Intensity monitor calibration for sFLASH

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1. Introduction

The Free-electron LASer in Hamburg (FLASH) is currently working in SASE regime. Starting from autumn 2009 there will be an upgrade of the machine. In the new configuration it will be possible to externally seed FLASH with High Harmonics generated (HHG) by an optical laser on a gas target (this project is called “sFLASH”). For the seeding option a new photon diagnostic branch will be installed to get detailed information about the beam. In the photon diagnostic branch a beam intensity monitor is foreseen. The intensity monitor relies on micro-channel plate (MCP) detectors and has to be calibrated. The aim of this work is to find the calibration factors for different beam intensities.

1.1. sFLASH

FLASH is working at the moment in SASE regime. Starting from noise, the SASE radiation consists of a number of uncorrelated modes and therefore there are shot-to-shot fluctuations in pulse energy and the longitudinal coherence is reduced. One possibility to reduce the fluctuation is to lengthen the electron bunch using a third harmonic cavity [1]. With this cavity bunches of about 200 fs can be generated and it will be possible to seed the electrons with a HHG source. This configuration allows to achieve higher shot-to-shot stability at GW-power level and the pulse duration will be in the order of 20-40 fs FWHM [1]. The output radiation will be in the range of 13-30 nm.

1.2. MCP detector

MCP (micro-channel plate) detectors are used in the intensity monitor in order to measure the radiation scattered from a gold mesh. The mesh scatters only a few percent of the incoming light. A MCP consists of conductive glass capillaries and every capillary works as an independent secondary-electron multiplier. Together they form a two-dimensional secondary-electron multiplier. The amplification factor is tunable in a great range by changing the voltage which is applied to the MCP.

In the intensity monitor designed for sFLASH, the scattered light can be detected with 3 different MCPs arranged as in Figure 1. Two MCPs are on axis with the incoming light and one is at 90° (at 45° with respect to the mesh). The MCPs on axis have a hole in the center so the light can pass through. All MCPs are double stage.

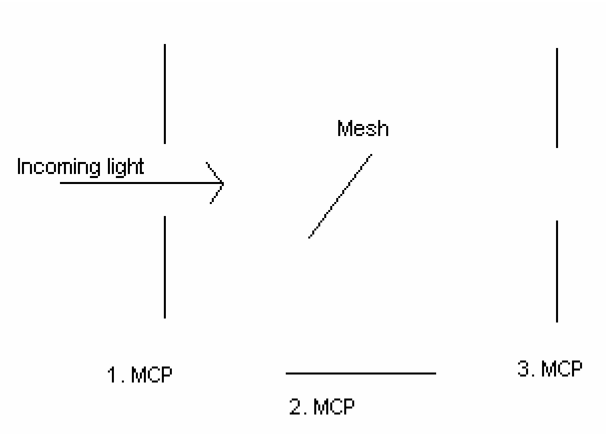

Figure 1. *Layout of the MCP detector*

2. Measurement

At different beam intensities the signal from the MCPs has to be cross-calibrated in order to get the absolute number of photons. The measurements have been performed at FLASH beamline BL1 (detailed description in [3]). The absolute number of photons is measured with two gas monitor detector (GMD). One GMD is installed in the FLASH tunnel before the attenuator and second is after the attenuator. The attenuator can be filled with different gases in order to change the transmission for the beam. Since the wavelength chosen for the measurements was 13.7 nm, the attenuator has been filled with Xenon which shows strong absorption exactly around this wavelength.

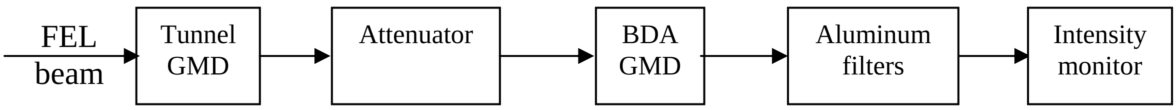

Figure 2. *Outline of the beamline BL1*

The transmission of the beamline is 65% [3]. Two aluminum filters with different thickness (200 nm and 137 nm) have been also used. The transmission coefficients at 13.7 nm are respectively 0.0042 and 0.0236.

During the measurements the FEL intensity has been attenuated combining the gas attenuator and the Al filters in order to span 6-7 orders of magnitude in photon flux. The voltage applied to the MCP has been changed in order to keep almost constant the output signal, this means the amplification factor has to be calculated offline.

The MCP signal goes through a stretcher and an ADC converter. The ADC output is sent to the DAQ and data are stored in a server.

3. Analysis and results

To access the data I used an interface tool [4] and to analyze the data I wrote a Matlab macro.

The MCP output is coming from the ADC. An example of ADC output is shown on figure 3. To evaluate the ADC output voltage I choose a window in the signal region, calculated the mean value and subtracted the noise level calculated from a window of the same length.

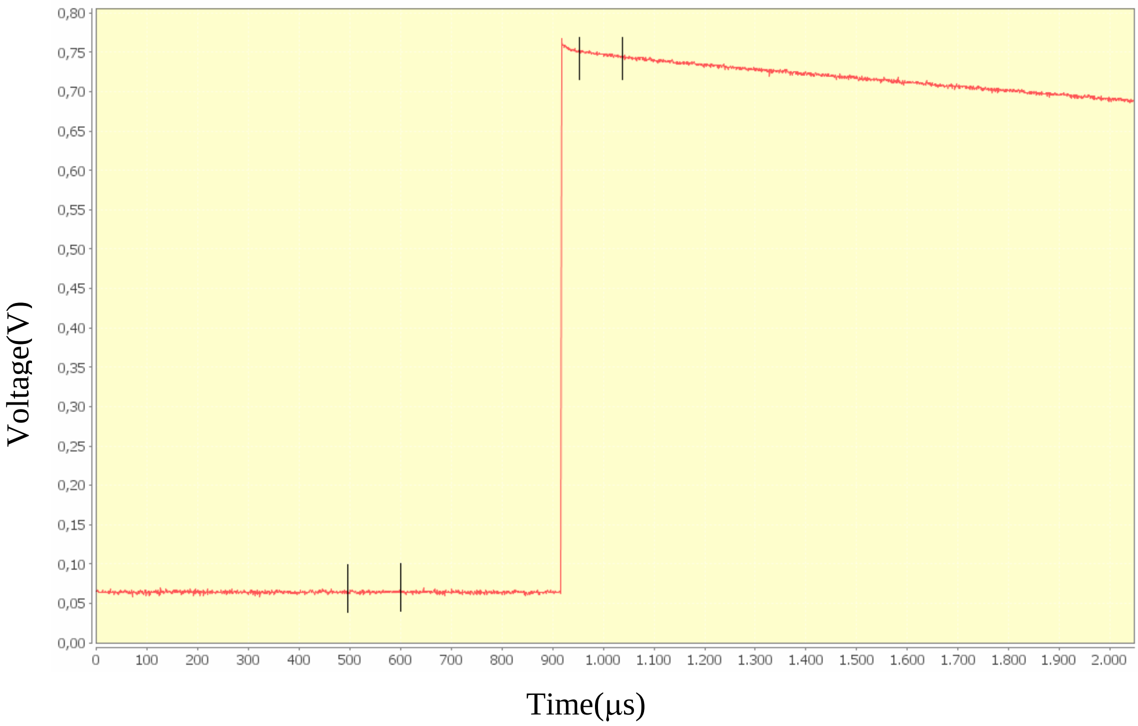

Figure 3. *ADC output. Taken area, for calculating noise and signal, is marked.*

The energy of the photon beam is derived from the GMD data. For each GMD there are two different channels. One channel is the (shot-to-shot) electron current and the other is the ion current (integrated over 20s). I normalized the electron current using the ion current.

When the transmission of the attenuator was more than 10% I used the data from the GMD after the attenuator. For lower transmission the GMD after the attenuator was not able to measure the energy of the beam, so I considered the GMD before the attenuator and I used the transmission of the attenuator in order to get the actual photon flux. I also took into account the beamline transmission and the attenuation due to filters.

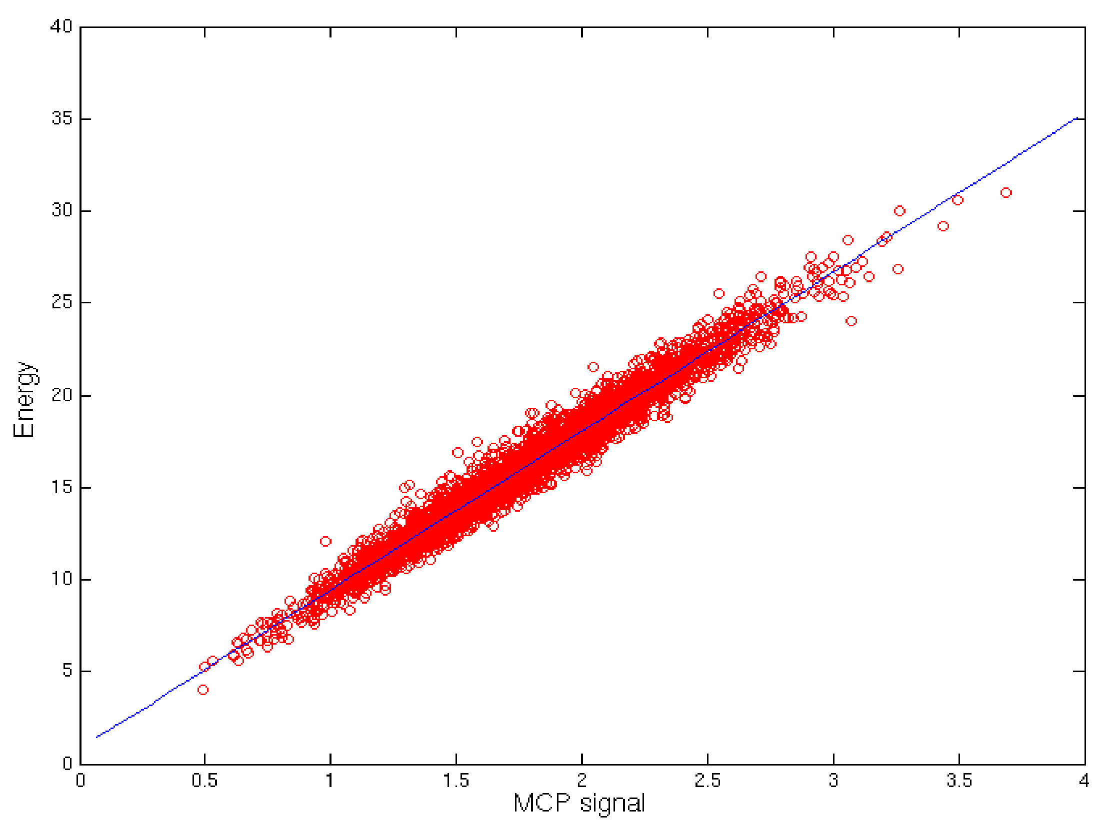

Figure 4. *Linear plot of beam energy (relative) versus MCP 3 signal.*

# run	attenuator transmission	filter1	filter2	mcp1 voltage	mcp2 voltage	mcp3 voltage
4295	100%	-	-	930	1130	670
4298	50%	-	-	970	1160	710
4300	10%	-	-	1040	1235	790
4302	1%	-	-	1110	1310	870
4306	100%	200nm	-	1350	1500	1050
4307	50%	200nm	-	1350	1500	1050
4309	10%	200nm	-	1500	1625	1190
4310	1%	200nm	-	1350	1500	1050
4313	100%	200nm	130nm	1650	1710	1350
4314	10%	200nm	130nm	1650	1710	1350
4315	1%	200nm	130nm	1650	1710	1350
4318	1%	200nm	130nm	1550	1610	1250
4319	1%	200nm	130nm	1500	1560	1200
4320	1%	200nm	130nm	1450	1510	1120

Table 1. *Used data sets*

The first step was to get for every data set a linear fit of the energy versus the MCP signal (figure 4) and then to combine into one graph all data for different photon fluxes in order to demonstrate the wide range (figure 5). After that I estimated the amplification factors for every run looking at regions where different runs (voltage settings) measured the same pulse energy. Once the amplification factor is found, it is possible to shift the corresponding ADC data in order to "normalize" with respect to the applied voltage.

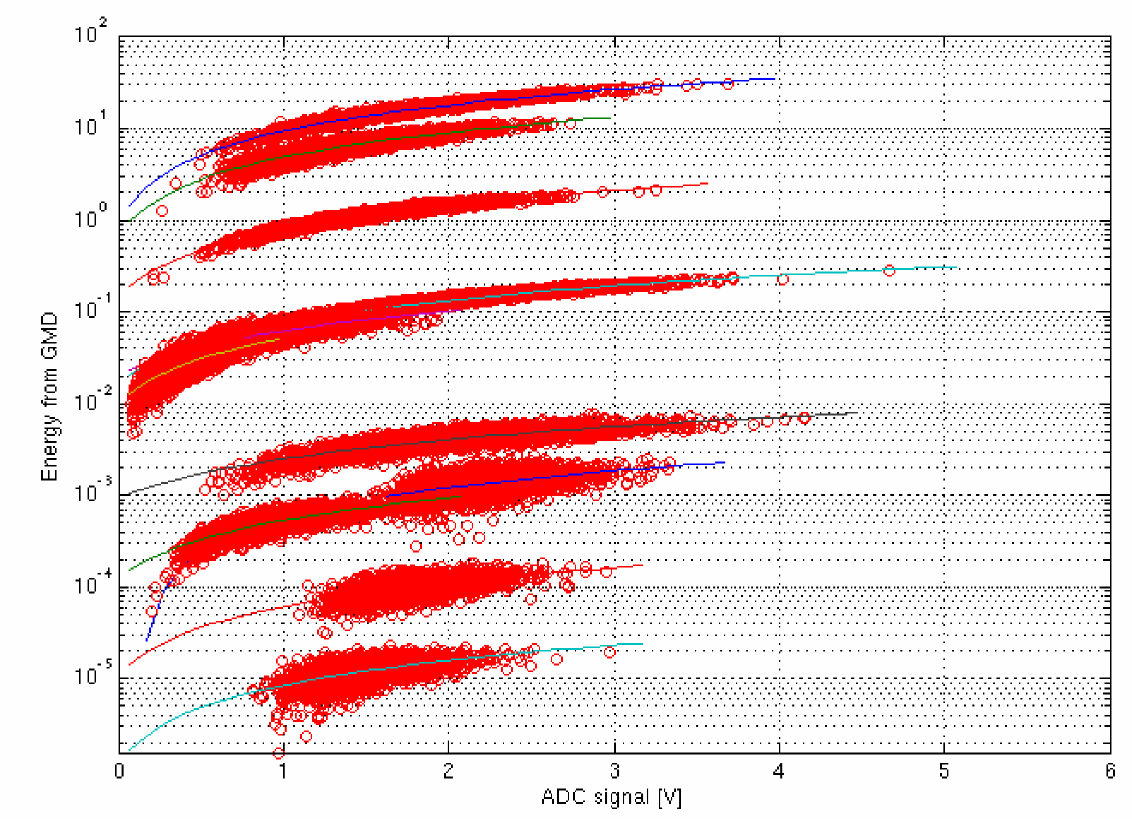

Figure 5. *Measurements data for MCP 3*

In the energy range where two runs have the same intensity, I found the mode value for the ADC output for both runs and then I used the mode value to calculate the shifting factor. I shifted the data with the lower photon flux. For all the three MCP channels the same shifting parameter was used and for all three MCP the results were similar. Results after the shifting for MCP 1, MCP 2 and MCP 3 are presented in figure 6, 7 and 8.

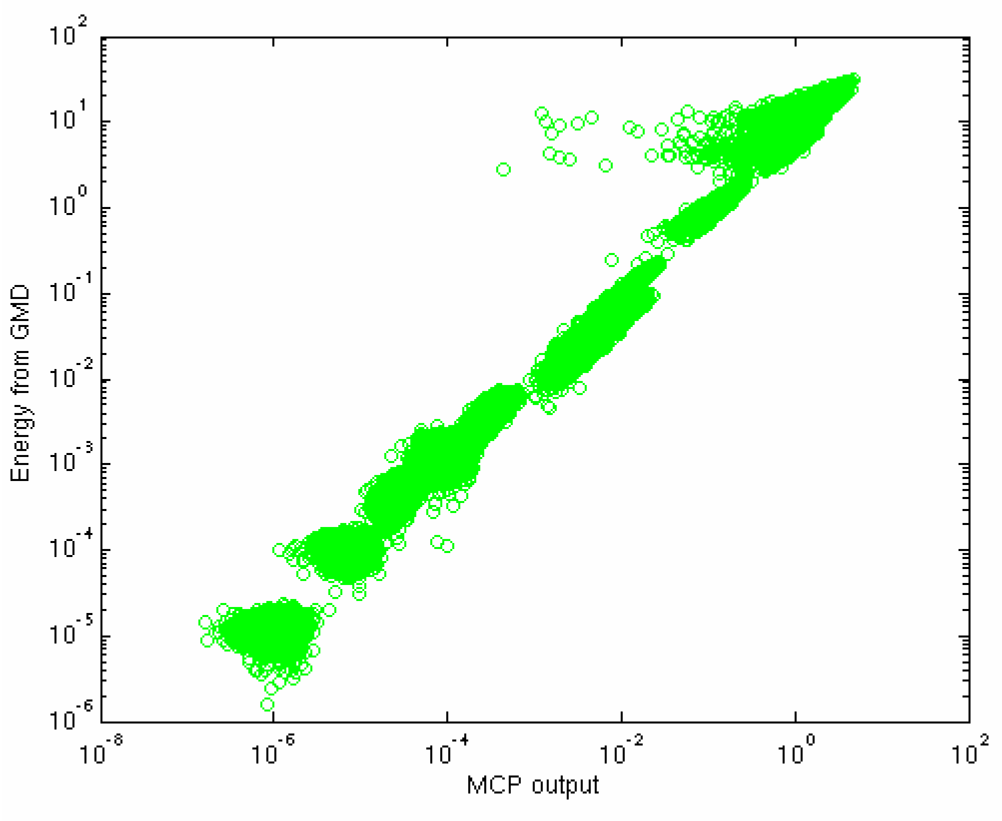

Figure 6. *Data after shifting for MCP 1.*

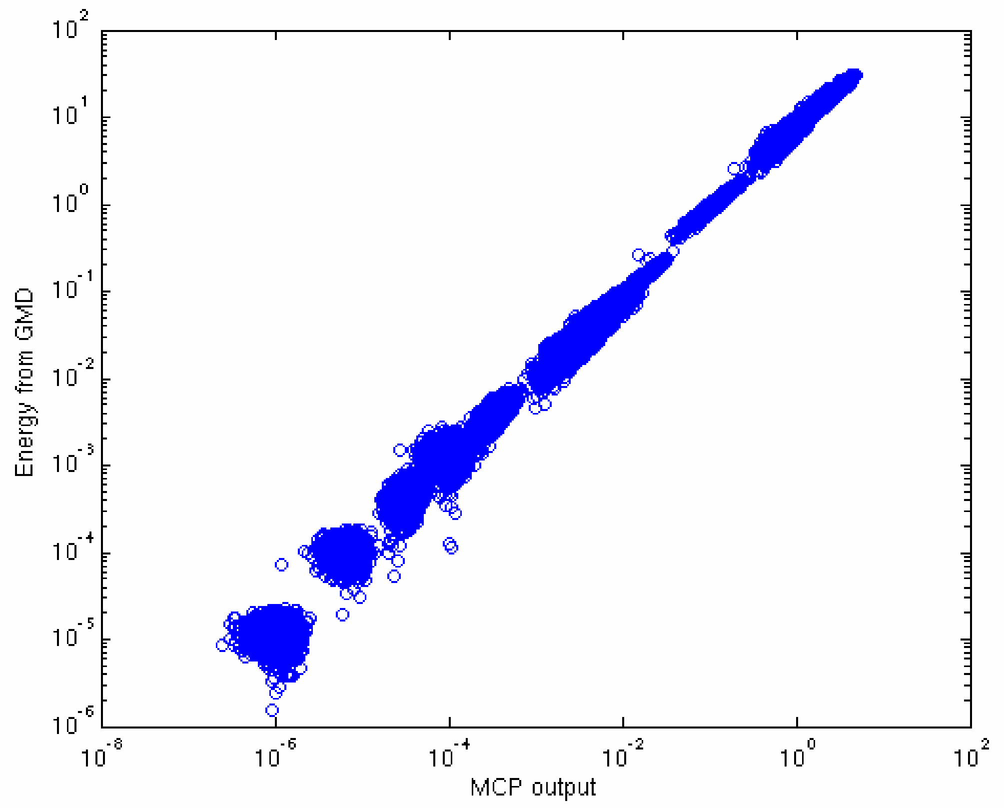

Figure 7 *Data after shifting for MCP 2*

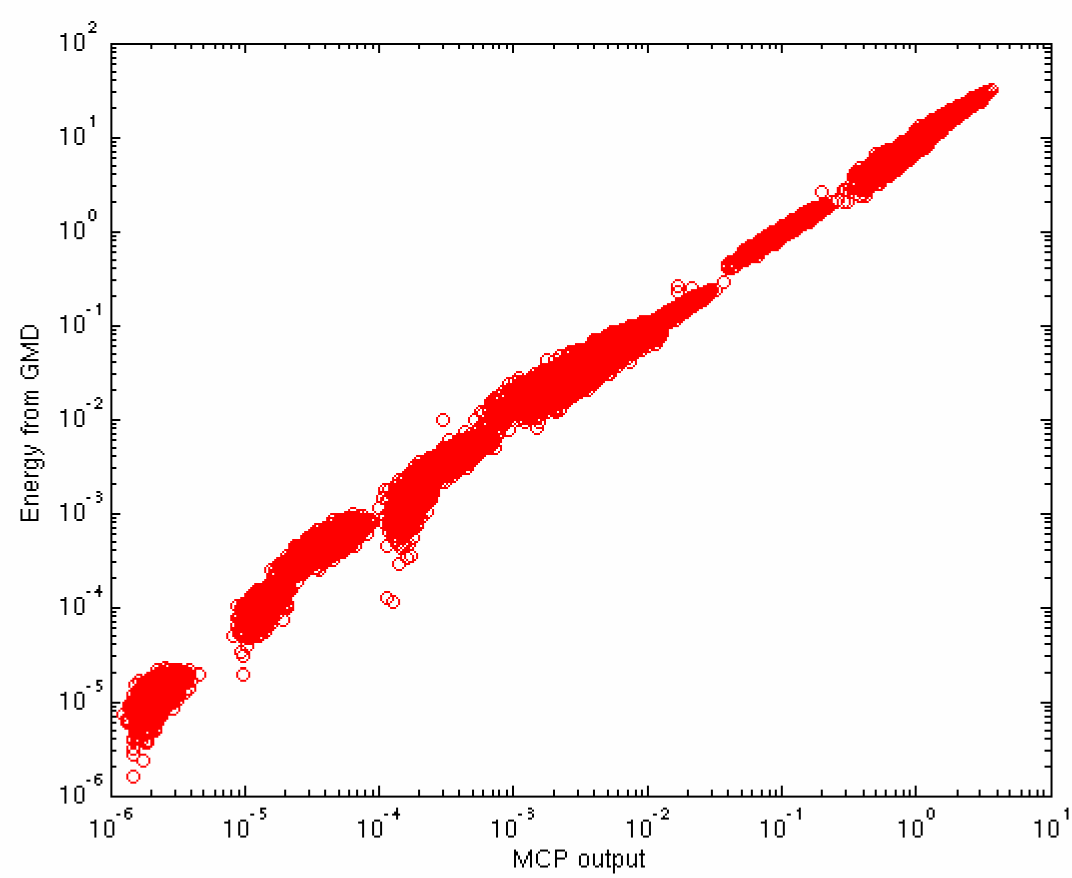

***Figure 8** Data after shifting for MCP 3.*

Four measurements have been made keeping constant the photon flux and changing the MCP voltage in small steps. From the shifting parameters for these four measurements it is possible to plot relationship between shifting parameters and MCP voltage. These shifting parameters are the gain with respect to the gain of the measurement which had the maximum MCP voltage. Knowing the absolute gain for the maximum MCP voltage it is also possible to calculate the absolute gain for other voltages. After finding a good fit it is possible to calculate for every voltage the relative gain. I fitted the data points with an exponential function which is shown on Figure 9. From the exponential fit it is possible to give an estimation of the shifting parameter but not an exact value. Four points are few points and for more exact values there are needed more data points.

In [2] the MCP gain curve was extrapolated with a polynomial. Polynomial is

$$\log_{10}(G) = a_0 + a_1V + a_2V^2 + a_3V^3.$$

I tried also this polynomial for extrapolating but I was not able to extrapolate the curve. In this case there are to view data points.

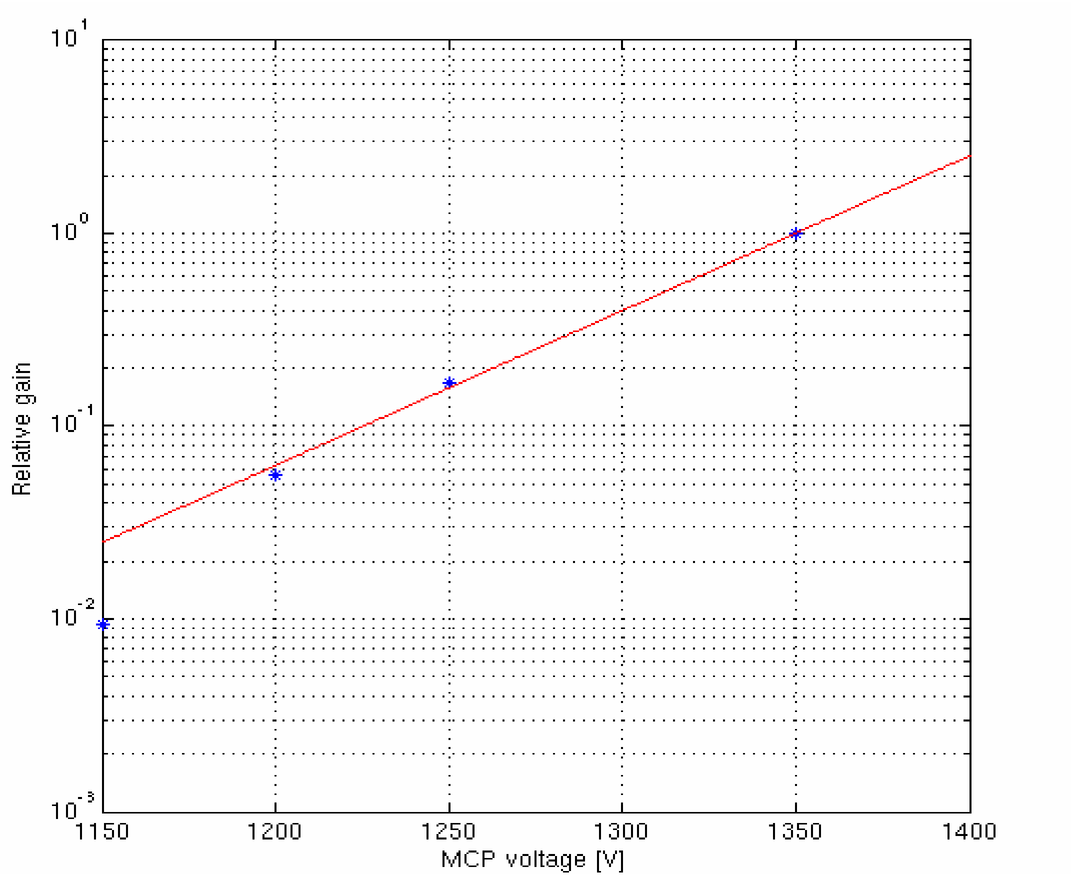

Figure 9 *Relative gain versus MCP voltage. Red line is exponential fit.*

4. Summary

MCP outputs were measured for different beam energies in order to cross-calibrate the intensity monitor with the GMD detector. For different beam energies the voltage applied to the MCPs was not constant and different amplification factors have been calculated. It was also possible to find a relationship between the relative gain and the applied voltage for the MCP and from this is possible to get an absolute gain curve.

References

1. A. Azima et al., “Experimental layout of 30 nm high harmonic laser seeding at FLASH”, Proceedings of EPAC08, 127-129, MOPC028 (2008)

2. A. Bytchkov et al., “Development of MCP-based photon diagnostics at TESLA Test Facility at DESY”, Nuclear Instruments and Methods in Physics Research A 528, 254–257 (2004)

3. K. Tiedke et al., “The soft x-ray free-electron laser FLASH at DESY: beamlines, diagnostics and end-stations,” New Journal of Physics 11, 023029 (2009)

4. V. Rybnikov, “FLASH DAQ for experts,” presentation 23.04.2009