TECHNICAL SUPPORT

Optimization of USB 3.0 Bandwidth

USB Cameras

Table

Glossary

- **HDR**: High Dynamic Range
- **ADU**: Analog Digital Unit
- **HG**: High Gain
- **LG**: Low Gain
- **ADC**: Analog to Digital Converter
- **NUC**: Non Uniformity Correction
- **IWR**: Integrate While Read
- **ITR**: Integrate Then Read
- **FPS**: Frames Per Second
- **CDS**: Correlated Double sample

FIRST LIGHT ADVANCED IMAGERY

1. Introduction

The purpose of this technical note is to describe the issue that may arise during the operation of a camera if the USB link is not optimized. It also provides tips to get the full USB 3 performance.

Before using USB 3 connection, the camera USB 3 drivers must be installed on the PC. The drivers are included in the FLI USB SDK library. By default, this library is itself included and installed by FliVision and FliSdk software if not already present on the computer.

It is indexed into 5 sections:

Section	Overview
1	Introduction section
2	Basic information on the USB norm: physical ports, cables, theorical and actual bandwidth
3	Issue and possible causes that a user can face using cameras USB port
4	Evaluation and optimization of the computer USB performances
5	Procedure to diagnose and solve USB issue

Table 1 : Section overview

2. USB in a nutshell

2.1. Introduction

Universal Serial Bus (USB) is an industrial standard that establishes specifications for cables, connectors, communication and power supply (interfacing) between computers and peripherals. A broad variety of USB hardware exists, including 14 different connector types. The most recent is the USB-C.

First Light Imaging is using different types of USB physical port, as presented in the following table:

Camera	USB Protocol	Plugged Connector	Necessary Byte Rate	Necessary Bandwidth
C-RED 2	USB 3.0	USB – C	395 MB/s**	3.16 Gbit/s*
C-RED 2 ER				
C-RED 3	USB 3.1 Gen 1***	Micro-B		

Table 2 : Necessary USB transfer rate for camera operation

*1 Byte = 8 bits
** MB/s stands for megabyte per second
*** USB 3.1 Gen1 is only the new name for USB 3.0

USB 3.0 adds a SuperSpeed transfer mode compared to the previous USB 2.0 standard.

SuperSpeed plugs and receptacles are identified with a distinct logo and blue inserts in standard format receptacles.

The SuperSpeed bus adds a transfer mode at a physical rate of 5.0 Gbit/s. Its efficiency depends on several factors including physical symbol encoding and link level overhead.

USB 3.0 uses an 8b/10b encoding scheme, each byte needs 10 bits to be sent, so the theoretical raw throughput falls to 4.0 Gbit/s. When flow control, packet framing and protocol overhead are considered, the estimated remaining bandwidth maximum is close to 3.8 Gbit/s.

As indicated in Table 2, the required bandwidth is 3.16 Gbit/s for First Light Imaging USB 3 cameras which is compliant with the theorical bandwidth.

2.1. USB: port and cable

There is a USB color port convention that indicates to the user which kind of USB can be connected:

White: Usually identifies an old USB 1.0 connector or port.
Black: Identifies a USB 2.0 Hi-Speed connector or port
Blue: Identifies a USB 3.0 SuperSpeed connector or port.

⚠ *The USB 3.0 SuperSpeed connectors are the only ones compatible with First Light Imaging's cameras. USB 2.0 ports are not supported, even at low framerates.*

C-RED 2 and C-RED 2 ER have a USB-C connector, whereas C-RED 3 includes a USB micro-B connector.
A USB-C to USB-3.0 cable is provided to the user of C-RED 2 and C-RED 2 ER.
A USB micro-B to USB 3.0 cable is provided to the user of C-RED 3.

Figure 1 : Ports and cables used for USB connection of First Light Imaging cameras
(a) Blue USB 3.0 native port on PC
(b) USB-C to USB-3.0 cable for C-RED 2 and C-RED 2 ER
(c) and USB micro-B to USB 3.0 cable for C-RED 3

2.2. Bandwidth calculation

Camera USB transfer rate can be calculated by using the following equation:

$$T_{RATE}\ (MB/s) = Image\ Resolution\ \times number\ of\ Byte\ per\ pixel\ \times Framerate \quad (1)$$

Each pixel is composed with 2 bytes. For example, consider a user operating his C-RED 2 camera in full frame (640 x 512) and at 600 frames/second. The transfer rate needed on the USB port is:

$$T_{RATE} = 640\ \times\ 512\ \times\ 2\ \times 600 = 393.216\ MB/s$$

To maximize USB3 performance, it is better to use native USB 3.0 port (meaning a USB 3.0 port directly handled by the processor). However, some bandwidth issues can still occur inducing default in the image readout. Possible causes of poor USB 3 bandwidth are detailed in the next section of this document.

3. USB 3.0 Image display: issue and causes .....

3.1. Issue: Image default

From the user's perspective the consequence of low bandwidth will be that the image may appear blinking. If the frame grabbing is stopped, the inspection of one frame shows an image that looks like a mosaic.

An example of such an image is provided in Figure 2 below:

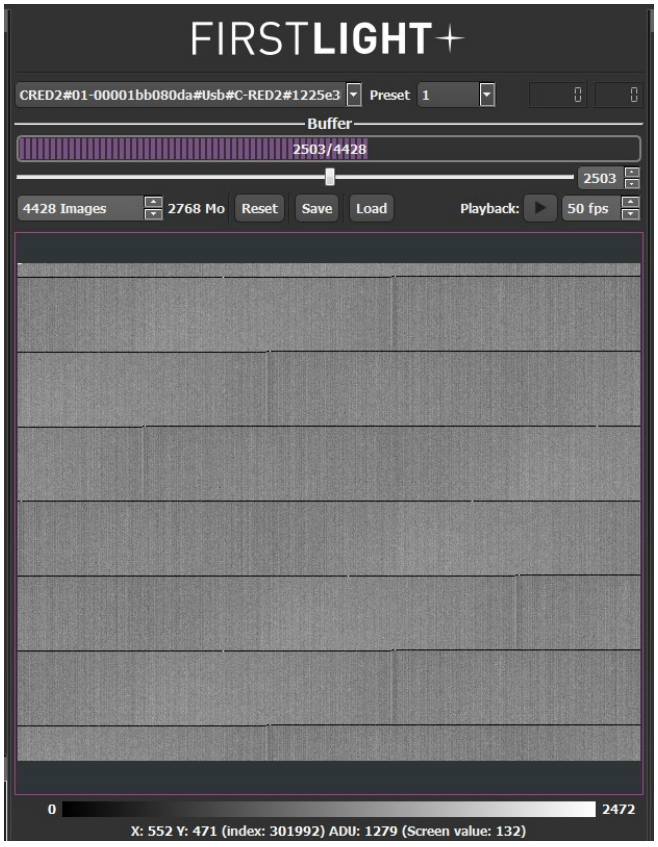

Figure 2: Effect of non-optimized USB 3.0 communication on the image display (First Light Vision software)

3.2. Cause 1: Power saving management

Due to an aggressive power saving management mode, some laptops do not provide the full USB 3 performance, they add an important additional latency on USB transfers.

Solutions to optimize the performances are given in section 4.

3.3. Cause 2: Operating system compatibility

Windows® 7 does not support USB 3.0 natively, support is heterogeneous, and performance is hardly predictable. For this reason, to use the camera USB connection, it is strongly recommended to use a Windows® 10 PC. For convenience, drivers for Windows® 7 OS are provided, but this OS is not officially supported by First Light Imaging.

3.4. Cause 3: USB 3.0 port bandwidth

The bandwidth of USB 3.0 is critical. When a user operates with a camera at full frame and 600 fps, it may happen that the USB 3.0 implemented in the user's computer is not compliant with the theorical bandwidth.

This issue is related to the computer used to operate the camera, and not to the camera itself. The problem is encountered when the 395 MB/s requirement is not fulfilled.

4. Optimizing computer USB performances

4.1. Initial recommendations

The use of the USB link should follow these recommendations:

- Do not plug a hub between the camera and the PC USB port.
- The camera must be the only one connected to USB 3 port.
- Before plugging the camera to an USB 3 port, the user should measure its bandwidth and check that it is superior to the 395MB/s required by First Light Imaging cameras.

4.2. Facing aggressive power management saving

4.2.1. BIOS set up

Depending on the user computer (see section 4.4), this issue can be solved by disabling the power saving management. Up to three settings can be disabled:

- Intel SpeedStep
- Intel TurboBoost
- C-State support

These settings can be found in the BIOS of the computers.

4.2.2. Example of BIOS settings for a DELL xps13

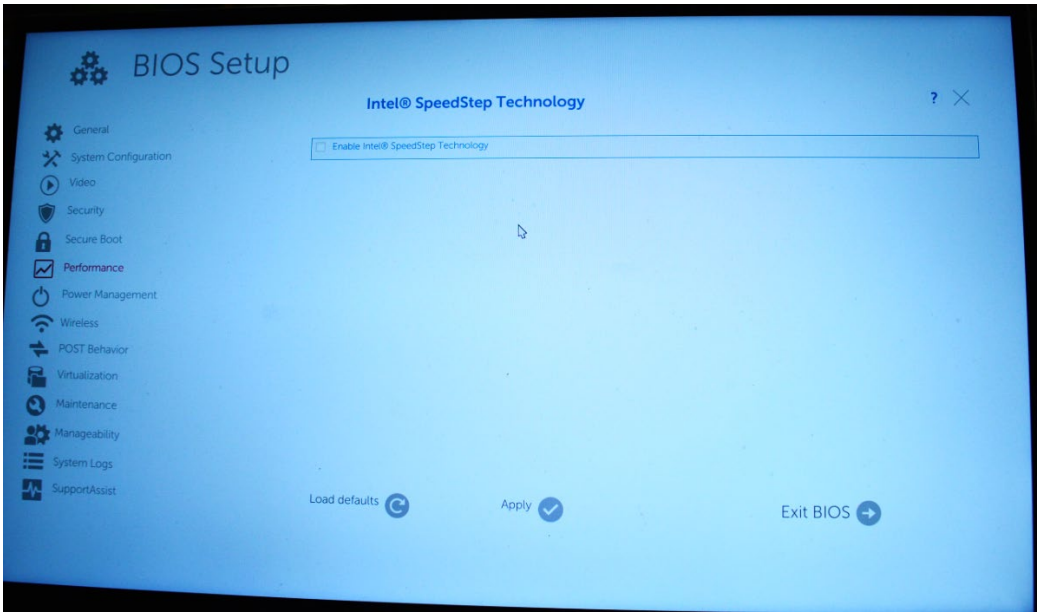

Figure 3: DELL BIOS setup settings -1

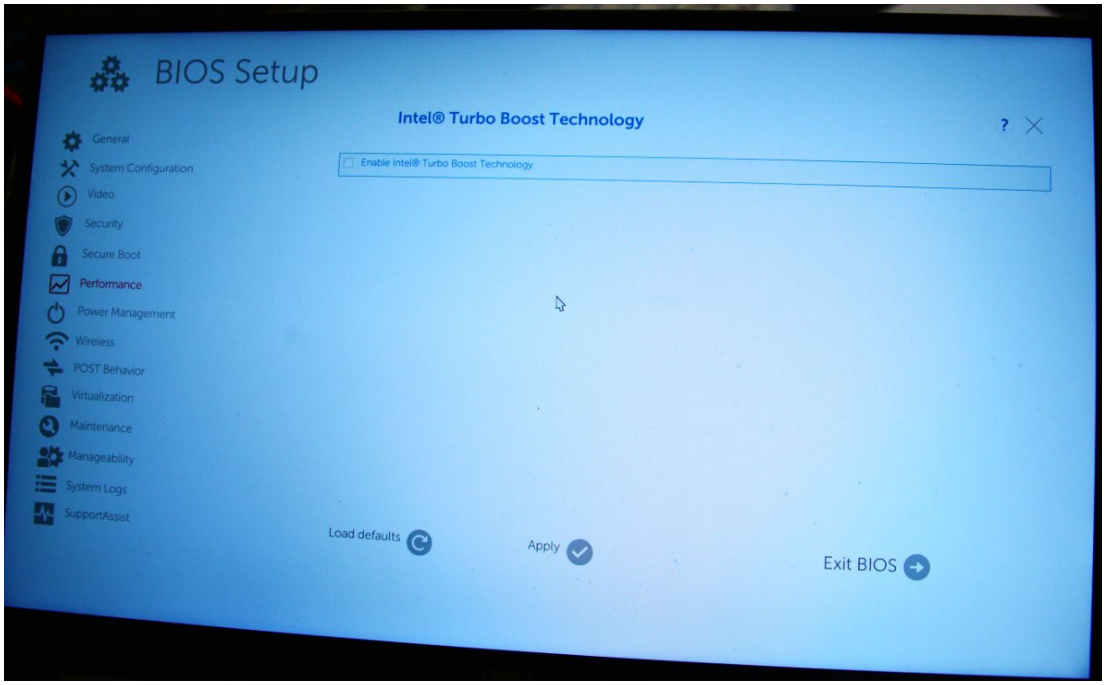

Figure 4: DELL BIOS setup settings -2

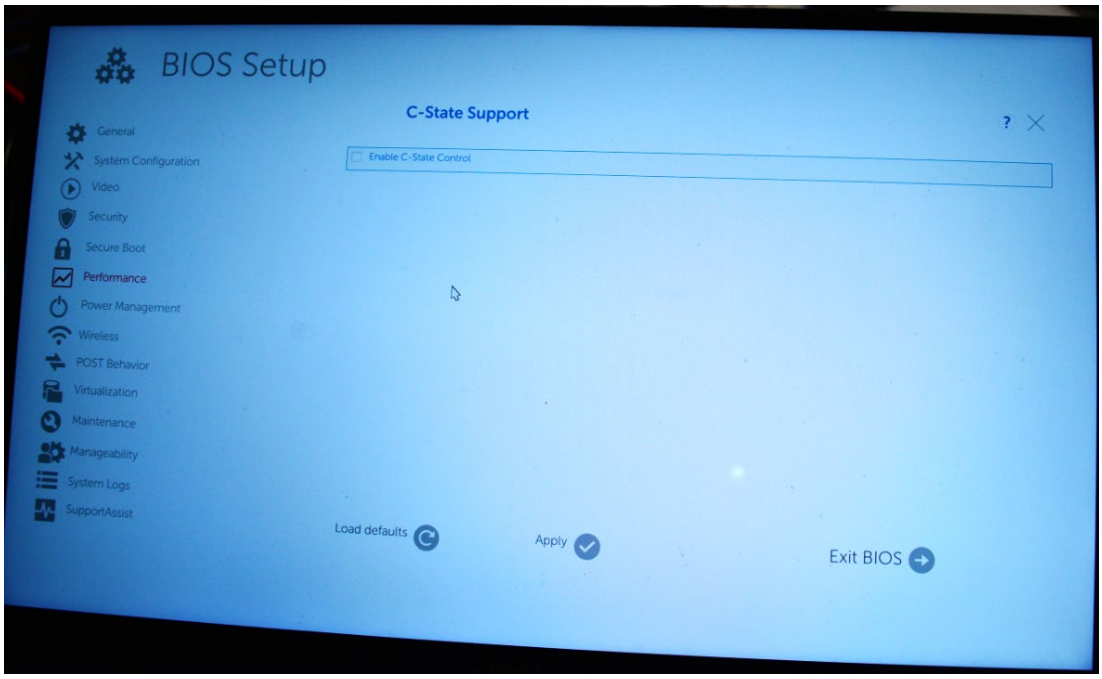

Figure 5: DELL BIOS setup settings -3

4.2.3. Example of BIOS settings for a desktop with an Asus motherboard.

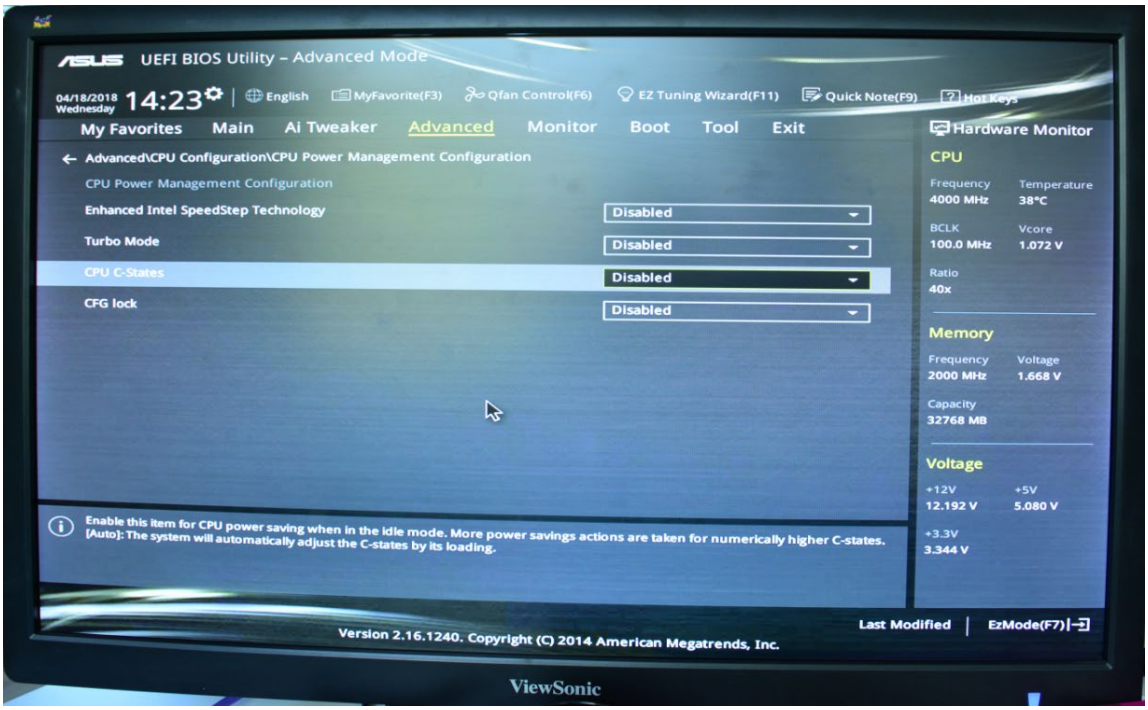

Figure 6: ASUS BIOS Power settings

4.3. Power modification settings

USB 3.0 performances can be optimized by Windows. To achieve this, go to the Windows® power modification settings (Figure 7) and select high performances parameters (Figure 8):

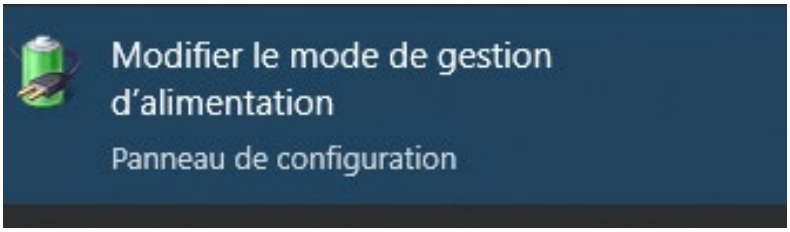

Figure 7: Power modification settings

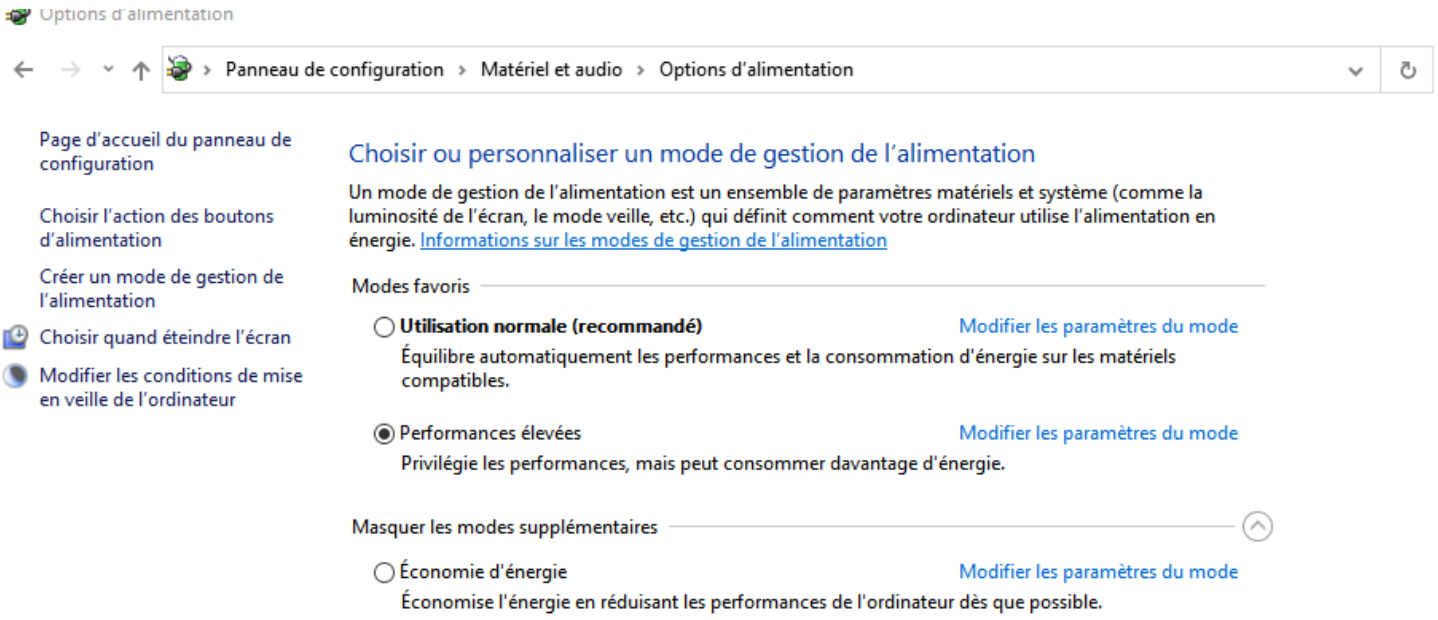

Figure 8: Choose high performance settings

4.4. Facing the bandwidth issue of USB 3.0

4.4.1. Testing the USB 3.0 port speed

To evaluate the USB port speed, a tool such as the USB 3.0 Loopback Plugs module from PassMark Software® is recommended.

The tables 4 to 7 below show the result of experimental tests to measure the real throughput of USB port on different systems using USB3 Loopback plug (firmware version 2.3). The analysis has been performed with a USB 3.0 Loopback plug directly attached to the host through several USB 3.0 port. The data rates

that are not compatible with First Light Imaging cameras are written in red. The compatible data rates are reported in green.

PC Information	i7-1075H CPU@ 3.6GHz			
PORT Type	C-State & Turbo OFF		C-State & Turbo ON	
	High Perf OFF	High Perf ON	High Perf OFF	High Perf ON
USB 3.0-Front 1 (Native)	363.3 MB/s	367.8 MB/s	311.4 MB/s	367.5 MB/s
USB 3.0-Front 2 (Native)	362.3 MB/s	367.8 MB/s	318.9 MB/s	367.5 MB/s

Table 3: Real USB 3.0 speed on tested PC 1

PC Information	AMD Ryzen Threadripper PRO 3945WX 12-Cores @ 4.00 GHz			
PORT Type	C-State & Turbo - OFF		C-State & Turbo – ON	
	High Perf OFF	High Perf ON	High Perf OFF	High Perf ON
USB 3.0-Front 1 (Native)	422.2 MB/s	422.2 MB/s	422.2 MB/s	421.2 MB/s
USB 3.0-Front 2 (Native)	422.2 MB/s	422.3 MB/s	422.2 MB/s	422.0 MB/s
USB 3.0-Rear 1 (Native)	384.6 MB/s	385.7 MB/s	385.8 MB/s	385.0 MB/s
USB 3.0-Rear 2 (Native)	385.4 MB/s	385.0 MB/s	385.0 MB/s	385.5 MB/s

Table 4: Real USB 3.0 speed on tested PC 2

PC Information	Intel(R) Core (TM) i5-6600K CPU @ 3.50GHz			
PORT Type	C-State & Turbo - OFF		C-State & Turbo – ON	
	High Perf OFF	High Perf ON	High Perf OFF	High Perf ON
USB 3.0-Front 1 (Native)	433.9 MB/s	434.3 MB/s	433.3 MB/s	432.6 MB/s
USB 3.0-Rear 1 (Native)	433.6 MB/s	434.3 MB/s	433.5 MB/s	432.8 MB/s
USB 3.0-Rear 2 (Native)	433.6 MB/S	434.3 MB/s	433.5 MB/s	432.5 MB/s

Table 5: Real USB 3.0 speed on tested PC 3

PC Information	DELL-PRECISION i7-10750H CPU @ 2.60GHz			
PORT Type	C-State & Turbo - OFF		C-State & Turbo – ON	
	High Perf OFF	High Perf ON	High Perf OFF	High Perf ON
USB 3.0-Right (Native)	427.5 MB/s	427.5 MB/s	427.5 MB/s	427.3 MB/s
USB 3.0-Left (Native)	427.2 MB/s	427.5 MB/s	427.3 MB/s	427.5 MB/s

Table 6: Real USB 3.0 speed on tested PC 4

Experimental results show large variations form one computer to another. Depending on the computer, disabling C-state and turbo parameters does not always impact the USB performances.

A similar conclusion is established regarding the activation of high-performance energy.

USB performances are far below the theoretical data bit rates mentioned in the USB 3.0 official norm. Furthermore, the fact of having a very high performances computer does not guarantee that its USB 3.0 native port can operate at high speed (table 6). Computer can operate with a 24-core processor and have a limited data rate bandwidth at its native port.

Our recommendation is to always check the real speed of the USB port (using a USB 3.0 loopback or similar device).

Note: In some other cases, it can occur that the USB 3.0 Loopback plug does not turn on once plugged to a computer USB port. It means that the USB port is not correctly powered and presents some internal hardware issues. However, for operating First Light Imaging cameras, this is not an issue as the USB 3 power supply is not used.

4.4.2. Recommendation on USB 3.0 speed

If the computer USB 3.0 port bandwidth is inferior to 395 MB/s, stable imaging is not possible with a First Light Imaging camera. In this case, the user must disable the 600 fps license which allows the camera to operate at 600 fps framerate in full frame. The maximum camera framerate will then be around 400 fps in full frame.

To disable the 600 fps license file:

(1) Open First Light Vision software, then go on Tool→ License Manager (Figure 9).
(2) Select the 600fps.lic file,
(3) Click on disable (Figure 10).
(4) Disconnect and reconnect the camera power cable to reboot it in the case you are using C-RED 2 or C-RED 2 ER. If you are using C-RED 3, just close the License Manager window and click on reboot button.

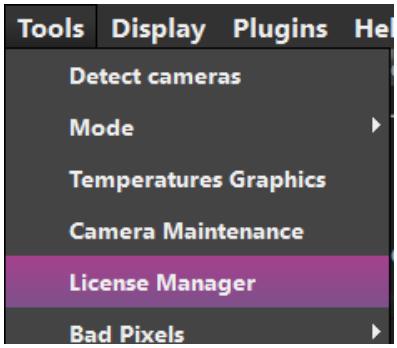

Figure 9: License Manager Settings

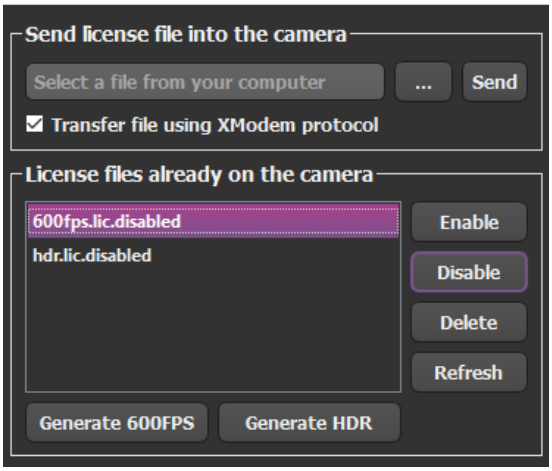

Figure 10: Disable the 600fps license

If you do not use GUI FLIVision software, there is a command that allows to disable the license file.

Disabling of a license is carried out using the "`exec disablelicense 600fps.lic`" command. Reenabling is carried out by using the "`exec enablelicense 600fps.lic`" command.

Note: When a license file is uploaded into the camera, it is enabled by default.

At 400fps, the transfer formula has shown that full frame imaging induces a transfer rate of about 262 MB/s which is approximatively half of the USB 3.0 theoretical bitrate transfers.

At such low-rate, USB port should be able to receive the image. If images received by the computer are not correct, check that C-state and turbo boost are disabled. Then, activate high performances energy.

5. Conclusion: steps to diagnose and solve USB issue

Working with a computer equipped with a USB 3.0 port does not necessarily guarantee compatibility with high-speed cameras. It depends on the degree of compliance of the USB3 port used with the USB norm requirements.

The following figure is a step-by-step procedure to diagnose USB issues. It summarizes all the recommendations given in this document.

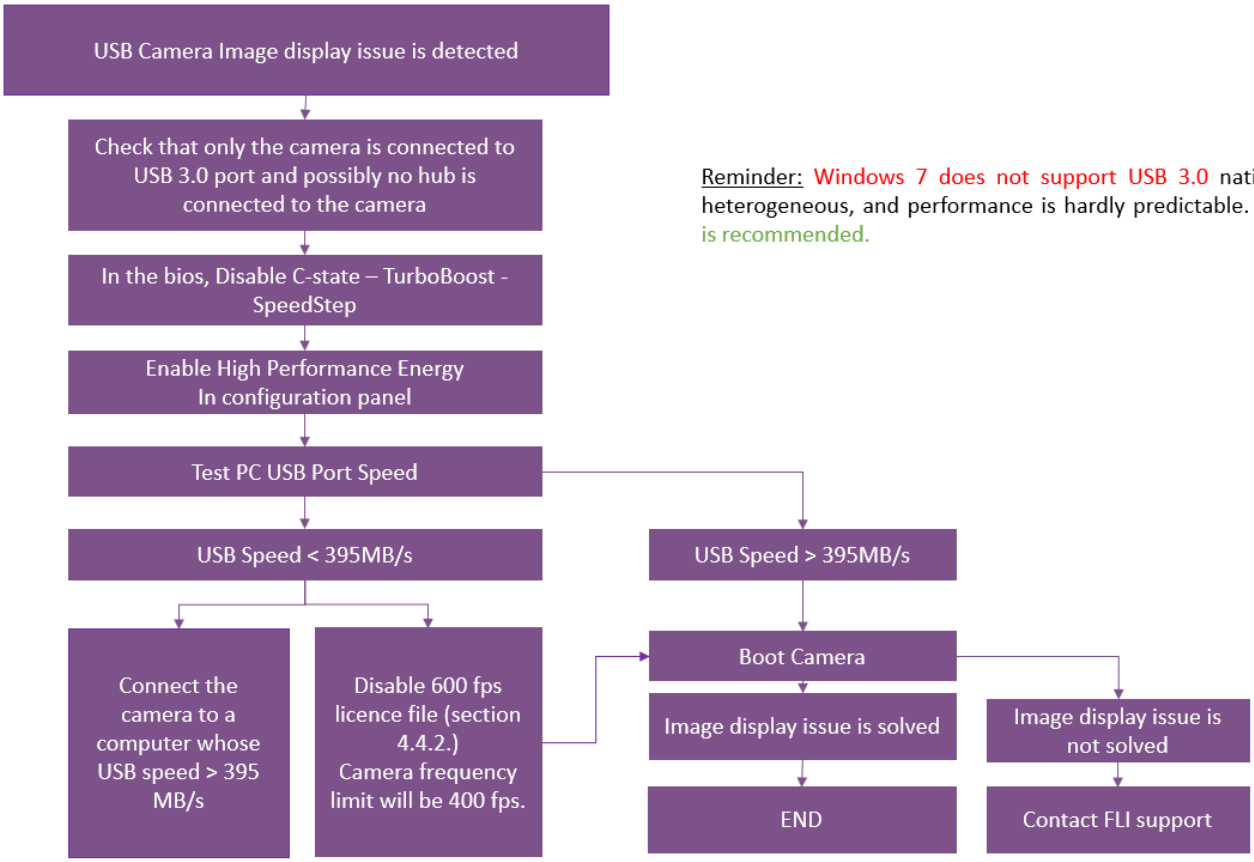

Figure 11: Procedure showing the steps to follow to diagnose and find a solution to USB issue.

For any further information, please contact First Light Imaging's support team (support@first-light.fr).

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