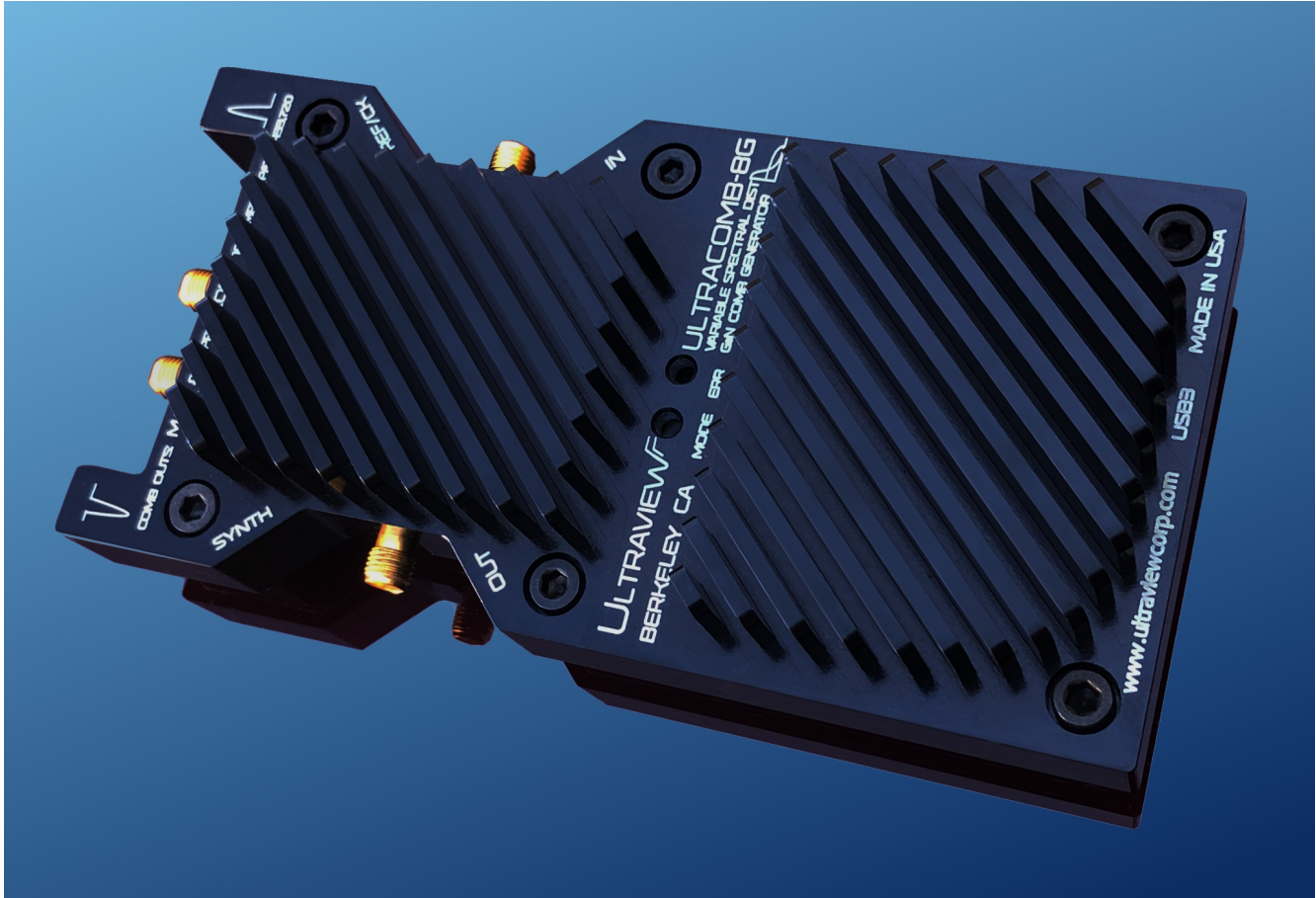




## Ultracomb-8G High Power Variable-Width Pulse/Comb Generator



### **GaN Pulse/Comb Generator with USB-programmable Pulse Width and Programmable 10MHz to 2GHz Pulse Repetition Rate and Spectral Comb Picket Spacing**

The Ultracomb-8G is a microwave pulse/comb generator providing formerly unattainable output power levels, low jitter and pulse width programmability. Based on a custom ultra-high-repetition-rate Furaxa GaN differential pulser IC, the palm-sized Ultracomb-8G is powered from any USB3.0/3.1 port through which the user can program comb amplitude up to 10V/-10V on the differential Pulse- and Pulse+ outputs, pulse repetition rate (i.e. comb picket spacing) and pulse width (and hence low/high-frequency spectral weighting). Leading edge rise times can be as fast as 50ps on the Pulse- output and 65ps on the Pulse+ output.

### **Ultra-flexible Ultrawideband (UWB) Comb Generation**

Pulse repetition rate and comb picket spacing, can be software-programmed to any frequency from 10MHz to 2GHz in single-ended-output mode (10-50MHz in differential output mode) in 0.01 Hz steps, generated by an on-board low-phase-noise LMX2594 synthesizer driven from either an internal 150fs-jitter reference clock or a 10-500MHz external reference.

The unit can also be programmed in 1:1 clock mode, enabling the pulse repetition rate (also the comb picket spacing) to be the same as the external reference/clock input. Its differential outputs provide a 3dB higher total output power than a single-ended pulse generator, and facilitate direct antenna connections without the use of an external broadband BALUN.

The Ultracomb-8G has the further unique ability to create pulses with widths varying from 95ps to 800ps, enabling it to generate frequency combs with usable energy to 10GHz or, alternatively, combs with much higher power, but with most of the energy concentrated below 2GHz. This is useful, for example, in antenna or materials testing, in which high volumes of lossy materials can be characterized with improved SNR using a low-frequency weighting, while smaller volumes can be characterized using a full-frequency weighting.

### **High Output Power**

At the narrowest pulse width setting, and with a 500 Million Pulse Per Second (500 MPPS) pulse repetition frequency (500MHz picket spacing), *each generated picket up to 3GHz has over +10dBm power level* (see Fig. 2). Even up to 6GHz, each picket has over 0dBm power. The picket at 8GHz has a level of -7.5dBm. Figure 3 shows the unit generating a comb with a finer 200MHz picket spacing and flat response with 0dBm/picket power to 3GHz, -3dBm at 5.4GHz and -10dBm at 8GHz. For higher power, the picket spacing can be increased. Figure 4 shows a 1250MPPs pulse repetition rate (i.e. 1250MHz picket spacing), resulting in the first picket being at +16dBm, and the 8.4 and 9.6GHz pickets being at -2dBm. The higher per-picket-power at higher pulse repetition rates is the result of the generator producing a higher number of pulses per second, and hence a higher aggregate power level.

### **Programmable Pulse Width and Corresponding Low/High Spectral Weighting**

The Ultracomb-8G has the further unique ability to create strings of pulses with widths varying from 95ps to 800ps, enabling it to generate relatively flat combs with usable energy to 10GHz or, alternatively, combs with much higher power, but with most of the energy concentrated below 2GHz. This is useful, for example, in antenna testing, in which low frequency antennas can be tested over very long ranges or transmitting through lossy media, while retaining the ability to test over a wider bandwidth when using shorter ranges. Figure 5 shows the generation of precisely matched differential pulses of 152ps FWHM (top blue traces) and then, by software selection, a 350ps FWHM differential pulse (yellow and green traces, shown at 200ps/div in the top window, and 1ns/div in the bottom window).

### **Cross-Platform Operability for Flexible Field Use Environment**

The palm size of the unit enables its use in the field, directly connected to antennas or devices using low-loss cables of only a few centimeters in length. Virtually any desktop or laptop computer can be used as the GUI software, is included for Windows10, OSX, Linux Mint 18 and RHEL/Centos 7.x. In addition to the GUI, full QT source is supplied, enabling users to dynamically control the comb amplitude, picket spacing, and frequency weighting in real time as part of a larger field or laboratory environment.

## User Software Installation and Basic Operation

The GUI included allows immediate operation of the Ultracomb-8G without the need to develop or recompile any software. To use the Ultracomb-8G, perform the following steps:

- 1) Plug the USB cord on the Ultracomb-8G into a USB3.0/3.1 port on any system with Windows 10, and wait for the system to recognize it. Windows 7 may require Adafruit driver package located at:  
[https://github.com/adafruit/Adafruit\\_Windows\\_Drivers/releases/download/2.3.4/adafruit\\_driver\\_s\\_2.3.4.0.exe](https://github.com/adafruit/Adafruit_Windows_Drivers/releases/download/2.3.4/adafruit_driver_s_2.3.4.0.exe).
- 2) Extract the .zip archive downloaded from the Ultraview or Furaxa website. Navigate to the 'release' directory.
- 3) Double click the executable program (.exe extension). A window similar to Figure 1 will appear. Select the appropriate USB port from the list at the upper left corner of the window. When you have selected the correct USB port, the "Alive" circle at the upper right will flash.
- 4) Click 'Restore Settings' to load default (or last saved) settings. The Ultracomb-8G should immediately then output a continuous pulse train, which can be viewed on any 10GHz or faster oscilloscope. **BE SURE TO USE 20dB ATTENUATORS BETWEEN THE PULSE OUTPUTS OF THE ULTRACOMB-8G AND THE INPUTS OF THE OSCILLOSCOPE – OTHERWISE THE HIGH VOLTAGE PULSES WILL DESTROY THE OSCILLOSCOPE FRONT END.** The SYNTH OUT jack on the Ultracomb-8G outputs a square wave at the pulse repetition rate, and may be used as a trigger input to the oscilloscope. The Settings can be saved from a previous setup to the .ini file with the 'save settings' button.
- 5) To adjust the pulse amplitude, use the Amplitude slider. In general the slider should be adjusted between ½ full scale and full scale, as pulse shape degrades below ½ of full scale. External DC-18GHz attenuators may be used if lower pulse amplitudes are needed.
- 6) To specify the pulse repetition frequency (or the comb picket spacing in the frequency domain), enter the desired value in the Pulse Freq field. Frequencies between 10 MHz and 50 MHz are acceptable for differential pulses on the Pulse+ and Pulse- outputs. Frequencies up to 2GHz can be specified, but only the Pulse- output will contain well shaped pulses.
- 7) If using an internal reference, click the Internal Reference box, and **BE SURE THAT NO SOURCE, NOT EVEN AN UNDRIVEN CABLE, IS CONNECTED TO THE REF/CLK INPUT.** If using an external reference, **unlick** the Internal Reference box, connect a low-phase noise reference signal with amplitude between +3dBm and +9dBm, and frequency between 10MHz to 250MHz. **The Reference Frequency field in the window MUST be set to the frequency being inputted.**
- 8) To adjust pulse width, adjust the "width" slider. The "Narrow" setting is most often used when the sharpest pulses are desired. For wider pulses, adjust the width slider upwards, and then fix the pulse shape by adjusting the W. Range, W. Adjust and Int Clk Pwr sliders to obtain smooth near-gaussian pulses. Generally, Int Clk Power should be set to 12 to ensure smooth edges when producing wide pulses.



Figure 1. Default settings for fastest pulses. Be sure to **select the appropriate COM port in the upper left and make sure the 'Alive' indicator is flashing** and a temperature is being displayed. Then click “Restore Settings” to set unit to default or last programmed settings.

## Recompiling software and firmware

Software is built using Qt version 5.12 or greater with MSVC compiler. Open the project from the .pro file, make changes to the source as desired, then rebuild. Note: sometimes clean/rebuild will not clean the executable and it will need to be deleted manually.

Firmware is a 'sketch' programmed onto the board and is built on Windows using Arduino 1.8.10 <https://downloads.arduino.cc/arduino-1.8.10-windows.exe> (later versions tested do not work due to java error). To install, follow the instructions on the adafruit site:

<https://learn.adafruit.com/adafruit-metro-m4-express-featuring-atsamd51/setup>

1. Arduino, file, preferences, additional boards Manager URLs:

[https://adafruit.github.io/arduino-board-index/package\\_adafruit\\_index.json](https://adafruit.github.io/arduino-board-index/package_adafruit_index.json)

2. Tools, Board, Boards Manager, install Arduino SAMD

3. Tools, Board, Boards Manager, install Adafruit SAMD

Additional steps: As of this writing, manual changes need to be made to header files to accommodate inconsistent headers. The header files are included with the project and their definitions need to be transplanted onto the Arduino installation header files. These files that need to be changed from the 1.8.10 installation are located at:

C:\Users\\AppData\Local\Arduino15\packages\arduino\tools\CMSIS-Atmel\1.2.0\CMSIS\Device\ATMEL\samd51\include\samd51j19a.h

and

C:\Users\\AppData\Local\Arduino15\packages\arduino\tools\CMSIS-Atmel\1.2.0\CMSIS\Device\ATMEL\samd51\include\component\nvmctrl.h

After all of these changes are done, open the .ino file in Arduino, make the desired changes, select the appropriate port from the tools menu then upload the sketch from the sketch menu.

## FEATURES AND SPECIFICATIONS:

- A) Differential Pulse Outputs with amplitude up to 20V into two 50 ohm loads or 100 ohm differential load, or two opposing single-ended 10V pulses. Also can produce 28V differential into 75 ohm loads.
- B) Pulse leading edge rise time (10-90%) **60 to 380ps programmable**
- C) Pulse width (FWHM) **95 to 800ps programmable**
- D) Pulse rate: Differential mode: **10 MPPS to 50 MSPS**  
Single-ended mode: **10 MPPS to 1.5 GPPS (to 2GPPS with added spurs)**
- E) Differential Phase Matching (10-50MPPS) **18 ps max**
- F) Differential Amplitude Matching ( “ ) **3% typ, 6% max**
- G) Output Amplitude Range - each output (Pulse- or Pulse+) into 50 ohms, diff=twice this value:
  - 1. 100-400ps rise time setting: **4V to 10V peak (8-20V diff)**
  - 2. 65-100ps rise time setting: **4V to 14V peak (8-28V diff)**
- H) Pulse jitter, cycle-to-cycle, both + and – outputs:
  - 1. Internal Ref, Fpulse= 50 MPPS **1ps RMS (for 65ps pulses), <3ps (all)**
- I) Spurious pulse energy
  - 1. Recovery, ringing **<10% pulse amplitude**
  - 2. Inter-pulse energy of single spur pulse **<5%, width of spur pulse <20ps**
- J) Internal 150fs jitter reference or external ref/clock input, SW selectable. Internal LMX2594 synthesizer allows virtually any pulse rate with sub-Hertz resolution, including 1:1 clocking with external clock and programmable clock-to-pulse delay in 7.5° increments. External ref/clock amplitude should be between +3dBm and +6dBm.
- K) Concurrent low-jitter square wave SYNTH OUT sync/trigger output in sync with pulse outputs. May be used to trigger oscilloscopes and other instruments in sync with generated pulses.
- L) USB 3.0/3.1 Interface. No external power required – Draw from USB is 1.3A at full 20 pulse amplitude. (<1A for pulse amplitudes <12V).

Mechanical: Dimensions (LxWxD): 7cm x 14cm x 3.2cm  
Weight 13 ounces.

- M) QT C software interface and cross-platform Windows/Linux C libraries, with full source.
- N) Generates ultra-low phase noise combs to 10GHz in single-ended mode:
  - 1. Typ. comb energy at 1.2GPPS: **>16dBm@1.2GHz, >-2dBm@9.6GHz**
  - 2. Typ. comb energy at 600MPPS: **>10dBm@600MHzV, [-9dBm@9.6GHz](#)**

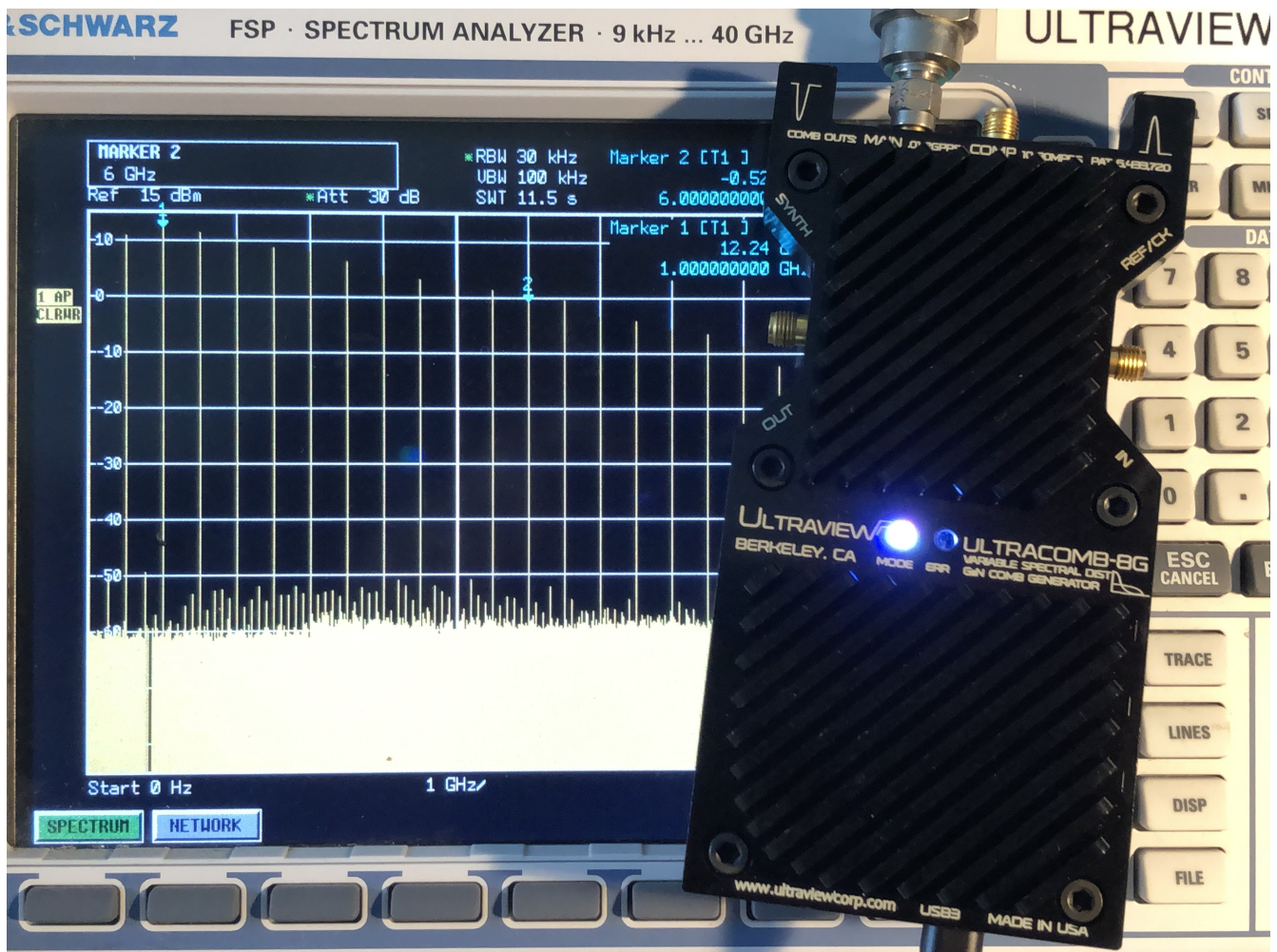


Fig 2. Ultracomb-8G generating comb with 500MHz-spaced pickets, with +10dBm amplitudes to 3GHz, -3dBm at 5.4GHz, 0dBm at 6GHz and -10dBm at 8GHz. The main and complementary comb/pulse outputs of the Ultracomb-8G are at the top. A jack for an optional reference or clock input is on the right side. The output of the internal synthesizer that generates the ultra-low-jitter clock to the pulse-comb multiplier is on the left side, has under 500fs of jitter with respect to the comb pulses, and may be used to synchronously trigger/clock external receiving electronics, such as samplers and ADCs.



Fig 3. Ultracom-B-8G generating comb with 200MHz-spaced pickets, with 0dBm amplitudes to 3GHz, -3dBm at 5.4GHz and -11dBm at 8GHz and -18dBm at 10GHz.

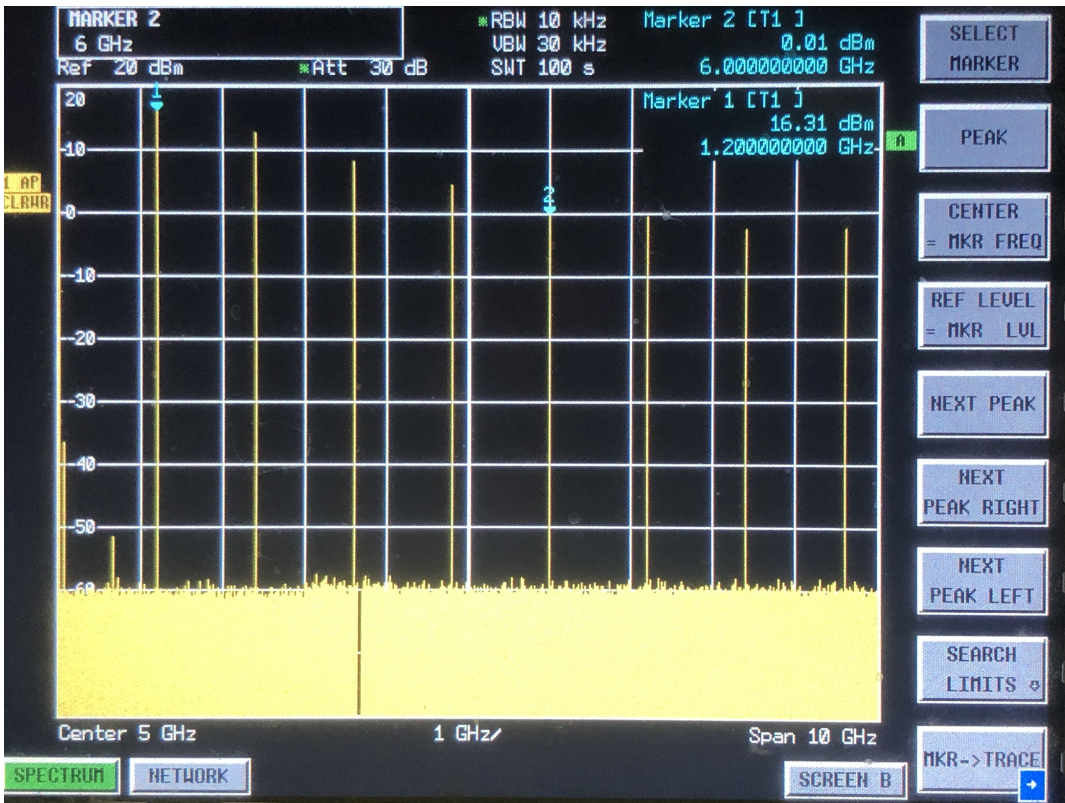


Fig 4. Higher power comb with 1.25GHz-spaced pickets, generating +16dBm amplitude at 1.25GHz, 12dBm at 2.5GHz, 0dBm at 6GHz and 7.2GHz and -2dBm at 8.4GHz and 9.6GHz



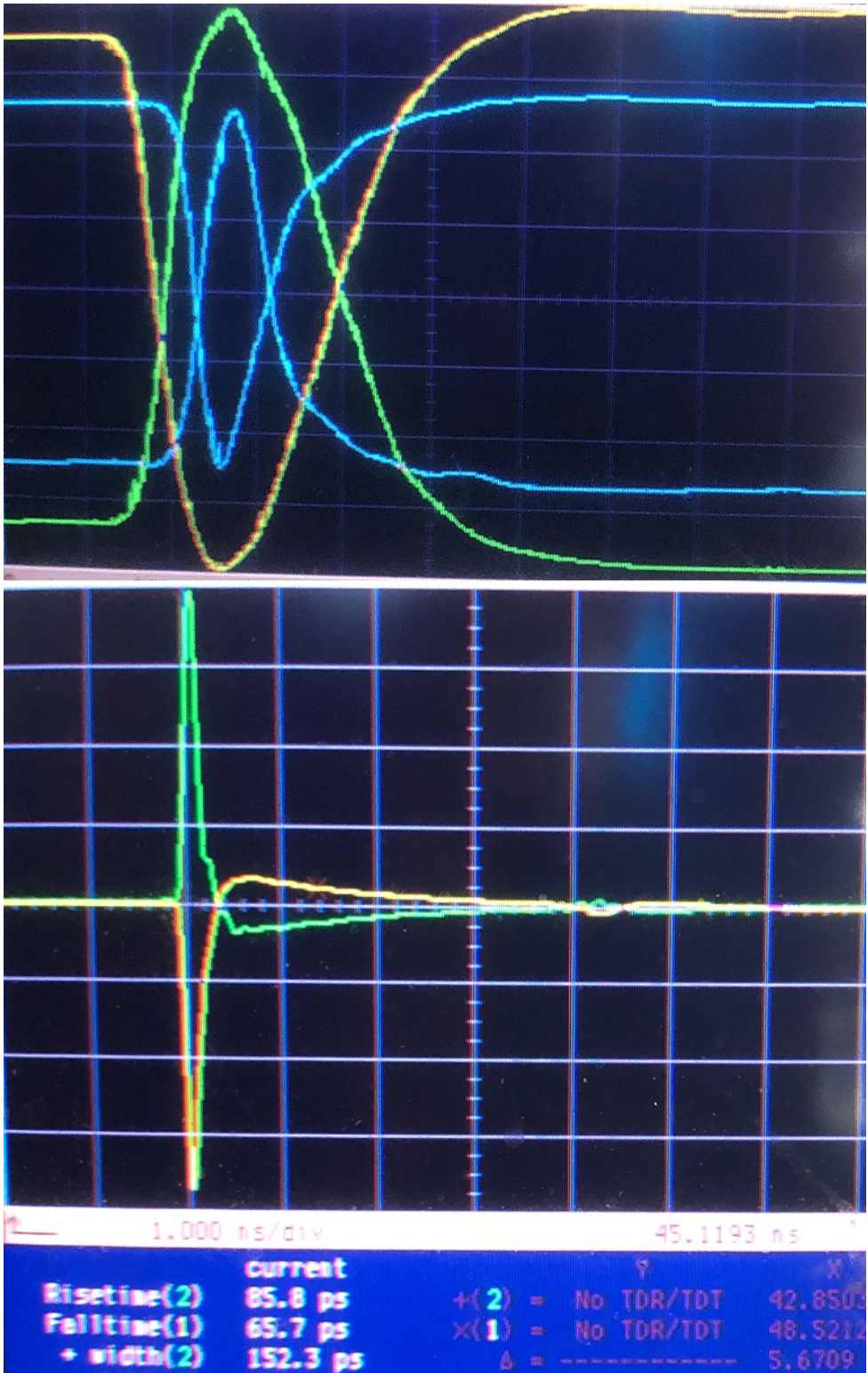


Fig 5 Adjustable pulse widths of 152ps FWHM (top blue traces) and 350ps FWHM (yellow and green traces), displayed at 200ps/div, and also displayed at 1ns/div in bottom window)