

When batch sizes go down and delivery schedules are tight, flexibility becomes more important than throughput

Highly Versatile Laser System for the Production of Printed Circuit Boards

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In the market for printed circuit boards, demand for prototypes and small volume production – including the high density interconnect (HDI) types – is soaring. Manufacturers intending to serve this particularly interesting market segment must be equipped to manufacture high end PCB's with microvias and ultra-narrow conductors and gaps. A new, particularly versatile laser system for drilling, structuring and cutting is especially suited for such tasks.

Confronted with big producers equipped with highly productive systems for the manufacture of large volumes, small to medium-sized printed circuit board manufacturers have to resort to their ability to react quickly to special demands from their customers. The decreasing lifecycle of products leads to increased demand for prototypes as well as test and initial production within the shortest possible times. Customers have less and less time to deal with the problem of planning their production and therefore prefer suppliers with the ability to deliver complete solutions at short notice. This implies the ability to perform most of the function of the final product as well as more versatility in the processing capability, since any step that makes it necessary to ship parts to third parties for additional processing inevitably increases delivery times – something a customer trying to stay ahead in his “time-to-market” race is not likely to accept with enthusiasm.

In addition to these challenges, the small to medium-sized PCB producers have to take into account the growing demand for HDI boards. The production of these complex and expensive boards calls for specific capital equipment hitherto not required for the production of “standard” multi-layer PCB's. For example, conventional mechanical drilling machines have very limited capability in the production of blind microvias at reasonable costs and yield, and the traditional photochemical processes are inadequate to achieve ultra-fine circuitry.

The pressure the market exerts on smaller PCB manufacturers to step up their processing ability confronts them with a return-on-investment dilemma. With the technology currently available, they would have to purchase a whole range of high-priced cutting-edge equipment to achieve the enhanced technology level the customers increasingly ask for. On the other hand, the small batch sizes they usually have to process will leave them few chances to reach the degree of utilization

needed to achieve adequate profitability from the investment.

“As microvia technology continues to improve in terms of performance and cost metrics, it will find it's way into broader product applications. As this trend occurs, regional supply chains without microvia volume capability could see a shrinking PCB market.” Wrote Ronald W. Gedney of the National Electronics Manufacturing Initiative in the July 2001 issue of Circuit Assembly Magazine.

One multi-talent for drilling, structuring and cutting

This scenario the smaller board houses are faced with induced LPKF to develop the new MicroLine Drill 600 system, which can be used to perform a wide range of different production operations. The main application field is the drilling of holes and microvias – with diameters down to 30 μm – through copper layers and a range of substrate materials in a single-step operation. Additionally, the system is able to directly produce conductors down to a width of only 20 μm in the outer copper layers of a board – which is well beyond the capabilities of photochemical processing.



Fig 1: Solid: Precision-ground granite is widely used as a highly accurate base for high end coordinate measuring systems. The upper granite beam supports the UV-YAG laser

Furthermore, equally fine structures can be produced in etching or solder resists, and flexible film polyimide printed circuits can be cut to shape just as easily as thin rigid glass fiber reinforced epoxy resin (FR 4) substrates. Other applications include the selective removing of links on circuits. The system is also able to process ceramics in different finishing states; operations that may be performed include drilling, notching or cutting to shape

Although the designers of MicroLine Drill primarily focused on a high degree of versatility, the system nevertheless achieves respectable processing speeds – up to 250 drill operations or 300 mm of structuring path per second –, allowing its economical use for the processing even of medium-sized batches, depending on the specific application. The system control accepts all standard input formats such as Gerber or HPGL, and its working area of 640 mm x 560 mm (25.2" x 22") with a maximum material height of 50 mm (2") will accommodate most of the usual substrate formats.

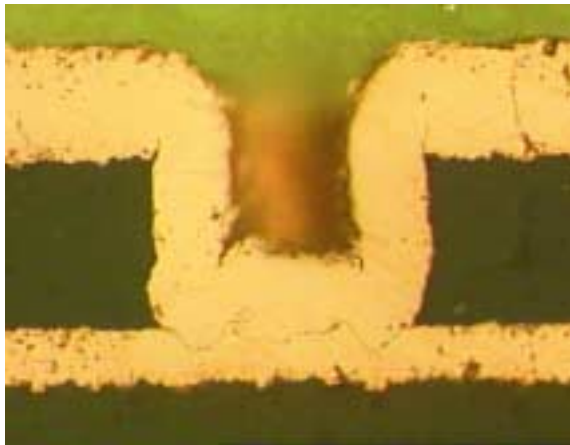


Fig 2: Future trend: A microvia produced with the MicroLine Drill after subsequent plating. The roughening the laser inflicts on the lower copper layer improves the adhesion of the plating

UV-Laser: the backbone of multi-material capability

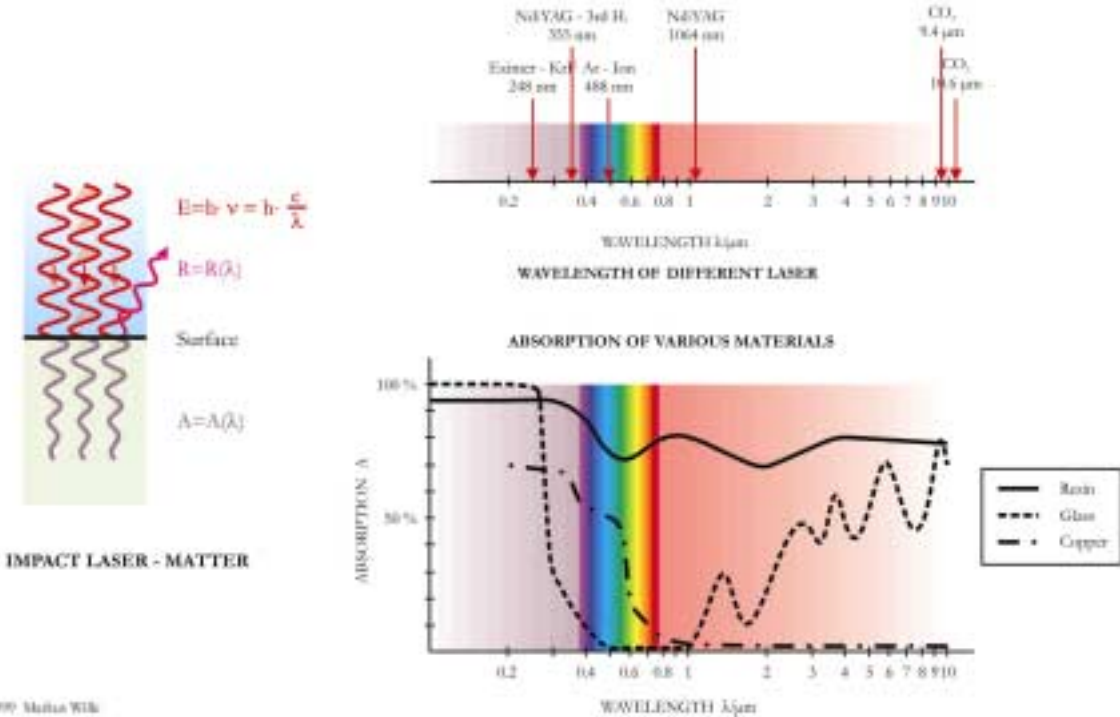
The key factor for the flexibility of the MicroLine Drill system is its cutting edge UV laser system suitable for processing virtually all types of

material. Many of the systems currently available on the market are equipped with a CO₂ laser system, whose wavelength is largely reflected by copper. Prior to using these systems for drilling, the copper layer at the appropriate positions must be removed by etching. The laser then takes over to remove the epoxy resin until reaching the next copper layer. This mode of operation implies certain limitations with respect to time, accuracy and minimum hole diameter. Other systems are equipped with a second laser system emitting in the UV band. In this case, the UV laser first removes the copper layer before the CO₂ laser performs the drilling of the substrate. Of course, resorting to two laser sources has a major impact not only on the investment itself, but also on the operating costs.



Fig 8: Filigree: MicroLine Drill has produced the fine conductor structures and vias on this board

A remarkable achievement of the LPKF design lies in the fact that, unlike many other manufacturers, it can perform all its operations with only one laser source specifically designed by LPKF Laser & Electronics. This laser emits coherent light with a wavelength of 355 nm, giving it good efficiency for the treatment of a wide variety of materials such as metals, plastics and ceramics, including the glass fibers inside the FR 4 material. Due to the good absorption of the UV radiation, the material ablation is a mainly “cold” process with minimal thermal side effects, causing only minor disturbances in the material adjacent to the area being processed. The process thus leads to clean, debris-free boreholes, largely eliminating the need for expensive subsequent cleaning operations such as plasma desmearing.



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Fig 3: Backbone: The wavelength of 355 nm emitted by the laser system is the key factor for its multi-material capability

Sophisticated precision strategy

Beside the functional aspects, it is important to note the care taken in the design of the system itself to insure its usefulness in the coming years. The designers paid special attention to provide high and reproducible processing accuracy, since the ongoing miniaturization of electronic components will boost demand for adequately miniaturized circuit board structures.

The machine table bed as well as its guides are made out of natural granite blocks, precision-ground to an accuracy of $\pm 3 \mu\text{m}$. The machine table is powered by linear drives and is supported on air bearings; thermally compensated glass scales control its position with an accuracy of $\pm 1 \mu\text{m}$. The designers cared not only for the accuracy of the mechanical system itself, but focused also on a strategy suited to minimizing other sources of error, e.g. the drift of the laser beam deflection system, distortions in the height topography of the substrate or deviations in the position of the fiducial points on the substrate surface caused by deficiencies in the optical system used to apply them.



Fig 5: Precise: Frictionless air bearings on ground granite ensure high precision over the entire service life



Fig 6: Time Saver: The optical positioning sensor integrated in the X-Y table provides fast and easy recalibration



Fig 7: Labor Safety: Gases, fumes or dusts that may be generated during processing are removed and cleaned by this vacuum and filtering unit. The control system signals when it's time to change the active carbon filter

The correction of the optical “pillow-type” distortions as well as the compensation strategy for long-term drift of the laser deflection system both rely on the precise determination of the beam position at different deflection angles of the mirror system. Positions are determined by means of an optical sensor integrated in the X/Y-table. The software uses this input to calculate compensation data for the whole scanning area. This compensation table is then transferred to the control system. The calibration process to readjust drift deviations takes less than a minute and can be repeated automatically at any time – even as a job is running – at intervals the operator can program at will.

Further measures aim at the compensation of dimensional deviations of the substrate material itself. The substrate material may vary in thickness,

and the fiducial points applied to the surface may be misaligned. The system is equipped with a high-resolution camera that identifies the substrate boundaries and the precise position of each fiducial point. Substrate shrinkage and layout distortions are taken into account during processing. A distance sensor monitors the exact height position of the substrate surface with an accuracy of $\pm 1 \mu\text{m}$ and adequately readjusts the laser-focusing system.

A vacuum unit accomplishes the mounting of the substrate on the processing table. Depending on the type of job to be performed, the workpiece rests either on a honeycombed structure or on a perforated steel sheet. The working area between substrate and laser optical unit is properly shielded. Any gases or fumes that may be generated during processing are aspirated and cleaned by a combined suction and filtering plant. This shield also guarantees the laser is class I.



Fig 4: On duty: Bright blue sparkling traces the path of the UV laser pulses. The adjacent red focus spot is that of a laser pointer used for adjustments

Easy fit with existing workflow structures

Another important feature of the new MicroLine Drill 600 is its excellent compatibility with the workflow organization and “process philosophy” of most PCB manufacturers. The system can be installed in standard shops equipped with a good climate control system and will interface conveniently with existing processes such as etching and plating. There is no need for additional costly investments such as clean room or “yellow room” technology.



Fig 8: Easy: For the vacuum-assisted mounting of substrates, the user can choose between a honeycombed structure or perforated steel sheet

Programming of the system is performed by user-friendly software packages. This includes CircuitCAM, a software system that accepts data from virtually any CAD and EDA software and performs the data preparation required for the production, and CircuitMaster, which is the direct user interface to the control system of the machine. The preparation of new jobs can be performed offline on standard business pc systems.