LPKF
Laser & Electronics

# LPKF® ProtoLaser H4, ProtoLaser S4, ProtoLaser U4, and ProtoLaser R4

## Application Comparison Details

The LPKF ProtoLaser models enable rapid PCB direct laser etching without any chemicals or resist for advanced prototype development, electronics research and production on-demand processing on a wide range of laminated, flex and ceramic based PCB substrates.

Each ProtoLaser system utilizes the LPKF patented Hatch & Delamination processing for copper removal on laminated materials and, allow for direct ablation processing for metal removal and engraving on a wide range of substrates.

The new ProtoLaser H4 benchtop model offers a lower cost option for rapid metal removal and now includes mechanical drilling and cutting standard PCB materials. The ProtoLaser H4 laser does allow for cutting and drilling of thin materials (e.g., RO CLTE-MW, RO3003, 4350, 5870 and 8100) up ~0.75mm in thickness.

The ProtoLaser S4 and U4 allow for even smaller traces and spacing as well as laser drilling and cutting of thicker materials up to ~2mm and, controlled depth engraving functions with the ProtoLaser U4. The ProtoLaser R4 picosecond laser enables the smallest traces and spacing (as small as 10µm traces with 15µm spacing) and drilling, cutting, and engraving of materials that are not able to be processed on the nanosecond models.

Specifications, general guidelines, and application details are included below to provide a summary of the capabilities possible with each model; specifications are subject to updating by LPKF as new and additional materials are processed.

**ProtoLaser H4**

**ProtoLaser S4**

**ProtoLaser U4**

**ProtoLaser R4**

| ProtoLaser H4 | ProtoLaser S4 | ProtoLaser U4 | ProtoLaser R4 |
| --- | --- | --- | --- |
| **Specifications** | | | |
| 1064 nm<br>1 - 15 W laser source<br>25 to 400 kHz<br>22 - 27 µm focused beam diameter<br><br>+/-1.98µm scanner resolution<br>Calibration better than 10µm across 9” x 12” working area/vacuum table<br><br>100 µm (4 mil) traces on FR4<br>Spacing as small as 50 µm on FR4<br>LPKF Hatch & Delamination Ablation Processing<br><br>Cu Removal speed of ~ 8.5 cm2/min on 18 µm / ½ oz Cu FR4 | 532 nm<br>3 - 12 W laser source<br>25 to 300 kHz<br>23 µm focused beam diameter<br><br>+/-1.98µm scanner resolution<br>Calibration better than 10µm across 9” x 12” working area/vacuum table<br><br>75 µm (3 mil) traces on .5 oz FR4<br>Spacing as small as 15 µm<br>LPKF Hatch & Delamination Ablation Processing<br><br>Cu Removal speed 650 mm/s (25”/s) on 18 µm / ½ oz Cu FR4 | 355 nm<br>up to 6 W laser source (low HAZ)<br>25 to 300 kHz<br>20 µm focused beam diameter<br><br>+/-1.98µm scanner resolution<br>Calibration better than 10µm across 9” x 12” working area/vacuum table<br><br>50 µm (2 mil) traces on .5 oz FR4<br>Spacing as small as 13 µm<br>LPKF Hatch & Delamination Ablation Processing w/ Minimum HAZ<br><br>Cu Removal speed 200 mm/s (7.8”/s) on 18 µm / ½ oz Cu FR4 | 515 nm picosecond<br>up to 8 W laser source<br>50 to 500 kHz<br>15 µm focused beam diameter<br><br>+/-0.23µm scanner resolution<br>Calibration better than 8 µm across 9” x 12” working area/vacuum table<br><br>25 µm/ 1 mil traces (down to 10 µm on thin coated ceramic or glass)<br>Spacing as small as 15 µm<br>LPKF Hatch & Delamination Ablation Processing with Thermal Cold processing<br><br>Slower & highly controlled Cu/metal removal with finer pitch trace/space |
| **Drilling & Cutting** | | | |
| - FR4 up to 2 mm thickness mechanically drilled & cut<br>- Ceramic filled and filled/ woven PTFE up to ~0.75 mm (30 mil) with laser settings<br><br>*A ProtoMat S64 or S104 would add 2.5D pocket engraving capabilities not provided with the H4 | - FR4, Rogers, Taconic up to ~2 mm in thickness<br>- Polyimide, SiPET<br>- Thin Cu, Brass, Stainless up to 10 mil<br>- Alumina (Al2O3), LTCC (slow compared to U4 or R4)<br><br>*Faster than ProtoMat for drilling materials at 1mm in thickness and less | FR4, Rogers & Taconic up to ~2 mm thickness. Flex polyimide, SiPET, Cu, Brass, Stainless Steel, Alumina (Al2O3), LTCC unfired or post fired, AlN, Silicon, GaN, Vespel, Torlon, Carbon Fiber & Blind Via drilling.<br>*1.5mm thickness or less for faster processing speeds; ProtoMat faster for drilling/cutting of FR4/laminated | FR4, Rogers, Taconic, Cu, CuFlon®, GaN, PET films, Alumina (Al2O3), Carbon Fiber, LTCC unfired and post fired. Thin Cu, Brass, Stainless Steel up to 10 mil<br><br>~1mm thickness or less recommended for faster processing speeds |
| **Controlled Laser Depth Engraving** | | | |
| Not recommended with PL- H4; see ProtoLaser U4 and R4 (right)<br><br>ProtoMat options also allow mechanical 2.5D engraving in FR4/PCB materials, Aluminum, brass, Cu and plastics | Not recommended with PL- S4; see ProtoLaser U4 and R4 (right)<br><br>ProtoMat options also allow mechanical 2.5D engraving in FR4/PCB materials, Aluminum, brass, Cu and plastics | - FR4, Woven or Ceramic Hydrocarbon filled PTFE, e.g. Rogers 4000, TMM®, Taconic RF-35TC<br>- Carbon Fiber, Carbon Tape, Green Tape, PI/Kapton®, Epoxy, Vespel-SP-1, Torlon 5530, Fired Ceramics (Al203, AlN, PZT, LTCC post fired<br>- Metal Sheets (Brass, Cu, Ni) | - FR4, Woven, Ceramic filled PTFE, Hydrocarbon and Thermoset resin; e.g. Rogers 4003 & 4350, TMM®, Taconic RF-35TC & CuFLON®Teflon®<br>- Carbon Fiber, Carbon Tape, Green Tape, PI/Kapton®, Epoxy, Vespel-SP-1, Torlon 5530, Fired Ceramics (Al203, AlN, PZT, LTCC post fired<br>- Metal Sheets (Brass, Cu, Ni) |

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## ProtoLaser H4 (1064nm) capabilities:

The LPKF ProtoLaser H4 provides a 1064nm fiber laser source with galvo scanner processing and includes a Fiducial Alignment camera, X/Y vacuum table and LPKF CircuitPro PL software as standard features. The ~27µm focused beam diameter can achieve up to 1oz Cu removal with traces of 4mil (100µm). The surface metallization removal is greater than 1.86 $in^2$/min on laminated substrates at 0.5oz copper thickness.

Rapid Surface Laser Etching/Structuring with delamination tool settings:

- FR4 Single Sided (4 mil trace/2 mil space; 0.004"/0.002" 100µm/50µm)
- FR4 Double Sided (4 mil trace/2 mil spacing; 0.004"/0.002" 100µm/50µm)
- Rogers 3000, 4000 (4 mil trace/2 mil spacing; 0.004"/0.002" 100µm/50µm)
- Rogers 5000, 6000 PTFE w/ ceramic fill (4 mil trace/2 mil spacing; 0.004"/0.002" 100µm/50µm)

*10 mil substrate thickness or greater is recommended for double-sided Cu removal. 1oz Cu removal is also a standard capability with on FR4 and woven/laminated PCB substrates; trace sizes are dependent on copper peel strength and laser settings applied. The ProtoLaser S4 or U4 is recommended for RO 5870 and double sided RO 3006 as H4 has higher heat affect on material.

- Flex DuPont™ Pyralux® TK 127512R, 187518R, 1810018R; single sided processing only (4 mil trace/2 mil spacing; 0.004"/0.002" 100µm/50µm)
- Flex PET 50µm thickness with 9um Al (PL-H4 ideal for PET processing)

Rapid Surface Laser Etching/Structuring with ablation laser tool settings:

- LTCC/DuPont™ 9K7, 951 GreenTape™ Co-fired (4 mil traces/2 mil spacing; 0.004"/0.002" 100µm/50µm)
- LTCC/DuPont™ 9K7, 951 GreenTape™ post fired (~2 mil traces with 1 mil spacing; 0.002"/0.001")
- Ceramic/fired Al2O3 (~2 mil traces with 1 mil spacing; 0.002"/0.001")

*The trace/pad size is dependent on peel strength of the metallization and substrate material. The minimum material thickness for single or double-sided designs is dependent on the absorption rate and/or transparency factor of the substrate with the 1064nm wavelength; e.g. RO3003 at 0.13mm thickness allows for double sided applications.

**Cutting/Drilling:**

The ProtoLaser H4 laser has limited cutting/drilling capabilities but the mechanical cutting/drilling is now included with a six (6) position auto tool change. Some ceramic filled PTFE and woven/ceramic filled PTFE based materials can be laser drilled with the H4 (e.g. Rogers 3003, 4350, 8100) up to approximately 0.75mmm (30 mils) in thickness. Results are dependent on the substrate type, absorption of the 1064nm NIR fiber laser energy, metal thickness and laser settings applied.

*Select materials may allow for NIR fiber laser cutting/drilling but higher quality laser drilling, cutting and engraving is provided with the ProtoLaser U4 and R4 models:

- Ceramic/fired Al2O3 Cutting of up to 0.5mm (0.020") with the H4 laser; ProtoLaser U4 or R4 recommended
- LTCC DuPont™ 9K7, 951 GreenTape™ ProtoLaser U4 or R4 recommended
- Thin Copper Cutting of up to 15 mil thick material (0.4mm or 0.015") with the H4 laser
- FR4 Up to 2mm thick mechanical drilling and cutting is standard for the ProtoLaser H4 system
- Rogers TMM® 3, 4, 6 10, 10i Up to 0.75mm (0.030") possible with H4 laser; Up to 2mm thick mechanically

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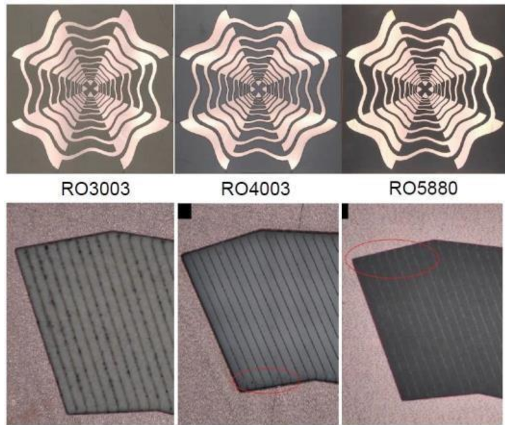
- PTFE/Rogers 3003, 3006, 3850, 4003, 4350, 5870, 6002, 6010, 8100
  - Cutting: Up to 0.75mm (0.030”) possible with H4 laser; Up to 2mm thick mechanically
  - Drilling: Up to 0.75mm (0.030”) possible with H4 laser; Up to 2mm thick mechanically
  - Thin Woven PTFE (Taconic): Up to ~0.75mm thickness; ProtoMat, ProtoLaser S4 or U4 recommended

(Our 355nm UV laser/ProtoLaser U4 or ProtoLaser R4 is recommended for pristine cut/drill edge quality as less heat is generated)

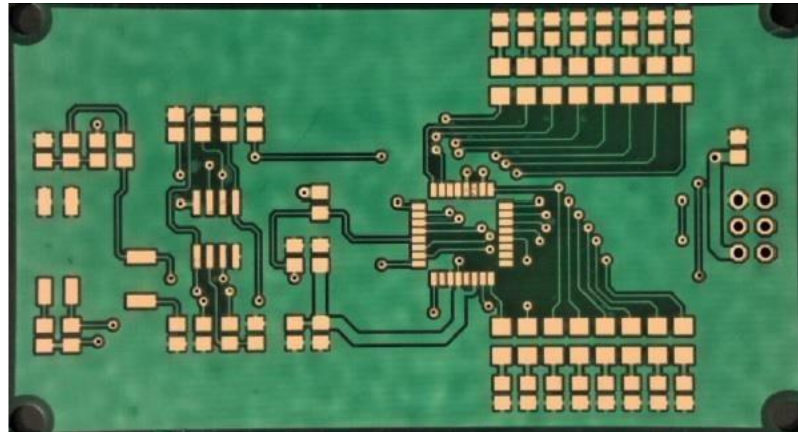
**Surface Skiving:**

- Solder mask/epoxy coating removal directly from Cu pads standard with ProtoLaser H4

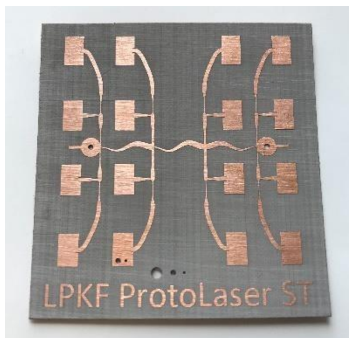
## Application Images ProtoLaser H4



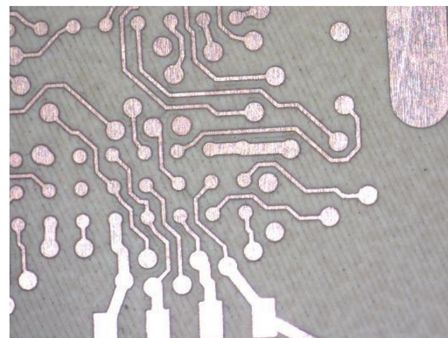

Various Rogers materials



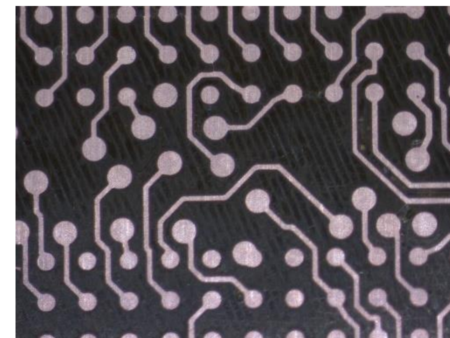
FR4 + solder mask skiving by laser etch




Rogers CLTE-MW 0.5oz 10 mil



Rogers 3003 0.5oz 5 mil thick



DuPont™ Pyralux® TK 127512R single sided

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## ProtoLaser S4 (532nm) capabilities:

The LPKF ProtoLaser S4 includes 532nm, green 12W laser source, Fiducial Alignment camera, X/Y/Z vacuum table, scan field resolution of +/- 2µm as standard features. The 23µm focused beam diameter can achieve spacing as small as 15µm depending on metal and substrate absorption/reflection rate.

**Rapid PCB Laser Etching with ProtoLaser S4:**

- Rapid surface removal of up to 1 oz (35µm) metal from FR4, Rogers PTFE, Taconic, etc. with the LPKF patented hatch & delamination method
  *up to 2oz Cu removal with hatch & delamination depending on material type and laser settings applied.
- Cu/metal ablation on Alumina, LTCC standard function as well
- Cu/metal removal speed of ~3.5 sq.in./min with 0.5oz (18µm) Cu hatch/delamination
- Processing window improved for Cu thickness variations; delamination is more consistent even with up to 6µm copper variance
- 532nm green laser absorption in copper higher compared with 1064nm

- Allows for ~3 mil (75µm) traces on laminated PCB substrates/0.5oz or 1oz Cu FR4 and similar including DuPont™ Pyralux® TK 127512R and TK 187518R (0.5oz Cu)
  *trace and spacing size is dependent on peel strength, metallization type/thickness and substrate absorption/reflection rate
- Allows for 70µm x 70µm isolated pads on 0.5oz FR4
- Allows for ~50µm (2 mil trace)/~23 µm spacing on Alumina/Al2O3 fired ceramic

ProtoLaser S4/U4 hatch/delamination method is ~7x faster than mechanical milling and over 100x faster than the ProtoMat D104 laser tool.

**Drilling/Cutting with ProtoLaser S4** is possible with the below materials and on similar substrates. Material thickness of 1.5mm or less is ideal but thicker materials can be cut on the S4 up to ~2mm; a ProtoMat is recommended for faster drilling and for multilayer stack-ups and is needed if using the LPKF ProConduct silver through-hole plating:

| | |
|---|---|
| FR4 | up to 2mm possible; ~1.5mm (0.060”) with minimum taper |
| Polyimide/flex cutting (polyimide, SiPET) | up to ~0.5mm common; dependent on material and absorption of 532nm wavelength |
| Rogers 3000 and 4000 series materials | up to 2mm possible; ~1.5mm (0.060”) with minimum taper |
| Ceramic filled PTFE materials (RO 6002, 6010) | up to 2mm possible; ~1.5mm (0.060”) with minimum taper |
| Alumina/Al2O3 fired | up to ~0.75mm (0.030”) but much slower than ProtoLaser U4; e.g. 93 min vs 16 min on U4 for a 0.5” x 1” sample |
| Thin Woven PTFE (Taconic) | up to 2mm possible; ~1.5mm (0.060”) with minimum taper |
| LTCC unfired/Green Tape | Up to 1mm; ProtoLaser U4 or R4 recommended |
| Fired LTCC | Up to 1mm ; ProtoLaser U4 or R4 recommended |
| Aluminum 1100 | Up to 0.75mm (30 mil) |
| Thin metals (copper, brass or similar) | Up to 0.75mm (30 mil) |
| Stainless steel | Up to 0.15mm (6 mil) |

*minimum drill diameter with ProtoLaser S4 dependent on material thickness and type; 50µm diameter possible with thin materials (e.g. 100um polyimide)

**Surface Skiving:**

- Solder mask/epoxy coating removal directly from Cu pads

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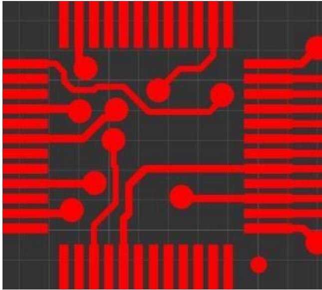
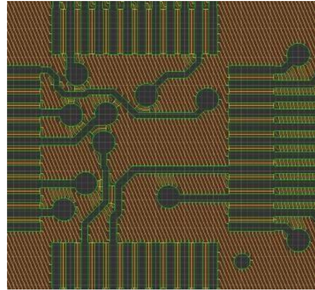
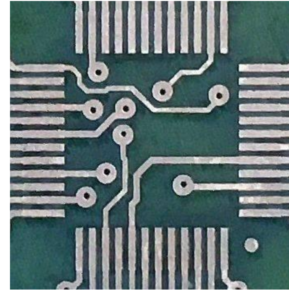
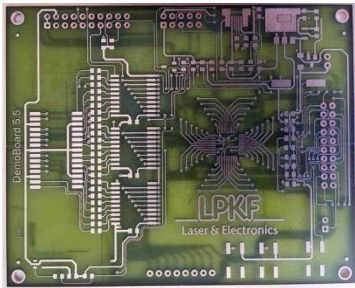
# Application Images ProtoLaser S4

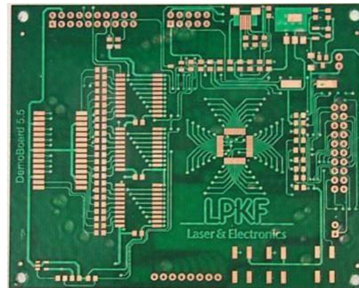

LPKF CircuitPro PL import


ProtoLaser path calculation

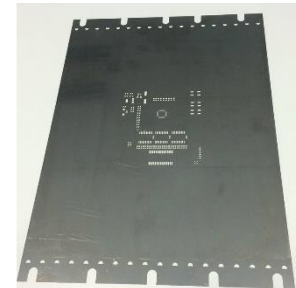

ProtoLaser S4 laser etched

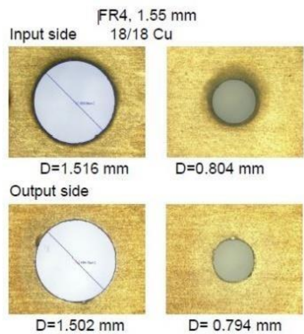
Polyimide Stencil 0.125 mm


FR4 laser etched, cut and drilled

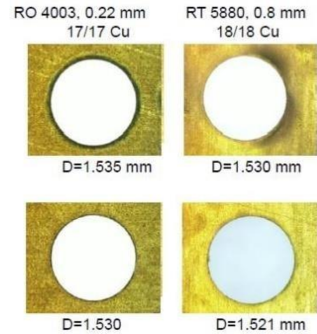

85µm trace; 55µm spacing FR4

Rogers 4730G3 laser etch, cut and drill

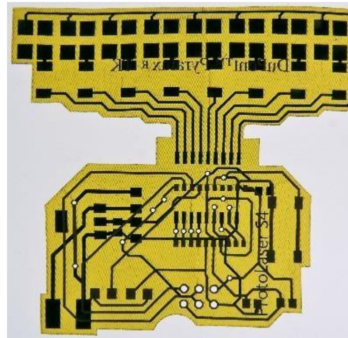

.125mm stainless w/ PL-S4 or U4

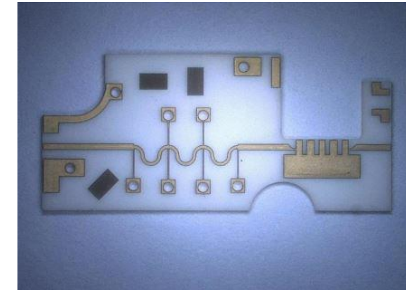


Drilling of 1.55 mm FR4 and S4



Drilling of Rogers 4003 and 5880


DuPont™ Pyralux® TK 127512R dbl sided


.38mm stainless w/ PL-S4

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## ProtoLaser U4 (355nm) capabilities:

The LPKF ProtoLaser U4 includes a 355nm, 6W power mapped LPKF UV laser source with a 20µm focused beam diameter and includes the auto Fiducial Alignment camera, X/Y/Z vacuum table, and scan field resolution of +/- 2µm as standard features.

**Rapid PCB Laser Etching with ProtoLaser U4:**

- ProtoLaser U4 allows for rapid surface removal at ~1.18 sq.in./min of up to 1 oz metal from FR4, Rogers PTFE, TMM®, Taconic or similar laminated PCB substrates with LPKF patented hatch & delamination process. With flex DuPont™ Pyralux® TK up to 1oz Cu can also be processed.
- Ablation of thin film metallization on green or fired LTCC, Alumina, PZT, DuPont™ Pyralux® AP (smaller designs), Pyralux® AG, AC, ITO/TCO from glass
- Ablation of DBC is also possible on Alumina, fired ceramics up to ~10oz; a ProtoMat/mechanical milling recommended for partial copper removal then laser etching of final surface copper; reduces processing time required.

- 2 mil (50µm) traces with 20µm spacing achieved with 0.5oz FR4; ~3 mil traces with 1oz FR4 or similar laminated PCB materials.
  *trace and spacing size dependent on peel strength, metallization type/thickness and substrate absorption/reflection rate
- 25µm (1 mil trace) and less than 20µm spacing on Alumina/ceramics, PZT or fired LTCC
- 50µm trace/spacing possible with green LTCC due to adjustable low power laser mode, controllable travel speed and pulse frequency
- LTCC depth engraving, drilling cutting in post-fired or green (pre-fired) state
- LPKF hatch/delamination proven on flex DuPont™ Pyralux® TK 125012R, 127512R and Datex Instruments Microclad™ flex polyimide creating 85µm traces and 55µm spacing; double sided. Pyralux® AP 7164E allows single sided.
- U3/U4 Ablation method proven on Krempel Group AKAFLEX KCL 2-9/25 polyimide and Pyralux® AP 8535R (smaller 15mm diameter design with the AP)
- Adjustable laser settings allow for minimal effect on substrate with U4 ablation or delamination
- Ablation of gold on PET/Mylar film possible with ability to lower power and increase laser travel speed

**Drilling and Cutting with the ProtoLaser U4 (lower HAZ):**

Up to 2mm thick laminated PCB materials can be drilled and cut with this UV laser system; faster processing and smaller taper when working with 1mm thickness or less; dependent on material type. LPKF CircuitPro software allows for a lowered focal point, additional laser reps and cut paths. Mechanical drilling on a ProtoMat is recommended for faster drilling and multilayer stack-ups with woven/laminated FR4, Rogers, Taconic and similar.

| | | |
|---|---|---|
| Epoxy glass fiber | (FR4, FR5, 104 ML, …) | |
| Ceramic, Woven or Glass filled PTFE | (Rogers 4003, 4350, 5870, 5880, 6002, 6010; Taconic RF 35, RF35-TC) | |
| Rogers LCP and newer substrates | (Rogers 3850 LCP, 4350B, 8000 and 8100) | |
| Taconic; various PTFE substrates | (TLX-6, 7, 8; TLC, TSM, etc.) | |
| Ceramic substrates | (AL2O3, SIO2, AIN, LTCC, PZT) | Up to ~30 mil (0.75mm) |
| Green LTCC | (DuPont™ 9K7, 951 GreenTape™) | |
| Vespel-SP-1, Torlon 5530, or similar | | |
| Metal sheets | (Cu, Ni, CuZn37, Au, Ag) | Up to 0.5mm or 0.020"/20 mils |
| Flex Substrates/Polyimide | (DuPont™ Pyralux®, DuPont™ Kapton®, Krempel AKAFLEX® KCL 2-9/25) | |
| Ferrite | (0.75mm or 0.030″ diameter drill holes in 1.25 mm or 0.050" thick ferrite; 5 mil brass used as a backing) | |
| Carbon Fiber | | |
| UHWMPE Epoxy and Thermoset Resin | | |
| C12 LTCC Carbon Tape for Microfluidic applications | | |

**Surface Cu/metallization removal with ProtoLaser U4 by LPKF hatch/delamination method:**

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- FR4 0.5oz Cu — 2 mil traces (0.002” or 0.05mm) with 20µm spacing
- Rogers 3000, 4000, 5000, 6000 — ~ 3 mil traces (0.003” or 0.075mm) with ~ 20µm spacing; ~ 75µm/20µm
- Rogers 3850LCP, 4350B, 8000, 8100 — ~ 3 mil traces (0.003” or 0.075mm) with ~ 20µm spacing; ~ 75µm/20µm
- PTFE based substrates including CuFlon® — ~ 3 mil traces (0.003” or 0.075mm) with ~ 20µm spacing; ~ 75µm/20µm
- Taconic (RF35, RF35-TC, TLX-8, etc.) — ~ 3 mil traces (0.003” or 0.075mm) with ~ 20µm spacing; ~ 75µm/20µm
- TMM® 4, 6, 10 and 10i — ~ 3 mil traces (0.003” or 0.075mm) with ~ 20µm spacing; ~ 75µm/20µm
- DuPont™ 50µm Pyralux® TK 125012R Teflon Kapton® Cu — 85µm trace/55µm spacing confirmed with 12µm
- DuPont™ 50µm Pyralux® TK 125012R - Double sided Cu — 85µm trace/55µm spacing confirmed with 12µm
- DuPont™ 50µm Pyralux® TK 1210012R - Double sided Cu — 85µm trace/55µm spacing confirmed with 12µm
- DuPont™ Pyralux® AP 8565R Cu — 85µm trace/55µm spacing confirmed with 18µm

*smaller designs recommended for Pyralux® AP (~15mm x 15mm)

- 1oz Cu Delamination (Taconic RF-35TC or similar) — 85µm traces/55µm spacing (hatch width adjusted

*1oz delamination is possible on similar materials using the ProtoLaser U4; the settings can be applied to PTFE, Woven and ceramic filled Rogers and Taconic substrates. However, results are dependent on peel strength, substrate properties, metallization type, etc. and hatch width settings which are adjustable within the software.

**Surface metallization removal with ProtoLaser U4 Ablation method**:

- Ceramic/fired Al2O3 — ~ 40µm trace with ~20µm spacing; under 0.002"/0.001"
- LTCC/ DuPont™ 9K7, 951 GreenTape™ post fired — ~ 40µm trace with ~20µm spacing; under 0.002"/0.001"
- LTCC/ DuPont™ 9K7, 951 GreenTape™ co-fired — ~ 50µm trace with ~ 30µm spacing; ~ 0.002"/0.001"
- Teflon (CuFlon®) — ~ 75µm trace with ~ 30µm spacing; ~ 0.003"/0.001"
- PET/Mylar Film with Cu or Cu/Au metallization — ~ 50µm trace with ~ 30µm spacing; ~200 Å etched
- PET with Ti/Pt — ~ 30µm trace with ~ 30µm spacing
- Krempel Polyimide (AKAFLEX KCL 2-9/25) 0.25oz Cu — 50µm trace/space on 2 mil thick substrate
- DuPont™ Pyralux® AP 8535R and 8565R; double sided — 50 µm trace/ 50 µm spacing confirmed with 12µm

  *smaller designs recommended for Pyralux® AP (~15mm x 15mm)

- Alumina/ceramics thin film — 25µm (1 mil trace)/~20µm spacing
- Alumina/ceramics thick film — 2 mil traces/1 mil spacing; 0.002"/0.001"
- PZT piezo ceramic — 25µm (1 mil trace)/25µm spacing
- DBC on Alumina up to 10 oz (13.7 mil) — Spacing dependent on the Cu thickness; 3 mil with ~5-10 mil thick Cu
- ITO (Indium Tin Oxides) Structuring on Glass — ~15-20µm gap/spacing width
- Iron Oxide or Low Reflective Chrome Removal on Glass — ~15-20µm gap/spacing width

* The minimum trace/ pad size is dependent on peel strength of the metallization and substrate material. The minimum material thickness for single or double sided designs is dependent on the absorption rate and/ or transparency factor of the substrate with the 355 nm wavelength.

**Controlled Depth Engraving (ablation and cross hatch ablation):**

- Polyimide/Kapton®, PE
- Epoxy glass fiber (FR4, FR5, 104 ML and similar woven materials)
- Rogers 4003, 4350, TMM® 10 and similar
- Vespel-SP-1, Torlon 5530, or similar

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- Fired Ceramic/Alumina ($Al_2O_3$), AlN, PZT, Silicon, GaN
- Co-fired LTCC (DuPont™ 9K7, 951 GreenTape™) Post Fired LTCC (DuPont™ 9K7, 951 GreenTape™)
- Metal sheets (Brass, Cu, Ni)
- UHWMPE Epoxy and Thermoset Resin
- C12 LTCC Carbon Tape

**Surface Skiving:**

- Solder mask/epoxy coating removal directly from Cu pads - laminated cover layers - UHWMPE Epoxy and Thermoset Resins
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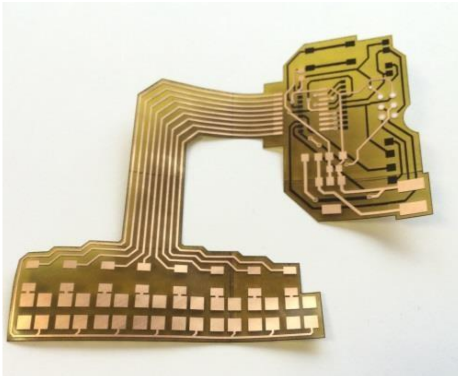
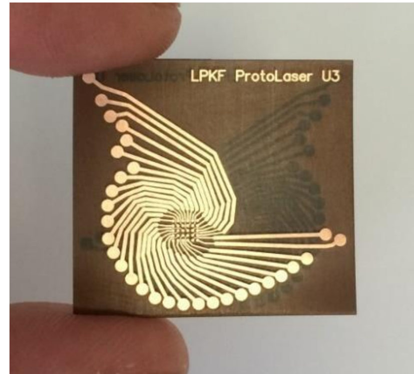
## Application Images ProtoLaser U4

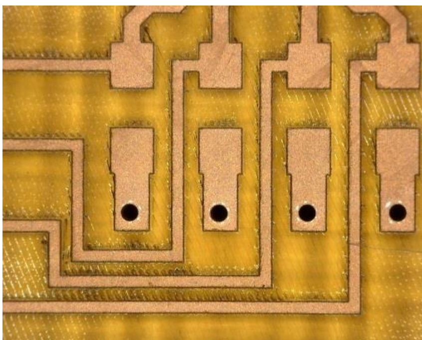


DuPont™ Pyralux® TK 127512R (3 mil thick) double sided w/ ProtoLaser U3 or U4

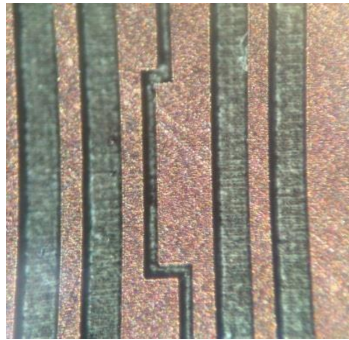



Pyralux® AP 8565R 18µm Cu

FR4 8 mil

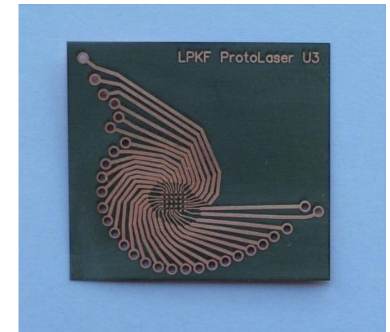


FR4 Cu delamination and drilled with PL-U4



TMM® 10 60µm gap

Taconic RF-35TC 1oz 85µm traces




Rogers 8100 85µm traces

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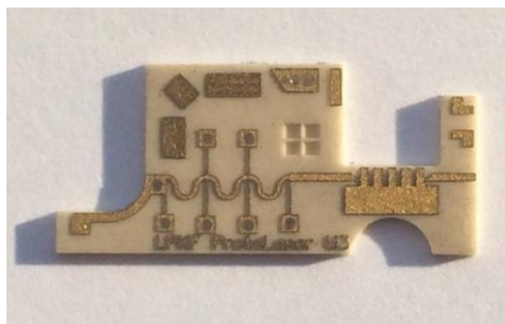
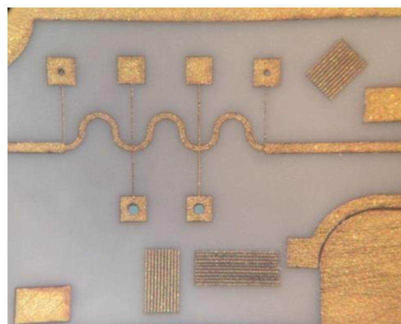
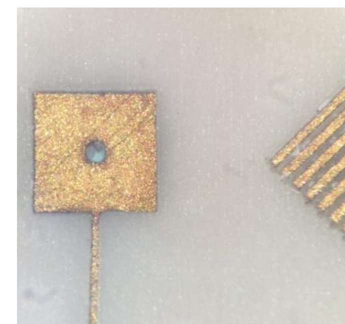
Rogers 3850

Al2O3 Laser etch, cut and drilled w/ ProtoLaser U4



0.1mm vias & .05mm (50µm) traces

## ProtoLaser R4 (515 nm) picosecond capabilities:

The LPKF ProtoLaser R4 provides a 515 nm green picosecond laser source with galvo scanner processing and included Fiducial Alignment camera, X/Y/Z vacuum table, and LPKF CircuitPro PL software as standard features. The 15µm focused beam can achieve tracing as small as 1 mil (25µm) and spacing as small 15µm; traces as small as 10µm possible on thin film ceramics and metal removal applications on glass depending on the metal thickness and peel strength.

**Hatch & Delamination Processing now included enabling faster removal than ablation processing:**

| | |
|---|---|
| - FR4 with 0.5oz Cu | Traces at or below 50µm with 15µm spacing |
| - PTFE with 0.5oz Cu | Traces at or below 50µm with 15µm spacing |
| - Woven PTFE with 0.5oz Cu | Traces at or below 50µm with 15µm spacing |
| - Ceramic w/ Thermoset Resin, Hydrocarbon w/ Ceramic fill 0.5oz Cu (e.g. Rogers Duroid®, TMM®, Taconic and Panasonic materials, etc.) | Traces at or below 50µm with 15µm spacing |
| - DuPont™ Pyralux® CG (New Thermal Cold removal processing) | Traces at or below 50µm with 15µm spacing |

**Direct Laser Ablation processing:**

| | |
|---|---|
| - Ablation of Pt on Glass | Traces down to 5µm with 9µm spacing |
| - Ablation of Au on Polyimide | Traces down to 8µm with 13µm spacing |
| - Ablation of Cu/metal on FR4 | Traces below 50µm with 15µm spacing |
| - Ablation of Cu on Rogers PTFE, TMM®, Hydrocarbon | Traces below 50µm with 15µm spacing |
| - Ablation of Cu/metal on Taconic (PTFE/Woven/Filled) | Traces below 50µm with 15µm spacing |
| - Ablation of Thick-Film Au Paste (DuPont™/Heraeus) | Traces below 50µm with 15µm spacing |
| - Ablation of Pt on LCP films | 10µm traces with 15µm spacing |
| - Ablation of Thin Film or Vapor Deposition metal: | 25µm traces with 15µm spacing; smaller possible |
| - Fired Ceramics (Alumina), PZT, AlN, BeO, SiO2 | 10µm traces and 15µm spacing |
| - Ablation of DBC Cu on fired ceramics/piezoceramic | ~25µm traces/spacing dependent on metal thickness |
| - Flex PCBs and Flexible Hybrid Electronics (FHEs) | 10µm and 15µm spacing |

**Micro-machining and channel or pocket engraving:**

- Si, SiN, CoFe, GaN, FR4, Rogers, Taconic, CuFLON®/pure PTFE, Alumina, LTCC Carbon Tape
- Controlled Depth Engraving Cu, Ni, Brass, Tungsten, etc.

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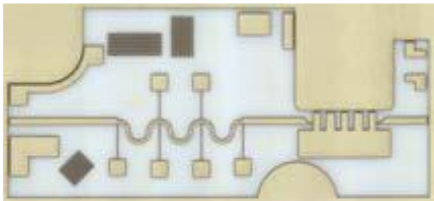
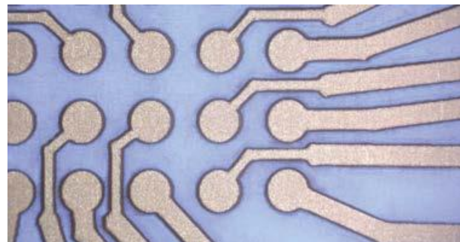
- Controlled Depth Engraving Polyimide/Kapton® and many additional materials
- Controlled Depth Engraving Fired Ceramic/Alumina (Al2O3), AlN, PZT, Silicon, GaN

**Drilling/Cutting with ProtoLaser R4 picosecond laser:**
- Borofloat & Schott glass, Si, SiN, CoFe, GaN up to ~1mm thickness
- Fired ceramics; Alumina (Al203), AlN, GaN, LTCC up to ~1mm thickness
- FR4, Rogers, Taconic, Panasonic, CuFlon®/pure PTFE
- Flex Polyimide/Kapton®, additional materials, etc.
- Pure metals, Au, Cu, Ni, Pt, Brass, Tungsten, etc. up to ~0.5mm and Stainless Steel up to 0.25mm

**Controlled Depth Engraving (ablation and cross hatch ablation):**
- Polyimide/Kapton®, PE
- Epoxy glass fiber (FR4, FR5, 104 ML and similar woven materials)
- Rogers 4003, 4350, TMM® 10 and similar
- Vespel-SP-1, Torlon 5530, or similar
- Fired Ceramic/Alumina (Al2O3), AlN, PZT, Silicon, GaN
- Co-fired LTCC (DuPont™ 9K7, 951 GreenTape™) Post Fired LTCC (DuPont™ 9K7, 951 GreenTape™)
- Metal sheets (Brass, Cu, Ni)
- UHWMPE Epoxy and Thermoset Resin
- C12 LTCC Carbon Tape
- Glass engraving; Borosilicate, Reinforced Willow®, Sapphire
- CVD synthetic diamond
- Teflon (CuFlon®/pure PTFE)

## Application Images ProtoLaser R4


Al2O2 w/ copper, structured and cut


Cu removal from transparent PET film

Double sided DuPont™ Pyralux® CG

30µm channel in Kapton®

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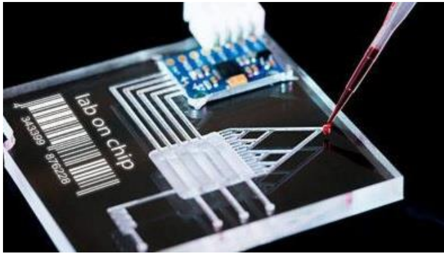
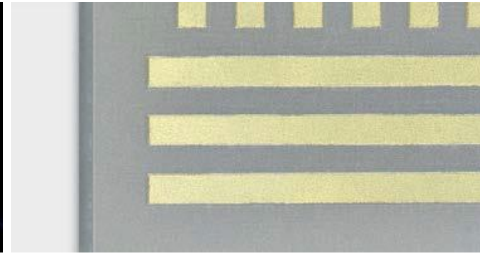



PL-R4 Lab-on-chip



Structuring and Cut GaN with gold layer

Controlled engraving in Alumina (Al2O3) and similar ceramics

The latest LPKF ProtoLaser models continue to provide advanced development capabilities for PCB prototyping, RF/MW/mmW applications and MEMS research. Controlled depth engraving and laser micromachining with the ProtoLaser U4 and ProtoLaser R4 models enable a vast range of research applications.

With the rapid laser etching speeds, on-demand production is possible on a wide range of applications. The LPKF CircuitPro software is included with each machine allowing for design import and machine operations in one platform. The operator can also adjust laser travel speed, pulse frequency, power and repetitions to dial in and save new “laser tools” within the software.

This document was created as a general guideline to help detail the differences between each LPKF ProtoLaser; specifications are subject to updating as new and additional materials are processed.

Demonstration Videos are available on our website through the LPKF ProtoLaser System Options and on our YouTube Group Channel through some of the following links:

LPKF ProtoLaser H4 — (1064nm NIR Fiber laser for rapid PCB laser etching + mechanical drilling and cutting)

LPKF ProtoLaser S4 — (532nm Green Laser Etching with Contac S4 copper plated FR4)
*Rapid PCB laser etching with expanded laser cutting/drilling capabilities

LPKF ProtoLaser U4 — (355nm UV Advanced PCB Laser Etching Applications)
*Rapid PCB laser etching, cutting, drilling and depth engraving w/ almost no HAZ

LPKF ProtoLaser R4 — (515nm Picosecond laser for Micro ablation and delamination processing with 15 µm diameter cut width) *Virtually no thermal effect on wide range of materials

Flex Pyralux® TK with U4 — LPKF ProtoLaser U4 flex processing 1oz Cu at DuPont™ SVTC on Pyralux® TK

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We look forward to earning your business and if there are any questions, please do not hesitate to call.


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