temSlowDriftCompensator

Release 1.0

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Introduction

The TemSlowDriftCompensator device is designed to provide a compensation to PPL [1] beam pointing instabilities, such as drift of steering mirrors, air turbulence, and thermal effects of the optical elements. This feedback loop [2] is obtained here using the Aligna system by TEM Messtechnik [3] in combination with a Basler camera. Hereafter the Aligna device will be referred to as TEM.

The TEM is capable to maintain the beam axis stable over relatively fast time-scales in the area where its actuators (mirrors) and position detectors (cameras) are located. Unfortunately, a slower drift is also observed after the super-continuum generation (SCG) downstream the beamline. To overcome this issue, a Basler camera was added as position sensor to measure the beam pointing (far-field) after the SCG (using an image processor). The TEM hardware is controlled by a Karabo device of class TemBeamLock via one of the two channels of a Lantronix interface [4]. The principle of operation of the TEM-related feedback loop as well as the description of its corresponding Karabo device are described in TemBeamLock.

The principle of operation of the *slow* feedback loop is described in the following. Via calibration, a linear correlation is extracted between the position to be set and kept in one sensor (S_x, S_y) of the TEM (its *setpoint*) and beam position measured in the camera (B_x, B_y), determined using Gaussian fits of the profiles along the x- and y-axis,

$$S_x = \alpha_x \cdot B_x + k_x,$$
$$S_y = \alpha_y \cdot B_y + k_y,$$

and the coefficients α_x and α_y are determined.

Using this correlation one can shift the beam position at the camera location by accordingly changing the setpoint in the TEM, e.g.,

$$\Delta S_x = \alpha_x \cdot \Delta B_x.$$

Thus, in case a beam drift $\Delta B_x = B_x' - B_x^0$ was observed, to bring the beam back to the desired position in the camera the shift $\overline{\Delta B_x} = -\Delta B_x$ should be induced. This is achieved using the calibration linear function, above mentioned,

$$\Delta S_x = \alpha_x \cdot \overline{\Delta B_x},$$

changing the TEM setpoint to the new value

$$S_x' = S_x^0 + \alpha_x \cdot \overline{\Delta B_x} = S_x^0 - \alpha_x \cdot \Delta B_x.$$

[1] M. Pergament et al., "Versatile optical laser system for experiments at the European X-ray free-electron laser facility", Opt. Express 24, 29349-29359 (2016)

[2] K. J. Åström and R. M. Murray, "Feedback Systems: An Introduction for Scientists and Engineers", Princeton University Press, ISBN 978-0-691-13576-2, https://resolver.caltech.edu/CaltechBOOK:2008.003

[3] Automated Laser Beam Alignment and Stabilization System (Aligna), TEM Messtechnik, http://www.tem-messtechnik.de/EN/aligna.htm

[4] Lantronix External Device Server UDS2100, https://www.lantronix.com/products/uds2100/

The temSlowDriftCompensator device will thus change the TEM setpoints S_x and S_y in order to keep the beam at the reference coordinates (B_x and B_y, respectively) on the camera.

The drift compensation loop parameters are configurable. Its functioning can be monitored through the Karabo device, Fig. 1.1,
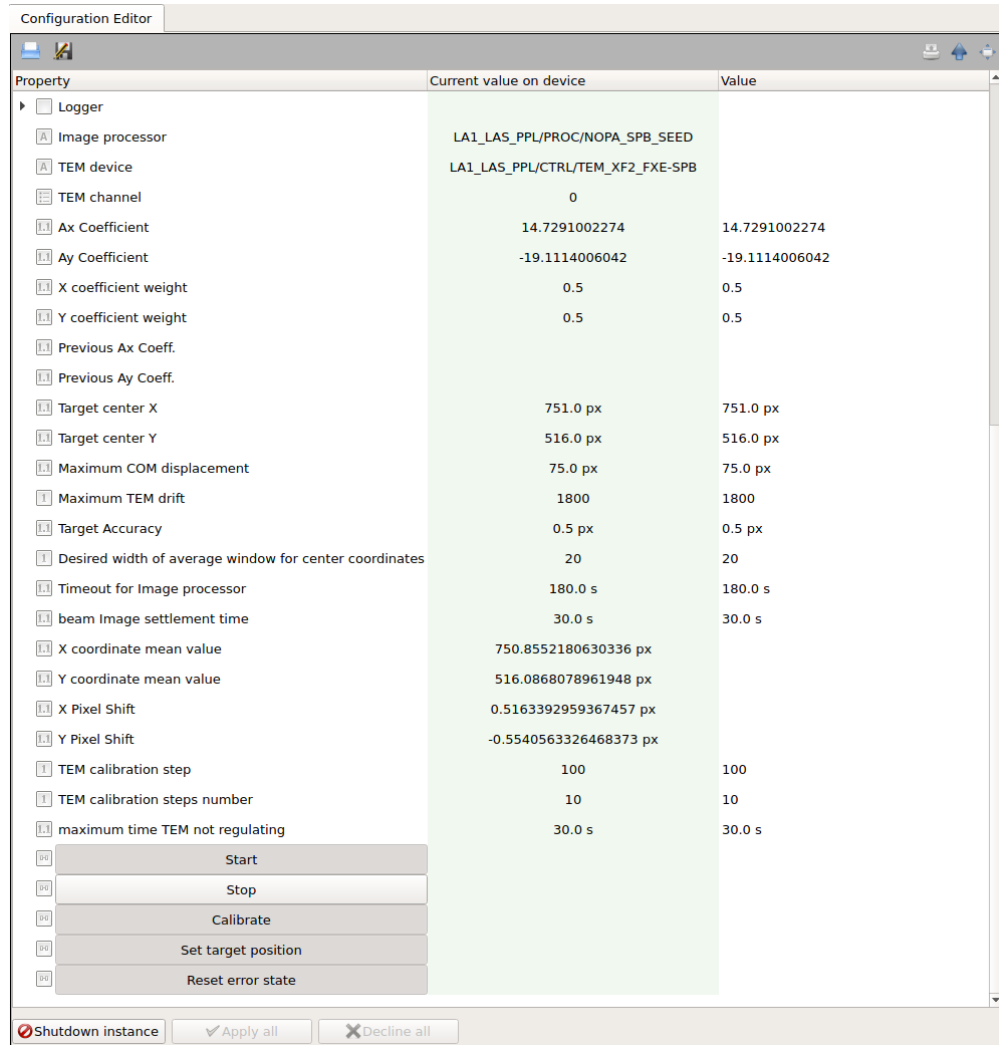

Fig. 1.1: Configuration Editor of the temSlowDriftCompensator device.

The Karabo ID of the image processor device (analyzing the data from the camera external to the TEM) should be provided before instantiation in the "**Image processor**" parameter, as well as the name of the karabo TEM device ("**TEM device**"). The channel to be used ("**TEM channel**") is also mandatory.

The desired value for the beam coordinates in the camera should be set in the parameters "**Target center X/Y**". The actual beam position and displacement from the reference coordinates are displayed by the parameters "**X/Y coordinate mean value** and **X/Y Pixel Shift**", respectively. The beam position is presented as the average over N measurements, where N is set by "**Desired width of average window for center coordinates**". The maximum allowed displacement with respect to the reference coordinates should be set in "**Maximum COM displacement**" (here COM stands for center of mass of the beam profiles measured along the camera x- and y-axis). In case the beam displacement exceeds this value the device state will go to error. The parameter "**Timeout for Image processor**" is the time to wait before going into error when the image processor is not updating its values.

By clicking the button **Calibrate**, the calibration procedure is performed and a functional relation between the beam position values in the camera and the setpoint values in the TEM is extracted (for both the x-axis and y-axis) via a linear fit. The slope parameters extracted in the calibration are shown in the variables "**Ax Coefficient**" and "**Ay Coefficient**". In case those values were known from a previous calibration the user could type them directly in the editor. Saving them before instantiation (thus storing them in the project database) will allow to use them as default values for the device. If a new calibration is performed (due to possibly a change in the environmental or setup conditions), the previous calibration values are saved (for safety reasons) in the variables "**Previous Ax/Ay Coeff**". The calibration is done measuring the beam position during the scan of the setpoints. The scan start and end points are taken symmetrically with respect to the current setpoint. The number of steps and the step size can be set in the parameters "**TEM calibration steps number**" and "**TEM calibration step**".

The automated drift correction is enabled (disabled) by clicking **Start** (**Stop**). When the monitoring is active, as soon as the beam position displacement is larger than the value set in "**Target Accuracy**" the device will send to the TEM a new setpoint value in order to bring closer to the reference position. In case the proposed setpoint exceeds the maximum allowed value of the setpoints ("**Maximum TEM drift**") the device state will go to error. The control loop can be slowed down for safety (e.g., to prevent oscillations or overshooting) by setting "**X/Y coefficient weight**" to a value lower than unity (this acts as damping for the feedback loop). The time to wait before reading beam center coordinates after changing the TEM setpoint can be set in the variable "**beam Image settlement time**". The interval between two subsequent checks of the beam mean position is also set by this value.

An example of beam stability taken when correcting for the drift the ppl beam for the SPB instrument is presented in Fig. 1.2,

In case the current position of the beam should be considered as the reference position, the user should use the button "**Set target position**".

When the TEM device is not regulating, wait for the time interval "**maximum time TEM not regulating**" before going into error state. This parameter should be tuned when dealing with temporary HW failures.
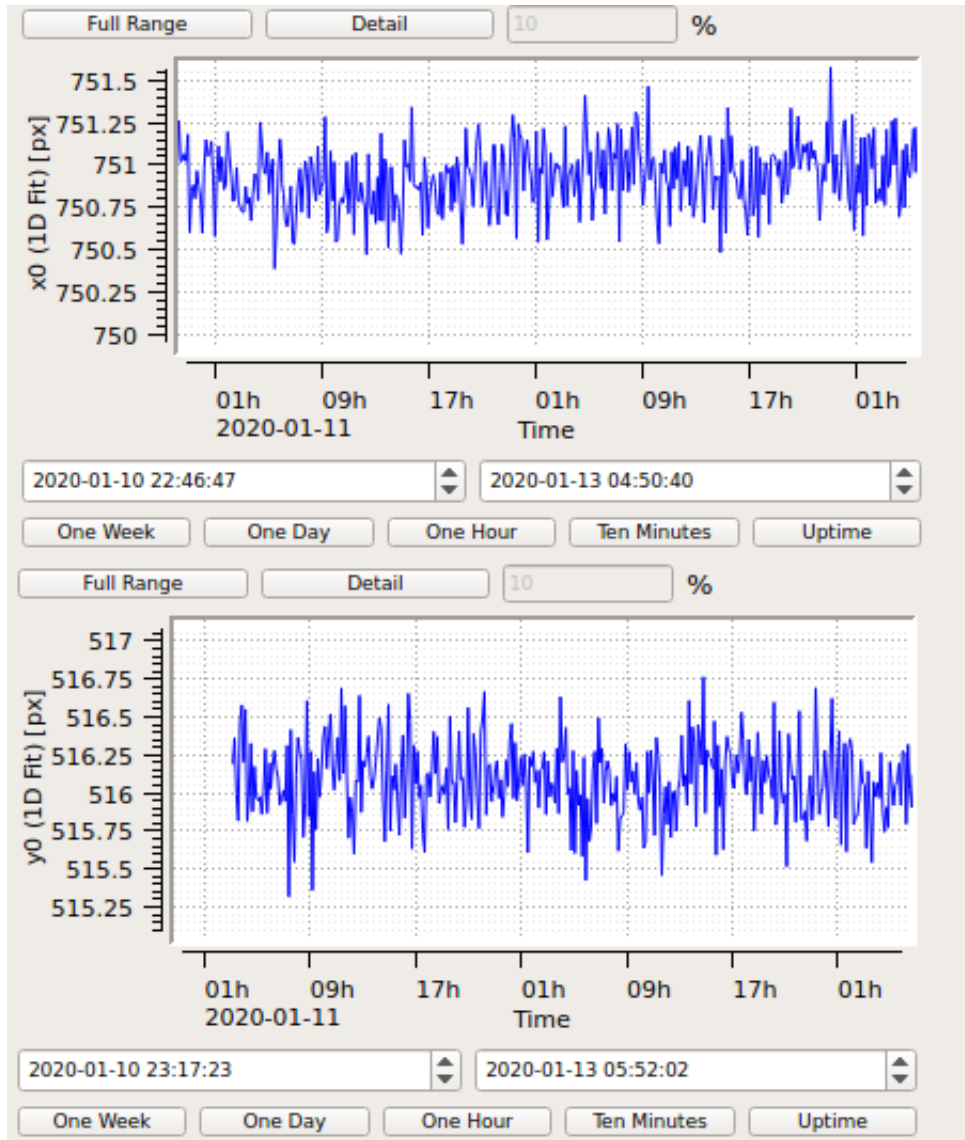
Fig. 1.2: The SPB beam trajectory is stabilized by the temSlowDriftCompensator device.

Troubleshooting

Some typical errors have been identified up to now:

- The device instantiates but remains in **UNKNOWN** state: in this case, likely the device cannot connect to one of the needed devices (TEM and Basler camera). The corresponding mandatory parameter might be either missing or wrongly spelled. If this is instead not the case, the state of that device should be investigated. It may be in error state, or not instantiated;

- In case the device is in error, and the device state displays "*Beam center value is too far away*", the user should manually optimize the beam alignment, or change either the reference position or the maximum allowed displacement;

- In case a new beam position is desired, the button "**Set target position**" should not be used. This action will set as reference position the current position of the beam. Instead, the desired values should be written in the parameters "**Target center X/Y**".

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