44. 301

BDX-613-933

LASER CENTERING DETECTOR

Technological Spinoff Report

July 1972

Bendix Corporation
Kansas City, Missouri

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22151.

Price: Paper Copy \$4.00
Microfiche \$0.95

LASER CENTERING DETECTOR

Published July 1973

Project Leader:
L. D. Wonnell
Department 415

Project Team:
K. E. Moser

Contract Number AT(29-1)-613 USAEC

THE BENDIX CORPORATION

KANSAS CITY DIVISION

KANSAS CITY, MISSOURI

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

LASER CENTERING DETECTOR

July 1973

Prepared by L. D. Wonnell

A compact, battery-powered laser centering detector, constructed specifically for use with the low power output of laser interferometers to align the interferometers and to measure machine pitch and yaw errors with a resolution of 100 microinches ($2.54 \mu\text{m}$), was designed, built, and evaluated by the Bendix Metrology Laboratory.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

Section	Page
SUMMARY	7
DISCUSSION	9
SCOPE AND PURPOSE	9
ACTIVITY	9
<u>Laser Centering Detector Design</u>	9
<u>Laser Centering Detector Evaluation</u>	13
ACCOMPLISHMENTS	14
REFERENCES	15

ILLUSTRATIONS

Figure		Page
1	Laser Centering Detector (P-76130).	10
2	Simplified Block Diagram of Centering Detector	11
3	Laser Centering Detector Circuit Diagram	12

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUMMARY

A battery-powered laser centering detector (LCD) has been developed for use with the low power output of laser interferometers. The detector is used for alignment of laser interferometers and can be used for checking pitch and yaw errors of measuring machines to a resolution of 100 microinches ($2.54\ \mu\text{m}$). Readout of displacement from a laser beam is given in horizontal and vertical coordinates. Design, construction, and evaluation of the LCD are discussed in this report.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

DISCUSSION

SCOPE AND PURPOSE

The Laser Centering Detector (LCD) is an instrument which electronically determines displacement of a target detector in horizontal and vertical coordinates from the center of a visible continuous-wave laser beam (normally helium-neon) used as a reference straight line (Figure 1). This detector was developed for use with low power output laser interferometers (50 to 150 microwatts). A number of such detectors are commercially available but lack the required sensitivity of less than 10 microinches ($0.25\mu\text{m}$) and respond only to lasers with a higher output: about 0.5 to 1 milliwatt.

The primary function of the detector was to align X and Y laser interferometers which are mounted on an SIP Trioptic Measuring Machine in the Bendix Kansas City Metrology Laboratory. These interferometers required alignment of less than 0.004 inch (0.10 mm) in the Y axis (for a 8-inch or 0.2 m travel length) and 0.005 inch (0.13 mm) in the X axis (for a 16-inch or 0.4 m travel length) in order to minimize cosine errors to less than 0.1 ppm. Visual alignment within these limits is very difficult, but the electro-optical method of alignment, using the LCD, is much faster and more accurate.

Secondary planned use of the LCD was for checking pitch and yaw errors in inspection, production, and measuring machines to provide a faster measurement method than currently provided by an autocollimator.

ACTIVITY

Laser Centering Detector Design

The basic design includes a photodetector and two voltage sensors, and the complete system is battery-operated. A simplified block diagram and detailed circuit diagram of the LCD are shown in Figures 2 and 3, respectively. The four-element silicon photodetector is connected to two bridge circuits which provide two output signals for vertical and horizontal positions. Changes in each bridge are sensed by two high-gain operational amplifiers and displayed on two zero-centered meters: one meter for horizontal displacement, and one meter for vertical displacement. The readout of these meters is directly proportional to displacement of the laser beam.

Figure 1. Laser Centering Detector

Figure 2. Simplified Block Diagram of Centering Detector

Figure 3. Laser Centering Detector Circuit Diagram

Each operational amplifier is connected in a potentiometric feedback configuration, providing high input impedance and a sensitivity of less than 1 microvolt. Electronic damping is built-in to reduce effects of light variations. Each amplifier is powered with two 6-volt batteries and draws a quiescent current of less than 1 microampere.

The centering detector has independent zero and sensitivity controls for the horizontal and vertical axis. There are four full-scale ranges of 0.05, 0.005, 0.0005, and 0.00005 inch (1.3, 0.13, 0.013, and 0.0013 mm) for each axis. Calibration is required on only one range and does not change when sensitivity ranges are switched. Each axis is calibrated by a screwdriver adjustment (designated CAL) on the front panel of the LCD.

Laser Centering Detector Evaluation

The LCD was evaluated on an SIP Trioptic Measuring Machine using a Spectra Physics Model 119 helium-neon gas laser as a light beam source. Power output of the laser was about 100 microwatts with a beam diameter of 4 millimeters. Position linearity and repeatability from a reference zero center setting for both axes on the 0.05 inch (1.3 mm) and 0.005 inch (0.13 mm) full scale ranges were within 5 percent of full scale. However, on the 0.0005 inch (0.013 mm) range, and particularly the 0.00005 inch (0.0013 mm) range, readings were unstable and a great deal of drift was experienced, although the detector had resolution of less than 10 microinches (0.25 μm).

From these tests it was concluded that the LCD was more than adequate for aligning the laser interferometer but did not have sufficient stability for measuring pitch and yaw errors of inspection machines since the useable resolution was about 100 microinches (2.54 μm).

The six causes of drift and instability of the two higher sensitivity ranges were found to be these:

- Air turbulence in the laser beam path,
- Temperature changes of the sensor head which changed the photodetector's dark current,
- Amplitude variations in the laser output,
- Background light variations,
- Thermal effects on the mounting of the laser barrel, and
- Input bias current temperature coefficient of the operational amplifier.

Enclosing the air path between the laser and sensor reduced drift enough that a usable resolution of 10 microinches ($0.25\ \mu\text{m}$) was obtained. Other methods for reducing drift and instability would include use of a operational amplifier with a lower input bias current temperature coefficient, use of a fan blowing air in line with the beam, use of a tooling laser, and use of an ac, rather than dc, detection system. 1, 2, 3

ACCOMPLISHMENTS

A battery-powered LCD has been developed and fabricated for determining position of a low power laser beam, used as a straight line reference, in horizontal and vertical coordinates.

The LCD was developed for two uses:

- Alignment of laser length measuring interferometers to reduce cosine error; and
- Measurement of pitch and yaw errors of various types inspection and measuring machines.

The final design was found to be adequate for alignment of laser interferometers but marginal for checking machines which have position measurements requiring a resolution of less than 100 microinches ($2.54\ \mu\text{m}$). The basic detector can resolve displacements of better than 10 microinches ($0.25\ \mu\text{m}$). However, air turbulence and air temperature variations normally limit its usable resolution to about 100 microinches ($2.54\ \mu\text{m}$).

REFERENCES

¹George Carey, Developments In Laser Alignment Techniques. Bethpage, NY: Grumman Aerospace Corporation.

²Martin R. Hamar, Laser Alignment In Industry. Dearborn, Michigan: Hamar Laser Instruments, Inc., 1969.

³M. J. Landry, An Investigation of Some Problems Involved With The Use of Lasers in Alignment Systems. Sandia Laboratories, Albuquerque: SC-DR-69-714, 1970.