TUPV018

# KEK LUCX facility Laser-to-RF&RF-to-RF stability study and optimization

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**Q** is quadrupole magnet

**B** is bending magnet

**St** is steering magnet

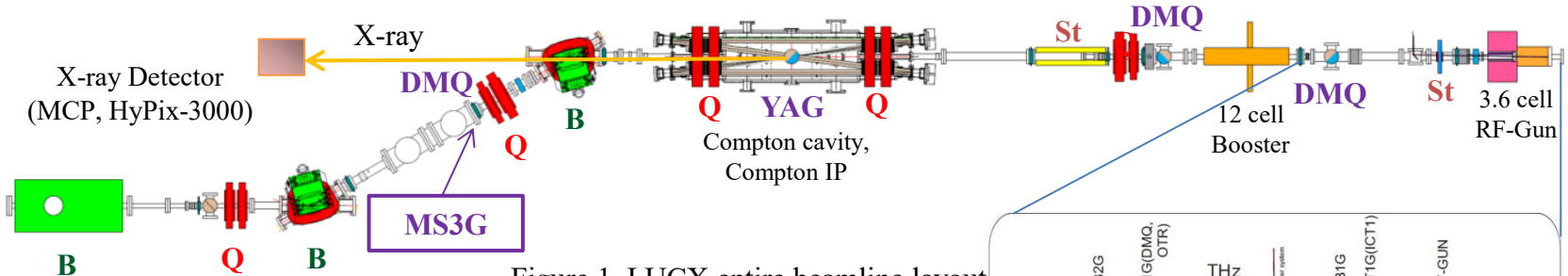



Figure 1. LUCX entire beamline layout

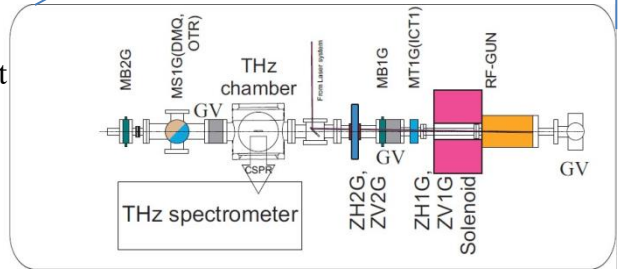



Figure 2. LUCX RF-Gun section zoom

10 button type BPMs; 1 ICT & 1 FCT & 1 FC; 6 transverse profile monitors

2 klystrons (Toshiba E3729 and Toshiba E3712) to feed normal conductive RF-Gun and 12-Cell accelerating structure (Booster).

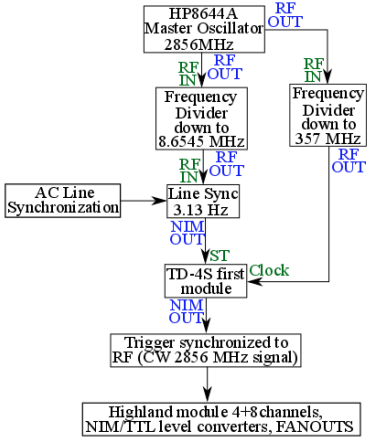



Figure 4. LUCX trigger system block diagram

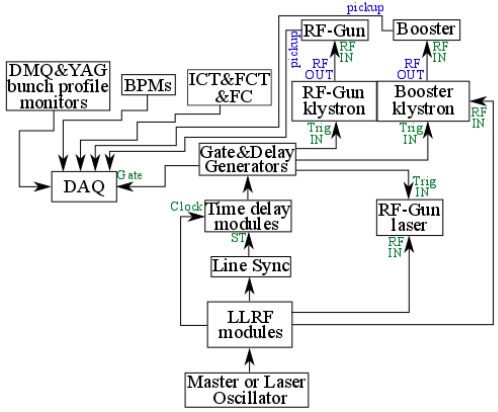



Figure 3. Block diagram of LUCX control


Figure 5. 2856 MHz klystron drive signal phase stability from 1Hz to 100MHz

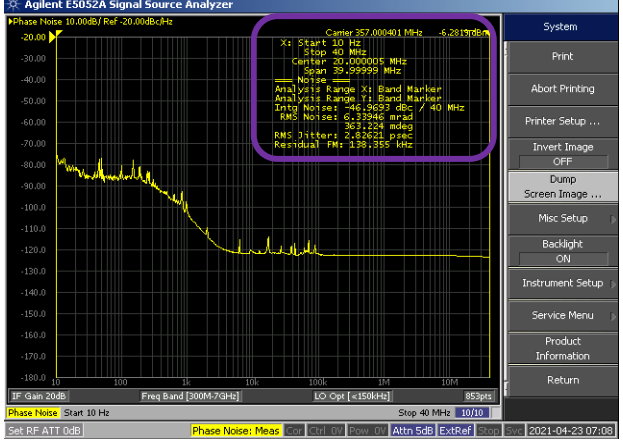



Figure 6. Nd:YAG laser oscillator phase stability from 10Hz to 40MHz

**Rough RF-to-RF jitter estimation**

All drive and reference signals jitter go to Klystron outputs. So, the rough estimation of existing jitter is $\sigma_{RFtRF} = \sqrt{\sigma_{RF}^2 + \sigma_{RF}^2} = \sqrt{(1.487ps)^2+(1.487ps)^2} = 2.103ps$. It is very high.

**Rough Laser-to-RF jitter estimation**

All drive and reference signals jitter go to Klystron output and laser output signal. So, the rough estimation of existing jitter is $\sigma_{LtRF} = \sqrt{\sigma_L^2 + \sigma_{RF}^2} = \sqrt{(1.487ps)^2+(1.920ps)^2} = 2.428ps$. It is very high.

All measurements were systematically made from 11:00 o'clock till 24:00 o'clock. Measurement results deviation is only 50 fs. Jitter values are the same for Ti:Sapphire laser system.

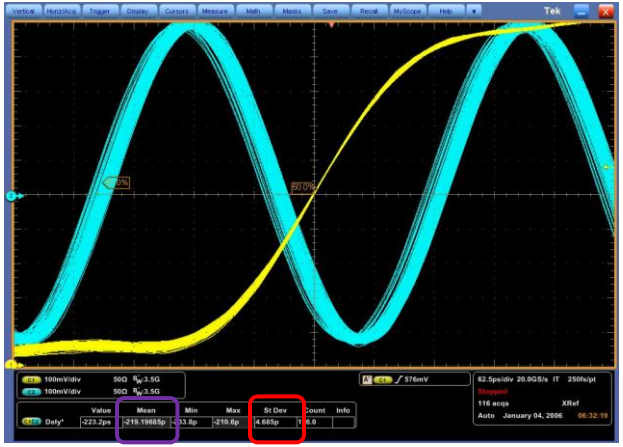



Figure 7. Laser-to-RF 100 counts (short-term jitter, 4.7ps)


Figure 8. RF-to-RF 100 counts (short-term jitter, 1.5ps)

Laser –to-RF jitter was improved from 4.7ps to 3.2ps after Master Oscillator replacement from old HP SG to new Agilent SG. Also, RF-to-RF jitter was improved from 1.5ps to 900fs.
All results were crosschecked with down conversion technique. 2856 MHz signals were down converted to 10 MHz.

Figure 9. Tektronix DPO7354 Oscilloscope

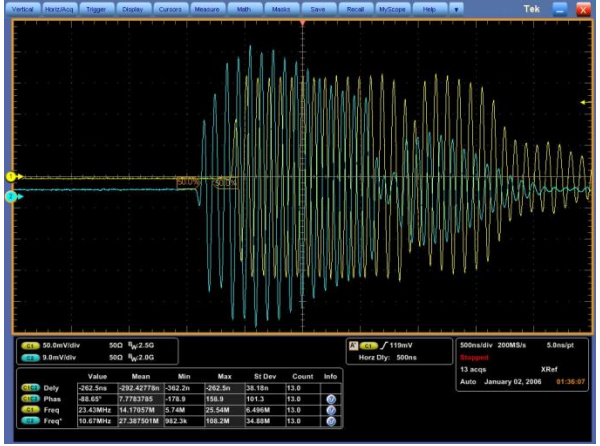


Figure 10. Gun-to-Booster panorama screenshot

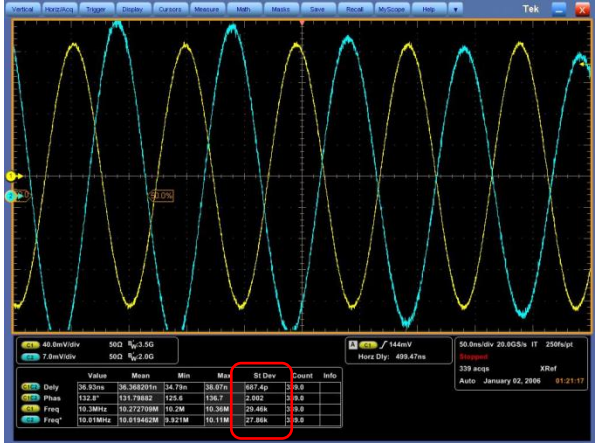


Figure 11. Gun-to-Booster short-term phase stability at direct sampling (300 machine cycles)

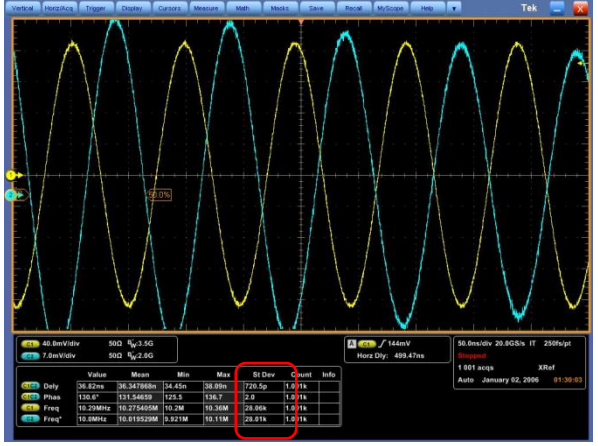


Figure 12. Gun-to-Booster long-term phase stability at direct sampling (1000 machine cycles)

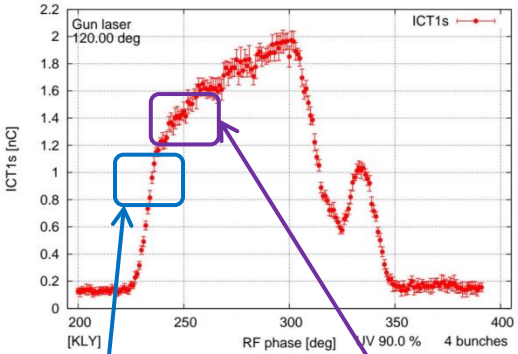



Figure 13. Measured phase scan for 4 bunches

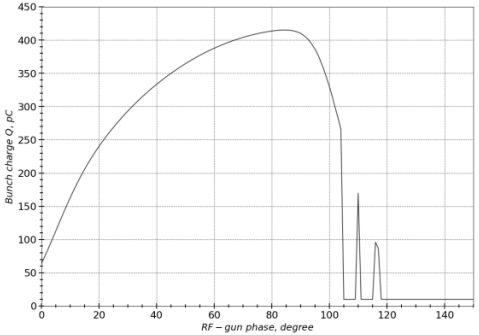



Figure 14. Simulated phase scan for 1 bunch

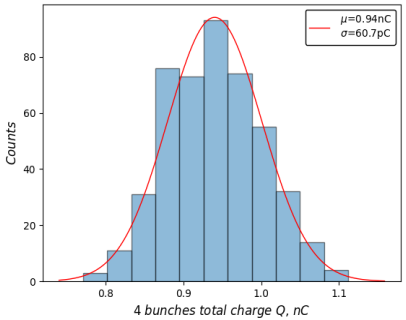



Figure 15. Measured 4 bunches charge jitter

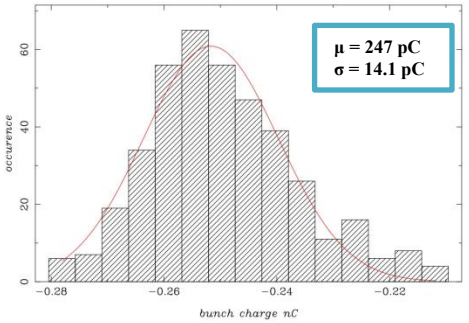
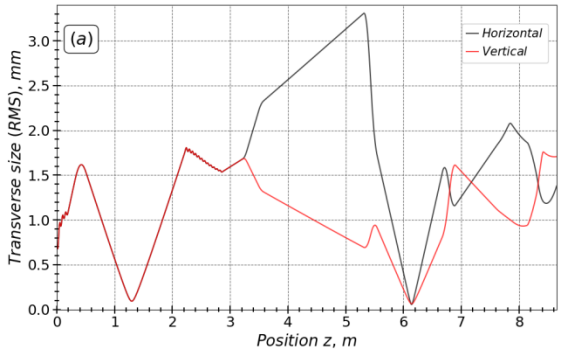



Figure 16. Simulated 1 bunch charge jitter

The first point 233deg (or **23deg**)

The first point 247deg (or **30deg**)

According to datasheet of ICT and Low Noise preamplifier, the measurement resolution of electron bunch charge with ICT1s is 1 pC.



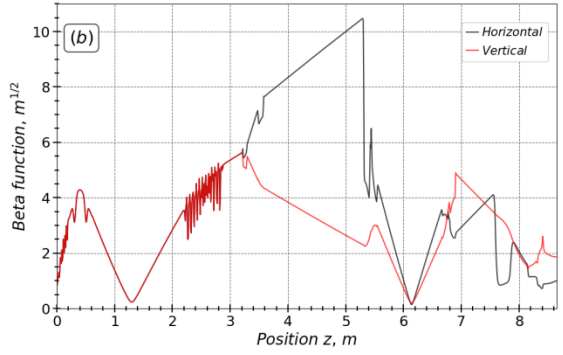




Figure 17. KEK LUCX facility beamline simulation in ASTRA. (a): transverse size (RMS) vs position along beamline, (b): beta function vs position along beamline

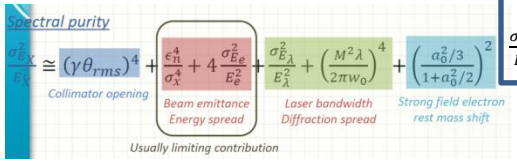
| Input parameters | |
|---|---|
| Laser pulse RMS length at the photocathode | 7ps |
| Laser pulse RMS transverse size at the photocathode | 700μm x 700μm |
| Bunch charge, Q | 250pC |
| Space Charge | enabled |
| Desired bunch parameters at Compton IP | |
| Energy, E | 18-24MeV |
| Energy spread, ΔE/E | 0.3 – 0.5% |
| Bunch size (RMS) | 80μm x 60μm |
| Bunch length (RMS) | 4 – 6ps |
| Normalized transverse emittance, $\varepsilon_x$x $\varepsilon_y$ | 8π x 6π mrad mm |

Bunch transverse size at Compton IP is 92 μm x 51 μm.

Energy at Compton IP is 21.34MeV.

Bunch RMS length at Compton IP is 1.21 mm (or 4ps).

Energy spread at Compton IP is 73.35keV (or 0.34%).

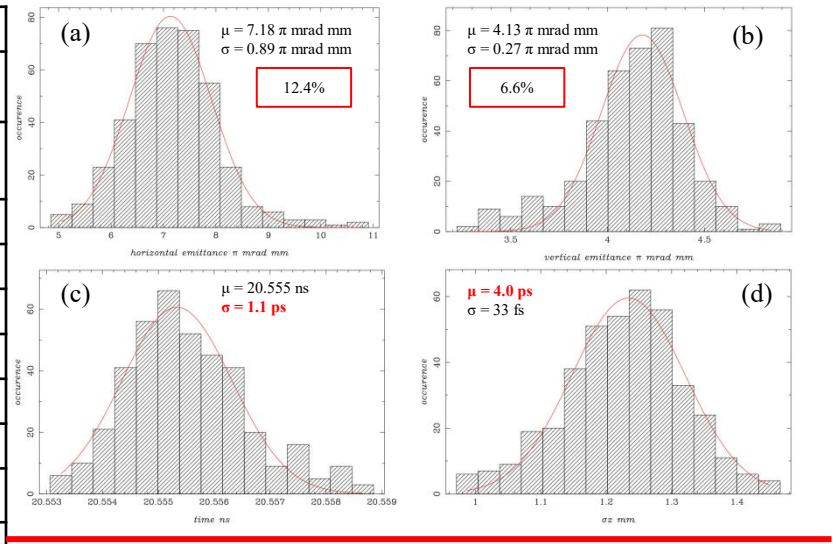


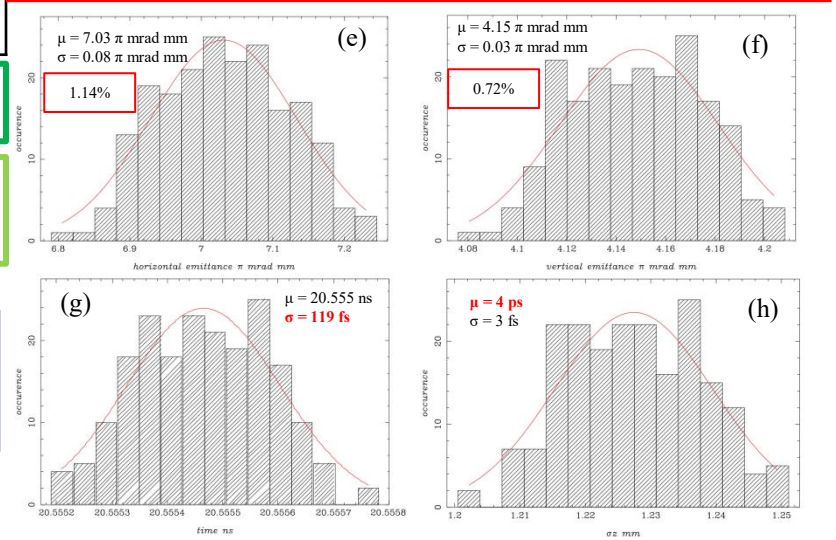

$$\frac{\sigma_{Ex}}{E_x} = 6.9\%$$

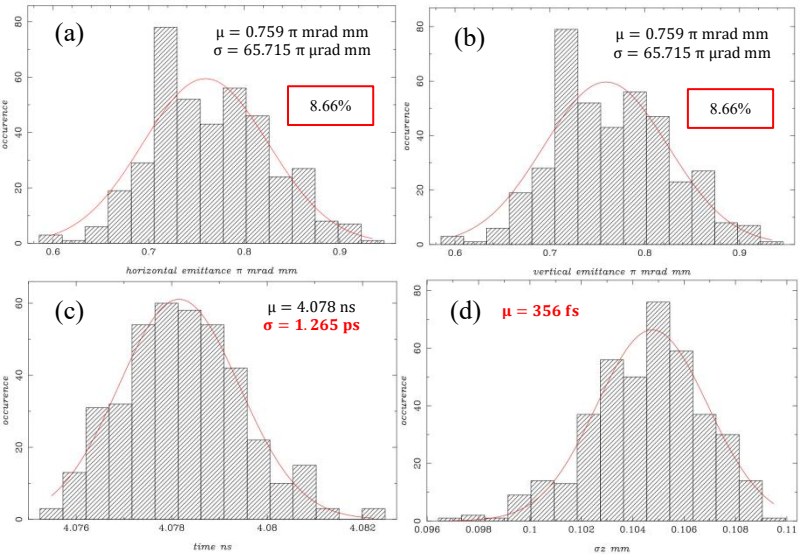
$$\frac{\sigma_{Ex}}{E_x} \pm \Delta\left(\frac{\sigma_{Ex}}{E_x}\right) = 6.9\% \pm 2.8\%$$

$$\frac{\sigma_{Ex}}{E_x} = 6.9\%$$

$$\frac{\sigma_{Ex}}{E_x} \pm \Delta\left(\frac{\sigma_{Ex}}{E_x}\right) = 6.9\% \pm 0.28\%$$






| Input parameters | |
|---|---|
| Laser pulse RMS length at the photocathode | 100fs |
| Laser pulse RMS transverse size at the photocathode | 500μm x 500μm |
| Dynamics type | on-axis |
| Bunch charge, Q | 50pC |
| Space Charge | enabled |
| Schottky effect (Phase scan) | enabled |
| Laser-to-RF gun jitter, ps | 3.2 ps |
| RF-to-RF jitter, ps | 900 fs |
| RF-gun phase, degree | 23 deg |

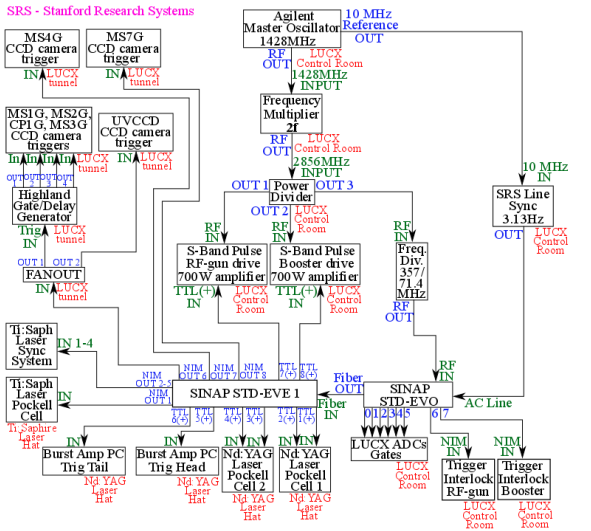



Figure 18. Event Generator & Event Receiver based trigger system

Figure 19. SINAP STD-EVO module (Event Generator)

Figure 20. SINAP STD-EVE module (Event Receiver)

Only first module uses coaxial cable. The rest of connection between EVG and EVR uses optical fibers. There are not noisy fluctuations because temperature fluctuations and radiation interfere with High Power devices.

Figure 21. Stanford Research Systems DG535 Line Sync


Figure 22. RedPitaya SIGNALlab 250-12 FPGA board

Further distribution. There are not necessity to adjust jitter for fast timing and misfire problems. SINAP Event Generator is Line Sync, first TD module to get synchronized RF and Trigger signals, as well as Digital Time Delay and Gate Generator.

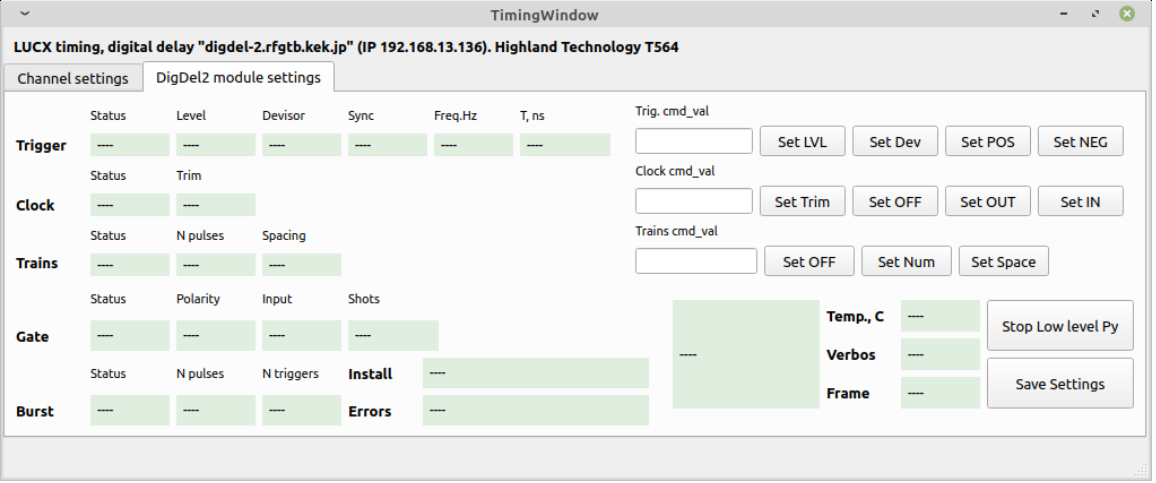



Figure 23. LUCX timing system control window written at PyQt with EPICS PV

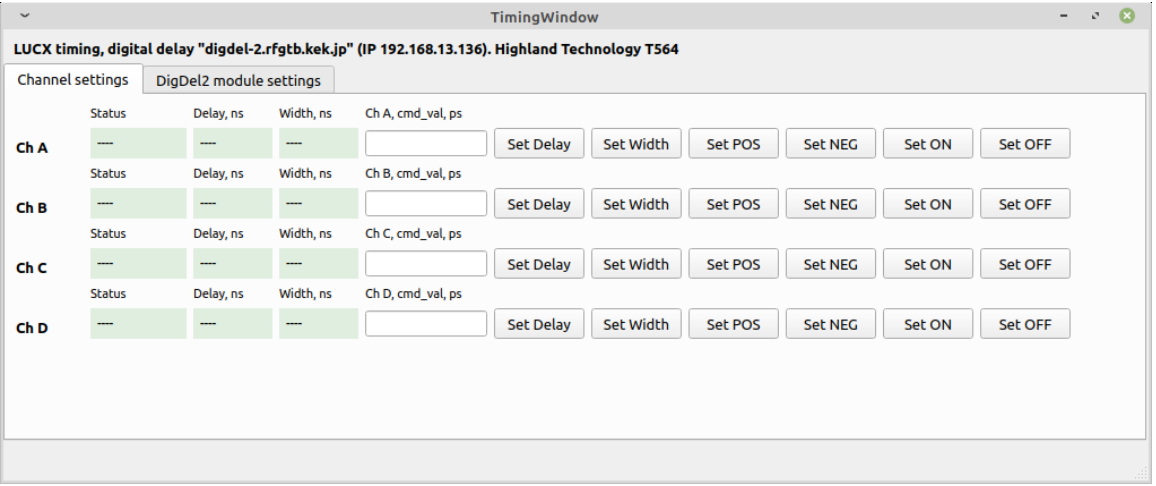



Figure 24. LUCX timing system delay values setup window written at PyQt with EPICS PV

The accelerator control software is based on EPICS and has a various useful tools written using python, Qt.

**SINAP STD-EVO and STD-EVE:**

- event clock delay, 1/20 event clock delay, 5ps/step delay;
- RF clock frequency range is 60 – 500MHz;
- Embedded IOC installed (uclinux 2.6.30.4)
- Every channel is independently programmed (delay, width, polarity).
- Number of NIM channels is 8;
- Number of TTL channels is 20;