Printed circuit board fabrication facility: SEE Fab

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While common research needs in physics can be met with off-the-shelf electronics in the form of computers, FPGAs, and modular crate electronics, the construction of novel detectors (and interfaces for those detectors) still frequently involves one-off or prototype printed circuit boards (PCBs). The production lines of most commercial PCB manufacturers are only suited for high-volume fabrication using fairly conventional processes. This is antithetical to the production methodology most useful to scientists and researchers: an iterative, low-volume prototyping process with the flexibility to include unconventional fabrication steps. Furthermore, the use of existing cost-effective manufacturers overseas can lead to problems including lengthy delivery delays (particularly in recent years) and export controls for material and intellectual property.

For these reasons, it was recognized that the Cyclotron Institute would greatly benefit from having an in-house PCB production capacity once again. It was also recognized that there is a significant educational opportunity present in allowing our Doctoral and Master's students to be closely involved with manufacturing process of the electronics essential to their research.

Following consultations with other laboratories and our own researchers, the primary equipment for the "SEE Fab" PCB fabrication facility was purchased from LPKF North America (see Fig. 1). This included their ProtoMat S104, a specialized CNC mill for processing copper-clad boards, their ProtoPlace E4, a surface mount device (SMD) manual placement jig, and their ProtoFlow S4, a reflow soldering oven. Other equipment purchased included an LPKF ProtoPrint S4 stencil press, LPKF's ProConduct through-hole plating kit, a lab oven for heat curing, an ultraviolet light exposure chamber, a high-resolution printer with UV-blocking ink for photomasks, a stereo microscope, and several narrow chemical immersion tanks. Together this equipment, shown in Fig. 1 enables a wide range of PCB production schemes while maintaining the option to easily acquire any additional capabilities that prove necessary.

Fig. 1. SEE Fab manufacturing facilities (left) and general workroom (right).

We anticipate that most PCBs designed for research at the Cyclotron Institute can be created by removing relatively small amounts of copper from stock copper-clad boards, which is the perfect job for a milling machine. The precision of traces and pads cut by the ProtoMat S104 rivals the stated precision of any commercial PCB manufacturer. The chemical etching system we have also implemented allows for designs that require the removal of large areas of copper, but this is expected to remain an optional pre-processing step. Chemical etching is not intended to be the primary PCB fabrication process at the Cyclotron Institute as it was many years ago.

SEE Fab is currently being optimized around a production scheme for simple but robust PCBs: two-layer boards with soldermasks, legends, plated through-holes, and a mixture of SMD and through-hole (THT) components. The ProtoMat S104 handles milling out the traces in the copper, drilling holes, routing the PCBs to their finished size, and even optionally dispensing solderpaste. Plated through-holes and conductive vias will be formed by sucking a heat-curable silver-loaded conductive paste through drilled holes to coat the interior walls of the holes. Soldermasking and legend printing will be performed using UV-curing inks. The first PCBs being manufactured under this production scheme are the SRAM-based particle beam dosimeters for Ryan Rinderknecht's Master's , shown in Fig. 2 (see *"Status of the Radiation Effects Master's Program: Using an SRAM Based Dosimeter to Measure LET, Fluence, and Beam Uniformity"*).

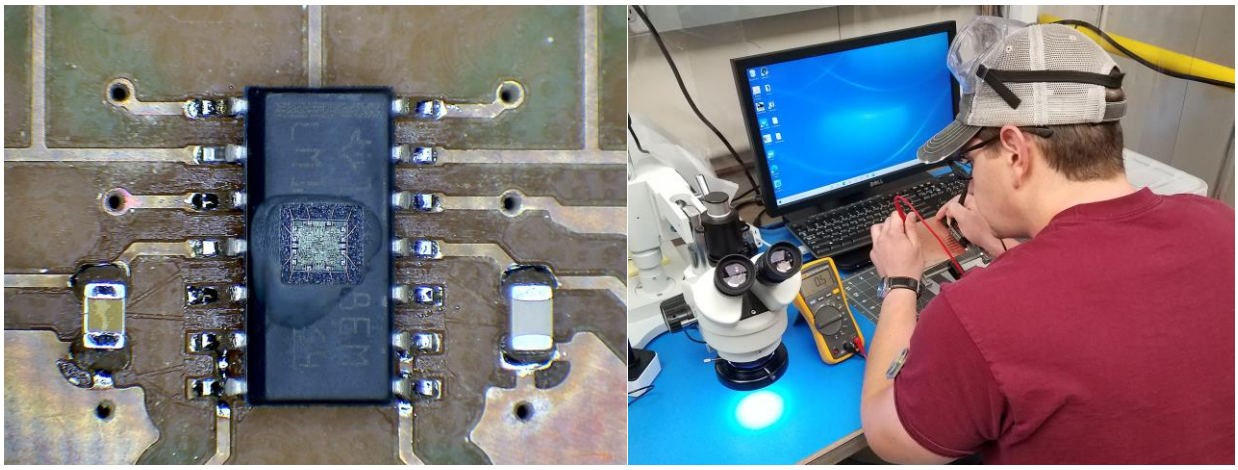

Fig. 2. PCBs produced by SEE Fab for testing purposes. To the left is a close-up of delidded LM124 on prototype interface PCB. On the right is Ryan Rinderknecht checking for electrical continuity on a row of vias to establish the reliability of the ProConduct through-hole plating process for various drilled hole sizes.

SEE Fab will also be capable of handling the more complex and precise production schemes for microwave-frequency PCBs. The first PCBs that will be produced under these schemes are PCBs needed by Lawrence Ethan Henderson's doctoral research (see "*Development of an Electron Cyclotron Emission Imaging System"*). The production of that project's microwave metamaterials involves pre-milling chemical etching, milling of tiny features on thin PTFE substrates, and precise application of blended silver/carbon heat-curable inks to form circuit elements. The microwave receiver antennas and receiver electronics for that project are slightly less complicated to manufacture, but they still require tight dimensional tolerances.

End user guidelines, general procedures, and safety protocols are currently being drafted to make SEE Fab accessible and useful to research groups at the Cyclotron Institute. Research groups will be expected to submit PCB drawings in the form of Gerber files as they would for any external manufacturer, but our in-house fabrication staff will be able to easily provide detailed feedback in-person. This means we can instruct students and staff on basic PCB design practices and avoid burdening commercial manufacturers with that particular task of education.