Mike Rieger
Director of Technical Support

Speed Measurement Lidar Technology and Conformance Testing
Centennial Colorado
Brief History of Laser Technology, Inc.
1985

International Measurement and Control

Dredge Guidance

Hydrographic Mapping
1988 US Navy Project

(Airborne Turret Infrared Measurement System)

30,000 ft. to a prism on an aircraft
The ATIMS was modified to measure vehicle speed and demonstrated to the California Highway Patrol.

The demonstrations showed that there was a market for laser speed measurement technology.
The company was incorporated and the name changed to Laser Technology, Inc. (LTI)

1990 LTI 20-20

A laser-based speed detector sends out an invisible beam to snare speed-limit violators.
LTI 20-20 Speed Measurement Laser

TECH UPDATE
News Of Tomorrow’s Technology Today

Laser Thwarts Auto Radar Detectors

LITTLETON, CO—A new police speed gun that uses a laser beam instead of radio waves could render automobile radar detectors useless, and set the stage for focused, and the gun needs only a 1/4 second to take a reading, detecting a laser speed trap in time to slow down is nearly impossible. The new threat is not likely
1992 Surveying Products And Worldwide Distribution
1993 NASA

The **NASA** laser project was used for closing speed monitoring when docking with the space station or for satellite recovery missions.

The instrument measures velocity in feet per second.
United States Patent

Dunne

12

[54] LASER-BASED SPEED MEASURING DEVICE.

[75] Inventor: Jeremy G. Dunne, Littleton, Colo.


[*] Notice: The portion of the term of this patent subsequent to Mar. 1, 2011 has been disclaimed.

[21] Appl. No.: 945,233

[22] Filed: Sep. 14, 1992

Related U.S. Application Data


[51] Int. Cl. 5 G01C 3/08; G01P 3/36

[52] U.S. Cl. 356/5; 342/94; 342/95; 342/105; 356/28; 368/120

[58] Field of Search 356/5, 28; 368/120; 342/94, 95, 105

References Cited

U.S. PATENT DOCUMENTS

3,698,811 10/1972 Weil 356/5
4,346,989 8/1982 Gert et al. 356/5
4,527,894 7/1985 Goede et al. 356/28
4,569,599 2/1986 Bolkow et al. 356/5
4,948,246 8/1990 Shigematsu 356/5
5,046,839 9/1991 Krangle 356/5

Primary Examiner—Stephen C. Buczinski
Attorney, Agent or Firm—Trask, Britt & Rossa

ABSTRACT

A laser speed detector is described which includes a laser rangefinder which determines the time-of-flight of an infrared laser pulse to a target and a microprocessor-based microcontroller. The device is small enough to be easily hand-held, and includes a trigger and a sighting scope for a user to visually select a target and to trigger operation of the device upon the selected target. The laser rangefinder includes self-calibrating interpolation circuitry, a digital logic-operated gate for reflected laser pulses in which both the “opening” and the “closing” of the gate can be selectively set by the microcontroller, and dual collimation of the outgoing laser pulse such that a smaller portion of the outgoing laser pulse is sent to means for producing a timing reference signal.

35 Claims, 8 Drawing Sheets
US Patent 5,359,404
Laser Technology Patents

5,521,696
5,528,518
5,539,513
5,949,529
0776458
6,064,330
6,282,803
2,203,278
10-0278806
5,652,651
690003
5,880,821
6,057,910
2,203,278
5,617,199
5,574,552
5,703,678
5,612.779
6,226,077
6,445,444
5,617,199
45799
5,715,045
714599
2,254,897
729605
5,696,705
5,938,717
5,780,999
718038
2,263,918
5,781,147
5,790,244
729572
2,263,853
5,889,583
6,377,186
5,926,260
5,806,020
5,859,693
6,043,868
6,055,490
2,303,843
735001
Finally
an affordable laser and radar docking aid system that will increase safety and reduce “HARD” dockings.

Laser Communications, Inc.
Laser and Radar Docking Aid System

1994 Ship Docking Systems
1994 Speed Measurement with Digital Image
1994 Bushnell Partnership

Other features of Yardage Pro 500DX, 600 and 1000 models

- Through-the-Lens liquid crystal display.
- Inaudible operation.
- Automatic shut-off.
- Invisible, eyesafe Class 1 laser.
- Operates in rain and brush without need for reflectors.
LTI 20-20 Court Acceptance

The ‘landmark’ case on Laser speeding tickets in New Jersey:

Judge Reginald Stanton wrote:

“I am satisfied from the evidence presented in the proceedings which led to the issuance of my Opinion of June 13, 1996 and from the evidence presented during the recent hearings before me that the general concept of using lasers to calculate the speed of motor vehicles is generally accepted within the relevant scientific community and is valid.”
1995 - 2000

Impulse series

UltraLyte Series

Micro Digi-Cam System
2001 Digital Signal Processing

ASIC

Bushnell (digital)

Survey

Industrial
The 3rd generation of Speed Measurement

TruSpeed 2007

TruCAM 2009
The Digital Generation (4<sup>th</sup>)

TruSpeed S  2011
Principles of Operation

1. Laser Pulse Generation
2. Timing Analysis and Processing
Laser Pulse Generation

- Laser light (laser diode) is the working component of a LiDAR* system.
- Speed of light is a constant: 299,792,458 m/s.
- The time it takes the infrared laser light to travel to an object and return is measured. The time of flight is proportional to the range to the target.

<table>
<thead>
<tr>
<th>Diode Type</th>
<th>GaAs microstripe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>905 nM (nominal)</td>
</tr>
<tr>
<td>Spectral bandwidth</td>
<td>5 nM</td>
</tr>
</tbody>
</table>

- Typical laser pulse duty cycle (pulse duration) = 5 nanosecond to 30 nanosecond.

*Light Detection And Ranging*
Laser Pulse Generation

With the use of optics, the diverse energy produced by the laser diode is focused into a tight, narrow beam.
Target Discrimination

BEAM WIDTH COMPARISON

RADAR

LASER

90 m

0.4 m

150 m
Focused laser energy → Laser Class 1

The laser energy is **below** the level at which it is believed eye damage will occur.
Conformance Testing

*Laser Pulse Generation*

1. **Laser Safety Classification.** (manufacturer to provide certification?)
   (includes: pulse duration, wavelength, pulse energy, pulse repetition rate, etc.)

2. **Beam Width --> Target Discrimination.**
   (IACP MPS requires beam width of ≤ 5 milliradians)

**Typical Beam Widths**

<table>
<thead>
<tr>
<th>Beam Width</th>
<th>Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0 milliradian</td>
<td>0.29°</td>
</tr>
<tr>
<td>3.0 milliradian</td>
<td>0.17°</td>
</tr>
<tr>
<td>2.5 milliradian</td>
<td>0.14°</td>
</tr>
</tbody>
</table>

[http://www.stalkerradar.com](http://www.stalkerradar.com)
1. Laser Pulse Generation

2. Timing Analysis and Processing
Timing analysis and Processing

The lidar device measures the time it takes the laser pulse to travel to and return from an object. Distance to the object is proportional to the time-of-flight of a laser pulse divided by two.

Distance = velocity * time

\[ d = c_{AIR} \times t_{RT} \div 2 \]
Timing analysis and Processing

A counter is started when the laser light is transmitted, and the counter is stopped when a portion of the signal is detected.

One event (distance) per laser pulse

By definition, a lidar device is a precise time measurement device which performs complex mathematical calculations.
Timing analysis and Processing

\[ v = \frac{|d_1 - d_2|}{\Delta t} \]

By sending out multiple pulses (2 or more) we can calculate speed.

\( \Delta d \) = quantitative change in distance
(distance change from pulse 1 and pulse 2)

\( \Delta t \) = quantitative change in time
(elapsed time from pulse 1 and pulse 2)

Distance traveled / Elapsed Time
In theory, it is possible to make a speed measurement using only two laser pulses.

In practice, this would be prone to errors, such as a shift of the aiming point between the two pulses during the measurement. (often referred to as ‘sweep’ error)

To eliminate the possibility of such errors, most LiDAR devices use multiple pulses (40 to 100) to calculate the target's speed. The actual speed calculation is not the simple distance divided by time formula; the target speed is instead derived from the entire data set using statistical analysis.
Timing analysis and Processing

Given perfect distance measurement and a constant vehicle velocity, all distance measurements would fall on a single straight line. The slope of the line represents vehicle speed and direction.
Timing analysis and Processing

Using a multiple pulse measurement provides information on the steadiness of the beam on the vehicle during the measurement and is used to assure accuracy in the speed calculation. In other words, the system can detect ‘sweep’ error, or unintentional errors due to operator hand shake.
Conformance Testing

Timing analysis and Processing

1. Verify Accuracy of Internal Time Base
   (a precise time measurement device must operate from an accurate internal clock)

2. Accurate Range Measurement
   (ability of instrument to accurately measure time and perform a calculation)

3. Accurate Speed Calculation
   (ability of instrument to accurately calculate speed under perfect conditions)

4. Measurement Analysis
   (software is able to detect and reject ‘sweep’ and other unfavorable measurement conditions which could effect speed accuracy)
Conformance Testing
Timing analysis and Processing

**Speed Accuracy can be Confirmed through:**

- Field testing
- Laboratory Simulations
  - Low and high temperature limits
  - Low source voltage
  - Electromagnetic interference
  - Simulated sweep error
LiDAR Target Simulator (LTS)

NISTIR 6418

User’s Manual for Lidar Target Simulator

James A. Worthey
Electronics and Electrical Engineering Laboratory
Office of Law Enforcement Standards
National Institute of Standards and Technology

March 2000

U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary

TECHNOLOGY ADMINISTRATION
Dr. Cheryl Shavers, Under Secretary of Commerce for Technology

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Raymond G. Kummer, Director

March 2000
The ideal computer is an AT compatible with a 486 chip running at 66 MHz. Hardware floating-point support is required. Useful data have been taken using a 20 MHz 386 PC.
Lidar Target Simulator (LTS)

Key Points:

• PC loads delay into DDG via GPIB between pulses
  • Max pulse rate = 390 Hz
• Lidar unit must operate using a fixed pulse rate
• Pulse rate is part of simulation calculation
• Optical interface converts laser pulses into electrical signals
• Designed to use off the shelf parts to maintain independence from manufacturers
• Includes a sweep test
  (simulates sweeping towards the lidar, 1.52 m (5 ft.) along a smooth sheet-metal area in 0.178 s )
Lidar Speed Measurement Simulator

The LTS hit obsolescence in the early 2000’s when replacement parts were difficult to find. In 2004, the IACP contracted with Laser Technology, Inc. to design a replacement LTS. The LSMS was designed and 3 systems delivered to IACP. Since then many systems have been sold worldwide.

Key Points:

• Built for purpose system
• All timing and delays loaded internally
• Original Specification = 1 KHz max pulse rate
  • Has since been increased to 13 KHz
• Based on lidar units which operate using a fixed PRR
• Optical interface handles high pulse rates
• Includes a sweep test
  (simulates sweeping towards the lidar, 1.52 m (5 ft.) along a Smooth sheet-metal area in 0.178 s )
Pulse Repetition Rate

For many years the Lidar pulse rate was a fixed frequency. Thus this is the reason that the Lidar speed simulators, old and new, are based on fixed pulse rates.

However appearance of Lidar jammers on the market have given manufacturers incentive to move away from fixed pulse repetition rates.
Laser Jammers

Fixed pulse rates are more easily detected than random pulse rates (or pseudo random), as fixed frequencies do not naturally occur.

A random pulse rate is hard to detect from normal background noise. In many cases, the jamming device will not activate.

Image from: www.blinder.net
Laser Jammers

Adjustable collimation lens spreads beam
From a point to a wide area wedge, pre-tuned
To a distance of 500m

904nm laser matched LIDAR frequency and overwhelms receiver. Current technology only uses LED to blind source.

Future Technology

Laser jammer avoidance and improvements in Lidar technology will change the way speed measurement Lidar devices transmit laser pulses.
Digital Signal Processing

14 pulses @ 4 KHz

2.8 KHz average rate

LTI TruSpeed S

Class 1 eye safety provides the limits. Burst rates greater than 55 KHz may be considered a single pulse increasing the laser classification, thus it is expected that the burst rates will be limited to 55KHz or less.
The future of speed measurement Lidar technology is here today. Performance standards and conformance testing must take into consideration new technologies such as:

• Digital signal processing and high pulse repetition rates.
• Laser jammer avoidance techniques.
• On board data storage.
• Integrated cameras.
• Ability to transfer data wirelessly, in real time.
• GPS
Thank You