxidized to a target aperture of 9 microns. After the VCSEL processing was completed, polyimide is applied to the device for encapsulation and to allow bond pads for integration with the rest of the assembly. A cross section of the device is shown in Figure 2.13.

![Cross section of completed VCSEL-PIN device](adapted from [8])

2.3 Integration for Sensing

For the sensing application, a package was needed to allow electrical wires to be connected for power and output of the laser and the detectors, respectively. In addition, the electrical connections could not extend above the surface of the die, as the die must be as close to the grating as possible. Typical laser packages, such as TO headers, would have bond wires extending high above
the surface of the die.

To address these constraints, a silicon host was fabricated with this application in mind [8]. Areas of the silicon wafer were etched away using an inductively coupled plasma Bosch process etch, to a depth approximately equal to the thickness of the VCSEL-PIN die. Then the silicon was steam oxidized to render the exposed surfaces nonconductive. Metal runners were deposited on the silicon host wafer to provide the electrical connections to the VCSEL(s) and detector(s). The dies were cleaved into individual die and attached into the etched pockets using conductive epoxy, and the gaps around each die were subsequently filled with polymer. The polymer secured the die and created ramps to allow electrical connections to the die, also created from conductive epoxy. For connection to equipment and power supplies, standard electrical wires were soldered and epoxied to the outer pads on the silicon host. A close-up of the die is shown in Figure 1.2, and the entire low profile assembly is shown in Figure 2.14.

Figure 2.14: Silicon assembly with wires attached to VCSEL die (location shown in red)
2.4 Characterization

Both the VCSELs and the PIN detectors are characterized prior to the assembly into the microsystem. To confirm that the VCSELs are functioning as expected, the light versus current properties are measured. Figure 2.15 shows the light versus current characteristics of 19 neighboring VCSELs from the integrated VCSEL/PIN sample [7]. To record these curves, the sample is placed on a grounded test station stage and a probe is pressed against the top contact. A semiconductor parametric analyzer is used to vary the current injected into the laser diode. The laser emission is captured with an external photodiode, calibrated for the wavelength of 850 nm, and recorded.

![Light vs. current curves for neighboring VCSELs](image)

Figure 2.15 confirms that there is high uniformity across devices, as the curves for each device are very similar. The average threshold current is 0.52 mA, with an average slope efficiency of 0.66 W/A and an average maximum output of 6.7 mW. This is excellent performance and indicates that the VCSEL facets were not damaged during fabrication.

In order to investigate the performance of the PIN photodetectors, current versus voltage curves were recorded under various illumination levels [7]. From these curves, one can find the dark current, turn on voltage and
series resistance, which are all important characteristics of photodiodes. To obtain these curves, a semiconductor parametric analyzer was once again used to sweep the voltage across the device. For each sweep a constant incident light source was incident on the detector. A fiber-coupled tunable laser with a wavelength of 840 nm was aligned to be at normal incidence with the surface.

The current versus voltage curves for a 406 micron diameter PIN detector are shown in Figure 2.16. The shape of these curves is typical of photodiodes, with more light creating more photocurrent when the device is under a negative bias. From this data, the diode turn-on voltage was about 1 V and the series resistance was 22 ohms. With a 2 V reverse bias applied, the dark current was about 40 nA and the responsivity at 840 nm was 0.38 W/A. This data indicates that the detectors should be suitable for the position sensing application.

![Figure 2.16: Current versus voltage under various illumination levels [7]](image)

Figure 2.16: Current versus voltage under various illumination levels [7]
3.1 Experiment Parameters

A schematic demonstrating how the assembly is used as a position sensor is shown in Figure 3.1. The continuous wave lasing emission is reflected off a metallic grating facing the die and detected by a detector that is adjacent to the VCSEL. As shown in the simulation mentioned in Section 1.3, one would expect the output of the photodetector to vary periodically as the laser emission strikes different points on the grating. One period of this detector output represents the movement past one period of the grating. By analyzing that photocurrent data, one can calculate the total distance traveled and the velocity.

![Figure 3.1: Schematic of the experimental setup](image)

The grating chosen for the experiments was a sawtooth metallic optical grating. The period of the grating was 3.499 microns. The surface of the grating was inspected using an atomic force microscope (AFM) to insure that the period was uniform and that the walls of the sawtooth were planar. The AFM showed that the grating period and sawtooth pattern were consistent and that the grating should function as desired.
An important component of the measurement system is the transimpedance amplifier. This circuit takes as an input the output current of the PIN photodetector, amplifies the signal, and converts the signal to a voltage which can be read in by an oscilloscope. The circuit should not create excessive noise, and requires an external voltage supply to power the operational amplifier. A circuit diagram is shown in Figure 3.2.

![Figure 3.2: Schematic of the transimpedance amplifier](image)

3.2 Air Gantry System

One of the translation stages measured with the assembly was a high-precision air bearing gantry system built by Aerotech. This system had 3-dimensional control with a resolution of 0.2 microns and also 2 goniometers for tilt control. The system (position assembly not attached) is shown in Figure 3.3. The grating is attached to the moving stage, and the assembly is attached to a stable point above the grating. When aligning the grating with the assembly, the tilt of the stage was first adjusted by visual inspection, and the grating was brought as close to the die surface as possible. The distance was estimated to be several to tens of microns.

The stage was commanded to move at 5, 25, 50, 200, 500, and 1000 µm/s. For each velocity, several time traces of the detector output were recorded using the amplifier circuit and an oscilloscope. To capture the data, a time window is chosen on the oscilloscope to capture a certain number of traces, and then a snapshot of the data is recorded on the screen. A typical data capture is shown in Figure 3.4. The periodic modulation of the reflected light is apparent in Figure 3.4, with identifiable peaks and valleys. While
recording data using the air gantry system, nearly all the outputs exhibited this basic shape; the few that were noisy and/or aperiodic were the result of optical scattering from imperfections on the optical grating.

Figure 3.4: Sample data capture with air gantry system, velocity of 200 µm/s

3.3 Motorized Stage

In addition, the assembly was investigated using a high-resolution motorized linear actuator. The actuator used was a Zaber Technologies T-LS28-I with
a microstep size of 0.1 microns. The software interface allowed for many control options to be manipulated, such as anti-backlash and anti-stiction routines. These settings were all tested to find the mode of operation that offered the smoothest operation. However, even with the setting optimized for smooth travel, the stage vibrated as it moved. This vibration of the stage had an obvious effect on the recorded data. If the stage vibrated such that the distance between the grating and the assembly was not constant, then the power would vary unpredictably; and if it vibrated such that the forward motion of the grating was not constant, this would create noisy data as a result of non-constant velocity. The system (assembly not attached) is shown in Figure 3.5.

![Figure 3.5: Image of the motorized stage system](image)

As before, data was recorded at 5, 25, 50, 200, 500, and 1000 µm/s. A typical data capture using the linear actuator is shown in Figure 3.6. In comparison to Figure 3.4, the output is not smooth, and there are multiple peaks and valleys per period. Also, the time between each of the major peaks is not constant. For every periodic waveform recorded, there were several other waveforms observed with no apparent periodic features with high levels of noise.

### 3.4 Data Analysis

The experimental results obtained from both stages were analyzed to determine the accuracy of position and velocity measurement. To find the
Figure 3.6: Sample data capture with linear actuator, velocity of 100 µm/s

total distance traveled using a waveform similar to Figure 3.4, the peaks can be counted and multiplied by the grating spacing. The waveforms from the air gantry system have peaks that are easily identifiable and countable, and in fact fractions of a period can also be estimated. This accuracy can be estimated as one-quarter of the grating spacing, or 0.875 microns. The waveforms recorded from the motorized stage experiments, like the sample in Figure 3.6, are not periodic, although peaks can still be identified. These can be used to estimate the distance traveled to within one grating spacing, if the peaks can be identified, but in many cases with the motorized stage the results were noisy without any apparent period. Over any appreciable distance of several grating periods, there is a high chance a portion of the data would appear very noisy and aperiodic, and therefore finding the total distance traveled would be inaccurate.

To investigate the velocity sensing capability, Fourier analysis was performed on each data set to find the dominant frequency of the waveform. This frequency multiplied by the grating spacing gives the measured velocity. The corresponding frequency spectrum of the waveform in Figure 3.4 is shown in Figure 3.7. From the plot it is clear that there is a dominant peak; this frequency is used to determine the velocity.

Figure 3.8 shows the difference between the velocity measured by the position assembly and the speed determined internally by the air gantry sys-
The air gantry system included an optical encoder for accurate position tracking. By monitoring the position over time, it was verified that the speed measured by the position assembly was extremely close to the commanded speed of the stage. For all velocities, the measurement was within 3% of the actual speed, and became more accurate at higher speeds, for example to within 0.5% at 1000 $\mu$m/s. There were no waveform data sets excluded from these measurements; waveforms recorded from the air gantry system gave consistent results.

The same analysis was performed on the position data measured from the motorized stage. The corresponding frequency spectrum of the waveform in Figure 3.6 is shown in Figure 3.9. As is typical from the Fourier transforms of the waveforms recorded from the motorized stage, there are multiple large peaks that are only a few times the background noise spectrum. The maximum peak is taken as the frequency used for the velocity calculation.

Figure 3.10 shows the difference between the velocity measured by the assembly and the commanded speed of the motorized stage. In an attempt to verify the accuracy of the commanded speed, a ruler was used to find average velocities over time intervals. The commanded speed appeared to match the actual speed very closely, but this method of verifying the speed is very crude. As apparent in Figure 3.10, the percent differences between the speeds measured by the position sensor and the commanded speeds are much higher.
than for the air gantry system; in addition there is much larger variation between trials. The motorized actuator has movement in discrete steps, which results in inconsistent, non-constant motion as well as vibrations. This
results in a noisy reflection off the grating and distance variations between the laser and detector that reduce the assembly’s capability as a position sensor.

Figure 3.10: Difference between measured and control velocities for the motorized stage; error bars indicate standard deviation over several trials.
CHAPTER 4

SUMMARY OF RESEARCH

In this work, the capability of an integrated VCSEL/PIN assembly as a position sensor was studied. VCSEL emission is reflected from an optical grating, and the reflected modulated light is measured by the integrated PIN detector. The VCSEL-PIN chip is packaged in a novel low-profile silicon coupon to form the microsystem. From the measured output of the detector, the distance traveled and the velocity of the grating over the assembly can be determined.

Two translation stages were tested with the assembly: an air gantry system and a motorized actuator. On the air gantry system, the assembly measured the distance traveled to within 0.875 microns and the velocity to within 3% of the actual speed, and in some cases to as close as 0.5%. With the linear actuator, due to its motion in discrete steps of operation, the measured distance was within 3.5 microns and the velocity to within 60%.

Therefore we have demonstrated that the VCSEL/PIN assembly in conjunction with an optical grating can be used as an accurate, low-power, non-contact, and long-range position sensor, provided that the motion is smooth. The sensor can be used to measure position and velocity in a low-profile mode, enabling a compact low power sensor that may be appropriate for many applications.
REFERENCES


