Quadrature Detector Readout using the TetrAMM Picoammeter

Introduction. The **position** and the **intensity** of a photon beam can be monitored with several techniques and using a variety of different detectors – e.g. blade gap-monitors, ionization chambers, diamond detectors, photodiodes. This task is commonly called photon beam position monitoring (phBPM).

The cited procedure is almost always performed in synchrotron light sources beamlines, where the intensity and the position of the emitted light can have a strong or at least a non-negligible impact on the experimental results.

All beam detecting systems give **charge-related** or **current-related** information that needs to be correctly evaluated and converted in order to extrapolate the desired information – i.e. position and intensity. A dedicated readout system, as the **TetrAMM**, shown in Figure 1, or the AH401D and AH501D picoammeters, is the turnkey solution both for the bias and for the readout of the sensor system.

Figure 1: *TetrAMM - Front View*

The information given by the TetrAMM picoammeter can be used either for local beam-alignment purposes or can be integrated into a global system – e.g. orbit feedback – in order to give the global control algorithms additional information, in conjunction with the electron BPMs, on the beam characteristics.

Example. The system object of this application note is composed by a single carved copper block on which four different blades, placed at 90° one from the other, are fixed and form the beam sensor core as shown in Figure 2. These blades ar made by TZM, a metallic alloy mainly composed by titanium, zirconium and molybdenum.

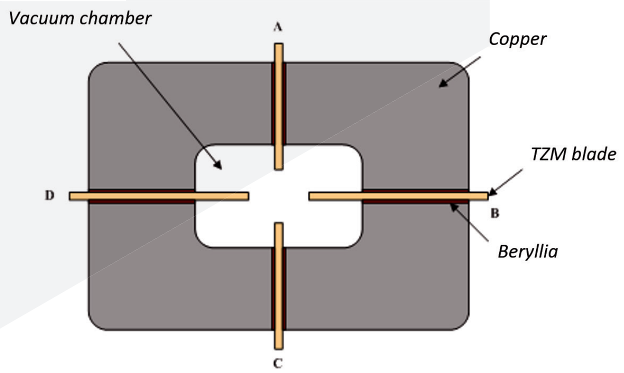

Figure 2: *Blade Quadrature Detector - Structure*

A thin layer of beryllium oxide – i.e. beryllia (BeO) – is placed between the blades and the copper block in order to avoid electrical contact between the parts; moreover, this particular building configuration allows only the fringes of light to come into contact with the beam in their "rear" part.

The application of a positive **bias voltage** between the metallic structure of the vacuum chamber and the copper block, as shown in the corresponding figure generates an electric field that favors the electron collection by the copper block itself. In doing this, the photo-emitted electron cloud is immediately removed from the chamber, thus limiting the recombination on the blades.

Setup. The application of a positive bias voltage between the metallic structure of the vacuum chamber and the copper block, as shown in Figure 3, generates an electric field that favors the electron collection by the copper block itself. In doing this, the photo-emitted electron cloud is immediately removed from the chamber, thus limiting the recombination on the blades.

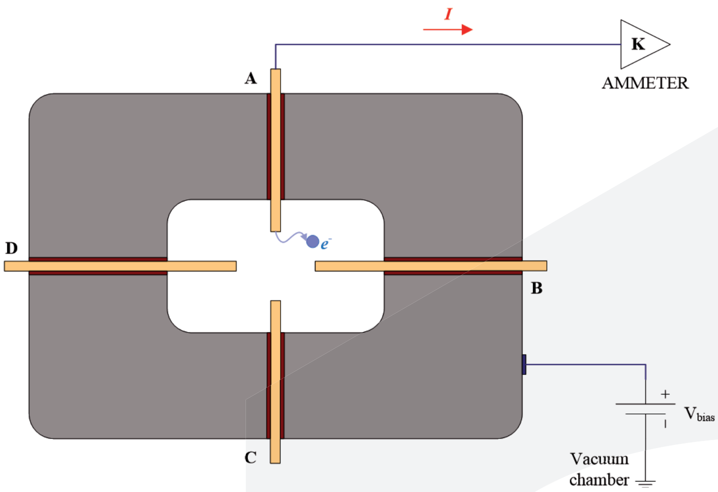

Figure 3: *Detector Bias and Current Readout scheme*

The application of this voltage, obtainable from the TetrAMM, which is capable of sourcing up a **programmable voltage** (up to 4 kV in some models), is feasible only by the presence of the dielectric material between the blades and the copper.

An external device, named K, in this case connected only to blade A, must re-establish the lost photo-emitted charge that, by convention, being composed by electrons – i.e. negative charge – implies that the current direction is "outgoing". It is now clear that the device K needs to be capable of sinking the current I from the blade. By the evaluation of the photo-generated current on each blade it is possible to obtain the photon beam position inside the vacuum chamber and its relative intensity.

The current generated from the blades by photoemission, in a real application, it is not directly proportional to the incident light intensity but is strongly influenced, in principle, by two main factors: the work function and the electric field. The work function, which is defined as the energy threshold that has to be supplied to metal in order to extract an electron, it is strongly dependent on the incident light wavelength; in this case, the light it is not monochromatic but it is extended over a wide range of spatial frequencies. Moreover, the generated current relies on the incident photon quantity. The extracted electrons tend to form an electric field that stands out against the additional extraction of negative-charged particles: for relatively high current values the ratio between the photo-emitted charges and the light intensity decreases and the signal does not proportionally increase with the light intensity.

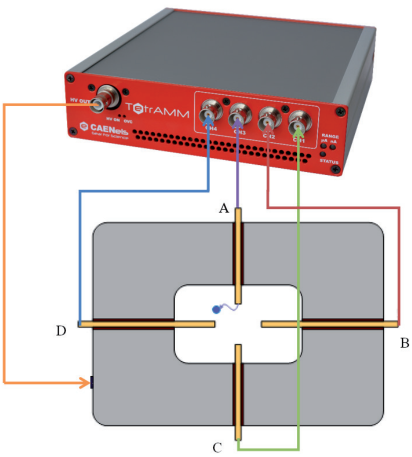

Figure 4: *TetrAMM connections*

Readout. The TetrAMM picoammeter has an **integrated voltage source** that can be used as the V_{bias} for the detector and can be set up to a programmable value and polarity. The connections of the TetrAMM to the blade gap-monitor need to be carried out as indicated in Figure 4. The current generated on each blade can be monitored by the **four independent input channels** on the front panel of TetrAMM and the copper block can be biased through the voltage source SHV connector on of the device, as shown in the same figure. The sampling of the current is performed at **100 ksps** and **24-bit** resolution.

It is thus possible to have a simple evaluation of the beam barycentre relative position inside the vacuum chamber for the used detecting system by simply applying the formulas presented in (1).

$$\begin{cases} X = \dfrac{I_B - I_D}{I_B + I_D} \\ Y = \dfrac{I_A - I_C}{I_A + I_C} \end{cases} \quad (1)$$

In some cases, where a second BPM is installed on the same beamline, the blade system is rotated CW by 45° in order not to get shadowed by the first blade set and the computation needs to be modified; equations presented in (2) are used for a 45-degree rotated blade BPM system. These computations – i.e. (1) and (2) – only give a simple estimation of the relative beam barycentre position inside the vacuum chamber: X and Y are normalized values included between -1 and 1 and they are simply obtained by dividing the non-normalized positions by the beam "intensity", which is the sum of the values used in the computation of the specific spatial coordinate.

$$\begin{cases} X = \dfrac{I_B+I_C-(I_A+I_D)}{I_A+I_B+I_C+I_D} \\ Y = \dfrac{I_A+I_B-(I_C+I_D)}{I_A+I_B+I_C+I_D} \end{cases} \quad (2)$$

The estimated beam position using (1) and (2) is only an approximation of the real barycentre and this is due to several physical and geometrical factors; anyhow, it is a good **linear approximation** around the point (X,Y) = (0,0), exactly where the system is meant to work during normal operation.

Software. The included software application, named **TetrAMM Oscilloscope**, allows for easy control and configuration of the TetrAMM units. Acquisition time window, sampling frequency, bias voltage and interlock can all be configured from this software package. The GUI also includes the possibility to select the **detector geometry**, to directly compute and plot **position** (X and Y) and **intensity** (I_0), to visualize **frequency spectra** on each channel (FFT) and a **real-time plot** for the beam position as shown in Figure 5.

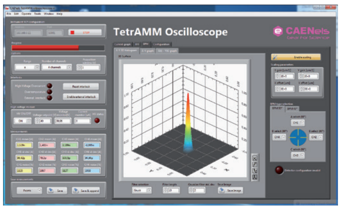

Figure 5: *Oscilloscope*

Results. Experimental results on several synchrotron beamlines have been collected during the years; some sample results are hereafter presented. The TetrAMM is directly mounted on a 90° blade gap-monitor detector installed in the first part of the beamline. The measurements are done in order to see the effects of the machine global orbit feedback,

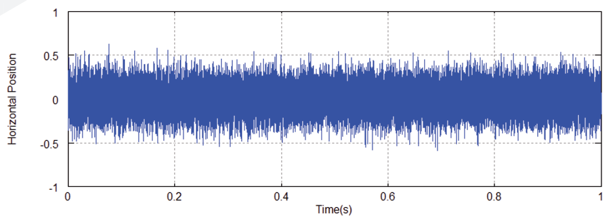

Figure 6a: *horizontal position with feedback off*

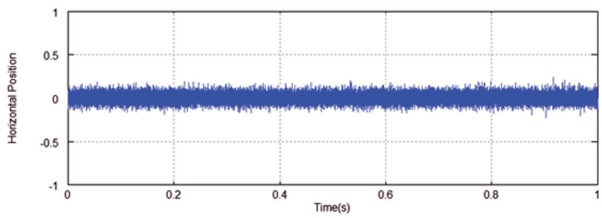

Figure 6b: *horizontal position with feedback on*

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performed by correcting the beam trajectory using corrector magnets.

The time-based waveforms of the estimated normalized horizontal position are shown in Figure 6a and 6b.

The measured beam barycentre relative positions are shown in Figure 7a and 7b.

Figure 7a and 7b are obtained from multiple TetrAMM samples of the measured photon beam position: the effects of the global feedback on the **beam barycentre** are clearly visible, being the electron cloud in Figure 7b - i.e. feedback enabled - a lot reduced compared to the one in Figure 7a. The results show how the global feedback reaches the goal of a photon beam stabilization as an indirect effect of the electron beam stabilization into the storage ring.

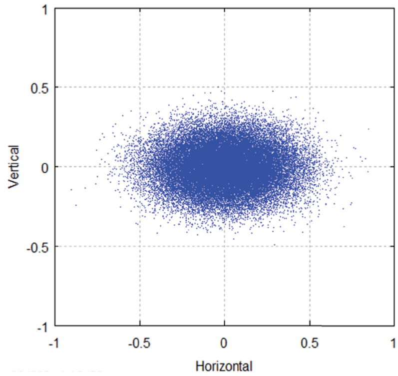

Figure 7a: *photon beam barycentre with global feedback off*

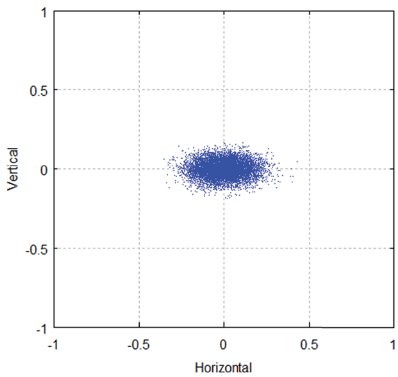

Figure 7b: *photon beam barycentre with global feedback on*

In this sample case, the beam stabilization caused by the enabling of the machine global orbit feedback can be easily evaluated by comparing the waveforms obtained from the TetrAMM readout system, demonstrating how the presented picoammeter can be a turnkey solution also for photon beam monitoring purposes. The **equivalent input noise** level of the TetrAMM devices is extremely low and it depends mainly on the full-scale range value and the sampling frequency. The equivalent input current noise of a standard TetrAMM with a full-scale range of ±120 microAmpere versus the sampling period is plotted in Figure 8.

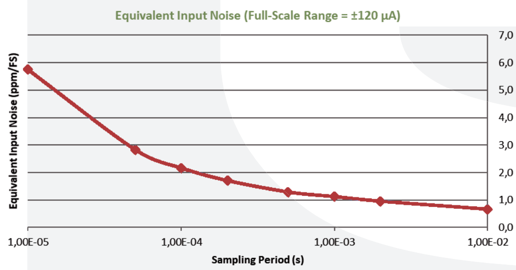

Figure 8: *Equivalent Input Noise*

Ordering. Different TetrAMM models, differing by the **full-scale ranges**, the **analog bandwidth** and by the High-Voltage bias configuration are commercially available. The **low-noise PS1112S AC adapter** is included in the bundle. Please visit the corresponding product page on our website www.caenels.com in order to choose the ordering code that perfectly fits your application.

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