CeleX-5 SDK User Manual

CelePixel Technology Co. Ltd.

Content

1 User Steps of CeleX-5 SDK

1.1 Install MIPI to USB3.0 Driver

1.1.1 Windows

Please install the driver from following folder:

Drivers/Windows

Installation Steps:

(1) Connect the CeleX-5 Sensor to the PC via the USB cable, double-click "**zadig-2.4.exe**" to pop up the interface shown in Fig. 1-1.

(2) Select Options → List All Devices (Fig. 1-2), then select device FX3 (Fig. 1-3).

(3) Click "**Install Driver**" or "**Reinstall Driver**" (Fig. 1-4) to install the driver. After the installation is successful, Figure 1-5 will be shown.

Notes: The data cable must be connected to the USB 3.0 port on the PC.

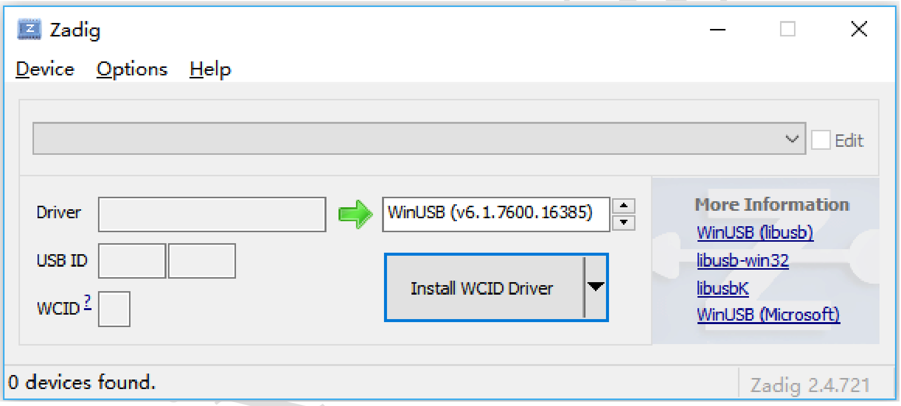


Fig. 1-1

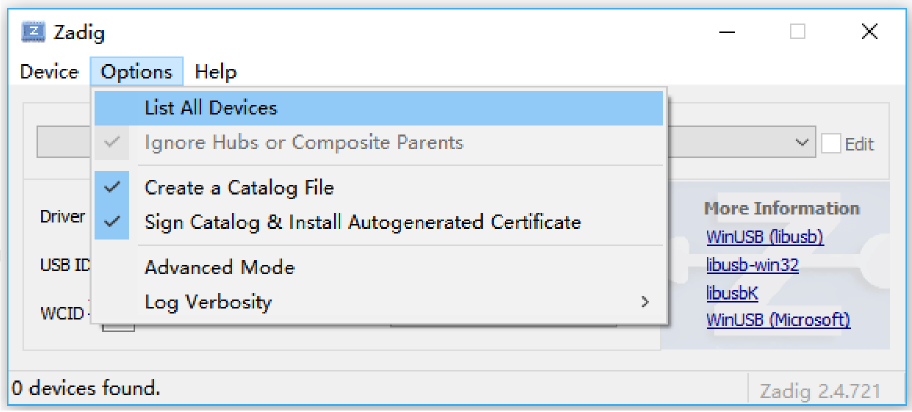


Fig. 1-2

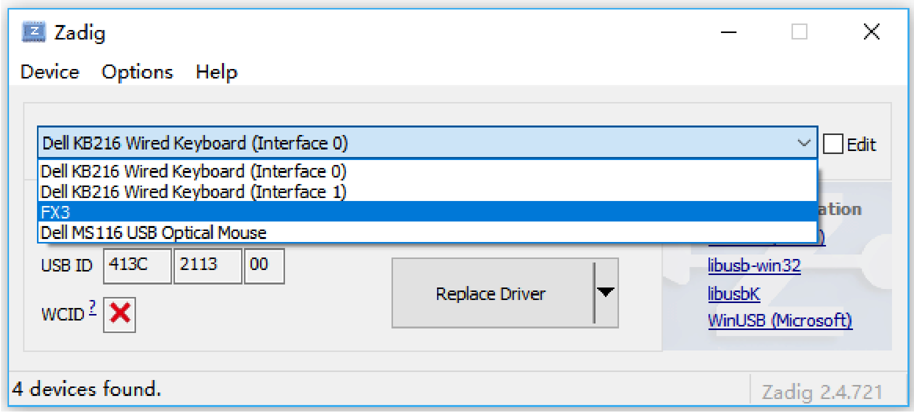


Fig. 1-3

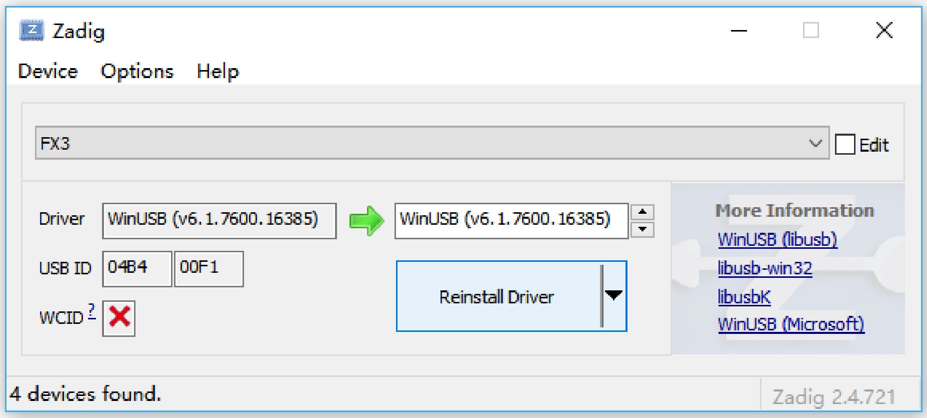


Fig. 1-4

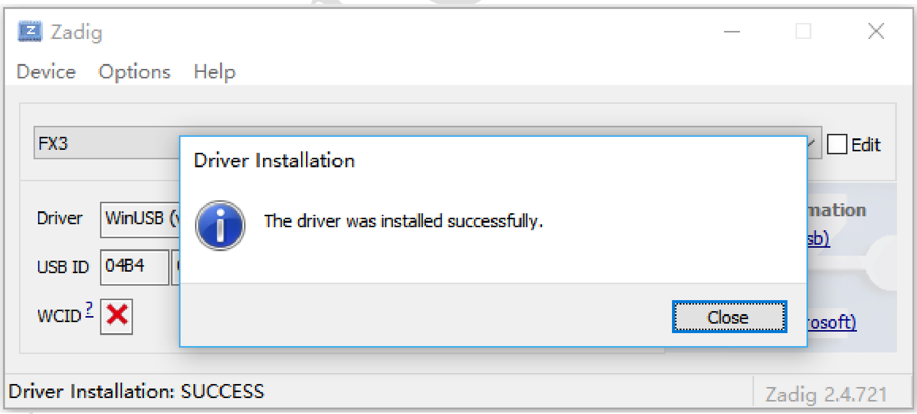


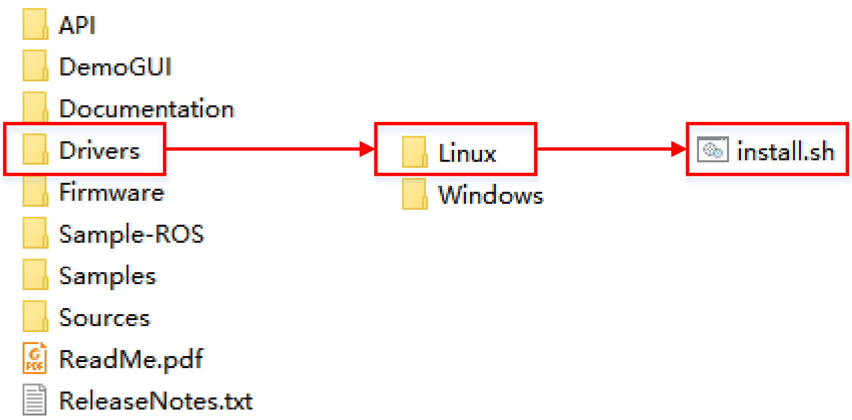
Fig. 1-5

1.1.2 Linux

Please install the driver from following folder:

Drivers/Linux

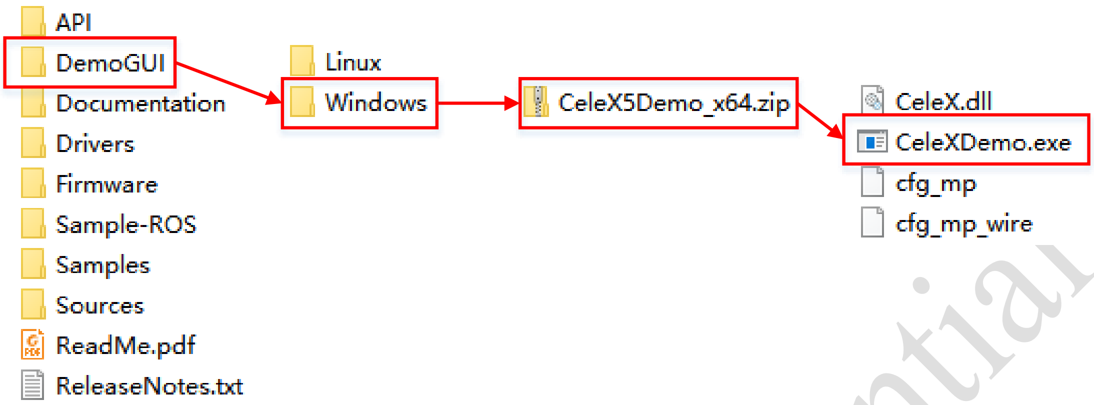
```
sudo sh ./install.sh
```


API
DemoGUI
Documentation
Drivers
Firmware
Sample-ROS
Samples
Sources
ReadMe.pdf
ReleaseNotes.txt
Linux
Windows
install.sh

1.2 Run CeleX Demo GUI

1.2.1 Windows

After installing the Driver, user could open the Demo GUI from following folder:

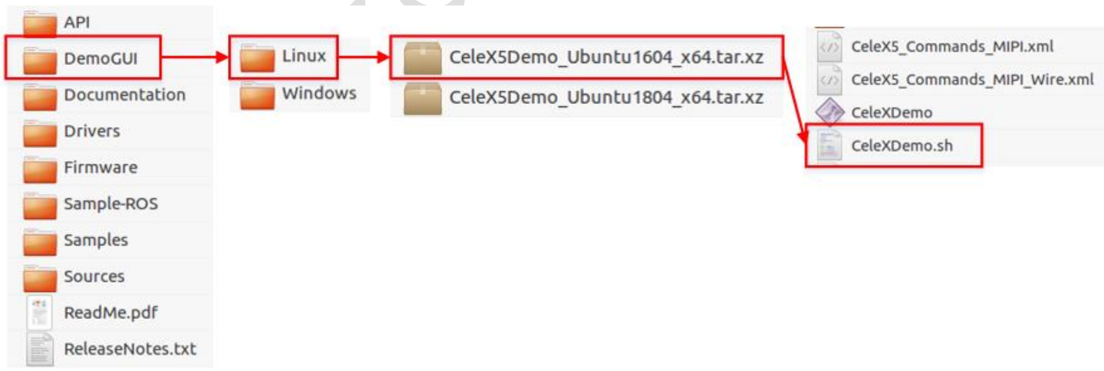


Double-click "CeleXDemo.exe" to open the CeleX-5 Demo GUI, as shown in Figure 2-2 in Chapter 2.

Note: If the software cannot be opened and some windows message box popped out saying so me dynamic library files was missing, which may be caused by lacking of Visual C++ supporting package. You can install the "***vc_redist.x64.exe***" under the folder <*Drives/Windows*> and try it again, the software should be working properly.

1.2.2 Linux

After installing the Driver, user could open the Demo GUI from following folder:



Open a terminal and enter the following command to open the Demo GUI, as shown in Figure 2-2 in Chapter 3.

```
$ sudo sh CeleXDemo.sh
```

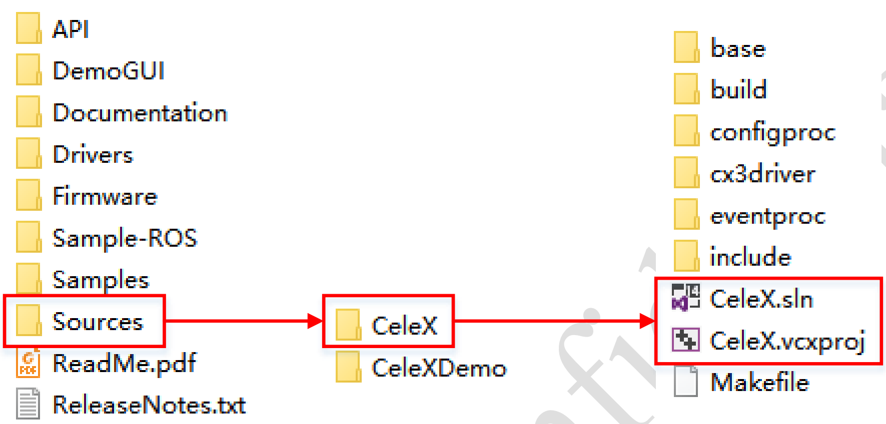
Note: Since we need to read and write the usb driver, we need to open the Demo with root privileges. Without the root permission, the usb device may fail to open.

1.3 Compile CeleX-5 Library Source Code

The OpenCV library (Version 3.3.0) is involved in the CeleX-5 API to develop some interfaces, so you need to install OpenCV and configure its development environment before compiling the source code of CeleX-5 library.

1.3.1 Windows

On the Windows platform, a VS2015 project file is provided to compile the source code, and the build library (CeleX.dll and CeleX.lib) will be imported into the directory *build/Windows*.



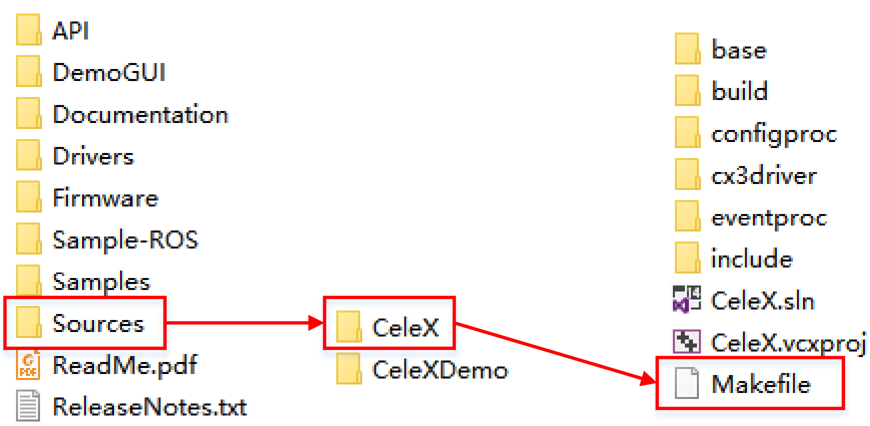
Note:

(1) You need to modify the settings of the OpenCV Include and Lib paths in the project properties. Otherwise, the compilation will fail because the OpenCV header files and libraries are not found.

(2) After the compilation is completed, a build/Windows directory will be automatically created in the directory where the project is located, and the compiled library files (CeleX.dll and CeleX.lib) will be automatically imported into this directory.

1.3.2 Linux

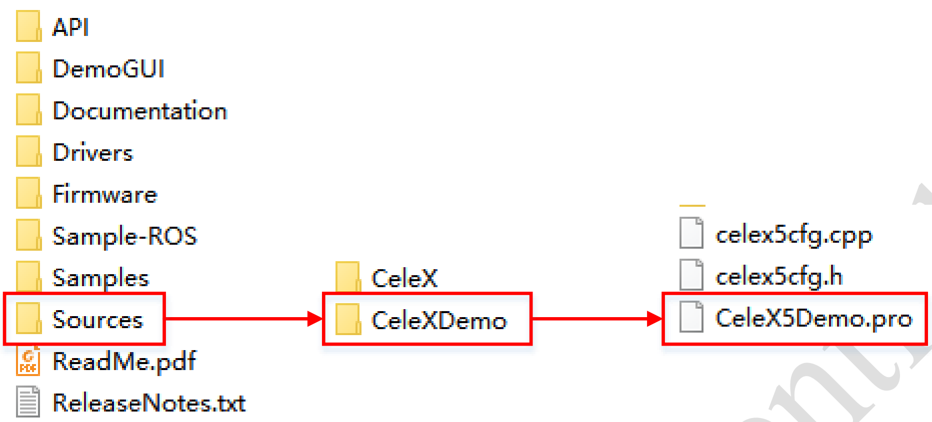
On the Linux platform, a Makefile is provided to compile the source code, and the shared library (libCeleX.so) will be generated in the current directory.



1.4 Compile Source Code of CeleX Demo GUI

Development Environment: Qt5.6.3 + OpenCV3.3.0

You could open the project in the following directory and compile it using Qt Creator easily.



Notes: It needs to modify the INCLUDEPATH and LIBS of OpenCV in the file *CeleXDemo.pro*.

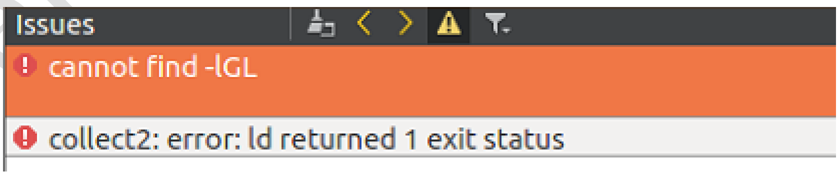
```
win32 {
    INCLUDEPATH += D:/opencv/build/include \
                   D:/Program Files/opencv/build/include/opencv \
                   D:/Program Files/opencv/build/include/opencv2
}
else {

    INCLUDEPATH += /usr/local/include \
                   /usr/local/include/opencv \
                   /usr/local/include/opencv2

    LIBS += /usr/local/lib/libopencv_highgui.so \
            /usr/local/lib/libopencv_core.so    \
            /usr/local/lib/libopencv_imgproc.so \
            /usr/local/lib/libopencv_videoio.so
}
```

Note: Problems that may occur during compilation (Linux):

(1) Cannot find -lGL



Solution:

sudo apt-get install libgl1-mesa-dev

(2) The OpenCV version is not compatible (the OpenCV version used in this SDK is 3.3.0)

If this issue occurs, you need to compile the API library first (see section 1.3), and then replace the compiled libCeleX.so file with ../Sources/CeleXDemo/lib/Linux/x64.

1.5 Generate FPN file

FPN (Fixed Pattern Noise) is the term given to a particular noise pattern on digital imaging sensors often noticeable during longer exposure shots where particular pixels are susceptible to giving brighter intensities above the general background noise. To get rid of FPN, we need to create FPN files for CeleX-5 Sensor. Each sensor requires its own FPN, and steps for generating FPN are illustrated in section 2.5.

2 The Functions of CeleX-5 Demo Kit GUI

If there is no sensor device connected, the interface screen is shown as Fig.2-1, when there is a sensor device connected, the interface screen is shown as Fig.2-2.

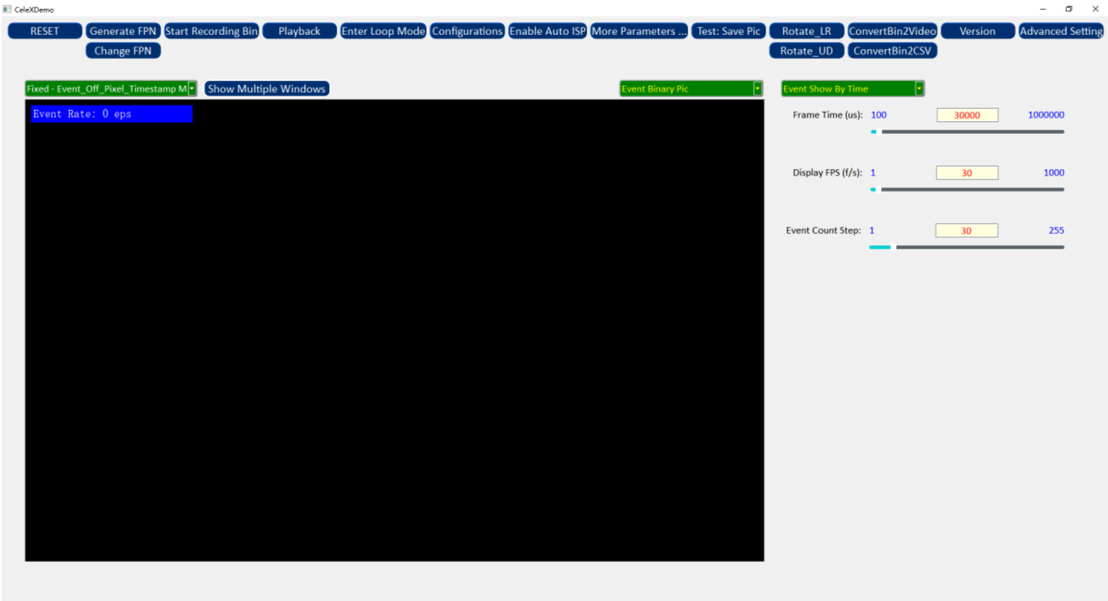


Fig. 2-1

Fig. 2-2

2.1 Sensor Fixed Mode

This SDK provides five kinds of Fixed modes of the Sensor. Users can switch between the five modes through the Demo GUI. The following figures show the name of each mode and the corresponding image.

Event Off Pixel Timestamp Mode

Event In-Pixel Timestamp Mode

Event Intensity Mode

Full-Picture Mode

Optical-Flow Mode

2.1.1 Introduction to various types of Event images in Event mode

In the Event Off-Pixel Timestamp mode, users could obtain ***Event Binary Pic***, ***Event Denoised Binary Pic***, ***Event Count Pic***, ***Event Denoised Count Pic***, and ***Event Count Slice Pic***.

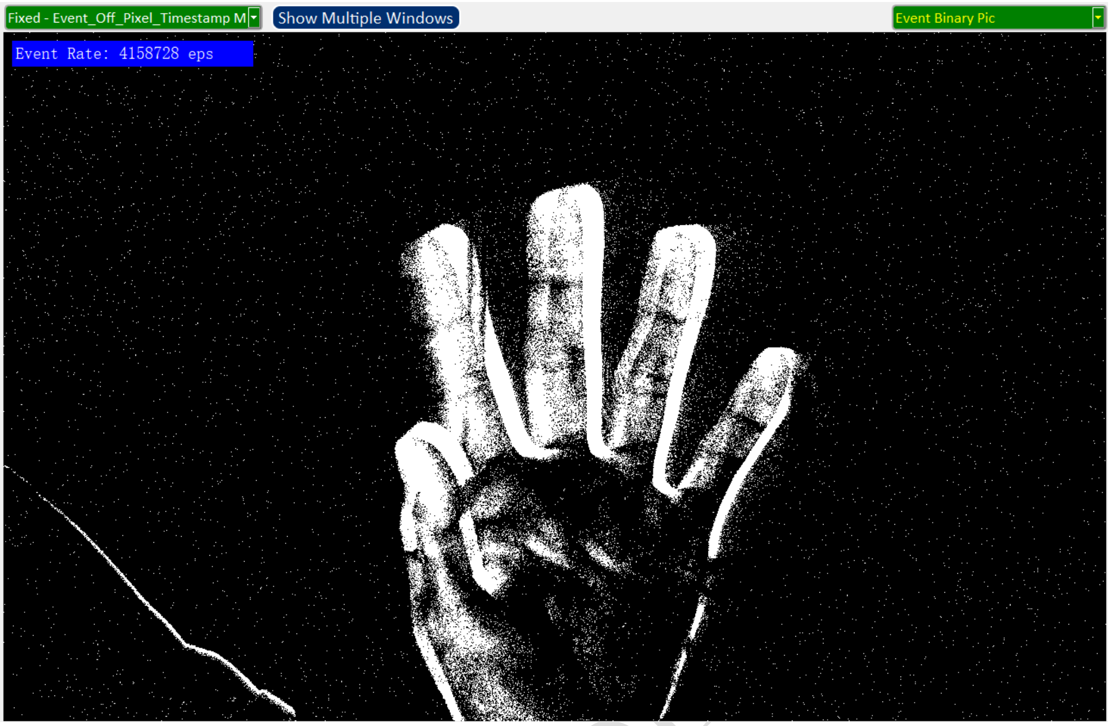
In the Event In-Pixel Timestamp mode, users could obtain ***Event Binary Pic***, ***Event Denoised Binary Pic***, ***Event Count Pic***, ***Event Denoised Count Pic***, ***Event Count Slice Pic*** and ***Event Optical-flow Pic***.

In the Event Intensity mode, users could obtain ***Event Binary Pic***, ***Event Gray Pic***, ***Event Accumulated Pic***, ***Event Superimposed***, ***Event Count Pic*** and ***Event Count Slice Pic***.

In the Demo GUI, you can view different types of Event images with a checkbox at the top right of the interface.

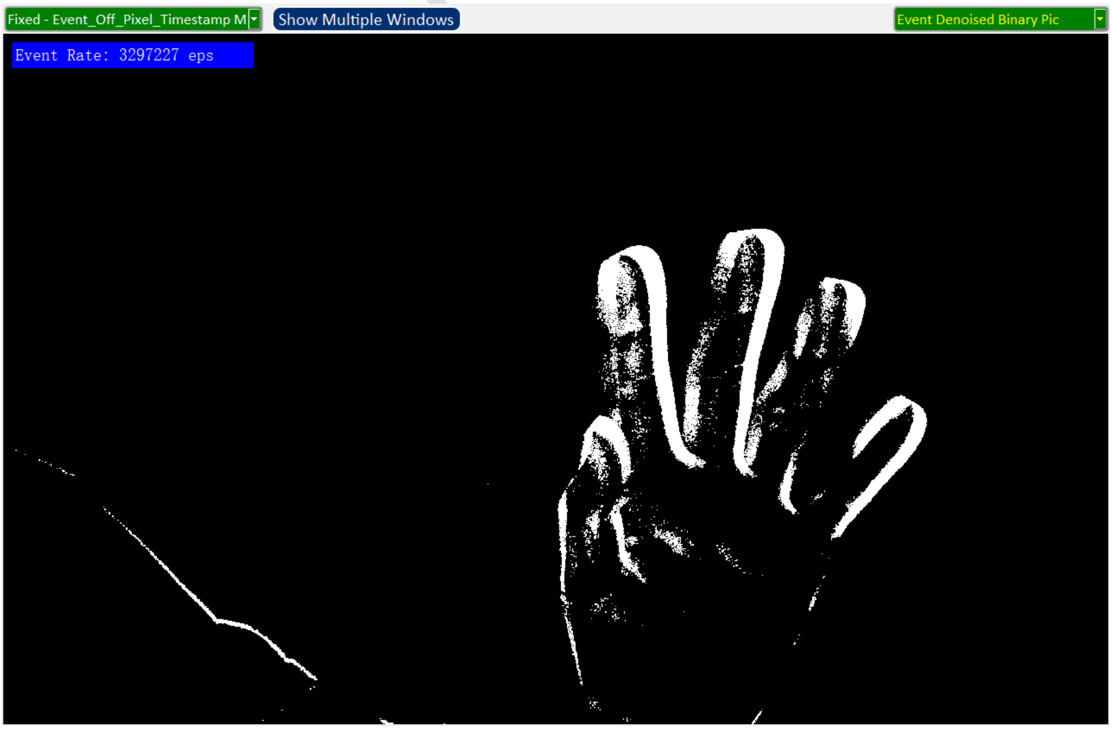
1. Event Binary Pic

The event binary image means that the grayscale value of the triggered pixel is **255**, and the grayscale value of the untriggered pixel is **zero**.



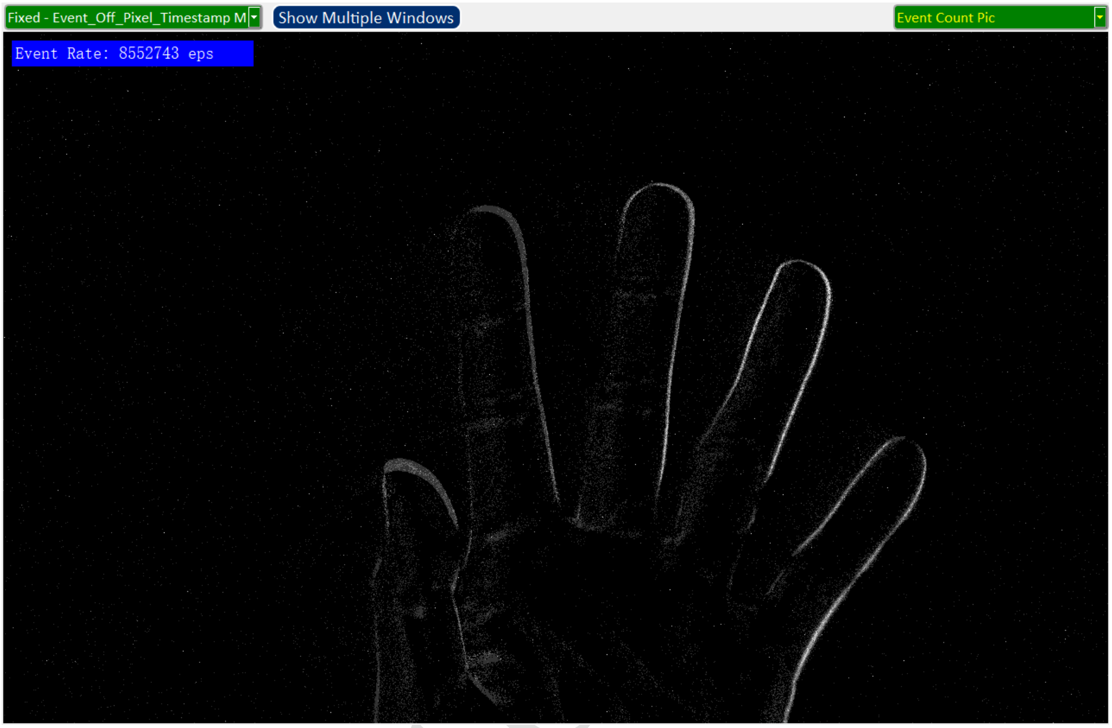
2. Event Denoised Binary Pic

The event denoised binary image means the event binary image with the isolated pixel removed.



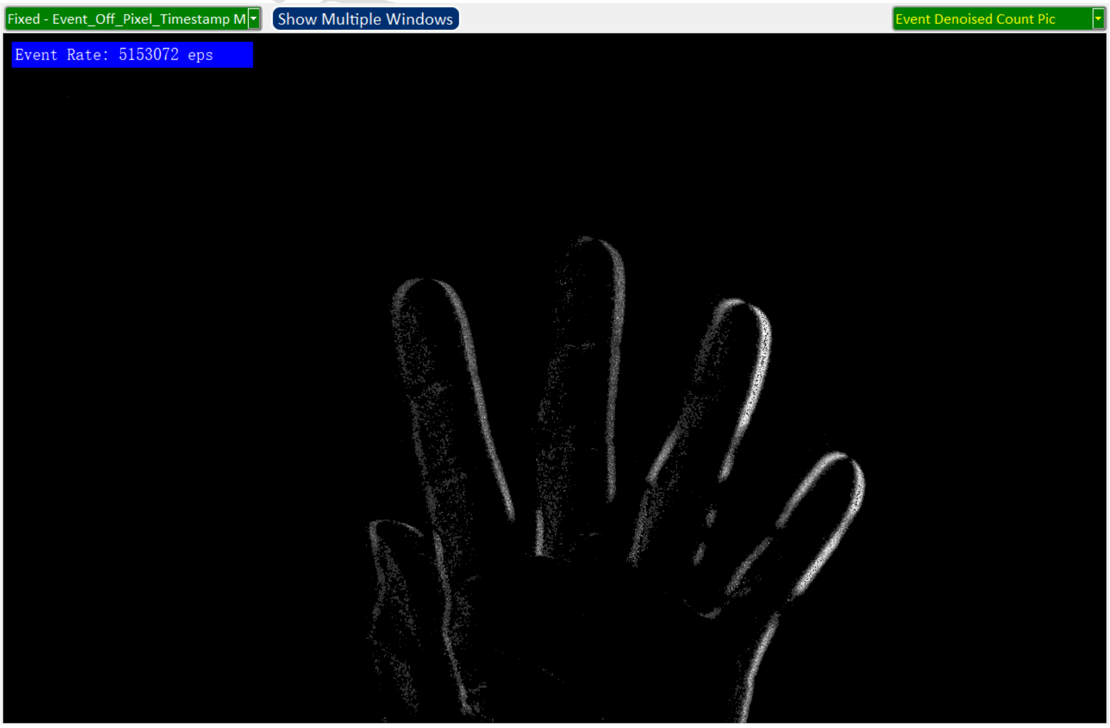
3. Event Count Pic

The event count image means that the grayscale value of the triggered pixel is **the number of times the pixel was triggered * the amplify factor**, and the grayscale value of the untriggered pixel is **zero**. Since the number of times a pixel is triggered is relatively small for a period of time (default 30ms). In order to show the image that the number of times is usually multiplied by a factor which can be adjusted.



4. Event Denoised Count Pic

The event denoised count image means the event count image with the isolated pixel removed.

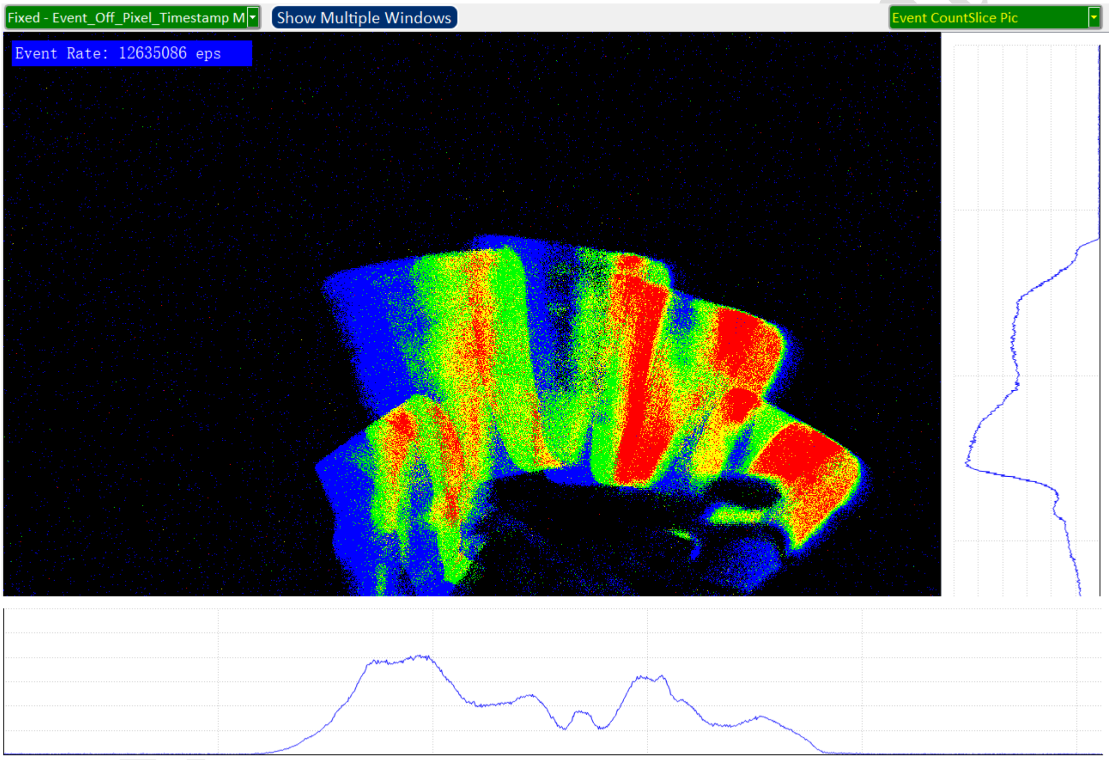


5. Event Count Slice Pic

The Event Count Slice image is also a kind of event count image, which takes a continuous number of frames (5~8) and then makes a linear superposition of the triggered number of times of each pixel. As shown in the figure below, red indicates the pixel with a large number of times trigger, and the blue indicates the pixel with a small number of times trigger.

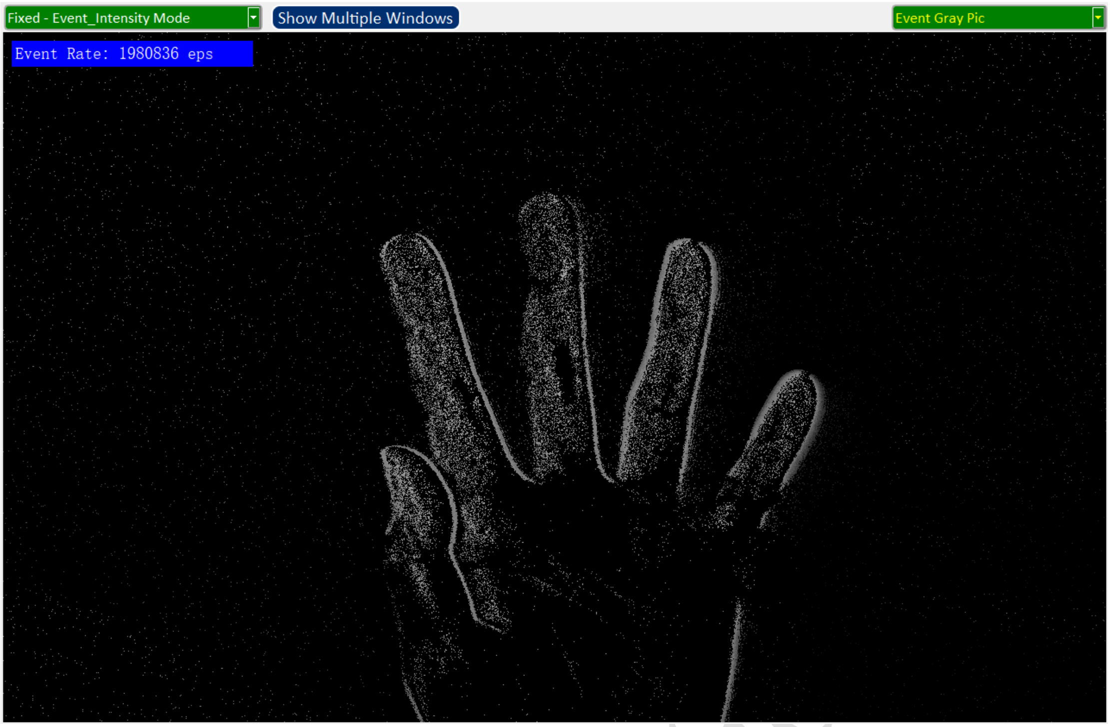
The curve on the bottom shows the number of real-time triggers for **all pixels in each column**. The abscissa represents the column of the image, and the ordinate represents the sum of the times of all triggered pixels in each column over a period of time (default 30ms).

The curve on the right shows the number of real-time triggers for **all pixels in each row**. The ordinate represents the line of the image, and the ordinate represents the sum of the times of all triggered pixels in each row over a period of time (default 30ms).



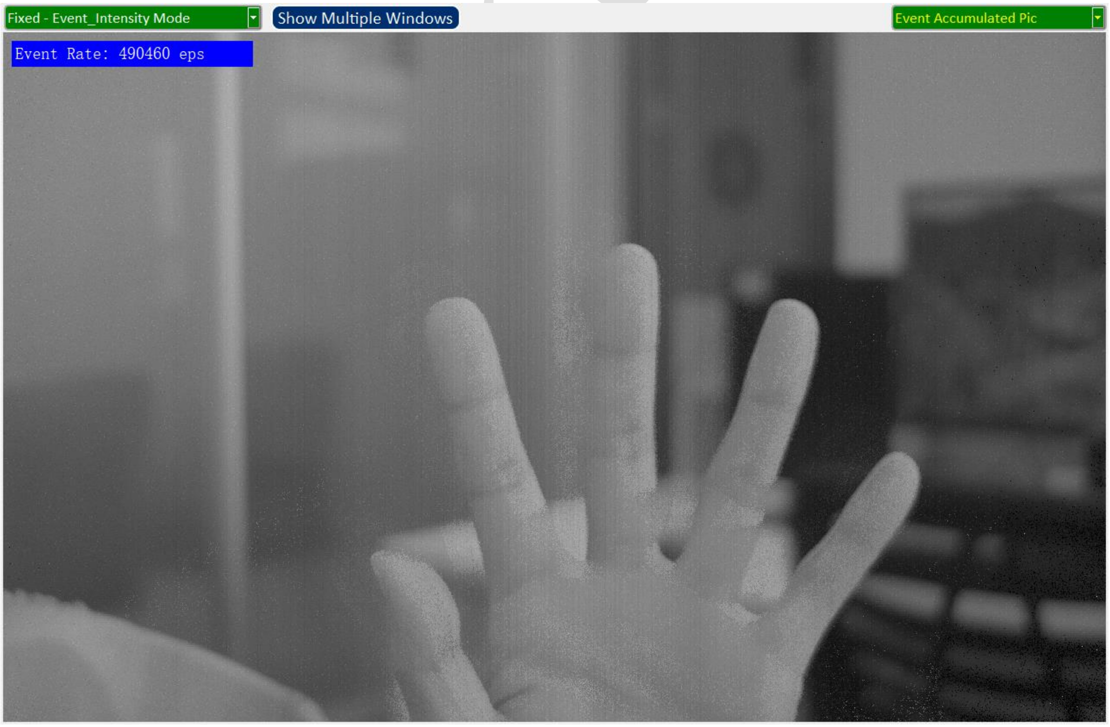
6. Event Gray Pic

The event gray image means that the grayscale value of the triggered pixel is **intensity**, and the grayscale value of the untriggered pixel is zero.



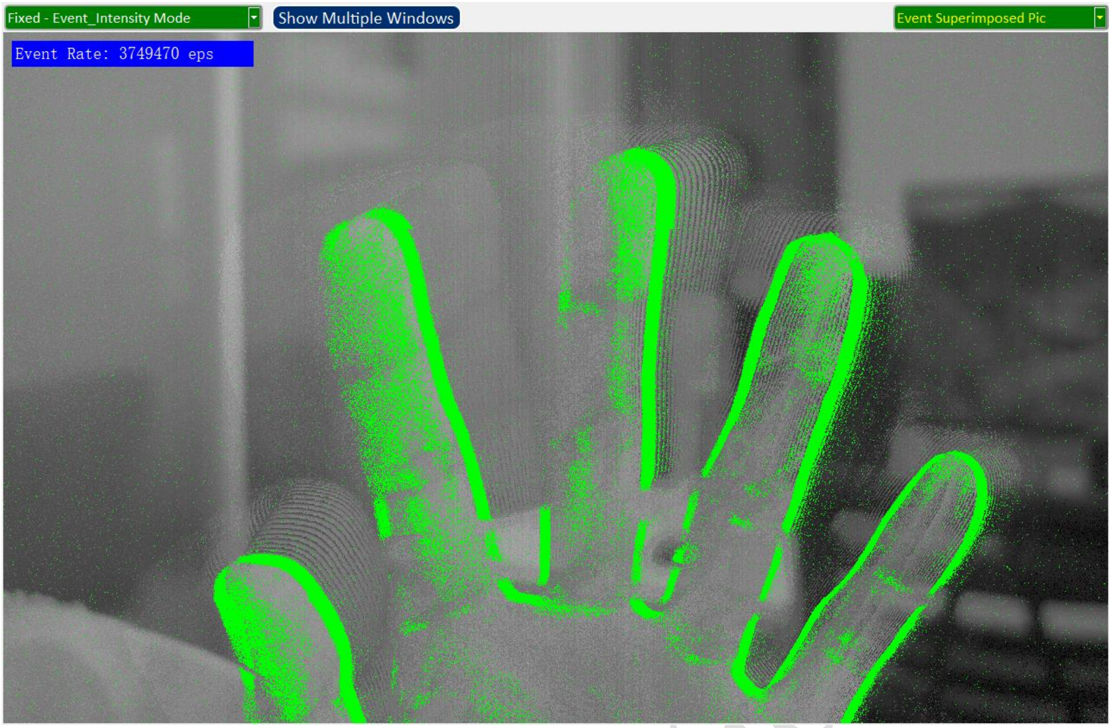
7. Event Accumulated Pic

The event accumulated image means that the grayscale value of the triggered pixel is **the latest intensity**, and the grayscale value of the untriggered pixel remains the previous intensity.



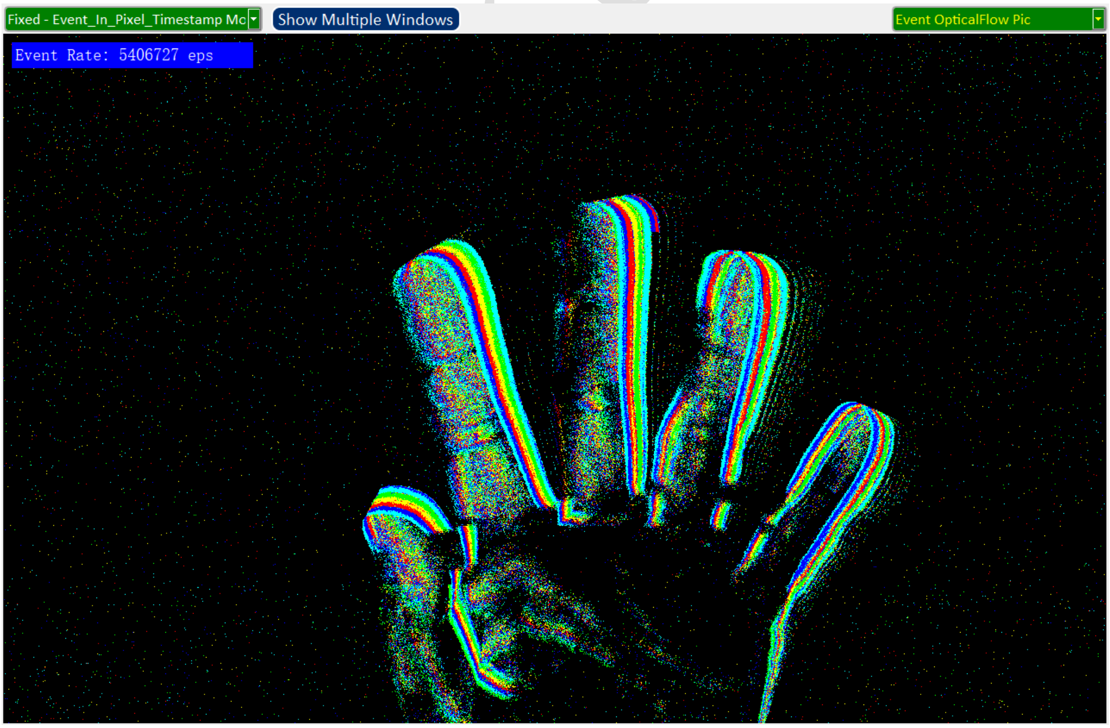
8. Event Superimposed Pic

The event superimposed image means that the *Event Binary Pic* is superimposed on *the Event Accumulated Pic*, where the green dot indicates *Event Binary Pic*.



9. Event Optical-flow Pic

The event optical-flow image means that the grayscale value of the triggered pixel is **in-pixel timestamp**, and the grayscale value of the untriggered pixel is zero.



2.2 Change Sensor Mode

In the Fixed Mode, click the button "***Enter Loop Mode***" shown in Figure 2-3-1 to enter the Loop Mode. The images of *Loop Mode* are displayed as shown in Figure 2-4. Loop A is the first loop, its mode is *Full-Picture mode*, Loop B is the second loop, its mode is *Event mode*, and Loop C is the third loop, its mode is *Optical-Flow mode*.

In the Loop Mode, click the button "***Enter Fixed Mode***" shown in Figure 2-3-2 to switch to the Fixed mode (the default mode is *Event mode*).

Fig. 2-2-1

Fig. 2-2-2

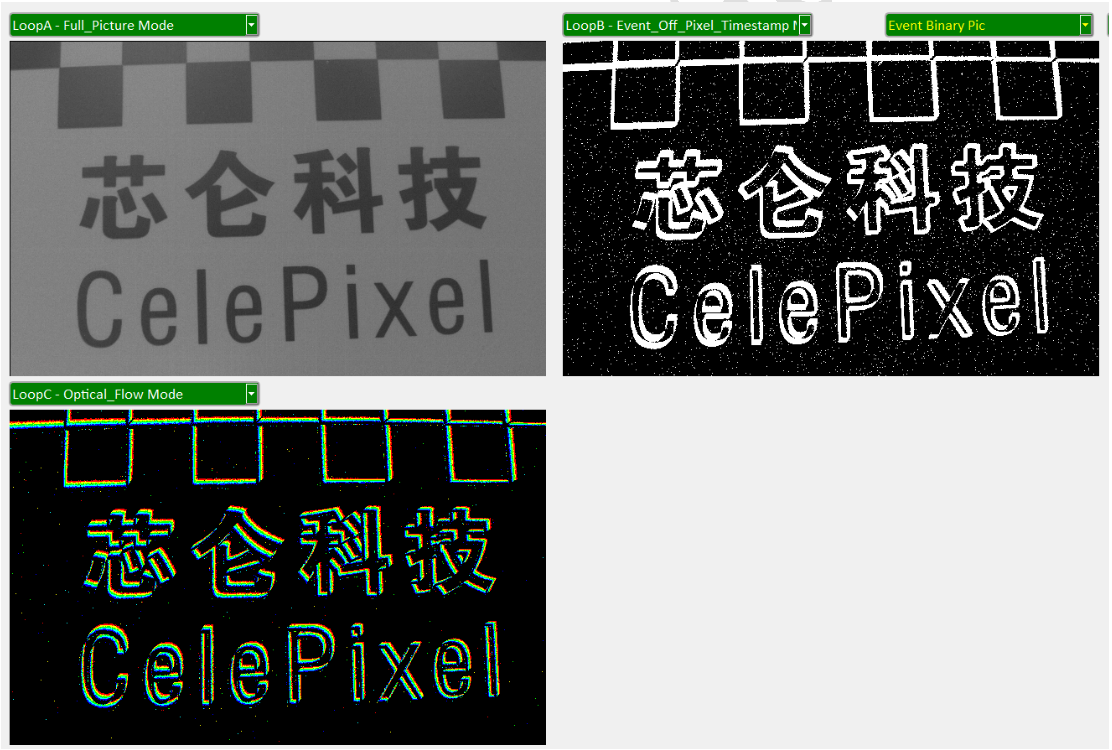


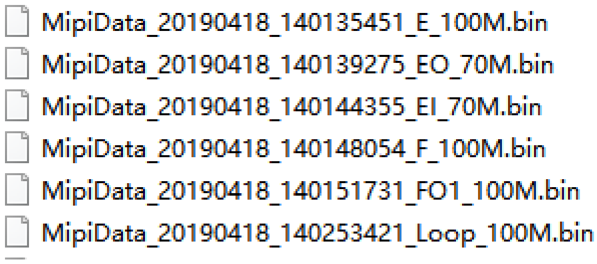
Fig. 2-2-3 Sensor works in Loop Mode

2.3 Record Raw Data of Sensor (Bin Files)

Click the "***Start Recording Bin***" button in Figure 2-5-1 to start recording bin data, then the text on the button will change to "***Stop Recording Bin***" as shown in Figure 2-5-2.

Click the "***Stop Recording Bin***" button to stop recording bin data. The recorded bin file will store in the same directory as CeleXDemo.exe and is named in the form of

MipiData_YYYYMMDD_HHMMSSSSS_SensorMode_ClockRate.bin, as follow:



(1) **E** *Event Off Pixel Timestamp Mode*

(2) **EO** *Event In Pixel Timestamp Mode*

(3) **EI** *Event Intensity Mode*

(4) **F** *Full-Picture Mode*

(5) **FO1** *Optical-Flow Mode*

(6) **Loop** *Loop Mode*

100MHz: The operating frequency of the Sensor is 100MHz

Fig. 2-5-1

Fig. 2-5-2

2.4 Playback Recorded Raw Data of Sensor (Bin Files)

Click the "***Playback***" button (as shown in Figure 2-4-1), select a bin file, and after starting playback, the text on the button will change to "***Exit Playback***" (as shown in Figure 2-4-2). Clicking the "***Exit Playback***" button will stop playing the bin file and exit the playback interface, returning to the real-time display interface. The content played in it is related to the Sensor mode when recording Bin data.

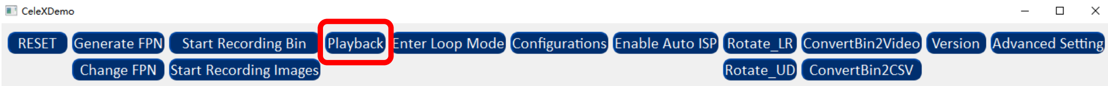


Fig. 2-4-1

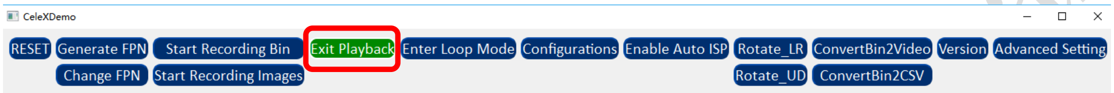
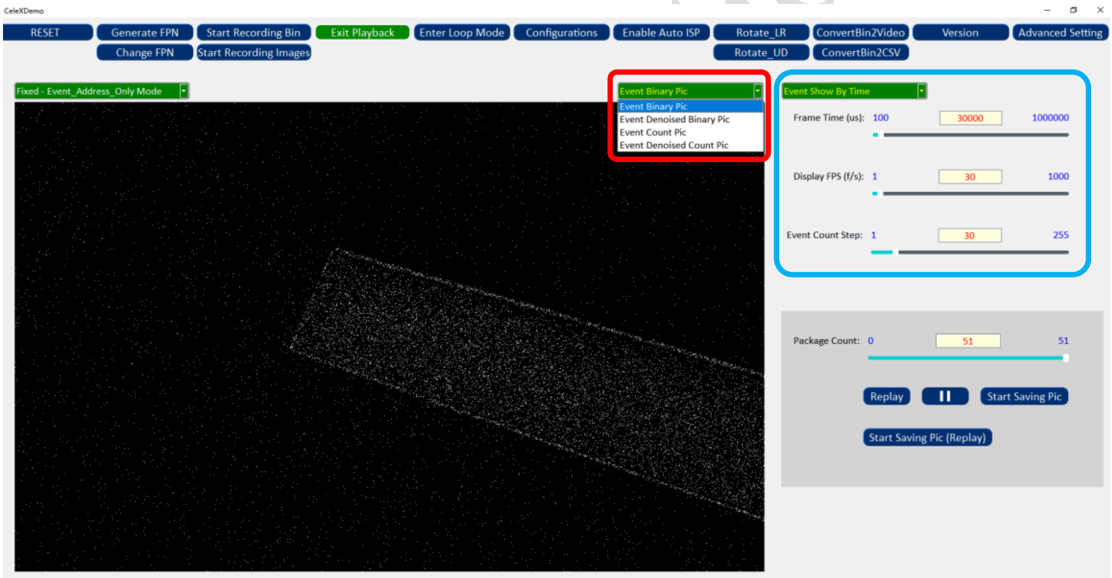


Fig. 2-4-2

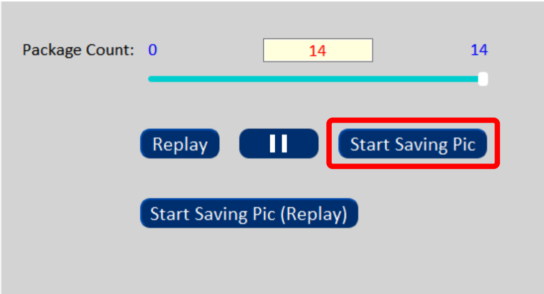
You can select various Pic modes of the Bin file for display, and can select the display mode (show by time, show by count, show by row cycle) and set parameters such as Frame Time or Display FPS.

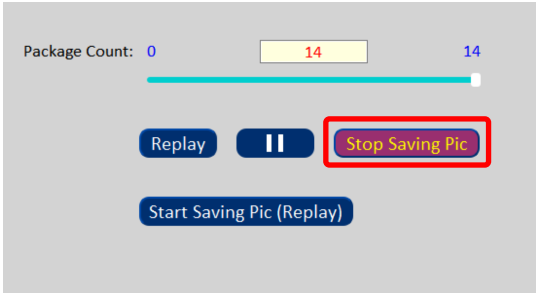


The user can select various Pic modes of the Bin file for display (shown in red in the figure above), or modify parameters such as Frame Time or Display FPS (the blue box in the figure above).

Playback also supports "***Replay***", "***Play/Pause***" and save pictures, where "***Start Saving Pic***" means to save the picture from the current playback position, and "***Start Saving Pic (Replay)***" means to save the picture from the beginning.

For example, clicking the "***Start Saving Pic***" button will start saving the picture; after you start saving the picture, the text on the button will change to "***Stop Saving Pic***", and then click the "***Stop Saving Pic***" button to stop saving the picture.

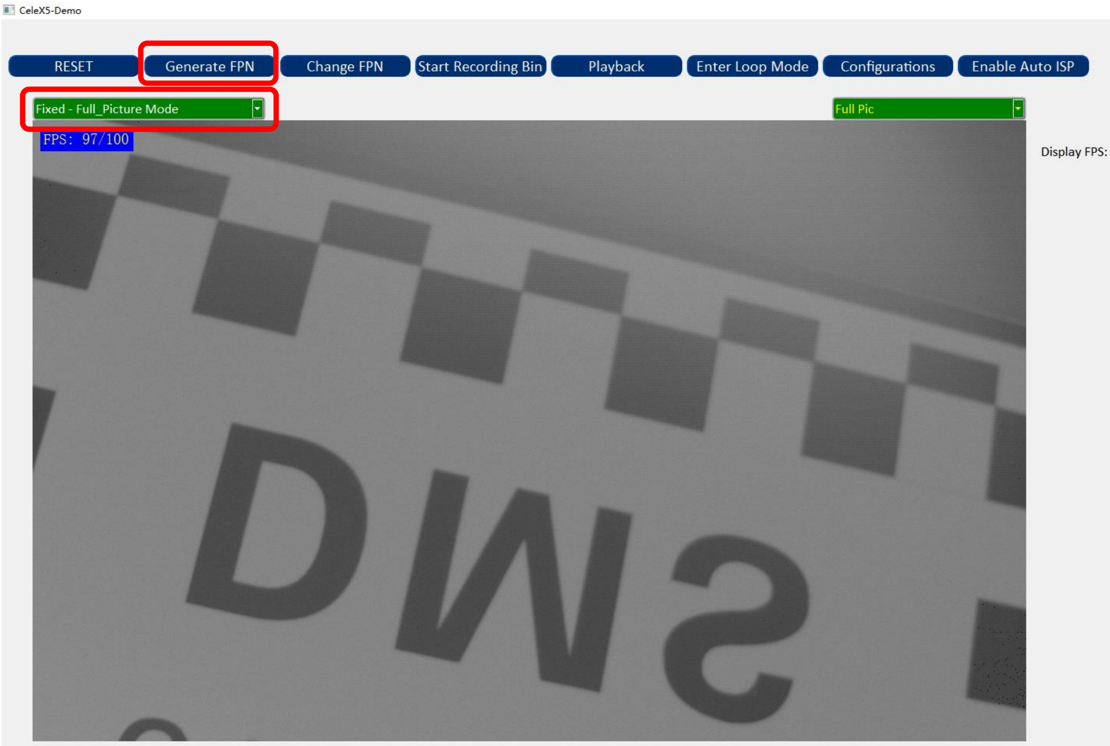

Package Count: 0
14
14
Replay
Start Saving Pic
Start Saving Pic (Replay)


Package Count: 0
14
14
Replay
Stop Saving Pic
Start Saving Pic (Replay)

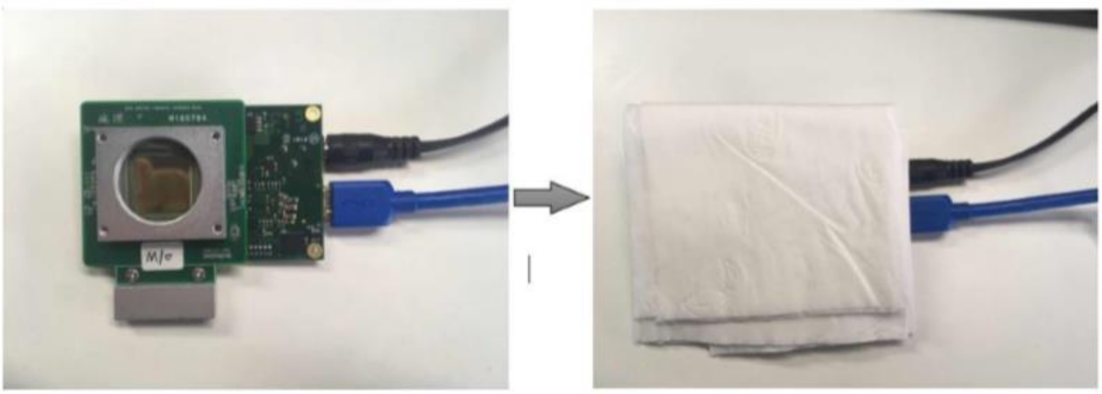
2.5 Generate FPN File for Full-Picture Mode

Each sensor requires its own FPN, and steps for generating FPN are illustrated as below:

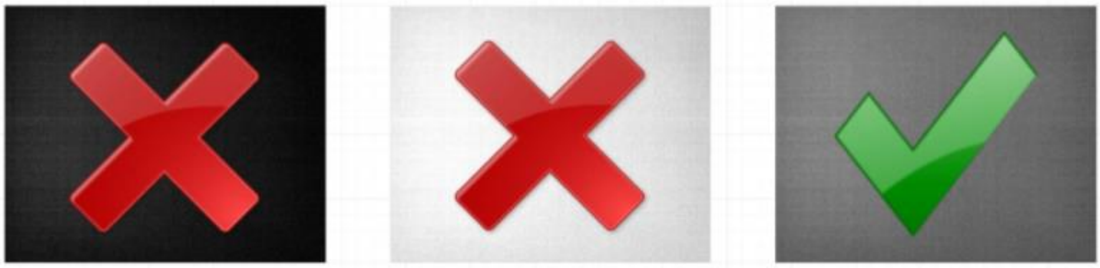
1) Switch the Sensor Mode to "***Full-Picture Mode***".



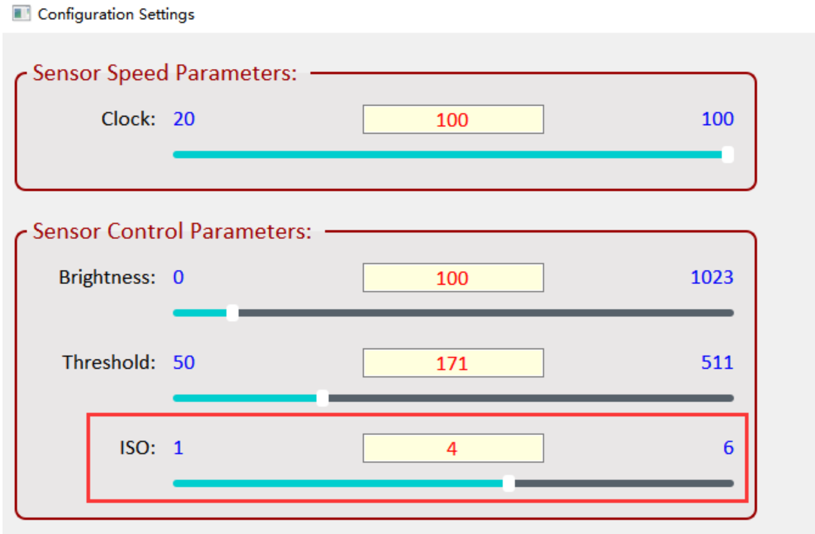
2) Since the FPN should be conducted under the condition of uniform illumination, we could use the way of removing optical lens and covering a piece of white paper (thin tissue or A4 paper) over the exposed Sensor. Make sure that paper completely covers the sensor and sheet is stationary. **NOTE: the effect will be better if you operate in natural light rather than the LED lamp.**



3) Before generating FPNs, please check the image screen and make sure it is normal, which is neither too dark nor too bright. Then, you could adjust the amount of paper over the Sensor or switch the "Brightness" slider in the GUI to change the luminance. **NOTE: the 3rd figure is the right luminance among the three figures below.**



4) Click the "***Generate FPN***" button in GUI. Then, you could see the FPN_3.txt file in assigned direction after FPN file was successfully generated. **Note: Different ISO levels correspond to different FPN files. ISO has a total of six levels. The default is the third level, which corresponds to the FPN_3.txt file. The user can obtain a brighter or darker image by adjusting the ISO level in the Configuration settings.**



5) After generating the FPN file under the corresponding ISO settings, we can choose to switch to the corresponding FPN by clicking the "***Change FPN***" button. **Note: If the FPN file is generated according to the steps, but the image resolution is not improved after switching, check whether the current ISO corresponds to the FPN; check whether the selected FPN path contains the Chinese path.**


With FPN Applied

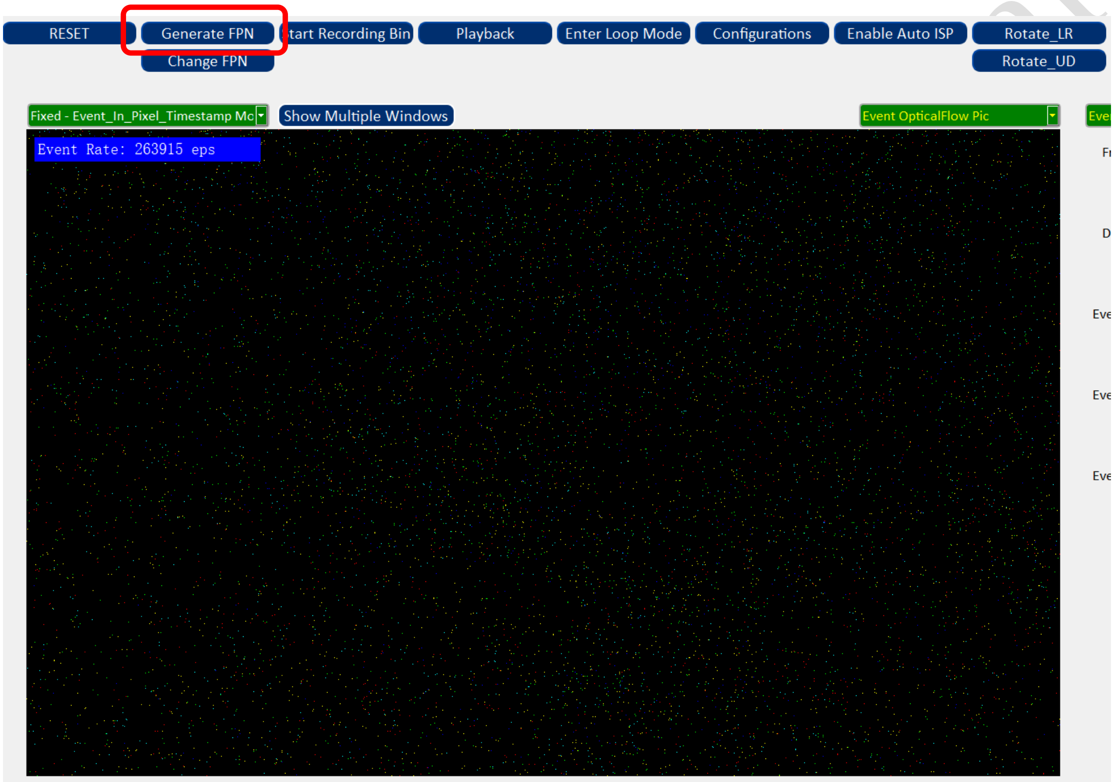

No FPN Applied

2.6 Generate FPN File for Event In-Pixel Timestamp Mode

When CeleX5 Sensor outputs in-pixel timestamp, there is a fixed deviation in the analog signal readout path of each pixel unit. In order to solve this problem, this deviation needs to be collected in advance to form an FPN file. Then subtract the corresponding FPN from the original in-pixel timestamp to get the corrected accurate in-pixel timestamp. The specific steps for collecting this FPN are as follows:

(1) Switch the Sensor Mode to "***Event In-Pixel Timestamp Mode***".

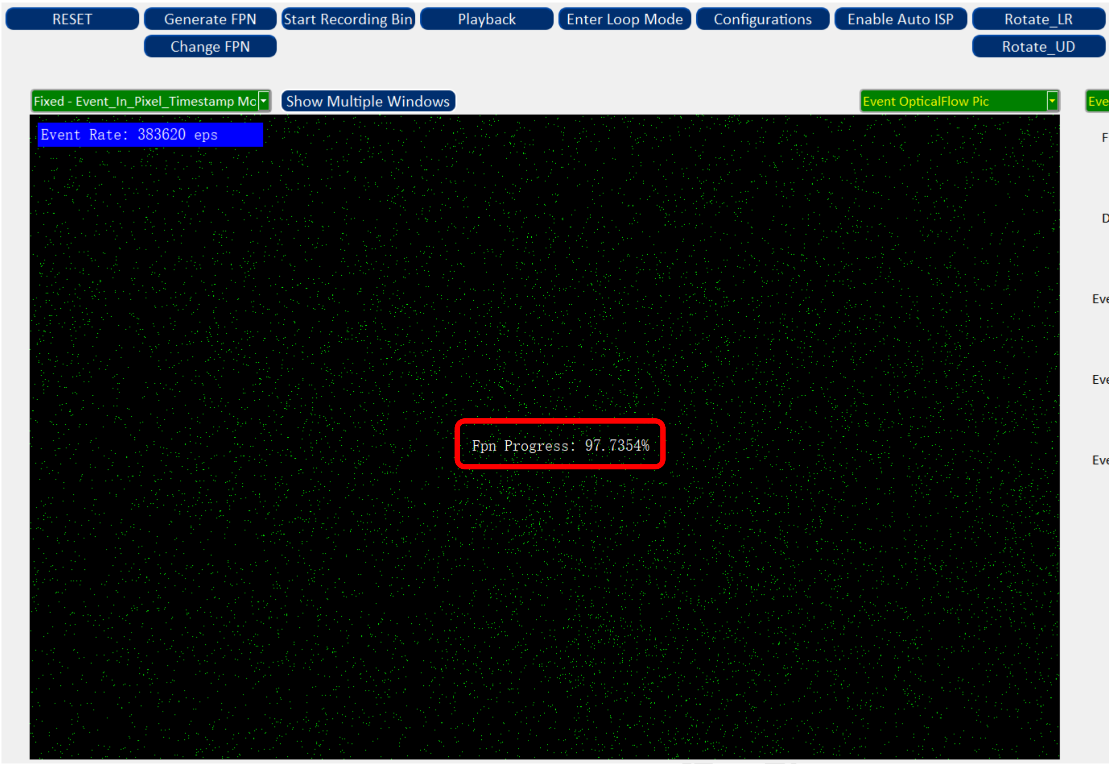
(2) Place the sensor in a uniform light environment and ensure that there are no dynamic objects in the font of the sensor, as shown below.



(3) Click the button "***Generate FPN***" on the CeleX5Demo GUI to start generating FPN, then the progress value is displayed on the center of the screen.

(4) After the collection is completed, the progress value will become 100% and disappear automatically. At this time, you can see a "***FPN_OpticalFlow.txt***" file in the same directory of the executable program, which indicates that the FPN file was successfully generated.

Note: It takes about 2 ~ 3 minutes to generate FPN in *Event In-Pixel Timestamp Mode*, especially the progress will be slow after 99%, please be patient.

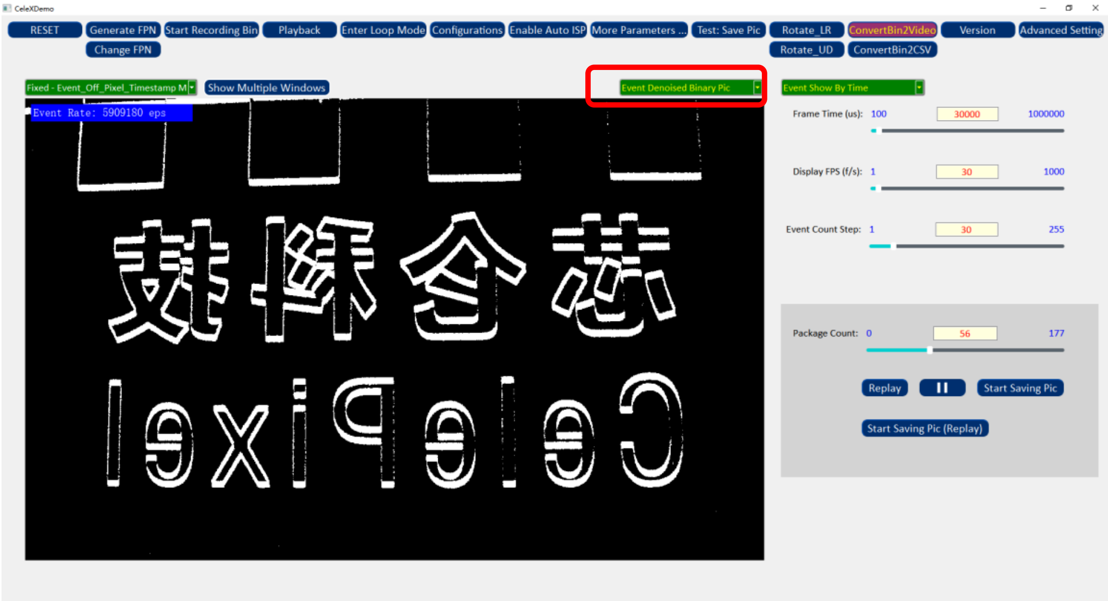

RESET
Generate FPN
Start Recording Bin
Playback
Enter Loop Mode
Configurations
Enable Auto ISP
Rotate_LR
Change FPN
Rotate_UD
Fixed - Event_In_Pixel_Timestamp Mc
Show Multiple Windows
Event OpticalFlow Pic
Event Rate: 383620 eps
Fpn Progress: 97.7354%

2.7 Flip image

Click the "***Rotate_LR***" or "***Rotate_UD***" button to flip the image left and right or up and down.

2.8 Convert bin to video

Click the "***ConvertBin2Video***" button, you can convert the recorded Bin file to a video file with the same name as the file. A video file in .mkv format is generated under Windows, and a video file in .mp4 format is generated under Linux. By selecting a different image format, you can convert the corresponding image format video of the Bin. For example, if you select the denoised image format, you can convert the Bin file of Event Off Pixel Timestamp mode into the denoised image video.



2.9 Convert bin to CSV

Click the "***ConvertBin2CSV***" button to convert the recorded Bin file to a CSV file.

2.9.1 CSV Format for Event Off-Pixel Timestamp Mode

For the ***Event Off-Pixel Timestamp*** mode, the CSV format is shown in the following table. Column A is the row address (range: 0 ~ 799), column B is the column address (range: 0 ~ 1179), and column C is the incremented Off-Pixel timestamp (time unit: **μs**).

A	B	C
124	840	0
124	863	0
125	178	0
125	420	0
125	621	0
125	625	0
125	626	0
125	627	0
125	629	0
125	630	0
125	862	0
126	378	0
126	490	0
126	617	0
126	618	0
126	622	0
126	624	0
127	55	10
127	635	10
128	122	10

2.9.2 CSV Format for Event In-Pixel Timestamp Mode

For the ***Event In-Pixel Timestamp*** mode, the CSV format is shown in the following table. Column A is the row address (range: 0 ~ 799), column B is the column address (range: 0 ~ 1179), column C is the In-Pixel timestamp (time unit: **μs**), and column D is the incremented Off-Pixel timestamp (time unit: **μs**).

A	B	C	D
238	613	10412	0
238	637	10453	0
238	647	9938	0
238	648	10375	0
238	652	10874	0
238	653	9290	0
238	654	9623	0
238	657	9607	0
238	708	10107	0
238	711	10334	0
238	718	10204	0
238	728	10379	0
238	739	9891	0
238	760	10133	0
238	978	9688	0
238	980	9678	0
239	176	10354	7
239	213	10254	7
239	215	9340	7
239	216	9759	7
239	224	10291	7

2.9.3 CSV Format for Event Intensity Mode

For the ***Event Intensity*** mode, the CSV format is shown in the following table. Column A is the row address (range: 0 ~ 799), column B is the column address (range: 0 ~ 1179), column C is the intensity (range: 0 ~4095), column D is the polarity (range: +1, -1, 0), and column E is the incremented Off-Pixel timestamp (time unit: **μs**).

A	B	C	D	E
573	648	2104	1	0
573	649	2116	1	0
573	650	2746	1	0
573	651	3317	1	0
573	652	2557	1	0
573	653	3221	1	0
573	654	2588	1	0
573	655	2695	1	0
573	656	3287	1	0
573	657	2707	1	0
573	658	2756	1	0
573	659	2705	1	0
573	660	2382	1	0
573	661	3031	1	0
573	662	2161	1	0
574	191	2379	1	7
574	194	2278	1	7
574	195	2596	1	7
574	205	2488	1	7
574	214	2818	1	7
574	220	2083	1	7
574	222	2153	1	7
574	232	2826	1	7
574	234	2534	1	7

2.10 Configurations

Click the "Configurations" button (as shown in Figure 2-9-1), open the configuration interface, you can perform some configuration on the Sensor. The configured configuration interface is displayed, as shown in Figure 2-9-2.

Fig. 2-9-1

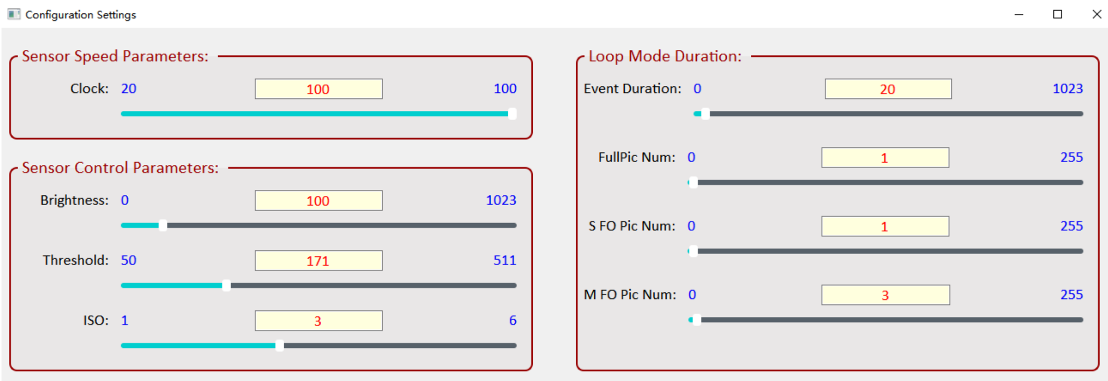


Fig. 2-9-2

All the parameters shown in the above figure are used to modify the configuration parameters of the Sensor (hardware parameters). Only in real time, these parameters can be modified to play a role. During playback, this set of parameters is not adjusted. The meaning of the control parameters is as following:

1. **Sensor Speed Parameters:**

   Clock: Adjust the working frequency of the Sensor. The default value is 100MHz. The larger the value, the faster the Sensor detects and is valid for all modes.

2. **Sensor Control Parameters:**

   Brightness: Adjust the brightness of the image, the larger the value, the darker the image will be. **Note:** Valid only for Full-Picture and Event Intensity modes.

   Threshold: Adjust the threshold of the trigger event. Under the same conditions, the larger the value, the smaller the number of triggered events. **Note:** Valid for Event Off Pixel Timestamp Mode, Event In-Pixel Timestamp Mode, Event Intensity and Optical-Flow mode.

   ISO: Adjust image contrast and dynamic range. The higher the value, the lower the contrast and the higher the dynamic range. If the value is modified, you need to reacquire the FPN (how to collect the FPN, please refer to section 2.5). If the FPN file corresponding to each ISO value is collected beforehand, the SDK will automatically switch and use the new FPN file. **Note:** Valid only for Full-Picture and Event Intensity modes.

3. **Loop Mode Duration:**

   Event Duration: In Loop mode, each time the Sensor is in the Event Off Pixel Timestamp mode, the mode value is 20, indicating that the Sensor will last for 20ms in this mode, and then automatically switch to the next mode.

FullPic Num: In Loop mode, each time the Sensor is in the *Full-Picture* mode, the default value is 1, indicating that the Sensor will continue to "generate 1 image frame" in this mode, and then automatically switch to the next mode.

S FO Pic Num: In Loop mode, each time the Sensor is in the *Optical-Flow* mode, the default value is 1, indicating that the Sensor will continue to "generate 1 image frame" in this mode, and then automatically switch to the next mode.

M FO Pic Num: In Loop mode, each time the Sensor is in the *Multi Read Optical-Flow* mode, the default value is 3, indicating that the Sensor will continue to "generate 3 images frame" in this mode, and then automatically switch to the next mode.

2.11 Advanced Settings

More advanced settings can be made by clicking the "***Advanced Settings***" button. When recording a Bin file, you can choose to turn off the screen display to ensure the integrity of the data (due to the time-consuming analysis of the data when displaying, it may result in data loss). Users can also set the "BinFile Time Duration" (in minutes) for recording each Bin file. Once the Bin file reaches the set length, the file will be saved automatically and a new file will be created.

When playing a Bin file, the user can save the picture at the same time. The interval for saving pictures can be adjusted by setting the "SavePic Count Interval" parameter (if the interval is set to 0, each frame will be saved; if the interval is set to 2, one image will be saved every 2).

In addition, a resolution setting is also available. The user can turn off the display of some lines by modifying the "Resolution Parameter". A detailed description of this feature can be found in the CeleX5_SDK_Reference documentation.