Laser Machining—A Status Report

By CHARLES W. McMILLIN*

The laser (an acronym for Light Amplification by Stimulated Emission of Radiation) provides a source of intense optical radiation. This energy can be focused to a very small diameter. At even moderate power levels, therefore, the energy at the focal point is sufficient to vaporize most materials.

In 1963, scientists at the University of Michigan investigated the feasibility of machining wood with light emitted from a ruby laser. Because of the low power output and the short-duration, pulsed nature of this type of laser, cutting was limited to holes about 0.03 inch in diameter and 0.06 inch deep.

A greater potential was realized with the later development of the carbon-dioxide molecular gas laser. Because its beam is steady and output powers are high, continuous saw-like cuts can be made. The cutting action is further improved by using a co-axial jet of gas, usually air, to assist in removal of vapor and particles from the cut region and to cool the top surface.

Advantages Shown

Research by the Southern Forest Experiment Station has recently demonstrated that Southern pine lumber can be cut with an air-jet-assisted carbon-dioxide laser (C. W. McMillin and J. E. Harry, "Laser Machining of Southern Pine," *Forest Products Journal*, October 1971, p. 34-37). While feed speeds and cutting efficiencies are considerably less than those obtained with saws, the laser nevertheless offers a number of advantages:

No sawdust is created.
The kerf is narrow.
Complicated profiles can be cut easily.
Cut surfaces are smooth.
There is no tool wear in the conventional sense.
Noise is minimal.
No reaction force is exerted on the work-piece.

A laser having 240 watts of output power was used in the research. A beam one-inch in diameter emerged horizontally from the laser and was deflected downwards by a 45° mirror (see drawing). It then passed through a water-cooled lens that focused it to a minimum diameter at about 0.04 inch outside the nozzle. The beam was held stationary and the work-piece was moved into it. In commercial practice, however, it would be possible to move the beam over a fixed work-piece.

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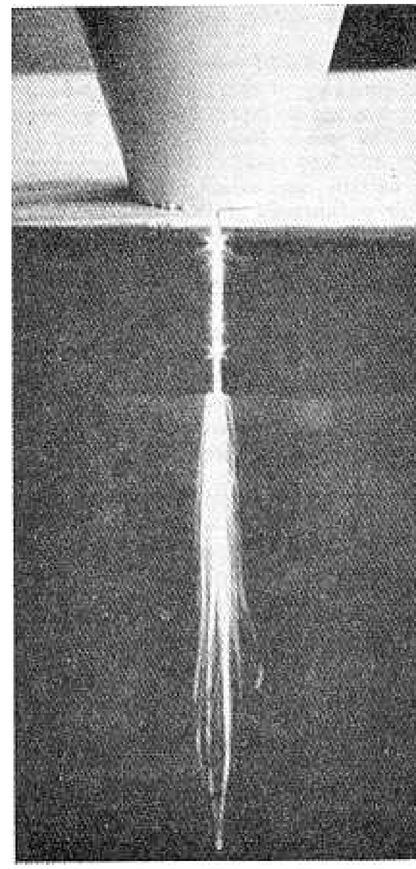
It was found that maximum feed speed along the grain did not differ from maximum speed across the grain. Thus, when complicated line profiles or holes are being cut, feed rates need not be varied with changes in cutting direction.

Speed of cutting decreased with increasing board thickness. In samples dried to 12 per cent moisture, speeds were 111 inches per minute for wood 0.25 inch thick and 17 inches per minute in lumber 1.00 inch thick. Speeds were about 25 per cent slower when the wood was green. For dry wood, speeds were somewhat slower in wood of high than of low specific gravity. In wet wood, cutting speed was unrelated to specific gravity.

Kerf width was unrelated to cutting direction, moisture content, and specific gravity, but it increased with increasing work-piece thickness. Widths were respectively 0.009, 0.012, and 0.015 inch for samples 0.25, 0.50, and 1.00 inch thick. By comparison, kerf of a conventional saw averages about 0.1 inch in stock 1.00 inch thick.

Miscroscopic examination revealed that laser-cut surfaces are far smoother than sawn surfaces. Band and circular saws leave bundles of fibers protruding, and tooth marks are also clearly visible. On laser-cut surfaces, there is little damage to wood structure. While surfaces are blackened, loose char can be easily removed with compressed air or by light brushing.



The carbon-dioxide laser easily burns through a 1-inch-thick Southern pine board in much the same way as an acetylene torch cuts through a piece of metal.

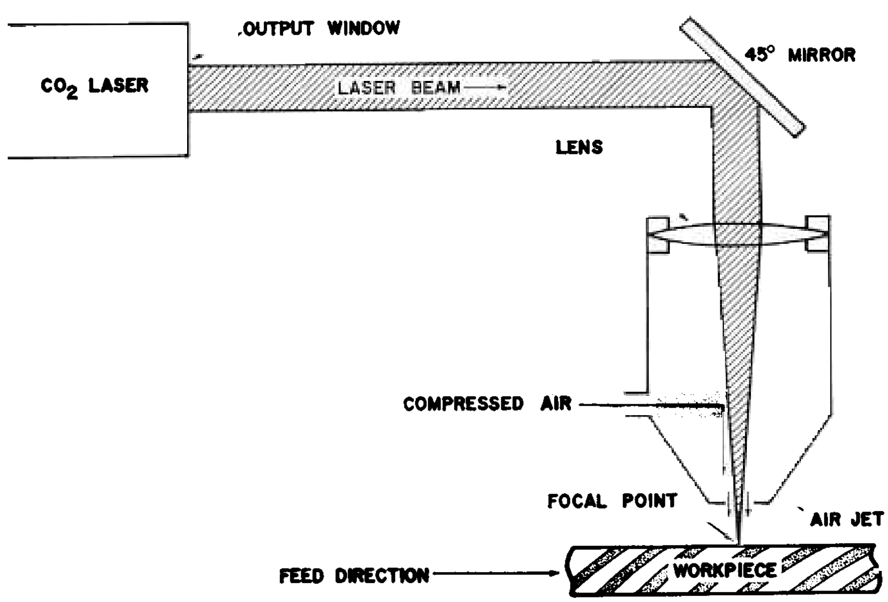


Diagram of experimental laser cutting device.

In the course of the study, several other wood-based materials were also cut. Table 1 provides a few examples. The speeds shown are not necessarily maximum.

Rapid Advances

Technology of the laser as a cutting tool has made rapid advances in less than 10 years. Power consumption is high and feed speeds are still slow, but in certain specialized situations the other advantages of the laser are redeeming. As an example, the preparation of steel-rule die blocks of the type for cutting or creasing paper cartons has been a highly skilled, manual, expensive operation. In this application, an intricate and accurate pattern of narrow slots is required in ¾-inch-thick plywood. Recently, a laser system has been developed to perform the operation. Even at a cutting speed of eight inches per minute, laser preparation of the die blocks is reported to be 10 times faster than the conventional method, and is more accurate. A similar cutting system could be applied to other products of repetitive design—such as chair seats and backs.

Further development of the laser can be expected to accelerate applications in wood cutting. For example, cutting speed is theoretically a linear function of the power level and a square function of the focal length of the lens. It is apparent that very substantial improvements in performance will be achieved when laser systems of higher output powers are developed. In the present study, a 240-watt laser having a lens of three-inch focal length cut ¼-inch-thick dry lumber at about 10 feet per minute. A 1,000-watt laser with a one-inch focal length lens would theoretically increase performance 36 times. Thus, it is conceivable that future developments may permit a cutting speed of 360 feet per minute on ¼-inch-thick lumber.

Table 1.--Laser cutting speeds in wood-based materials.

Material	Workpiece thickness	Power	Cutting speed
	Inch	*Watts*	*Inches per min.*
Southern pine plywood	0.50	240	20
Southern pine particleboard	.50	240	16
Hardboard	.25	180	12
Tempered hardboard	.25	240	13
Fiber insulation board	.50	180	14
Corrugated boxboard	.17	180	236
Illustration board	.10	180	91
Kraft linerboard	.02	180	207

Reprinted from SOUTHERN LUMBERMAN, volume 225, number 2795, pages 19-20. October 1, 1972.