TCT Analysis and DAQ

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Abstract

A sequence of measurements of un-irradiated silicon sensors using the Transient Current Technique (TCT) performed. Data analysis framework developed by Hendrik Jansen and Mykyta Haranko was extended. A new sensor has been prepared for test, bonded and tested. C++ based data acquisition system was developed and is presented in this report.

Contents

1 Introduction

Silicon is one of the most widely used materials in modern physics and electronics. It is used both in processors and in modern detectors. At the High Luminosity phase of the LHC (HL-LHC) inner sensors are expected to integrate a fluence of about $10^{16} n_{eq}/cm^2$. The main task is to design a completely new detectors with high radiation hardness. One of the most important characteristics is the signal after irradiation: it decreases due to low trapping times of the charge carriers in the irradiated materials.

Since transient current technique is widely used for detector testing, earlier it was decided to develop user friendly analysis and data acquisition frameworks. The TCT-analysis framework, developed by Hendrik Jansen and Mykyta Haranko, has been extended by adding several analysis methods. The brand new TCT-daq framework was developed to perform data acquisition.

2 Transient Current Technique (TCT)

Before describing the software and hardware components of my work, it would be necessary to describe the physical principles on which the data acquisition technique is based. In silicon detectors, as it is in most others, particle registration process is related to energy deposition in the detector. Charged particle passing the detector produces electron-hole pairs, which start to drift in the electric field and induce current on the strips due to Shockley-Ramo theorem (1).

$$i = qvE_w \tag{1}$$

Where i stands for induced current, q is the charge of the particle, v is its instantaneous velocity and E_w is the component of the electric field in the direction of v at the charges instantaneous position, under the following conditions: charge removed, given electrode raised to unit potential, and all other conductors grounded. To reduce detector's own conductivity, we apply a clamping voltage to it. That reduces amount of free charges in silicon and produces external field, which makes charge drifting.

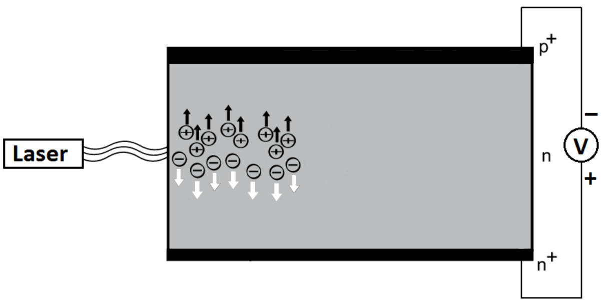

Figure 1: Schematic view of the charge creations, Edge-TCT.

3 Experimental Setup

3.1 Hardware layout

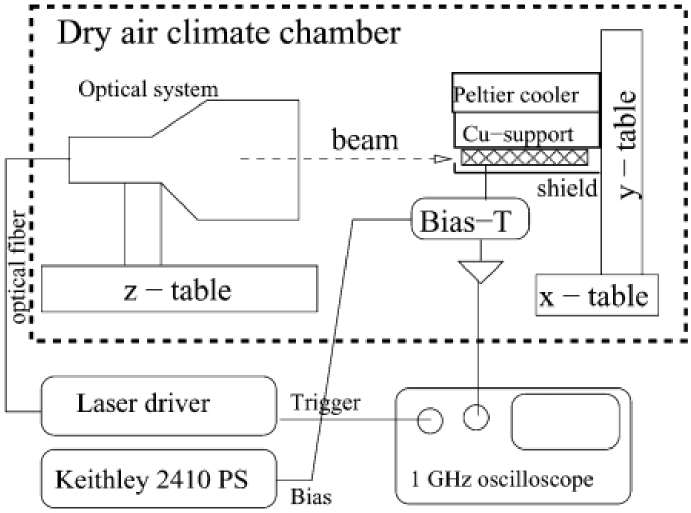

Figure 2: Hardware layout.

Experimental setup consists of the next items: All this hardware should work prop-

Instrument	Model	Description
Voltage Source	Keithley 2400	Allows us to apply bias voltage, and limit the current
Oscilloscope	WaveRunner 640Zi	Receive signals from amplifiers and send waveforms to PC
Translation Stage	Standa 8MT30-50 (3 items)	X and Y axes for sensor positioning and Z axis for laser focus
Laser	IR and Red laser from "Particulars"	Infra-red (1064 nm) and red (660 nm) lasers for sensor irradiation

Table 1: Hardware

erly for correct data acquisition. The hardware is connected to PC and controlled by data acquisition program developed using LabVIEW. This framework is quiet tricky and unstable. An alternative TCT-daq framework was developed and is described in chapter 5.

3.2 Sensor Bonding

The existing bounded sensor has undesirable behaviour. We we not able to get a clear signal that would indicate the full focus, which is necessary for the subsequent analysis. Due to this fact, it was decided to bond and use a new sensor. To bond sensor, we needed to polish the side edge of the detector. Careful polishing is necessary to be able to focus the laser on the edge, it is also needed for higher amount of light passing to internal parts of the detector. It is also necessary to avoid scattering of light on the surface irregularities, which can lead to incorrect measurement results.

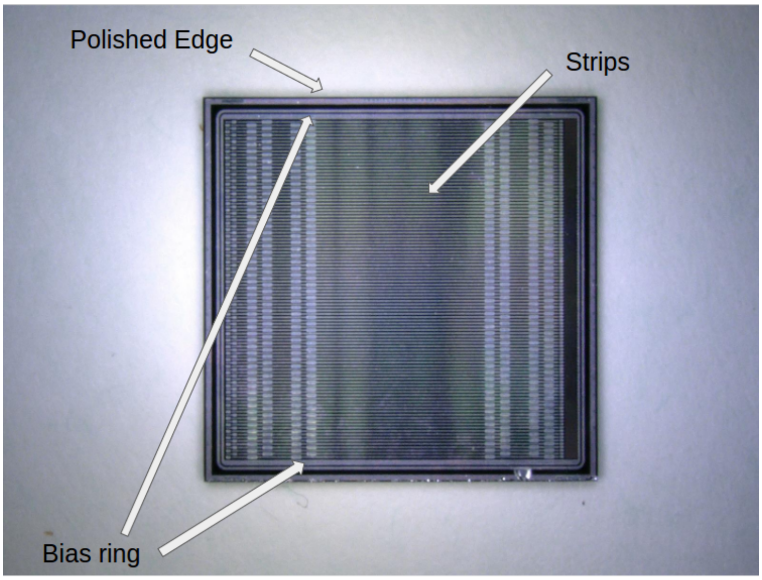

Figure 3: Photo of sensor top surface

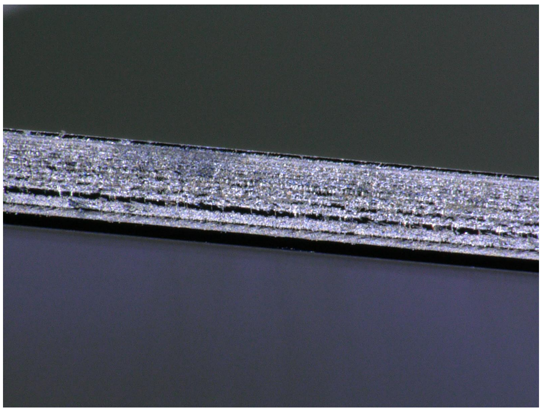

Figure 4: Unpolished sensor edge.

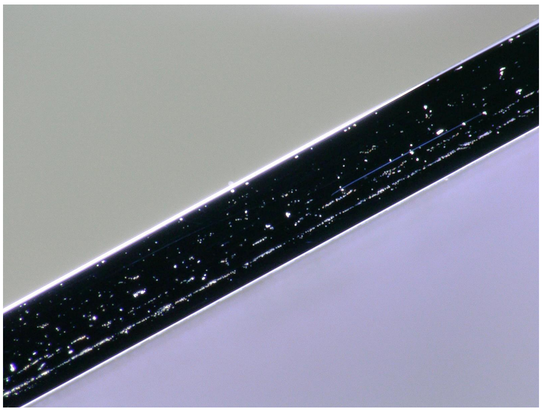

Figure 5: Polished sensor edge.

The next stop - is sensor bonding. It was done at DESY bonding laboratory. Tiny aluminium wires were connected to sensor with ultrasonic technique.

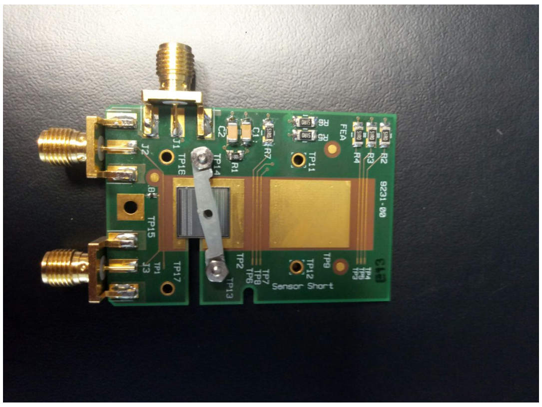

Figure 6: Test PCB.

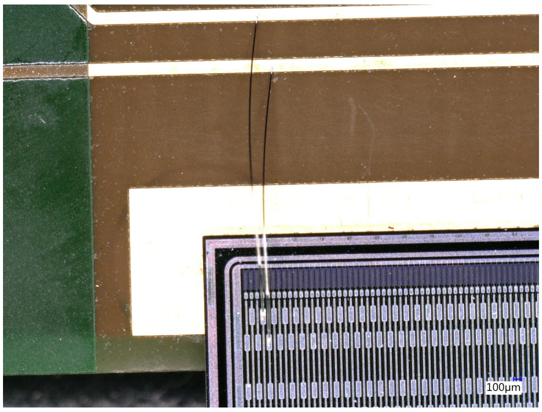

Figure 7: Channel bonds.

Strips 4 and 5 were connected to channels 1 and 2 of test PCB, designed at DESY for TCT measurements. Bias ring and strips 2, 6 and 8 were grounded. The PCB in the mounting case was installed on translation stage and tested. Results of the test are shown in Figure 8. This figure shows collected charges at each scanning point for X and

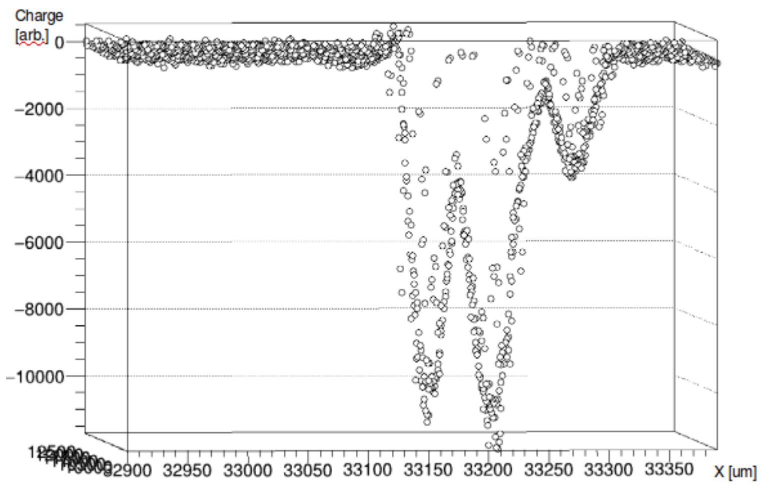

Figure 8: Charge distribution for X and Y axes.

Y axes. For X axis one can observe two big peaks. These peaks are signals from left and right sides of yhe strip. When the red laser crosses the strip, majority of light is reflected by aluminium strip and do not produce electron-hole pairs. One also can observe small a peak on the right. This is the noise from ungrounded neighbouring strip. This test shows us that it is necessary to ground all unused strips.

4 TCT Analysis

4.1 TCT Analysis Framework

The TCT Analysis Framework is C++ based software developed by Hendrik Jansen and Mykyta Haranko. It can be used to analyse raw data from measurements. Framework consists of several modules. Each module provides different type of analysis. Using this software one can do focus search, find depletion voltage, charge carries mobility or electric field profiles in the sensor. The GUI is available. My first task during the DESY

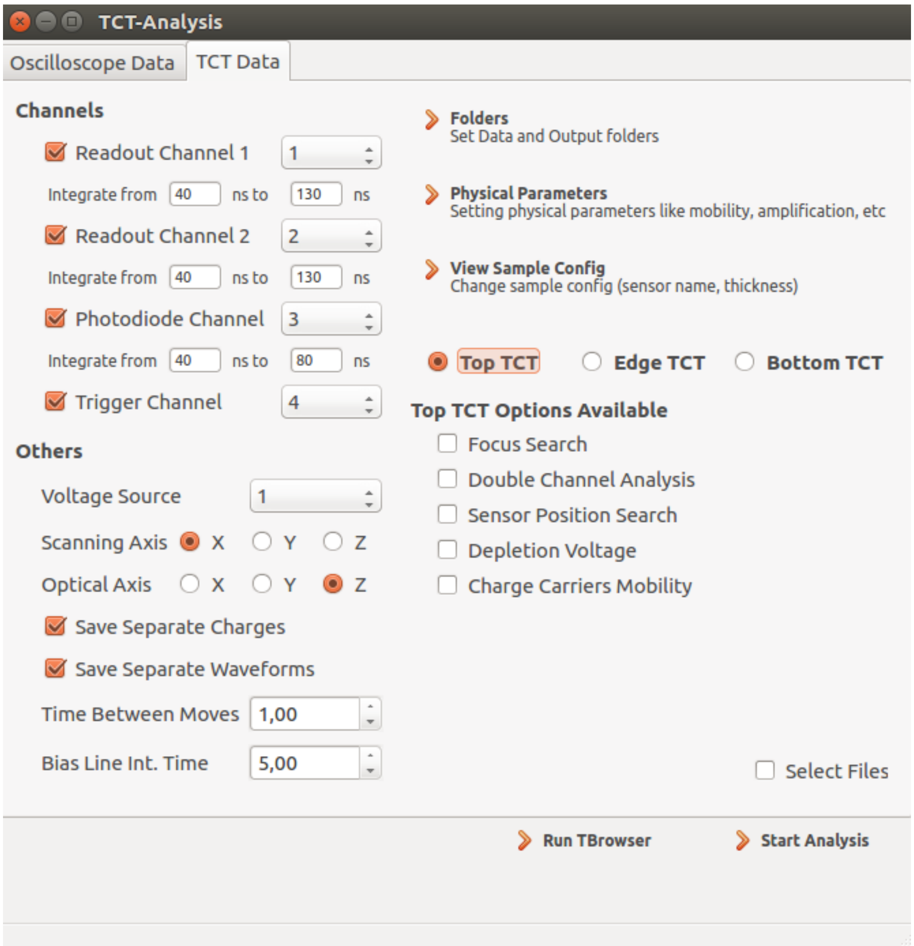

Figure 9: Graphical User Interface (GUI) for TCT-analysis

summer student program was to add new modules to this framework. Information about this part could be found in the next two sections.

4.2 Module "Find Sensor"

Since our sensor is light-sensitive, the whole setup is placed in a special black-box. This also affects safety reasons, since laser can be harmful for human eyes. This causes some problems: after installing the sensor we need to find the sensitive area of the detector. Moreover the detector is placed in a special case which limits sensitive area to 3-10 mm^2. In order to solve this problem the Find Sensor module was developed. It allows you to obtain a map of the collected charges if the sensor was scanned in an XY plane. This module integrates the waveforms received from oscilloscope at each point of the plane, which gives us the collected charge in arbitrary units, and then builds a three-dimensional distribution on the XY plane. After the sensetive area was found, and the

Figure 10: The sensor in case.

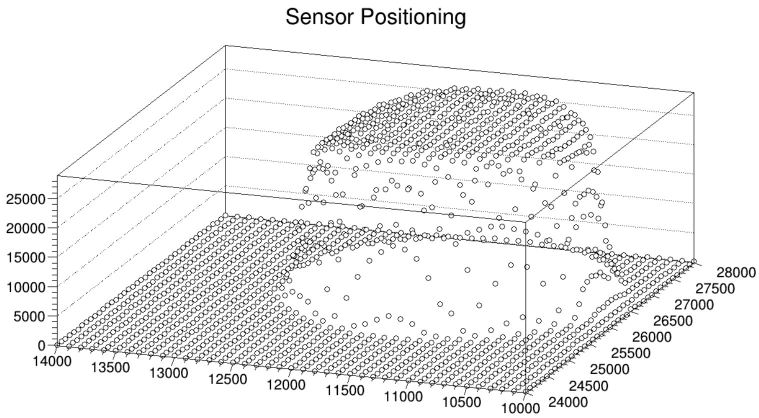

Figure 11: Collected charge map.

laser is focused, this module can be used to plot the map of collected charge on a strip along X and Y axes. This makes it possible to determine whether there are misalignment of the optical (Z) axis with respect to the scanning one. Axis misalignment can be corrected by rotation stage, if it would be necessary. Current setup does not include rotation stage, but it can be easily added and implemented in the TCT-daq framework. This will be discussed in chapter 5.

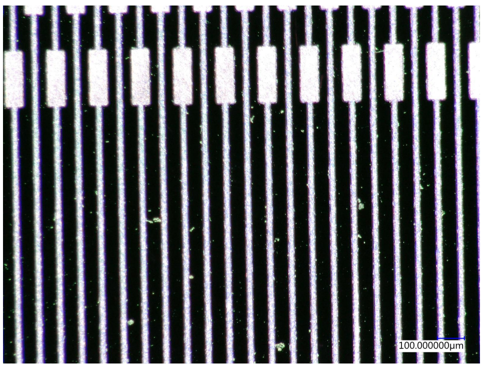

Figure 12: Sensor strips.

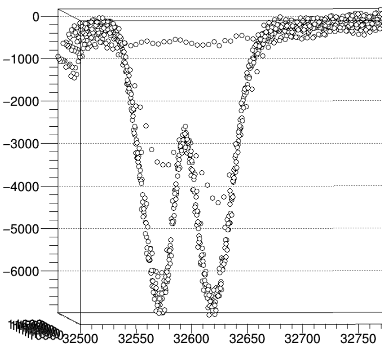

Figure 13: Collected charge map.

4.3 Module "Double Channel Analysis"

The resolution of our detector is directly related to the distance between the strips. Mathematically we get the resolution of $L/\sqrt{12}$ where L is a distance between strips. To achieve higher resolution we need to analyse charge distribution between strips. Obviously one will collect more charge at strip which was closer to the trajectory of the particle, which hit the detector. If we had high ratio of charge sharing between the strips, we can reconstruct trajectory more precisely. To characterize charge sharing of the detector Double Channel Analysis module was developed. It plots collected charge distribution along the scanning axis for both strips. At figure 15 one can observe,

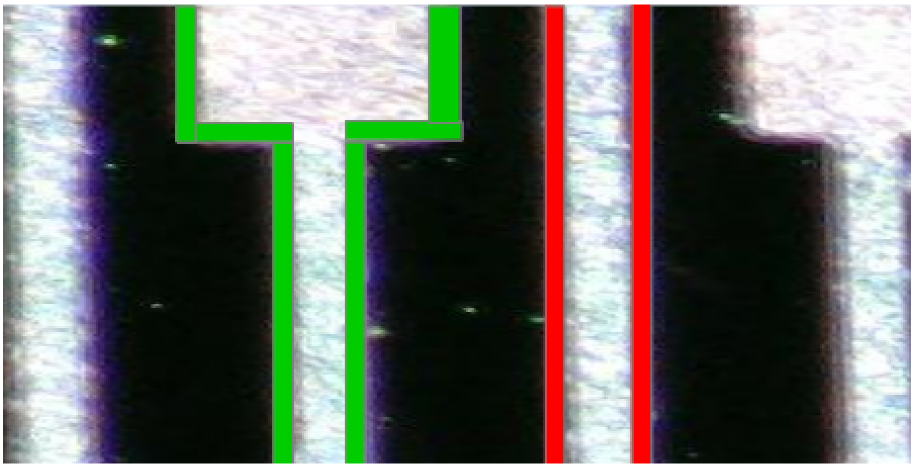

Figure 14: Two neighbouring channels at sensor.

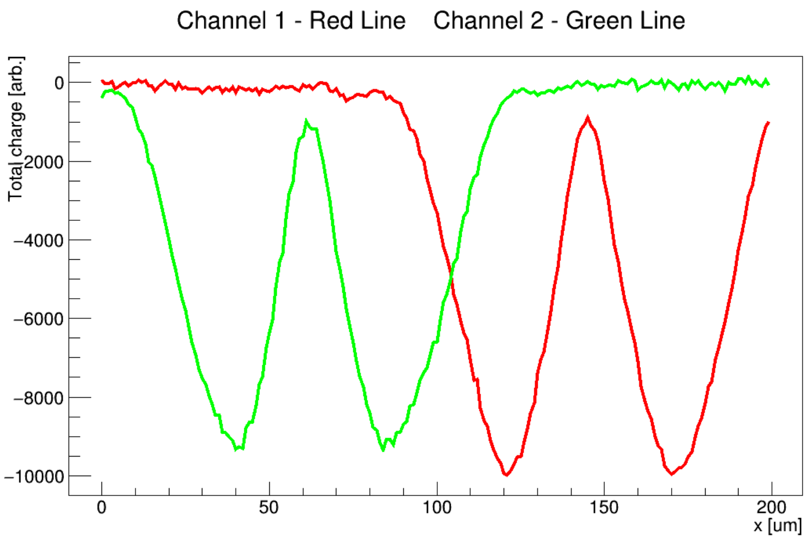

Figure 15: TCT data from two neighbouring channels of sensor.

a charge sharing between strips. This sensor has a thickness 300 μm. For thinner detectors, this slope turns into a step-alike function. New type of sensors is currently developed at DESY, and might have higher charge sharing - described analysis module can help to test the sensor.

5 TCT Data Acquisition

TCT Data Acquisition it is a framework that allows you to control data acquisition.

5.1 Structure of the TCT-daq

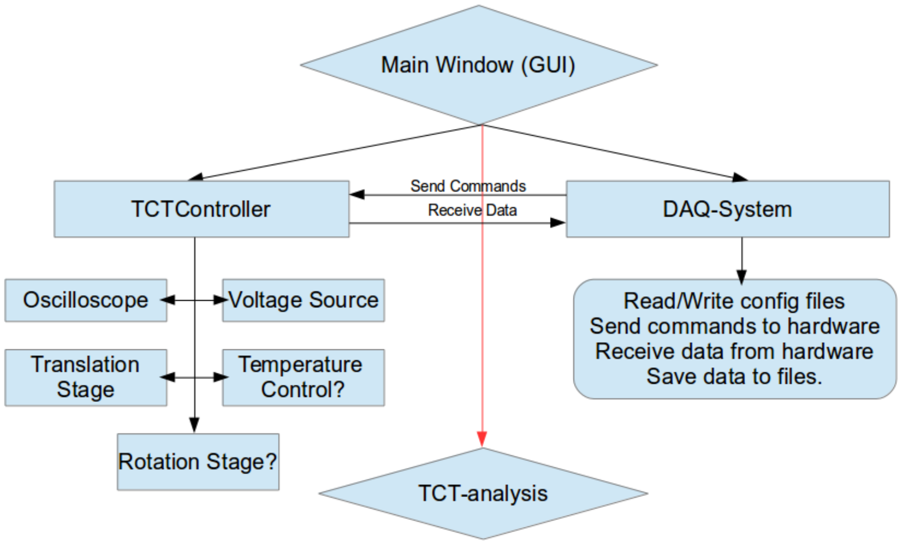

Figure 16: Structure of TCT-daq.

Since the old data acquisition system was written on LabView , it was decided to develop it in C++. The new framework should be more stable and easy to use, and also more flexible. Since the application is open-source, the next user will be able to easily implement new instruments and functions. The developed software consists of a graphical interface based on Qt. The master class is TCTController, which contains the whole set of instruments: Translation stage, Oscilloscope, Voltage source. One can implement more instruments as it shown in Figure 16. Each instrument has its own configurations: name, type, address, type of connection and extra configurations. All configurations can be easily saved to configuration file and loaded from it.

5.2 Functionality of the TCT-daq

TCT-daq allows user to interface with oscilloscope, connected through Ethernet port. In LeCroy X-Stream Oscilloscopes Remote Control Manual [3] one can find list of commands and their descriptions. For example command "WAIT;C4:INSPECT?\"DUAL\"\n" will force oscilloscope to wait until new measurement will be done and send waveform of channel 4 to PC. The GUI uses qcustomplot [6] object, which allows us to plot waveforms during the measurements. "TranslationStage" class allows user to control translation

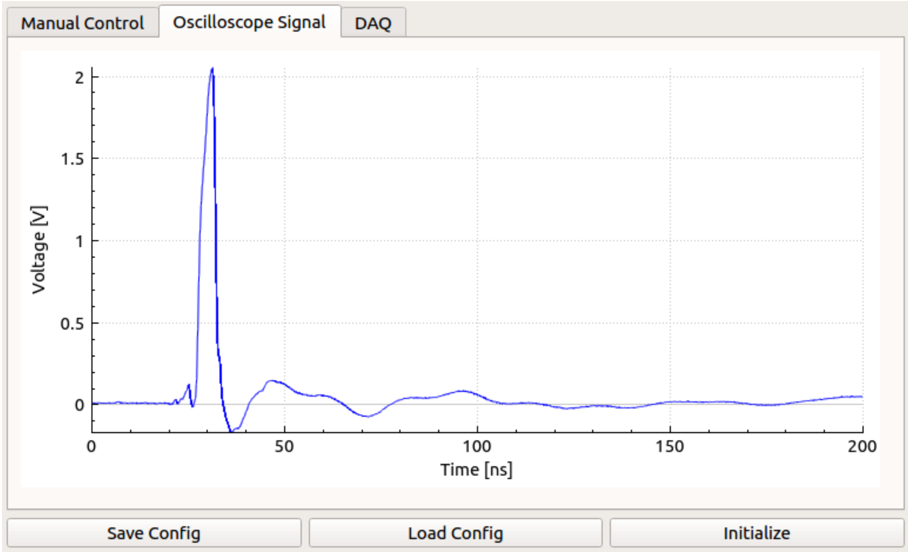

Figure 17: Waveforn plotted in qcustomplot object.

stage. One can send commands to each of the three translation stages. TCT-daq can move stages with precision of 0.1 μm and single step of 1 μm. The framework allows to set speed from 0.0026 to 6.25 mm/second. If translation stage reaches limits, program will stop moving stage element.

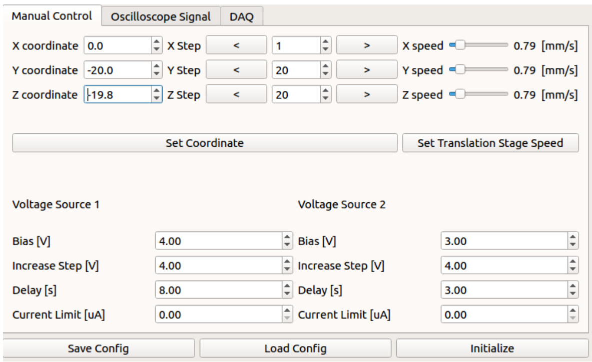

Figure 18: Manual controll GUI.

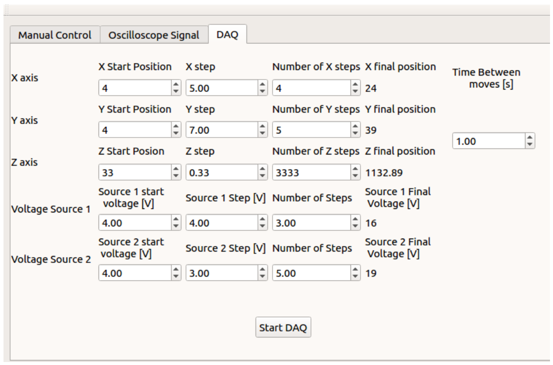

Figure 19: DAQ setup GUI.

Unfortunately, I have no time to finish my project. Voltage source control was not implemented. So program have some bugs, which should be fixed. By now, program allows to get waveforms from oscilloscope, move translation stage and receive it's precise position. I hope this project will be finished in future. Source code available on GitHub : https://github.com/korostysh/TCT-daq Documentation is going to be written.

6 Conclusions

During this summer student program the following results were obtained: sensor was polished, bonded and tested, TCT-analysis framework was extended with the new modules, which will simplify analysis process. Iitial version of the TCT-daq framework was developed. As well as new TCT-daq and TCT-analysis both written on c++ if gives us possibility to interface them, and probably add auto-focusing or auto find sensor functions. The TCT-daq might significantly simplify the data taking process, and allows some measurements to be atomized in future.

References

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[4] Mykyta Haranko Summer Student Report DESY 2015

[5] http://www.standa.lt/products/catalog/motorised_positioners?item=175

[6] http://www.qcustomplot.com/