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LASER-BEAM PROFILER AND
DETECTOR-SURFACE SCANNER

By L. R. Foulk

Published November 1978

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By L. R. Foulk

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A portable, relatively inexpensive laser-beam profiler and detector-surface scanner has been developed to map the intensity profile of laser beams and the cross-sectional response of optical detectors within a wavelength range of 633 nm to 10.6 μm . Equipment diagrams, circuit schematics, and examples of detector-response maps and laser-beam profiles are provided.

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SUMMARY

Because of the unavailability of suitable commercial equipment, a laser-beam profiler and detector-surface scanner has been designed and built at Bendix Kansas City to characterize laser beams and the response of optical detectors within a wavelength range of 633 nm to 10.6 μm .

Based on a design obtained from the National Bureau of Standards, the basic system consists of a laser beam directed toward two mirrors that move at right angles to one another to produce a raster pattern of the beam on the output detector.

The laser-beam profiler and detector-surface scanner, portable and relatively inexpensive, has proven very useful in mapping the cross-sectional response of various types of standard detectors and the intensity profile of laser beams, including the high-power CO₂ lasers used for welding.

DISCUSSION

SCOPE AND PURPOSE

The system described in this report was designed and built to measure both the intensity distribution (profile) of laboratory and production lasers and the relative response across the sensing area of laser power meters. Intensity distribution is an important parameter in obtaining good laser welds, and a knowledge of the detector response is essential in determining the accuracy of laser power measurements.

Commercial equipment capable of characterizing laser beams is expensive. Furthermore, no commercial equipment was found that had the capability for mapping both the profile of laser beams and the cross-sectional responsivity of detectors over the entire wavelength range from 633 nm to 10.6 μm .

PRIOR WORK

An integrating sphere photodetector for the measurement of continuous-wave and peak laser power has been developed.¹

The laser-beam profiler and detector-surface scanner described in this report is based on a design obtained from the National Bureau of Standards, Boulder, Colorado.²

ACTIVITY

Background

Laser-Beam Profiler

The quality and uniformity of laser-beam welding depend greatly on the operating mode of the laser source. Figure 1 illustrates the TEM₀₀, TEM₀₁, and TEM₁₁ laser-beam modes of operation. To the right of each example is a simplified, three-dimensional, five-raster-line plot of the beam intensity. Of the three modes, the gaussian-shaped TEM₀₀ mode is the most desirable.

Prior to the development of the laser-beam profiler and detector-surface scanner, mapping the intensity of a high-power laser beam at Bendix Kansas City consisted of taking a "burn" on an acrylic plastic sheet. By this method, the plastic is melted by the laser beam, and the melt depth is interpreted as an indication of the cross-sectional intensity of the beam. A

Figure 1. Examples of Laser-Beam Modes of Operation (Left) With Three-Dimensional, Five-Raster-Line Plots of Beam Intensity (Right)

major disadvantage is the self-focusing tendency of the plastic sheet on the beam. Also, the smoke from the burn degrades the optical components of the laser output.

A system was needed that could map the intensity variations in the cross section of a laser beam to determine whether the laser was operating in the desired mode, and to indicate the stability of the laser mode with respect to time. Monitoring the profile of a laser also can alert the operator to any degradation of the laser-system optics.

Detector-Surface Scanner

A determination of the uniformity of a detector is of great importance in accurately estimating the uncertainty of laser power measurements. Deterioration of a detector caused by rough handling, or burned spots on the sensing area caused by an overload often cannot be visually determined.

A system was needed for mapping the response of the sensing area of the detectors to determine their accuracy and provide for their removal from service, if damaged. A response map of the sensing area will indicate whether there is detector damage. By mapping the response, the condition of a detector can be initially and periodically verified, and a permanent record can be maintained.

Description of System

The laser-beam profiler and detector-surface scanner is a versatile system which consists basically of a laser beam directed toward two mirrors that move at right angles to one another to produce a raster pattern of the beam on the output detector. In the laser-beam-profiling mode of operation, it can be used either to monitor the initial alignment of a laser, or to continuously monitor an unstable laser.

Figure 2 is a diagram of the system being operated in the detector-scanning mode. The small laser beam is directed onto the center of the first mirror which deflects it in the X-axis. The beam being scanned in the X-axis then is reflected onto the center of the second mirror which scans in the Y-axis. The X-axis drive motor is controlled by a sawtooth waveform, and the Y-axis drive motor is controlled by a staircase generator that is synchronized to the sawtooth waveform and produces one vertical step in the staircase for each sawtooth segment.

Figure 2. Diagram Showing the Laser-Beam Profiler and Detector-Surface Scanner Being Operated in the Detector-Scanning Mode

The result of bending the beam through two axes is the creation of a raster pattern of the laser beam across the sensing area of the detector. The detector responds with an output that is fed into one vertical channel of a storage oscilloscope. The staircase generator is fed into the other vertical channel of the oscilloscope, and the horizontal deflection of the oscilloscope is controlled by the sawtooth waveform. The oscilloscope is operated in the summing mode, and the resulting trace is a three-dimensional map of the response of the detector over its surface area. The zero-reference and gain of the X- and Y-axis motors are adjustable, as is the number of steps in the Y-axis.

Typical detector-response maps are shown in Appendix A of this report, and response maps of integrating spheres are shown in Appendix B.¹

To change the operation of the system from that of a detector-surface scanner to a laser-beam profiler, a pinhole aperture is placed in front of the detector, and the gain of both axes is adjusted so that the beam scans a raster across the pinhole. The requirements for success in the laser-beam-profile measurement are that the detector sensitivity be compatible with both the power level and wavelength of the signal, and that the diameter of the pinhole aperture be much smaller than the diameter of the laser beam.

The X-sweep source, or sawtooth generator, is obtained from the sawtooth output of an oscilloscope. The Y-sweep source, or staircase generator (Figure 3), is driven from the positive-gate output pulses of the same oscilloscope. A schematic of the dc amplifiers that drive the torque motors which operate the mirrors is shown in Figure 4.

Typical profiles of laser beams are shown in Appendix C.

Mirror Choice

Experiments were performed with several different mirrors before a final choice was made. The mirrors used must meet the following requirements:

- Contain no surface defects;
- Reflect all wavelengths from 633 nm to 10.6 μm ;
- Exhibit no deterioration with time;
- Have the capability for reflecting 100 W of power without distortion; and

Figure 3. Schematic of Staircase Generator

Figure 4. Schematic of DC Amplifier

- Have a diameter large enough that a 25-mm-diameter (1 inch) beam will not overshoot the surface of the mirror while it is scanning.

The final selection consisted of copper mirrors having a thin-film-dielectric coating to prevent oxidation. These mirrors are approximately 6 mm (0.25 inch) thick and 38 mm (1.5 inches) in diameter.

ACCOMPLISHMENTS

A portable, relatively inexpensive laser-beam profiler and detector-surface scanner has been designed and built at Bendix Kansas City to characterize laser beams and the response of optical detectors within a wavelength range of 633 nm to 10.6 μ m. It has proven very useful in mapping the cross-sectional response of various types of standard detectors and the intensity profile of laser beams, including the high-power CO₂ lasers used for welding.

FUTURE WORK

An improved version of the laser-beam profiler and detector-surface scanner is being designed and built. Additional advantages will include the automatic location of the upper and lower scan lines of the raster, a digital-switch selection of the number of scans, better control of the scan-line spacing, and a much smaller electronics package.

An increase in the use of similar equipment at Bendix Kansas City is anticipated, both as a monitoring tool, and as a laser-beam monitor during the alignment and operation of production-line laser welders.

REFERENCES

¹L. D. Wonnell, *Integrating Sphere Photodetector for Measurement of Continuous-Wave and Peak Laser Power*. Bendix Kansas City: BDX-613-1419, August, 1976 (Available from NTIS).

²C. A. Hamilton, "Block Diagrams, Schematics and Notes on a Prototype Scanning System." National Bureau of Standards, July 26, 1974 and April 25, 1975.

Appendix A

DETECTOR-RESPONSE MAPS

Figure A-1. Map of UDT Silicon Photodiode,
Model PIN 10D

Figure A-2. Map of UDT Silicon Photodiode,
Model PIN 25

Figure A-3. Map of ADL Pyroelectric Detector
With Scan Rate of 500 ms/Line

Figure A-4. Map of ADL Pyroelectric Detector
With Scan Rate of 2 s/Line (Beam
input was chopped for detector
response.)

Figure A-5. Map of ITT Vacuum Photodiode, Model 4000 (Note response variations across detector surface and reflections around outer edge.)

Appendix B

RESPONSE MAPS OF INTEGRATING SPHERES

Figure B-1. Map of Integrating Sphere Designed and Fabricated at Bendix Kansas City¹ (Inside of sphere painted reflective white.)

Figure B-2. Map of Integrating Sphere (Figure B-1)¹ With Additional Raster Lines

Figure B-3. Map of Integrating Sphere
(Figure B-1)¹ With Sandblasted,
Gold-Plated Inside

Figure B-4. Map of Integrating Sphere Manu-
factured by Spawr Optical
Research (Ripple caused by
fluorescent lights.)

Appendix C

LASER-BEAM PROFILES

Figure C-1. Profile of University Labs 1-mW HeNe Laser

Figure C-2. Profile of Spectra Physics 3-mW HeNe Laser (Note nongaussian lobes on back side.)

Figure C-3. Profile of Hughes 3-mW HeNe
Laser With 19-mm (0.75 Inch)
Beam Expander

Figure C-4. Profile of Hughes 3-mW HeNe
Laser Without Beam Expander
(X-axis is expanded.)

Figure C-5. Profile of Photon Sources 1000-W
CO₂ Laser at 440 W (Energy at
left side of beam indicates
laser is not aligned.)

Figure C-6. Two-Dimensional Profile Across
Beam Center of Photon Sources
1000-W CO₂ Laser at 850 W
(Chopper wheel used in front of
monitor to attenuate signal.)

Figure C-7. Two-Dimensional Profile Across
Beam Center of Photon Sources
1000-W CO₂ Laser at 970 W
(Compare sideband intensity in
Figure C-6.)

Figure C-8. Profile of GTE Sylvania 5-W CO₂
Laser

Figure C-9. Profile of General Photonics
0.25-W YAG Laser

Figure C-10. Profile of 1-mW HeNe Laser
Through YAG-Laser Optics

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SPECIAL PROJECTS: Laser Monitoring

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