APPENDIX 1

G-CODE TRANSLATOR SOFTWARE

As explain in Sec. 3.2.1 custom commands were created to instruct the movements of the translation stages in the CO_2 machinning system for the cutting of the required patterns in the LTCC layers. The use of custom instructions prevented us from directly converting design drawings into text files containing movement instructions, such as G-Code, which can be recognized by the motion controller. Every command for the movement of the translation stages was introduced manually in the input text file. As the complexity of the design was increased, the manual input became time-consuming and more prone to typing errors. For example, some of our text files required the input up to 1800 code lines. To speed up the process, an interpreter on the LabView platform to translate a G-code file to a text file containing instructions recognized by the control software of the machining system was created.

The flow process involved drawing the required pattern on TurboCAD 2D (IMSI Design, USA) and saving it as DXF file. A layer of the design of the LTCC water-jet cooler for a single-emitter BA laser is shown in Fig. A1.

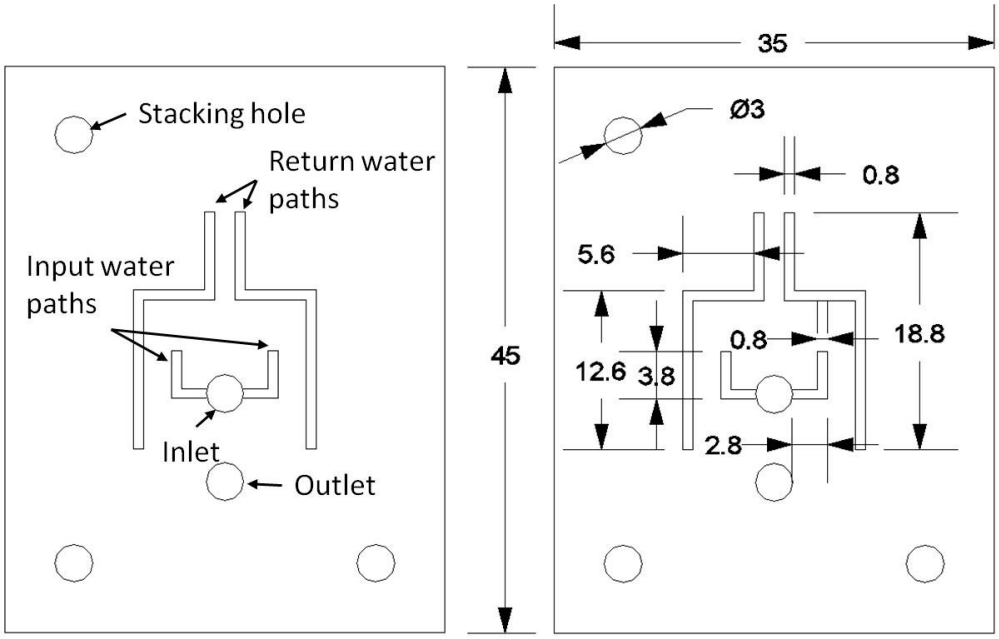

Figure A. 1. Drawing generated using TurboCAD 2D.

Next, the DXF file is converted to a G-code file using the CAM Expert (RibbonSoft, Germany) software. It generates a text file containing movement instructions. The next lines of code are the instructions needed to cut the pattern shown in Fig. A.1.

JET COOLERS IN HERAEUS.nc

```
N10 G00 Z100.000
N15 G00 X14.000 Y24.000
N20 Z2.0 F200
N25 G01 Z-0.2
N30 G03 X14.000 Y24.000 I-1.500 J0.000
N35 G00 Z2.0
N40 X38.000 Y24.000
N45 G01 Z-0.2
N50 G03 X38.000 Y24.000 I-1.500 J0.000
N55 G00 Z2.0
N60 X14.000 Y58.050
N65 G01 Z-0.2
N70 G03 X14.000 Y58.050 I-1.500 J0.000
N75 G00 Z2.0
N80 X26.000 Y37.500
N85 G01 Z-0.2
N90 G03 X26.000 Y37.500 I-1.500 J0.000
N95 G00 Z2.0
N100 X26.000 Y30.500
N105 G01 Z-0.2
N110 G03 X26.000 Y30.500 I-1.500 J0.000
N115 G00 Z2.0
N120 X7.000 Y63.500
N125 G01 Z-0.2
N130 Y18.500
N135 X42.000
N140 Y63.500
N145 X7.000
N150 G00 Z2.0
N155 X26.130 Y48.730
N160 G01 Z-0.2
N165 Y51.900
N170 X25.328
N175 Y48.730
N180 Y44.928
N185 X30.945
N190 Y33.099
N195 X31.747
N200 Y45.730
N205 X26.130
```

```
N210 Y48.730
N215 G00 Z2.0
N220 X22.880
N225 G01 Z-0.2
N230 Y45.730
N235 X17.253
N240 Y33.099
N245 X18.055
N250 Y44.928
N255 X23.682
N260 Y48.730
N265 Y51.900
N270 X22.880
N275 Y48.730
N280 G00 Z2.0
N285 X25.945 Y37.099
N290 G01 Z-0.2
N295 X28.747
N300 Y40.901
N305 X27.945
N310 Y37.901
N315 X25.945
N320 G00 Z2.0
N325 X23.055
N330 G01 Z-0.2
N335 X21.055
N340 Y40.901
N345 X20.253
N350 Y37.099
N355 X23.055
N360 G00 Z2.0
N365 M30
```

From the previous set of instructions, commands that need to be translated in order to be recognized by our software are:

- G00 XA YB, go to the position (A, B)
- XA, YB, go to the position (A, B).
- G03 XA YB IC J, it generates a full circle with centre in (A, B) and radius of C.
- XA, move the table A distance in the X direction.
- YB, move the table B distance in the Y direction.

The remaining lines are ignored. Next, the useful G-code lines are converted to recognizable instructions using our translator software and saved in a text file.

- G00 XA YB is replaced by g0 xA yB. This instruction indicates to the laser system to move the translation stages to the (A, B) position.
- XA, YB is replaced by g0 xA yB. This instruction indicates to the laser system to move the translation stages to the (A, B) position.
- G03 XA YB IC J is replaced by Arc A B C 0.000 360 1.000. This instruction indicates to the laser system to generate a full circle with centre in (A, B) and radius of C, firing a laser shot every dU mm.
- XA is replaced by LineX A. This instruction indicates to the laser system to move the translation stage X a distance of A mm, firing a laser shot every dU mm.
- YB is replaced by LineY B. This instruction indicates to the laser system to move the translation stage Y a distance of B mm, firing a laser shot every dV mm.

Additionally, the user must introduce manually the next parameters in the user interface (GUI) of the translations software:

- The name of the G-Code source file
- The focal position of the final lens mounted on the motorized vertical translation stage (“Header”)
- The speed of the translation stages (“Feed rate”)
- The pitch between laser shots in X and Y direction (“Raster pitch” dU, dV)
- Pulse width duration (“AOM pulse width”, x50 µs)
- Output power level on target (“AOM voltage”)

The Fig. A.2 shows the GUI of the translator software.

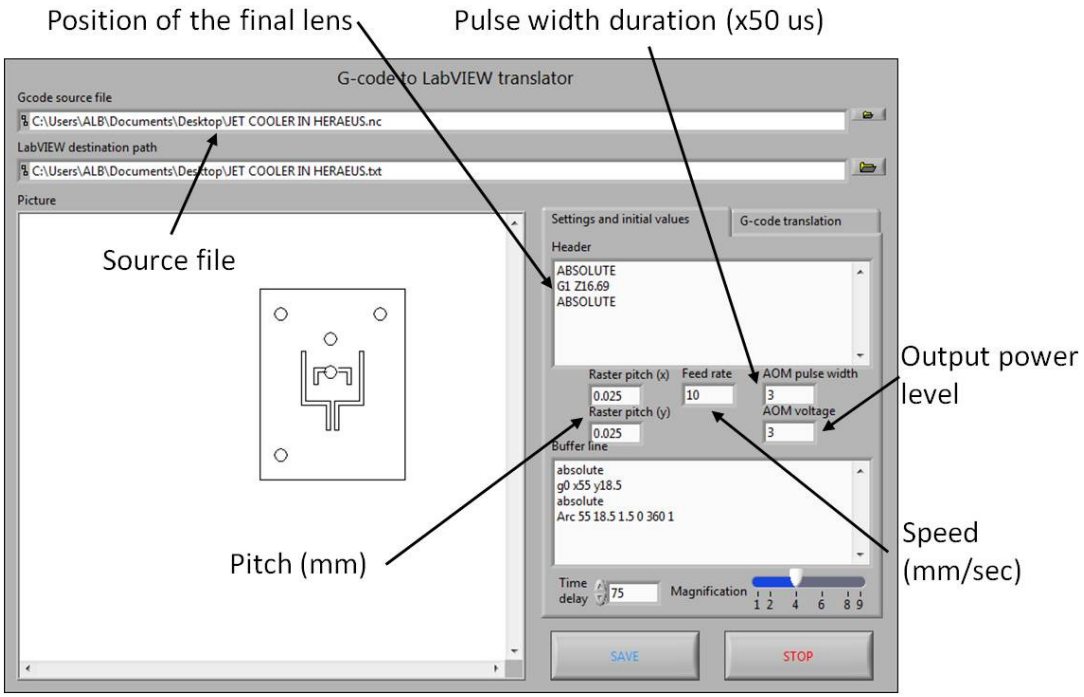

Figure A. 2. GUI of the translator software

The next lines of code are the instructions generated by the translator software. The text file is introduced in the CO_2 machining system for cutting the pattern shown in Fig. A.1.

JET COOLERS IN HERAEUS.txt

ABSOLUTE
G1 Z16.69
ABSOLUTE
RasterdU 0.025
RasterdV 0.025
FeedRate 10.000000
AOMPulseWidthTicks 3.000000
VAOM 3.000000
absolute
g0 x55 y18.5
absolute
Arc 55 18.5 1.5 0 360 1
g0 x14.000 y24.000
absolute
g0 x14.000 y24.000
Arc 12.500 24.000 1.500 0.000 360.000 1.000
Arc 12.500 24.000 1.500 0.000 360.000 1.000
g0 x38.000

absolute
g0 x38.000 y24.000
Arc 36.500 24.000 1.500 0.000 360.000 1.000
Arc 36.500 24.000 1.500 0.000 360.000 1.000
g0 x14.000 y58.050
absolute
g0 x14.000 y58.050
Arc 12.500 58.050 1.500 0.000 360.000 1.000
Arc 12.500 58.050 1.500 0.000 360.000 1.000
g0 x26.000 y37.500
absolute
g0 x26.000 y37.500
Arc 24.500 37.500 1.500 0.000 360.000 1.000
Arc 24.500 37.500 1.500 0.000 360.000 1.000
g0 y30.500
absolute
g0 x26.000 y30.500
Arc 24.500 30.500 1.500 0.000 360.000 1.000
Arc 24.500 30.500 1.500 0.000 360.000 1.000
g0 x7.000 y63.500
LineY -45.000
LineX 35.000
LineY 45.000
LineX -35.000
LineX 35.000
LineY -45.000
LineX -35.000
LineY 45.000
absolute
g0 x7.000 y63.500
g0 x26.130 y48.730
LineY 3.170
LineX -0.802
LineY -3.170
LineY -3.802
LineX 5.617
LineY -11.829
LineX 0.802
LineY 12.631
LineX -5.617
LineY 3.000
LineY -3.000
LineX 5.617
LineY -12.631
LineX -0.802
LineY 11.829
LineX -5.617

LineY 3.802
LineY 3.170
LineX 0.802
LineY -3.170
absolute
g0 x26.130 y48.730
g0 x22.880
LineY -3.000
LineX -5.627
LineY -12.631
LineX 0.802
LineY 11.829
LineX 5.627
LineY 3.802
LineY 3.170
LineX -0.802
LineY -3.170
LineY 3.170
LineX 0.802
LineY -3.170
LineY -3.802
LineX -5.627
LineY -11.829
LineX -0.802
LineY 12.631
LineX 5.627
LineY 3.000
absolute
g0 x22.880 y48.730
g0 x25.945 y37.099
LineX 2.802
LineY 3.802
LineX -0.802
LineY -3.000
LineX -2.000
LineX 2.000
LineY 3.000
LineX 0.802
LineY -3.802
LineX -2.802
absolute
g0 x25.945 y37.901
g0 x23.055
LineX -2.000
LineY 3.000
LineX -0.802
LineY -3.802

```
LineX 2.802
LineX -2.802
LineY 3.802
LineX 0.802
LineY -3.000
LineX 2.000
absolute
g0 x23.055 y37.099
END
```

Cutting instructions are repeated twice because as explain in Sec. 3.5, the optimal condition for cutting the 130 µm HL2000 tape are double pass, using 150 µs pulses spaced by 25 µm.

The use of this translation software reduced the time of generating the text file from hours to less than 15 minutes.