

RESEARCH OF THE SILICON PHOTOMULTIPLIERS FOR VARIOUS APPLICATIONS

Experimental techniques, methods, first results and
plans

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FULL SiPM CHARACTERIZATION

Full characterization of the SiPM can be divided in three 'stages':

- **Static**

Includes forward and reverse IV and CV measurements

- **Dynamic**

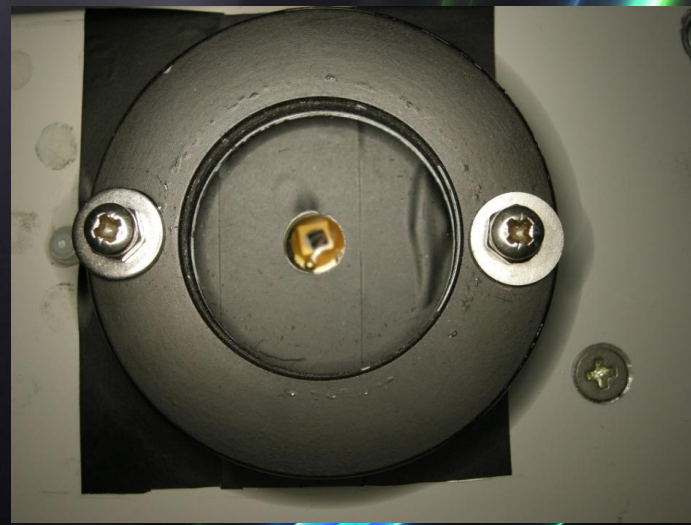
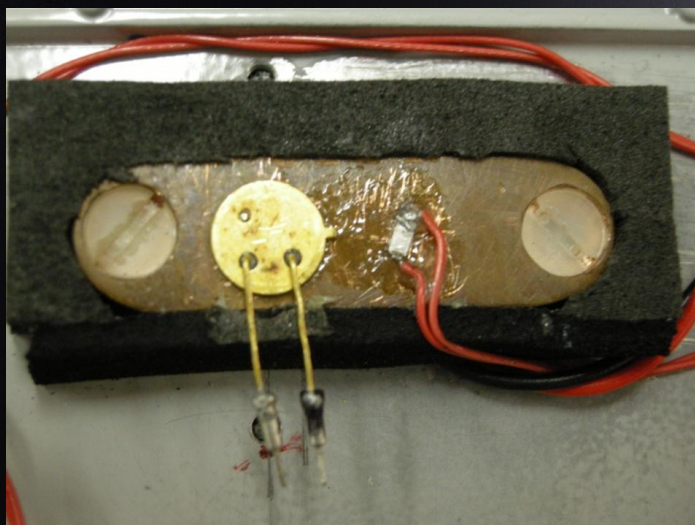
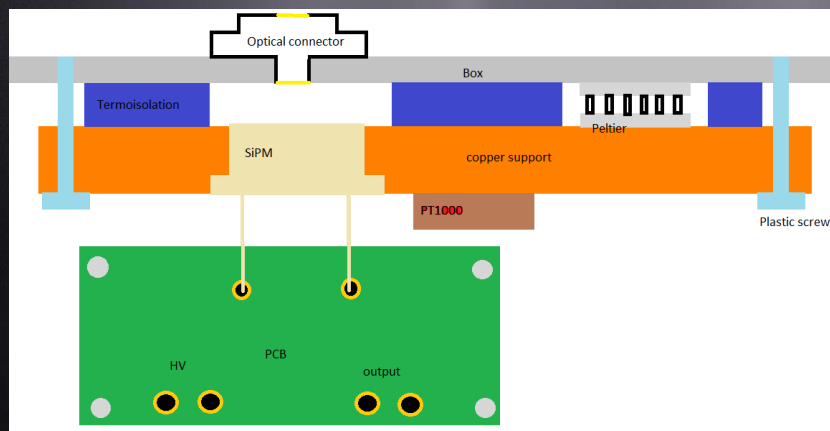
Includes dark count, gain, afterpulse probability, optical crosstalk measurements and temporal characterization

- **Optical**

Includes spectral sensitivity and photon detection efficiency measurements

EXPERIMENTAL SET-UP

- Set of instruments for IV and CV measurements;
 - HP 4142B , HP 4284
- Fast preamplifier and oscilloscope;
 - LeCroy SDA 760Zi: 6 GHz, 40 GS/s
 - Custom preamplifier: Gain = 10, bandwidth about of 2 GHz
- Fast laser;
 - pulse laser 76 MHz, 4 ps, 600 nm
 - Laser support equipment
- Mechanical support for temperature control, electrical and optical connection;



EXPERIMENTAL SET-UP

Mechanical support with SiPM and partially removed thermal protection.
Top side and bottom side views.

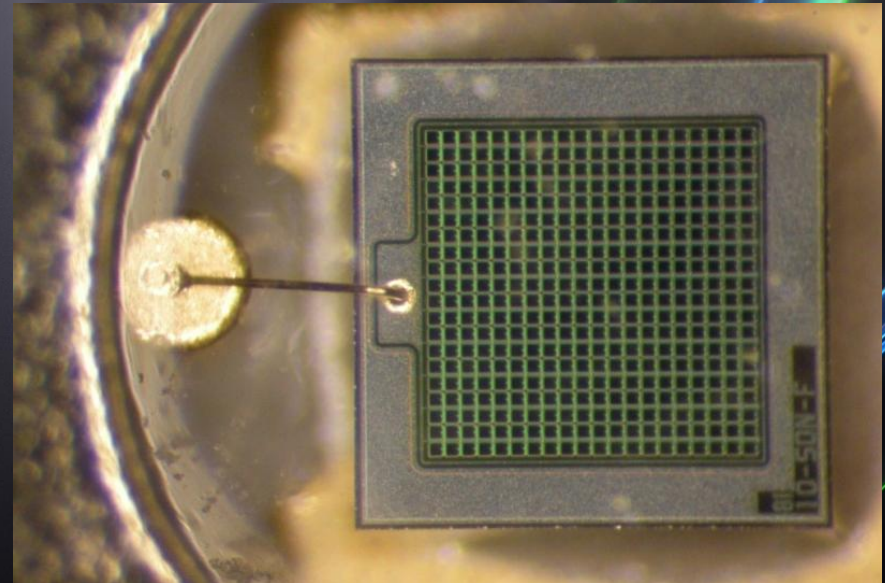
THE DEVICES

FBK - IRST



- Area 1,4 mm²
- Cell size 70x70 microm
- Cells number: 292

Hamamatsu

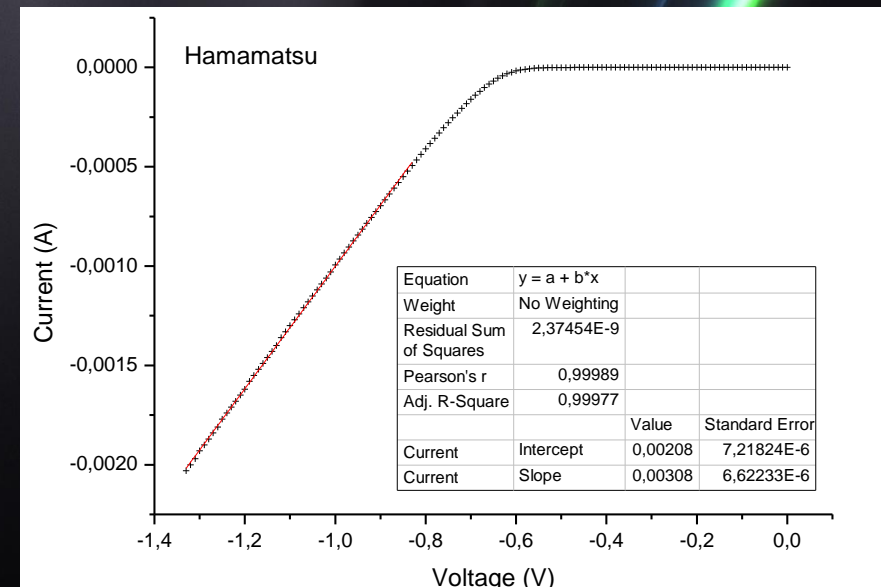
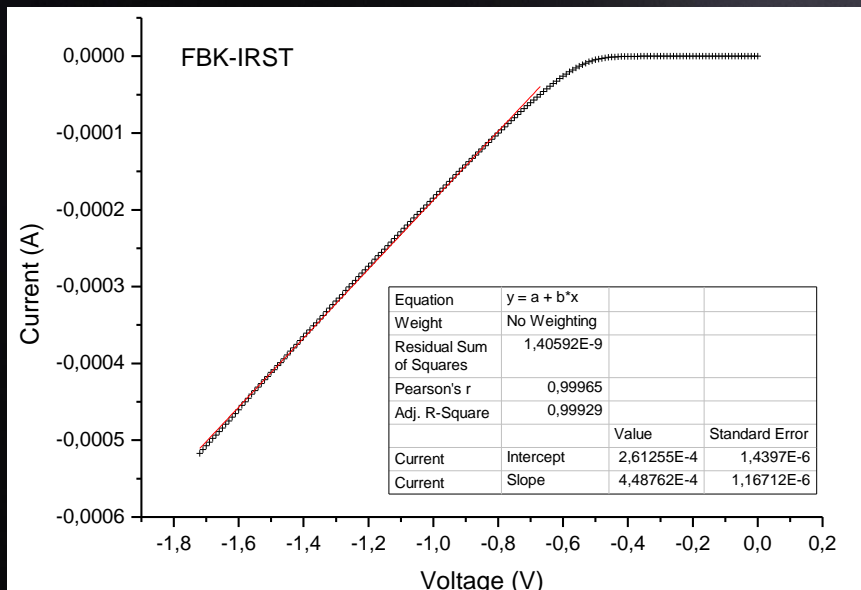


- Area 1 mm²
- Cell size 50x50 micron
- Cells number: 400

STATIC MEASUREMENTS

Forward IV

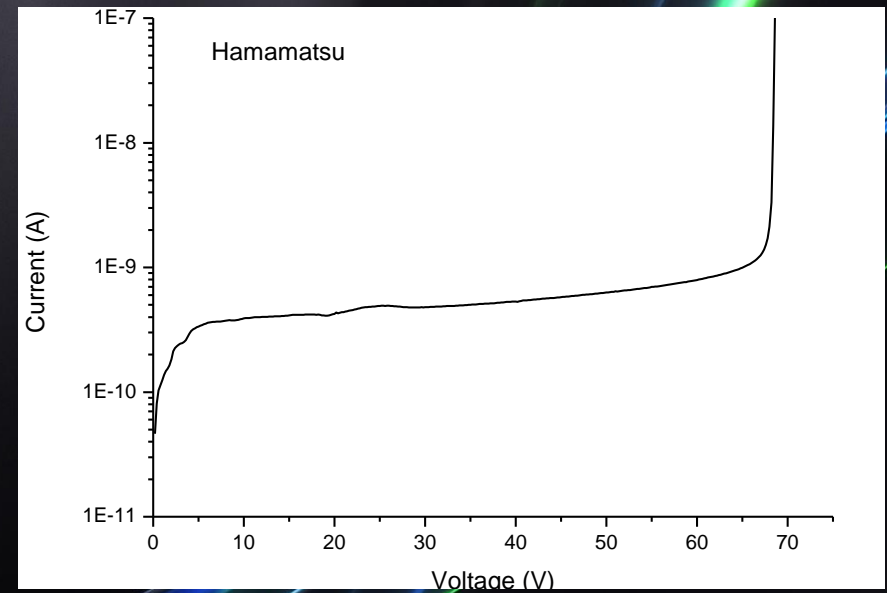
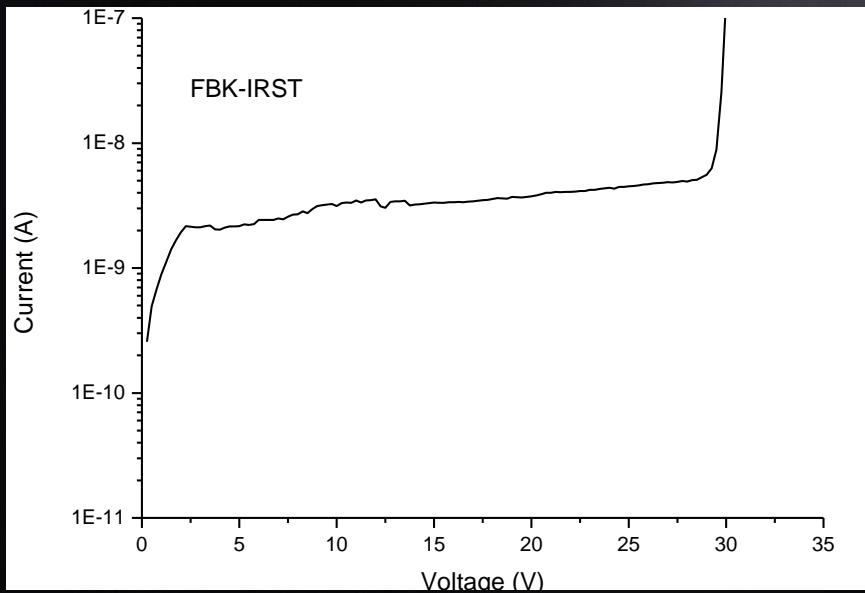
- Total resistance is 2228 Ohm.
Quenching resistor is $2228 * 292 = 650.6 \text{ k}\Omega$
- Total resistance is 324 Ohm.
Quenching resistor is $324 * 400 = 129.6 \text{ k}\Omega$



STATIC MEASUREMENTS

Reverse IV

- V breakdown is 29.25 V
- V breakdown is 69.7 V

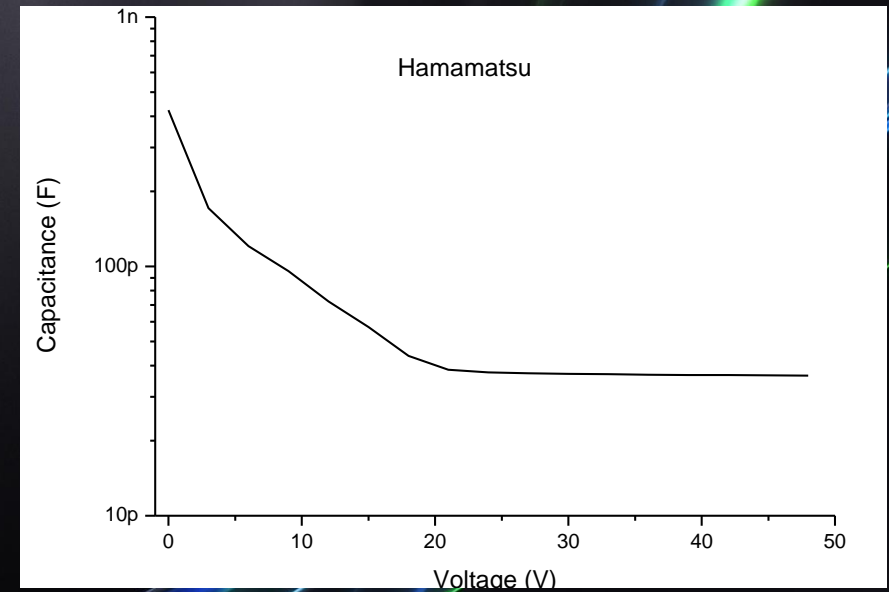
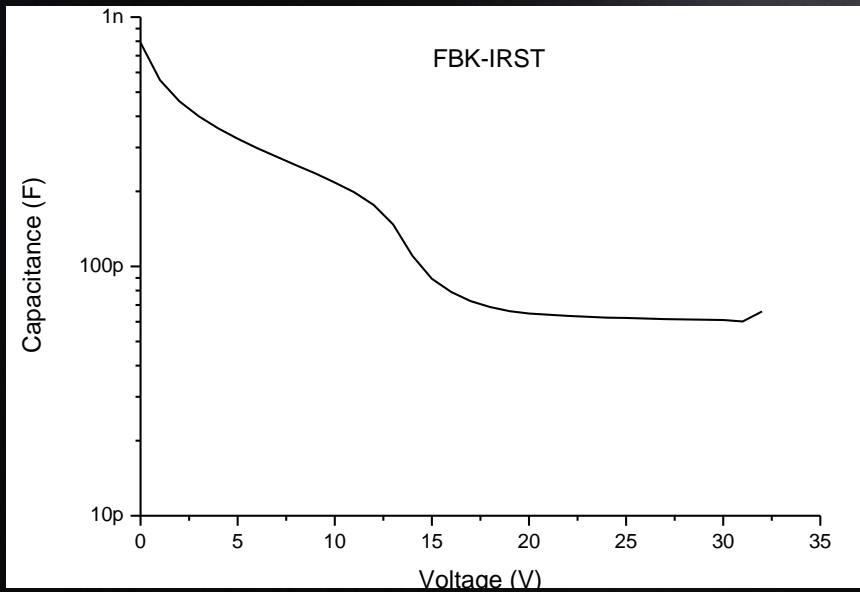


STATIC MEASUREMENTS

CV

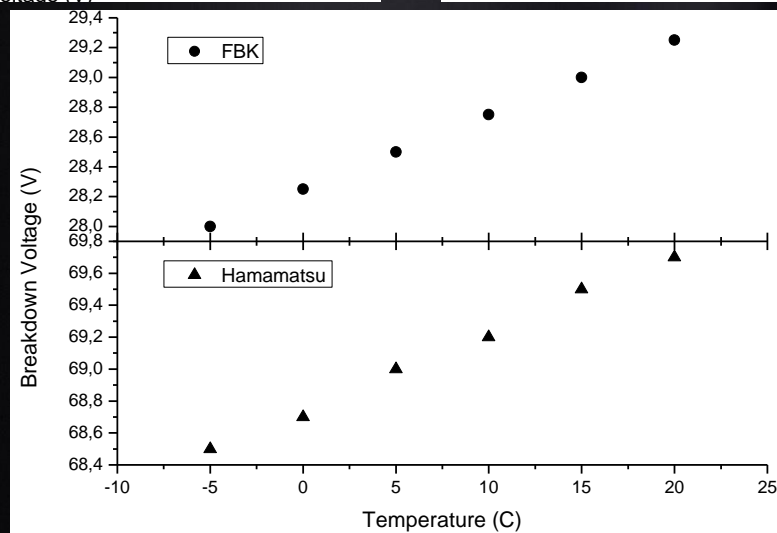
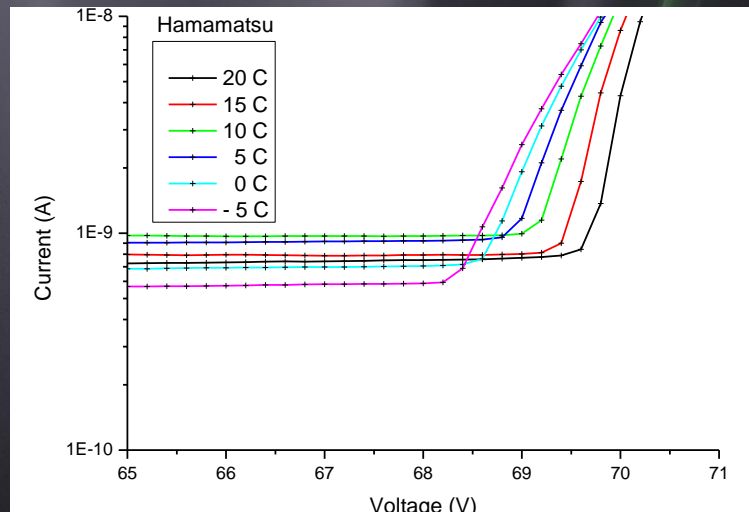
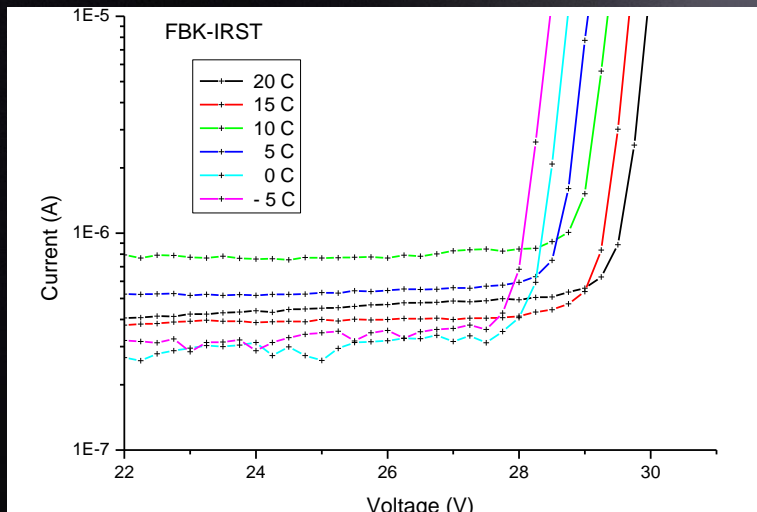
- $C_{op} = 61 \text{ pF}$

- $C_{op} = 36 \text{ pF}$

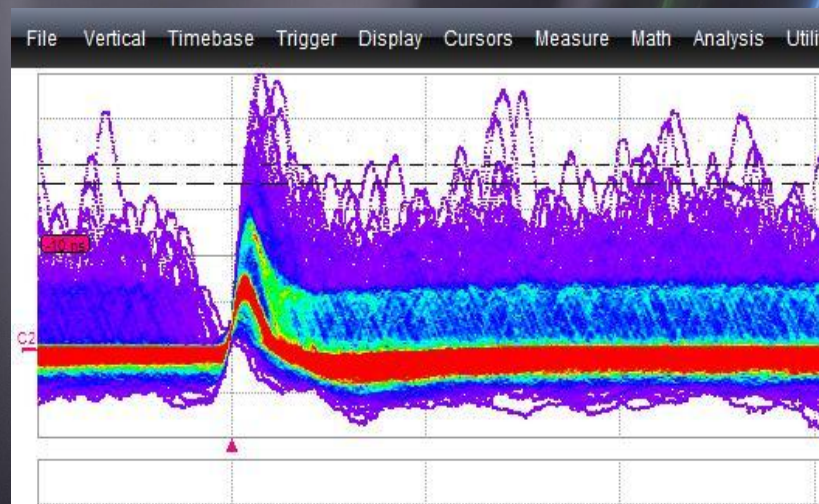
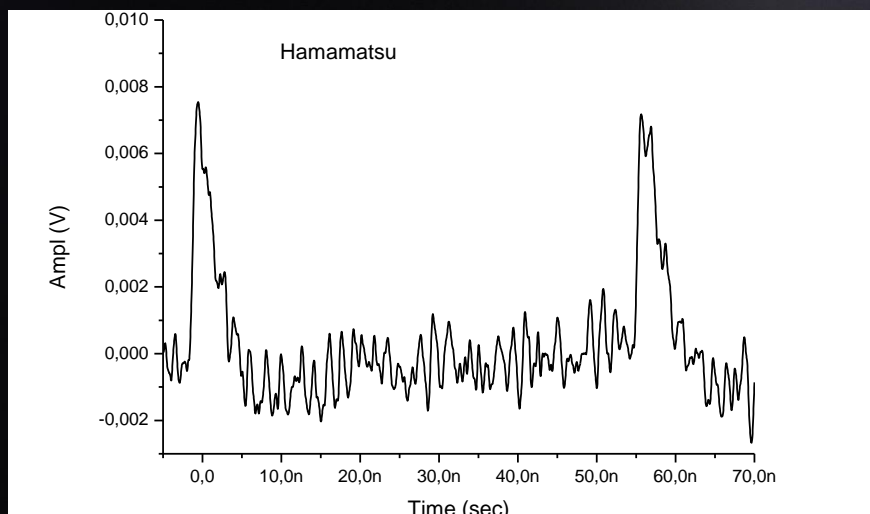
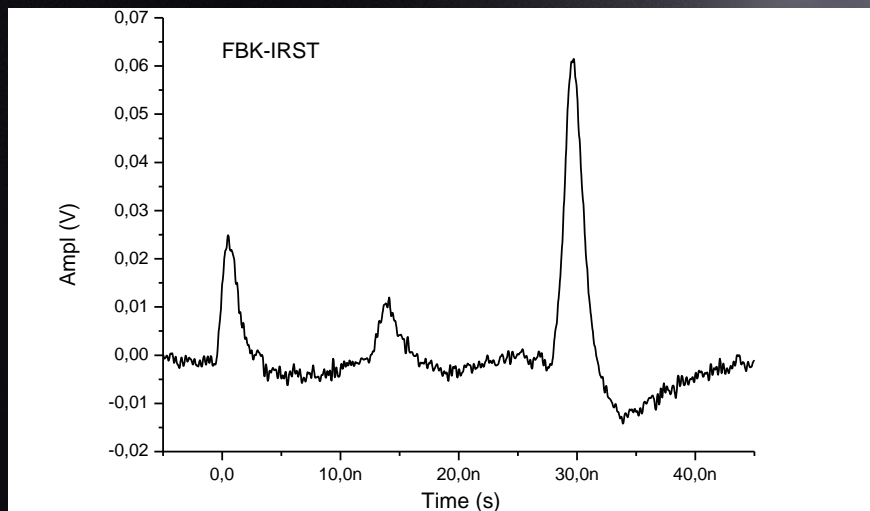


STATIC MEASUREMENTS

Temperature dependence



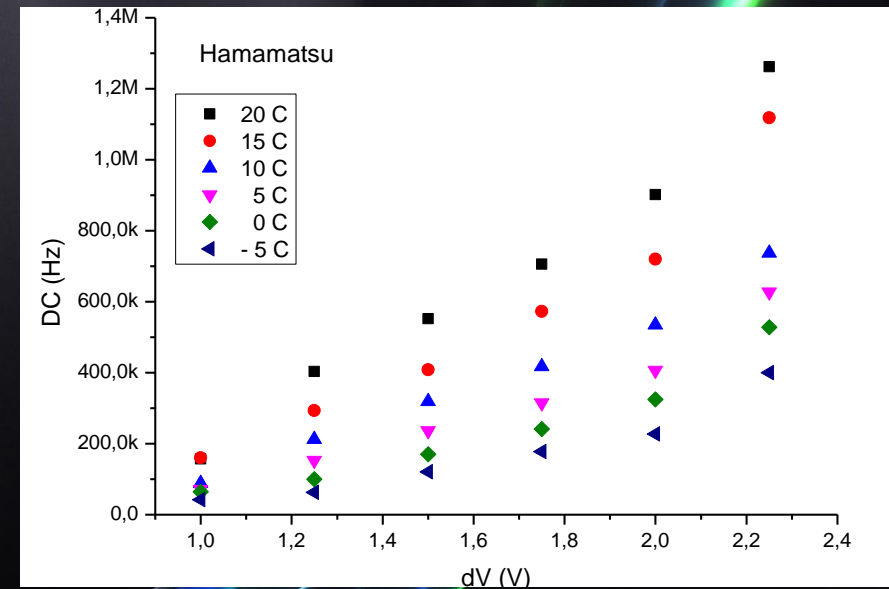
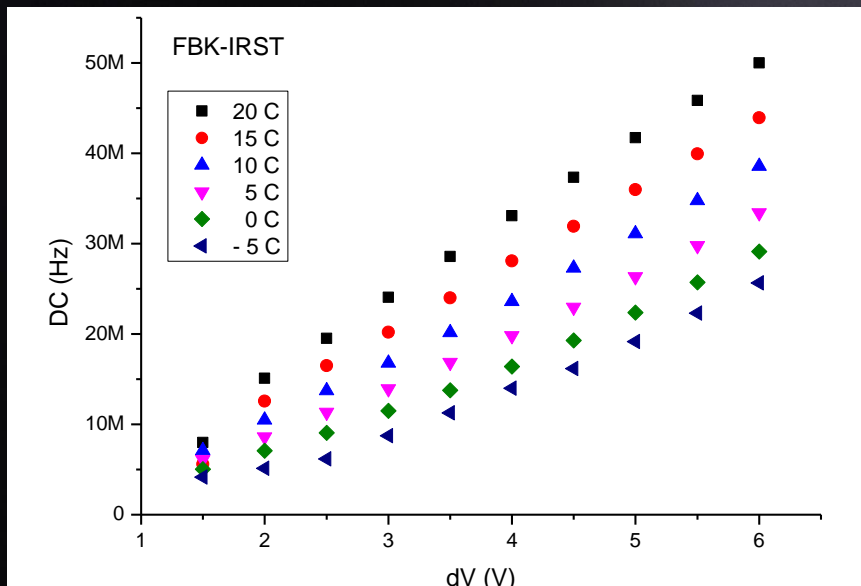
DYNAMIC MEASUREMENTS



- Hamamatsu has lower signal amplitude and makes more noise
- Rise time for both sensors is about of 550 ps
- Pre-amplifier makes some signal distortion (negative overshoot on the trailing edge of the pulse)

DYNAMIC MEASUREMENTS

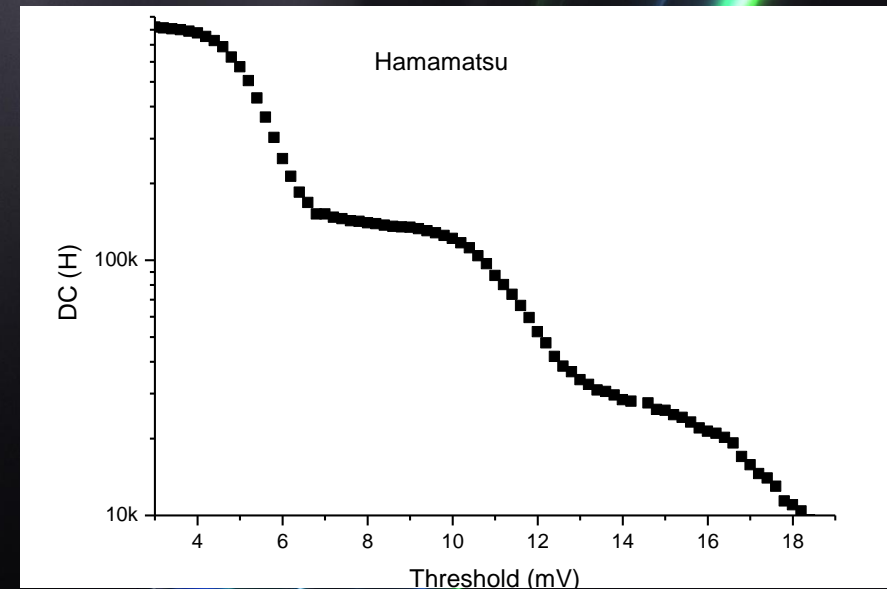
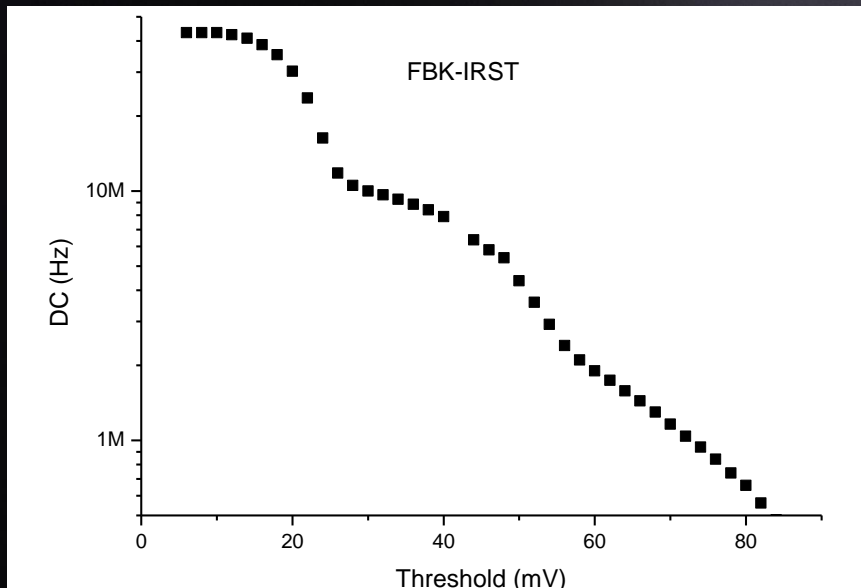
Dark count



DYNAMIC MEASUREMENTS

Dark count

- DC at 20 C and 5,5 V overvoltage
- DC at 20 C and 2 V overvoltage



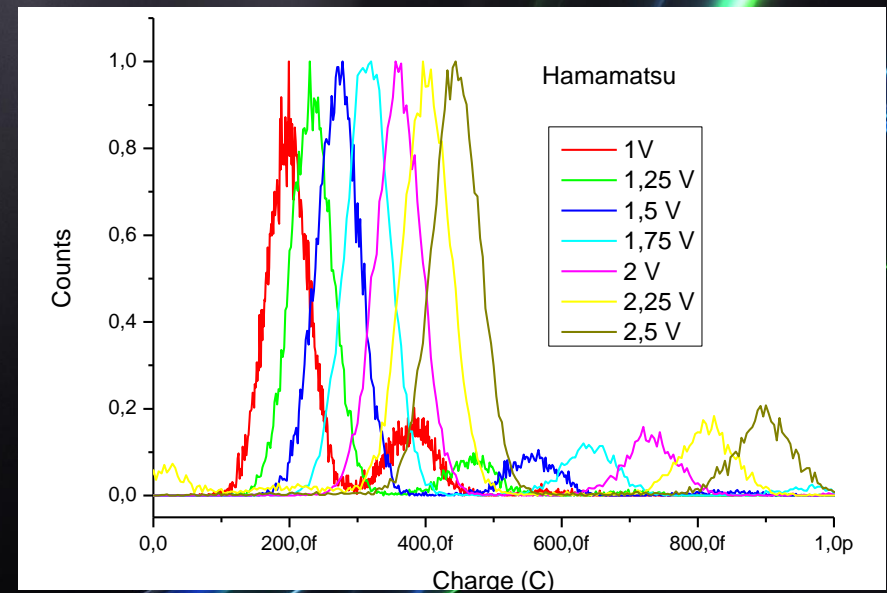
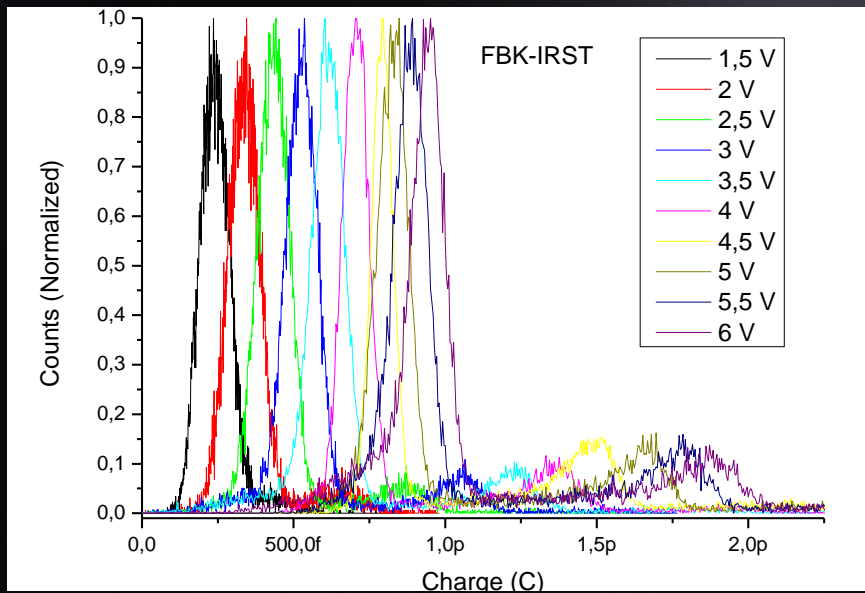
DYNAMIC MEASUREMENTS

Charge

Charge spectrum

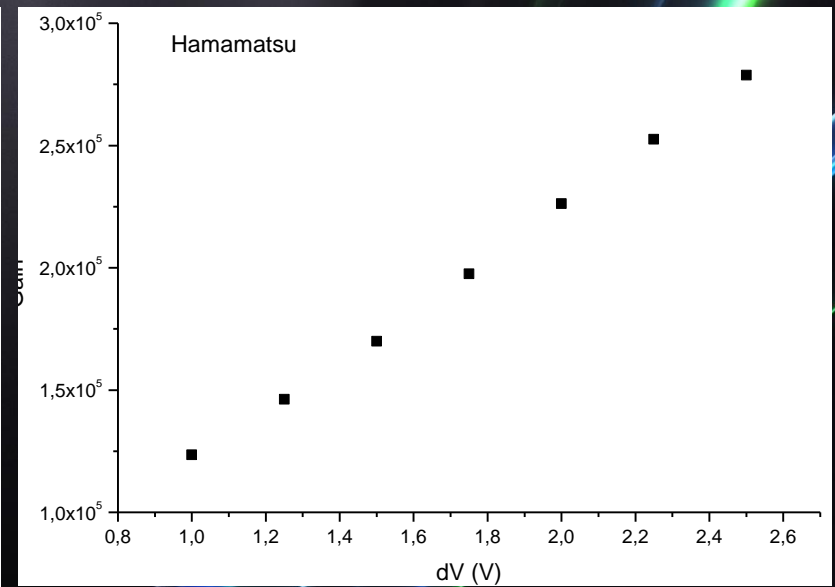
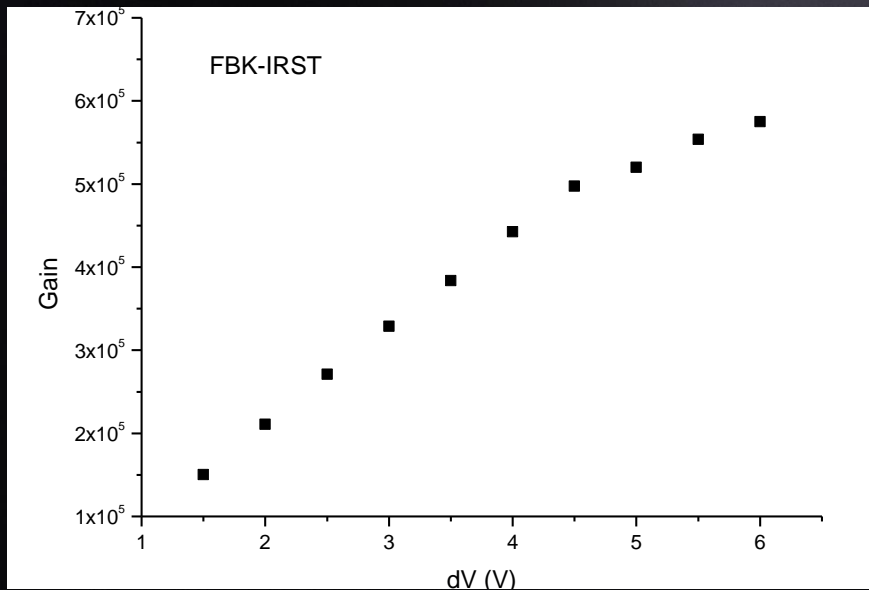
Integration time 5 ns

Signal is amplified by 10



DYNAMIC MEASUREMENTS

Gain



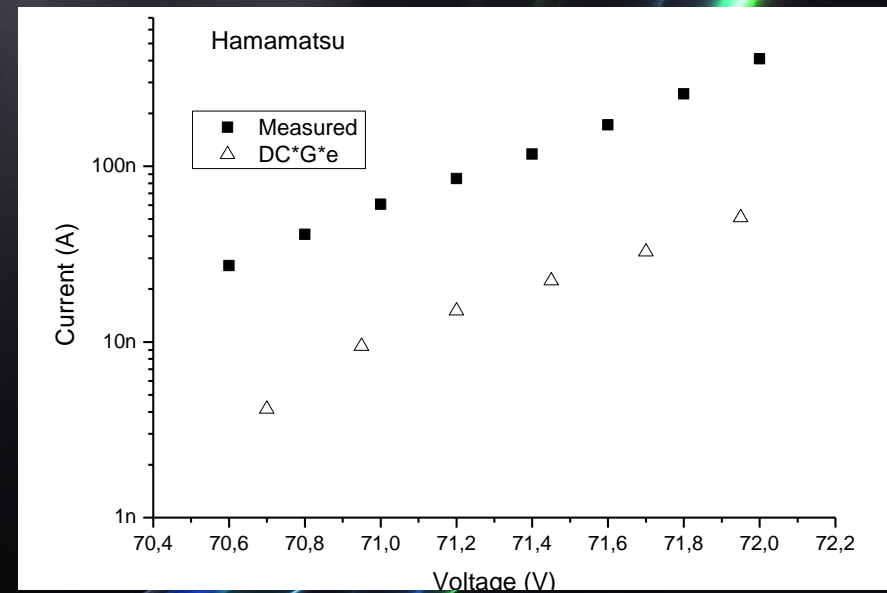
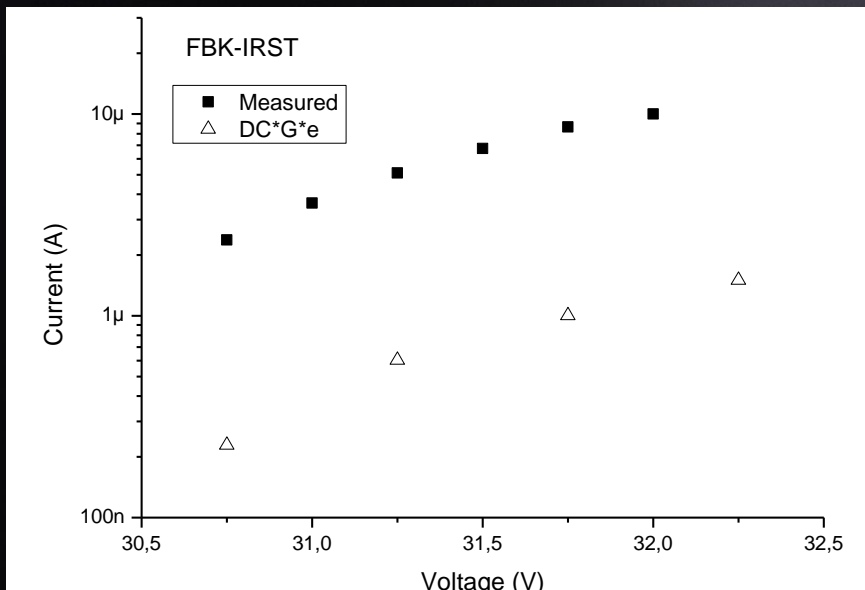
DYNAMIC MEASUREMENTS

Gain

- Current after breakdown measured and calculated

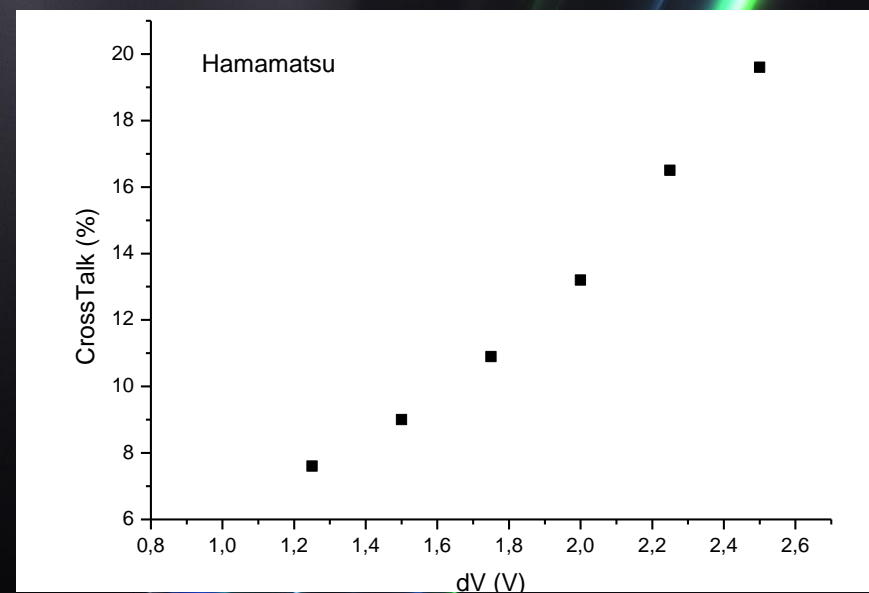
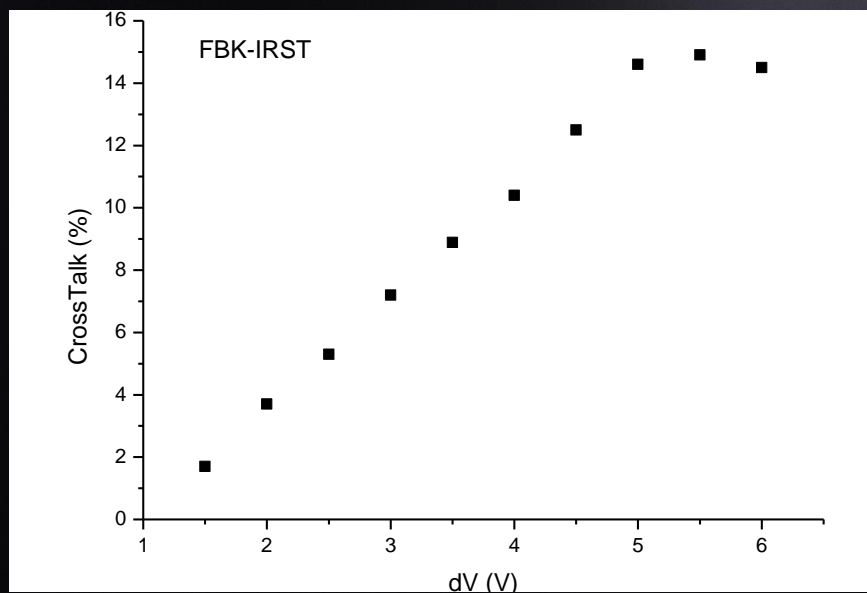
$$I = DC * G * e^-$$

Measured gain value is under-estimated in factor of 10



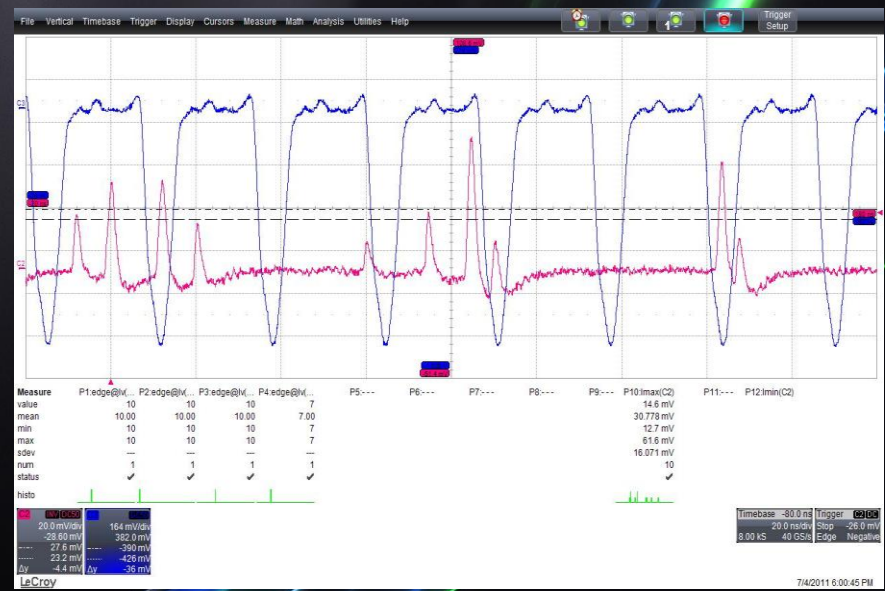
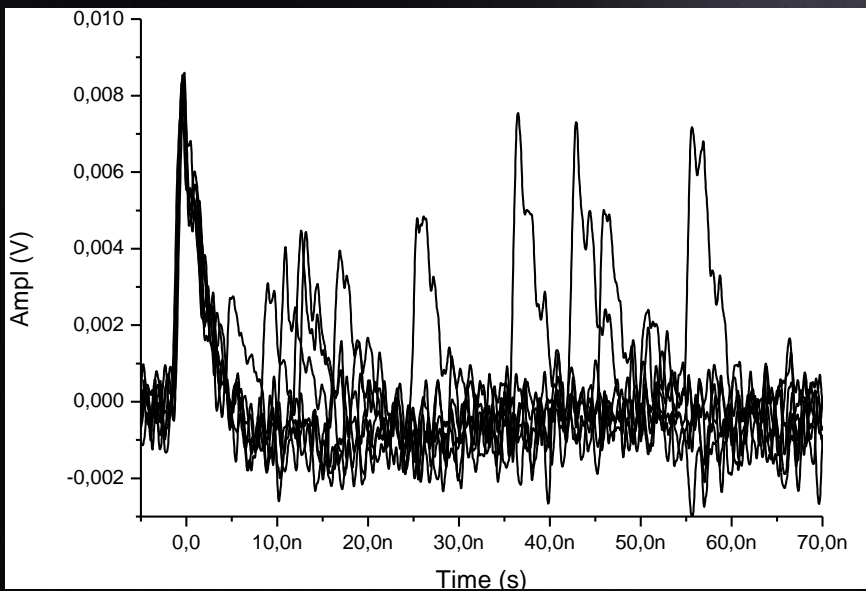
DYNAMIC MEASUREMENTS

Optical crosstalk



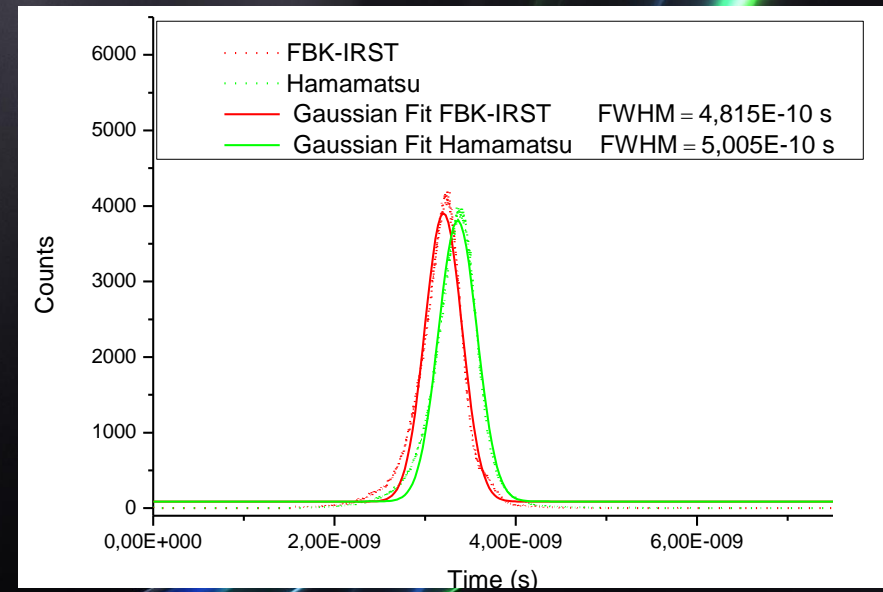
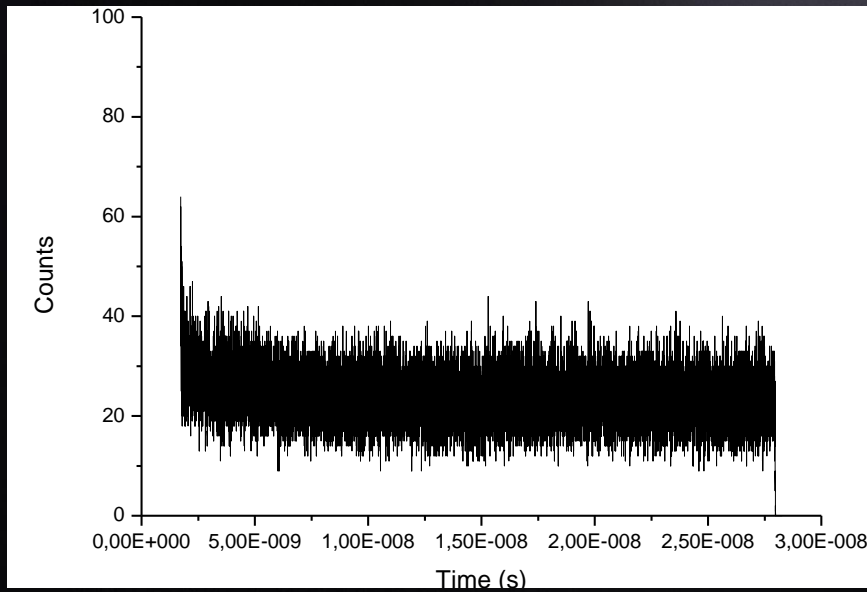
DYNAMIC MEASUREMENTS

Afterpulse



DYNAMIC MEASUREMENTS

Temporal characterization



CONCLUSIONS

FBK-IRST

- Operation voltage about of 32 V
- Work region = 5V
- Dark count = 5 – 50 MHz
- Signal amplitude = 5-30 mV
- Rise time = 550 ps
- Time distribution = 500 ps
- Gain = $1,5 - 5e5$
- Optical crosstalk = 2 – 15 %
- Preamp noise = 2.8 mV

Hamamatsu

- Operation voltage about of 70 V
- Work region = 2V
- Dark count = 0.05 – 1.3 MHz
- Signal amplitude = 3 – 8 mV
- Rise time = 550 ps
- Time distribution = 500 ps
- Gain = $1,2 - 2.8e5$
- Optical crosstalk = 7 – 20 %
- Preamp noise = 3.8 mV

CONCLUSIONS

Set-Up:

- Existing set-up allows perform static and signal characterizations. Received results show good capability and perspectives.

To improve:

- Optimize existing custom preamplifier. Test commercial amplifiers with high bandwidth
- Modify cooling system for temperature region up to -20 degree
- Afterpulse measurements
- Build set-up for optical measurements