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LASER BEAM DIAGNOSTIC EQUIPMENT FOR 'ON-LINE' USE WITH MULTIKILOWATT CO_2 LASERS

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Laser Beam Diagnostic Equipment For 'On-Line' Use With Multikilowatt CO_2 Lasers

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An assembly of three monitor systems is described which can perform quantitative measurements of CO_2 laser beam characteristics during machining operations at powers in excess of 5kW. Two microprocessor controlled monitors measure the near and far field intensity profiles from sample beams. These beams are scanned over a stationary single element detector by being optically moved around 18 equally spaced radii. The detector output is digitized into 288 pixels/profile and processed to give parameters describing the beam's intensity profiles, pointing stability and divergence. The third monitor measures laser power, the present frequency range being DC-1kHz.

1. Introduction

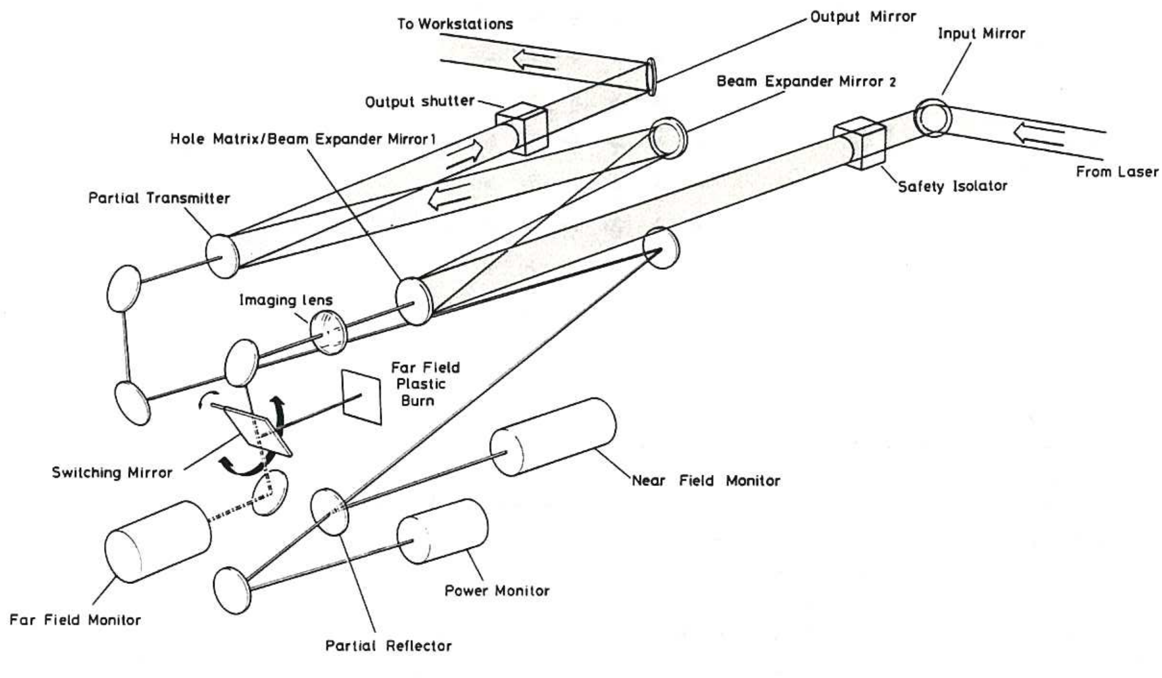


Fig. 1 Schematic of Prototype Laser Beam Monitor Assembly

The monitor assembly is installed between a multikilowatt CO_2 laser and its workstations. A schematic layout of the prototype system is shown in Figure 1. The laser beam is deflected from its normal path to the workstation by the input mirror. After passing through the monitor assembly it is returned, on demand, to its original path via the output mirror. Beam exit is controlled by means of the output shutter, which is interlocked so that it can only be opened when one of the workstations can safely receive the beam. The laser beam is sampled using partial transmitters to allow monitoring during machining operations. The beam sampling optics are a metal mirror having in it a matrix of small holes and a transmitting substrate having a partially transmitting dielectric coating. The transmittances of these elements are ≃ 3% and ≃ 0.5% respectively. The sample beams are analysed by systems monitoring the far field (focused beam) the near field (unfocused beam) and the laser power. The far and near field monitors have their operating sequences, data acquisition, storage, processing and display controlled by a microprocessor based system. Two other facilities have been included in the monitor assembly. These allow burns to be made, in plastic targets, of the far field sample beam and the laser beam divergence to be adjusted with a 1:1 beam expander.

2. Far Field Monitor

Beam sampling is performed by a hole matrix mirror, this being a mirror having a matrix of small transmitting holes of the type described by J.E. Harvey et. al. The holes are 1mm in diameter and spaced 5mm apart on a 11 x 11 matrix. The fraction of the beam transmitted by this element forms a matrix of images of the far field of the incident beam in the focal plane of a lens placed behind the hole matrix mirror. The image matrix can be switched from the far field monitor to a plastic burn target. The burn pattern in an acrylic target is shown in Fig. 2. The images are 2.0mm apart.

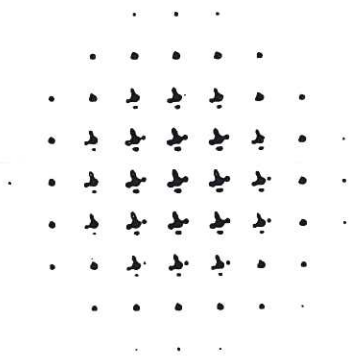


Fig. 2 Burn Pattern in Acrylic Target of Far Field Image Matrix.

The far field monitor scans along a spiral path centred upon the zero order of the far field images produced by the hole matrix. The spiral scanning path is produced by a pair of rotating optical wedges, as shown in Fig. 3. The sample beam passes through these wedges to the detector plane. A 50μm diameter pinhole in the detector plane allows part of the beam to pass to a suitable detector. The angle of wedge 'A' is less than that of wedge 'B', and the apices are parallel. The wedges rotate about the sample beam axis, to which the pinhole is also aligned. The distance between wedges 'A' and 'B' is adjusted so that the beam is stationary on the detector plane and centred on the pinhole. When 'A' is moved away from 'B' the centre of the beam will travel in a spiral path around the pinhole, in turn causing the pinhole effectively to travel in a spiral path on the beam cross-section. The diameter of this spiral can be varied to a maximum of 4mm. The detector output is digitized and recorded at regular intervals during the spiral scan by the microprocessor system, producing 16 digitized beam samples along each of 18 radii.

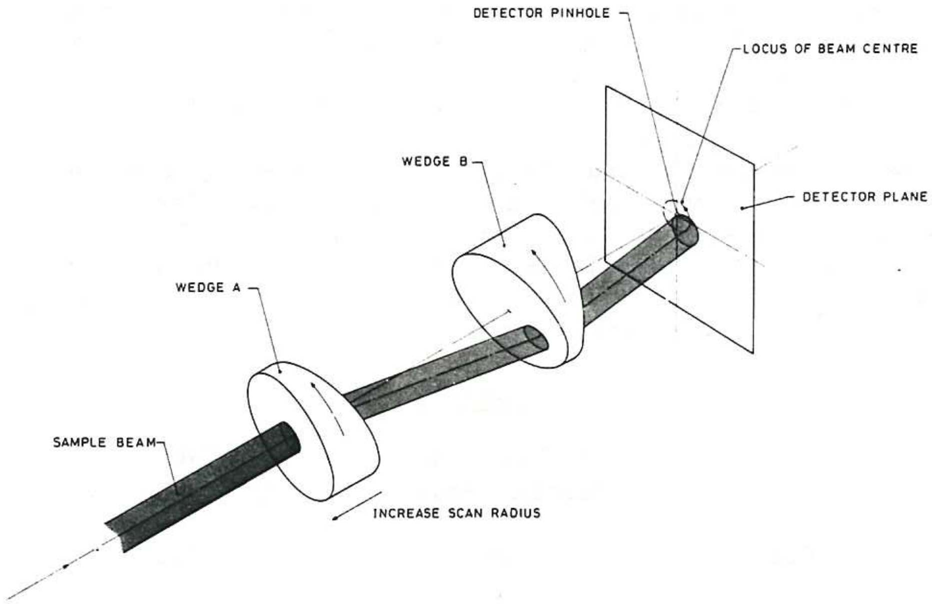
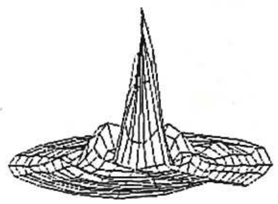
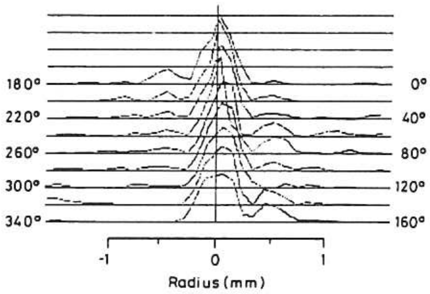


Fig. 3 Far Field Monitor - Operational Schematic.

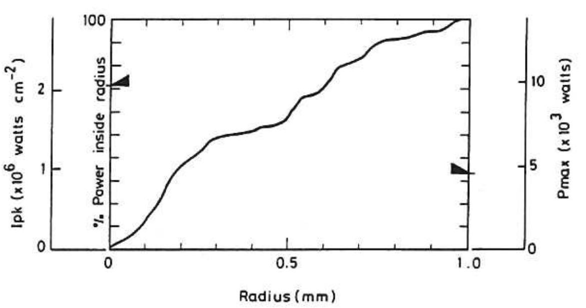
Quantitative analysis of the detectors output gives graphical displays such as those shown in Fig. 4.



a) Far Field Intensity Profile



b) Radial Plot



c) Power Characteristics

Fig. 4 Far Field Monitor - Microprocessor Displays

The radial plot (Fig. 4b) is a series of intensity profiles across each of the 9 diameters contained in the spiral scan. This form of display clearly shows the diffraction rings and their intensity relative to the central peak, the position of the centre of the beam and any variations in axial symmetry. The power characteristics display (Fig. 4c) shows enclosed power as a function of radius. Two other parameters are also displayed. The maximum intensity of the central peak (Ipk) is indicated by the position of the pointer on the left vertical axis and the power enclosed by the maximum radius (Pmax) is indicated by the position of the pointer on the right vertical axis. Table 1 summarises some of the far field parameters resulting from an examination of CL5, a 5kW unstable cavity CO_2 laser (Armandillo & Kaye). These are compared with the parameters expected in the far field of an annular beam (magnification M=2) having uniform intensity and phase.

Table 1

	% Power in Central Peak	Ipk ($\times 10^6$ watts cm^{-2})
CL5	≃50	2.1
M=2 beam	45-50	4.6-5.9

3. Near Field Monitor

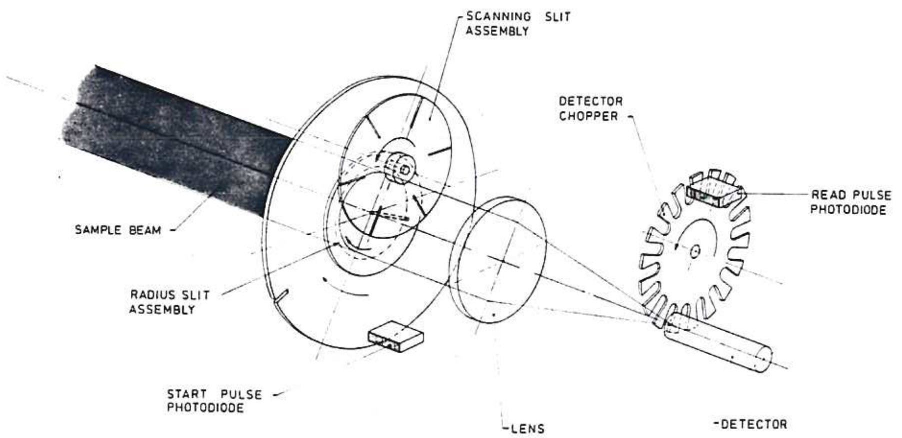


Fig. 5 Near Field Monitor - Operational Schematic

A sample of the unfocused laser beam (up to 55mm diameter) is obtained by using the beam transmitted by a 99.5% reflecting ZnSe window. Approximately 8% of this sample beam is diverted by a second partial reflector into the near field monitor. The remainder of the beam passes to the power monitor (section 4). The near field monitor scans the sample beam along a series of radii. A mechanical scanner (Fig. 5) performs this radial raster scan using a pair of slotted discs, the radius slit assembly and the scanning slit assembly. The radius slit assembly rotates about the centre of the monitor input aperture and has in it a slit which at all times defines a radius of the aperture. Mounted on the radius slit assembly is the scanning slit assembly, which has six equally spaced radial slits, and rotates three times faster than the radius slit assembly. The combined motion of these slits causes an aperture to pass sequentially along 18 equally spaced radii of the scanned aperture for each rotation of the radius slit assembly. Any part of the approximately parallel sample beam passing through this aperture is directed onto the detector by the lens. A chopper wheel in front of the detector is geared to the radius slit assembly to produce 16 samples along each radius. Output from the monitor is digitized and processed by the microprocessor system.

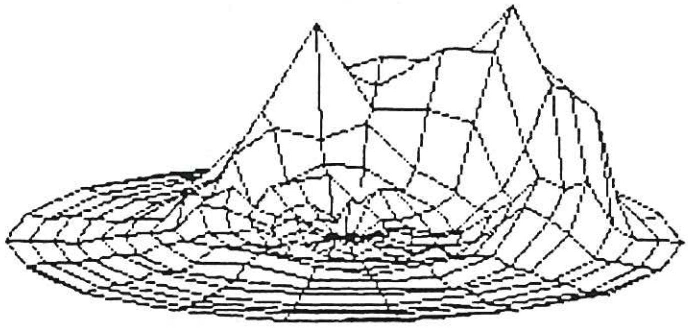
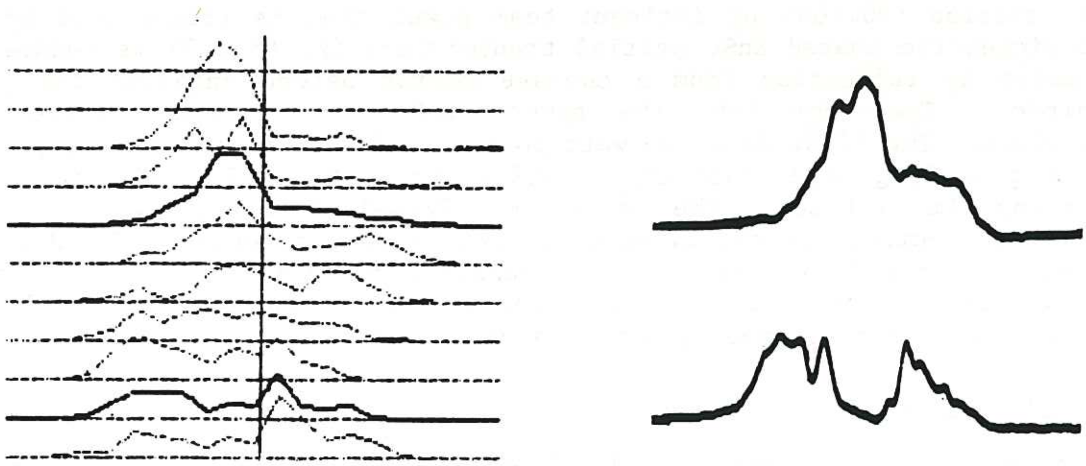


Fig. 6 Near Field Intensity Profile

The output from the near field monitor is presented in Figs 6 and 7. In Fig 7a the two enhanced diameters are those whose directions co-incide most closely with the simultaneous output from a commercial Laser Beam Analyser (G.C. Lim et. al.). This latter instrument produces oscillo-scope traces representing the intensity profile along two orthogonal diametrical scans of the full power beam (Fig 7b).



(a) Near Field Monitor (b) Laser Beam Analyser

Fig. 7 Comparison of Beam Intensity Profiles From the Near Field Monitor and The Laser Beam Analyser.

Quantitative analysis of the data from the monitor gives the diameter of the incident beam, and its position on the polar scanning matrix. An example of an application of the near field monitor is shown in Fig. 8.

This records beam diameter as a function of power at a number of times during the lifetime of the lasers output window, and indicates how the 'ageing' of this element affects the divergence of the output beam.

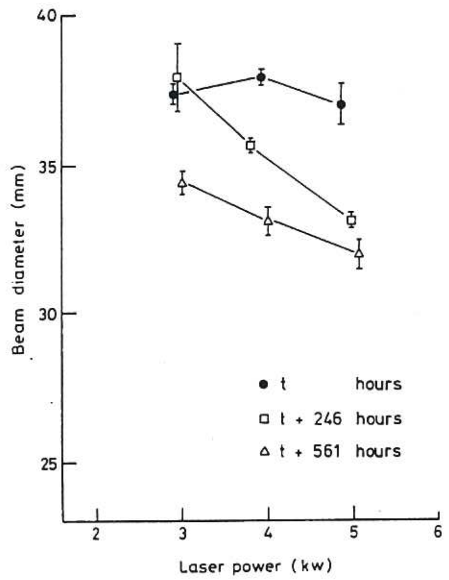


Fig. 8 Effect on Laser Output Beam Diameter of Laser Power and Age of Output Window.

4. Power Monitor

The fraction (≃0.46%) of incident beam power that is transmitted by the two dielectric coated ZnSe partial transmitters (section 3) is reduced in diameter by reflection from a concave mirror before entering the power monitor. The beam into the power monitor is divided between two detectors. The first is a 100 watt power meter disc (Coherent Inc), which gives good long term stability, a 90% response time of ≃0.2 sec. and a settling time ≃ 1 sec. The second is a Pyroelectric detector (Molectron P3-00) to monitor transients or oscillations to a frequency of 1kHz. The output from the first detector is usually displayed on a chart recorder, whilst that from the second detector is either displayed on an oscilloscope or processed by a frequency analyser.

5. Conclusions

A diagnostic package has been developed to monitor the parameters of the output beam from a multikilowatt CO_2 laser during machining operations. The apparatus has been used on the CL5 laser to facilitate accurate cavity alignment, to monitor output window condition, and to study the stability of the output mode, beam pointing and power.

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6. References

E. Armandillo, A.S. Kaye, J. Phys. D: Appl. Phys., 13(1980) 321-338.
J.R. Harvey, H.L. Scott, Opt. Eng. Vol. 20, No. 6, Dec 1981, pp881-886.
G.C. Lim, W.M. Steen; Opt. Laser Technol. 14 (1982) 149-153.