Internship Report

Smith-Purcell radiation and Reconstruction techniques

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Smith-Purcell radiation Smith-Purcell (SP) radiation is emitted when a bunch of electrons passes near a grating. This is characterised by a wide range of wavelengths emitted over a large angular spread. For an observer at infinity, the emitted radiation satisfies the following condition:

$$\lambda = \frac{l}{n}\left(\frac{1}{\beta} - cos(\Theta)\right)$$

When the parameters are properly chosen some of this radiation will be coherent and the spectrum of the radiation emitted will depends on the square of the Fourier transform of the bunch:

$$\left(\frac{dI}{d\Omega}\right)_{N_e} = \left(\frac{dI}{d\Omega}\right)_1 N_e^2 \left| \int_{-\infty}^{\infty} T e^{-i\omega t} dt \right|^2$$

Therefore a measurement of this spectrum gives some information on the beam longitudinal profile but the phase of the Fourier transform must be recovered.

From there we conclude:

- To measure SP radiation, array of detectors is required.
- To recover beam profile, phase reconstruction technique is require.

Creation data acquisition system and study phase reconstruction was dedicated my internship.

DAQ system Idea of DAQ system usage is described at figure 1 DAQ system consist of

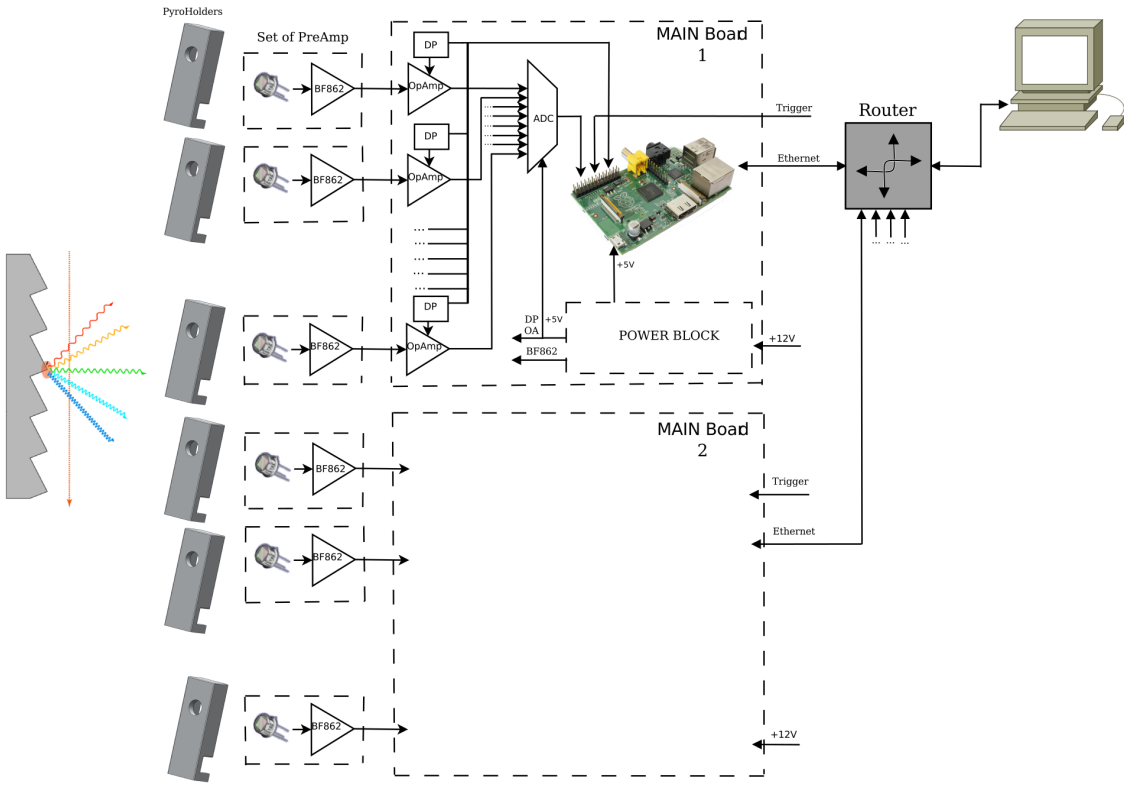
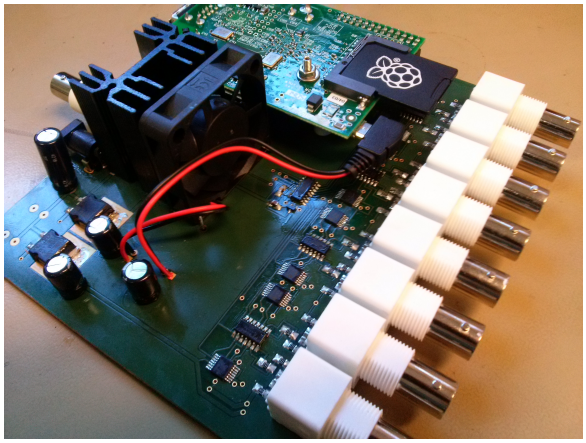


Figure 1: Diagram of DAQ system

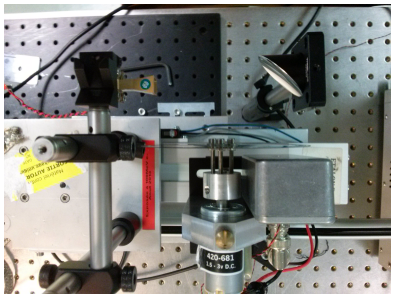
several DAQ boards. They all connected to routher and then to user computer. DAQ board consist from two parts: preamplifiear with detector holder and MAIN board. It was done from radiation consideration. Main board include part of preamplfier, operational amplifiers controlled by digital potentiometers, ADC, power stabilisators and Raspberry Pi. Constroll of board performed from user computer. System shown good response even for very low signals and can easely work at work frequency (figure 2).



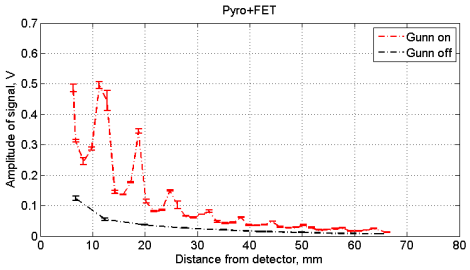
(a) Main board without shieldig box

(b) Preamplifier and pyroholder in test installation

Figure 2: DAQ board



(a) Installation example



(b) Decay curve for 25GHz source without horn

Figure 4: Detector efficiency measurements

Detector efficiency measurements Even with so powerfull amplification system, signal must be collected with mirrors system (figure 4). For this was used transition stage with stepper motors and linear encoder. Also in this measurments was used same amplifier as in DAQ board. So there was system RF source → mirror → chopper (to modulate signal) → detector with preamplifier → 5Gs/s Oscilloscope → user computer. Also was used optocouple to control chopped rotation, system linear encoder - stepper motor, remotely controlled power supply. Was written script in matlab that conroll all stuff and collect data. As thermal component is very strong (compared to RF signal) it's necessary also measure it. As can be seen from figure, strong difraction is presented if use RF source without horn. So for Mirror comparison was used other RF source with horn.

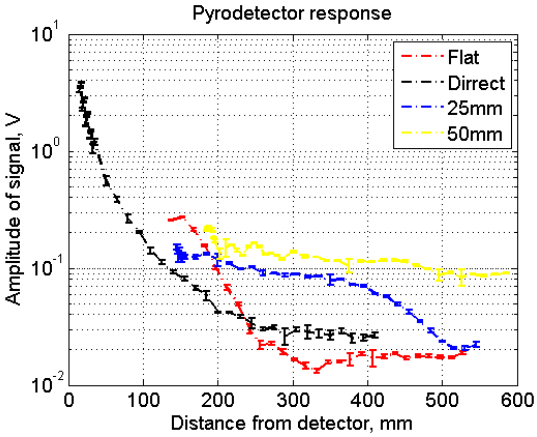
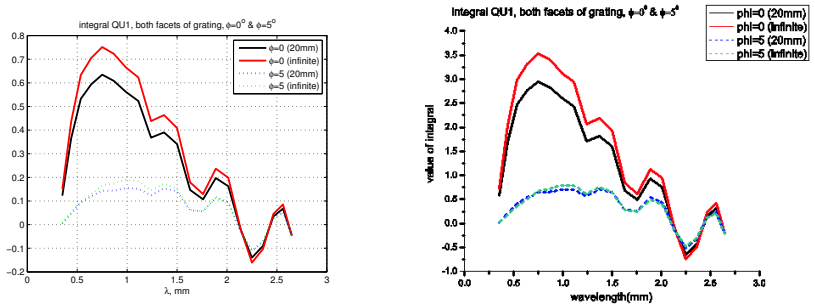


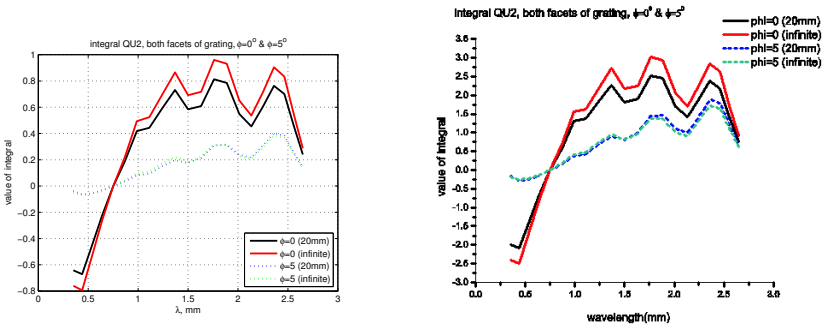
Figure 3: Mirror comparison

Linear encoder Except DAQ board was created system based on Raspberry Pi, that will help to use and control Linear encoder,4 switches, potentiometer for detector positioning, temperature and humidity sensors, LCD and interface buttons.Program for control all sensonrs and communication was written on c++. In general it has several classes for i2c, spi, lcd... All software could be compile with make command. Program have autostart. Also it generate it's own web-page and it's possible to read all data from user browser.

Surface current theory calculation To simplify calculation of emitted energy in experiment was proposed to rewrite code from C code to matlab. Work in this area is not finished,



(a) Matalab calculated QU1 (b) Cauchy 1 calculated QU1



(c) Matalab calculated QU2 (d) Cauchy 1 calculated QU2

Figure 5: Integral comparison

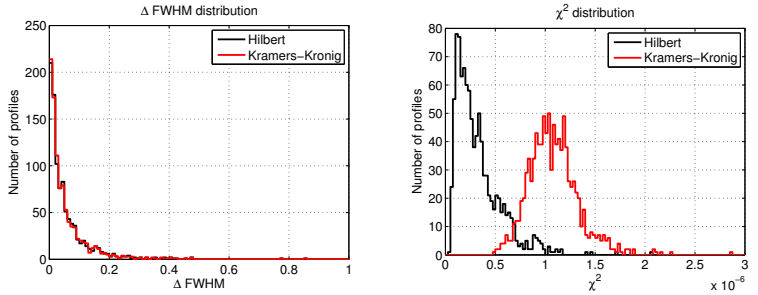


Figure 6: Two phase recovery method comparison

but there is presented some primary result according to reference code (cauchy 1). The main problem is corret integral calculation (QU1, QU2, QU3,QU4). So at figure 5 is presented it comparison.

Reconstruction study This part is continuation of previous study. The main study is related to spectrum sampling, low and high frequency extrapolation. According to new study was remaded simulations (Optimal number of detectors and it's position, noise impact, long-tail profile reconstruture, stability of parameter choise ect.) Comparison of two methods of phase recovery is presented at figure 6. Main results are:

- most satisfactory low frequency extrapolation is Gaussian, high frequency is Ae^B, interpolation - PCHIP.
- For this day most satisfactory sampling is Triple-sine sampling with 11 detectors.
- The best phase recovery method is Hilbert method.
- Correct choose of parameters give 15% reserve for reconstruction efficiency.
- Long-tail profilles are well reconstructed.
- Noise have low imact on reconstruction for small noise part in amplitude.

Now is procees work at article. Hope You will see it soon.