APPLICATIONS OF IEEE-1394 AND GigE VISION DIGITAL CAMERA IN THE TLS

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Abstract

Digital cameras comply with IEEE-1394 and GigE Vision standard are applied for beam diagnostic applications at NSRRC. These cameras provide low distortion for image transmission over long distance and flexible camera parameters adjustment with remote interface. These digital interfaces include of FireWire and gigabit Ethernet. The wide bandwidth bus can reduce latency time and timing jitter effectively and provides high quality image transportation. It also provides lossless compressed image with high update rate. Experiences accompany with both kinds of cameras will be summarized. System integration with control system and applications will also include in the report.

INTRODUCTION

Imaging applications in the accelerator community are often utilized to measure beam profile and interference fringes. The beam profile may convert form fluorescence, various optical diagnostics (SR, OTR, DR, etc.). A fluorescence screen/OTR and a synchrotron light source radiation monitor are mostly employed to measures beam profile and beam size of the accelerator system in order to optimize performance, check routine operation and study various beam physics. These tools are beneficial to characterize and analyze properties of electron beam. For example, the beam emittance is calculated from the measured beam size.

Digital cameras were adopted to enhance functionality of accelerator diagnostics [1-4]. The major upgrades of data acquisition and analysis have been implemented. The main goals are to increase the signal transmission quality, the dynamic range, the linearity of the profile monitor, and the superior supports for data analysis.

Using a fully digital camera has two major advantages compared to analogue CCD camera. First, the A/D conversion is performed closer to the CCD/CMOS sensor and therefore minimizes electronic noise. Once the digitized signal is immune to noise, we can implement long haul (10 m ~ 10^3 m) applications in the accelerator diagnostics. Various long hops solution is supported by the IEEE1394A/B interface. Noise immunity and isolation are provided by this solution that must be favourable in the accelerator environment. Second, unlike analogue camera systems, digital systems do not suffer from pixel jitter. Each captured pixel value corresponds to a well-defined pixel on the CCD/CMOS chip. The IEEE1394 interface is a hot swappable and self-configuring high performance serial bus interface that is capable of 400 Mbit/sec data transmission and will be enhanced to 3.2 Gbit/s for the next generation products. The interface supports asynchronous (guaranteed delivery) and isochronous (guaranteed bandwidth and latency) data transfers. By applying digital IEEE1394 camera system, we are able to eliminate the frame-grabber stage of processing and directly transfer data at maximum rates of 400 MB/sec. IEEE1394 general purposed CMOS cameras (Prosilica CV640, 659 x 494 4.65 μm square pixels) were chosen for screen monitor application. There is no frame grabber or additional power supply required. Frame rates of up to 30 fps can be achieved adequately in the full frame.

The GigE Vision standard from the Advanced Imaging Association (AIA) is a new interface standard for the latest vision of cameras with high performance. GigE Vision combined features of high data rates (required for uncompressed video or imaging applications), ubiquitous computer interface hardware, low cost cabling, and widespread popularity makes Gigabit Ethernet an attractive interface option for accelerator applications. The GigE Vision standard including of both the hardware interface standard (Gigabit Ethernet) and the communications protocols, can be utilized for controlling and communication of cameras. The GigE Vision camera control registers are based on a command structure called GenICam which is administered through the European Machine Vision Association (EMVA). GenICam seeks to establish a common camera control interface so that the third party software can communicate with the cameras from various manufacturers without customization. GenICam is incorporated as a part of the GigE Vision standard. GigE Vision is analogous to FireWire's DCAM (IIDC) and beneficial to facilitate system integration and thus reduce costs.

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FireWire camera was adopted for synchrotron radiation at the booster synchrotron and the storage ring very successful since 2003 [1]. Qimaging QICAM 12 bits camera was selected to capture synchrotron radiation profile. Parameters of the camera are completely programmable so that this is very useful to accommodate with various beam conditions and effectively increase reliability.

FireWire CMOS camera was adopted for the transport line screen monitor since 2004 [2] as shown in Fig. 1,2 and 3. Functionality is satisfactory while the only problem is less reliability near the injection kicker of the storage ring. The problem might be caused from bad grounding of the kickers and the cameras which might be hanged due to the noise induced by the long IEEE-1394 cable. After the kicker grounding improved and the camera with IEEE-1394B fibre interface replaced, the reliability is increased drastically.

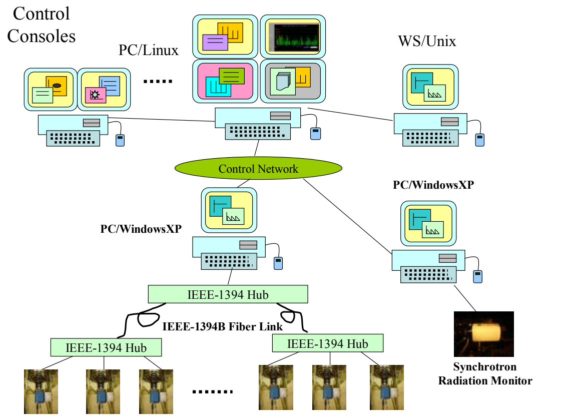

Figure 1: Topology of the IEEE-1394 camera installation.

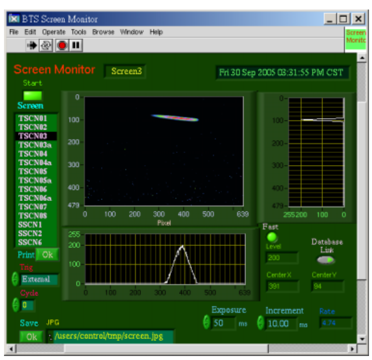

Figure 2: The VI for transport line screen monitors operation.

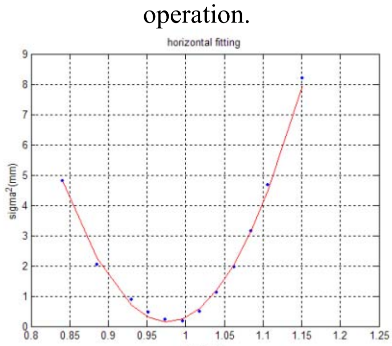

Figure 3: Example of transverse beam emittance measurements at transport line by using quadrupole scan method. Fitted emittance is ε_x = 238 nm-rad.

The new GigE camera interface is also applied for preliminary evaluation. Set up of the experiment is shown in Fig. 4. Figure 5 shown a typical profile measurement result. Emittance is measured by the quadrupole scan method in the exit of the 50 MeV linaer accelerator. The beam profile as a function of one nearest quadrupole strength was measured as shown in Figure 6. The profile image is captured and analyzed by using Matlab scripts. Emittance will be immediately adjusted and reduced from the machine parameter by the measured data. Performance and reliability of the GigE Vision camera is evaluated. Since the camera is installed near the klystron modulator, the camera is occasionally hanged during klystron power off. A remote power reset will be applied as a solution of this problem.

Figure 4: A GigE Vision camera installed at exit of 50 MeV linaer accelerator for test.

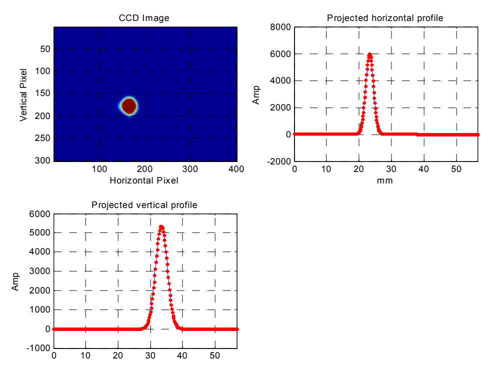

Figure 5: Profile measured by the GigE Vision camera.

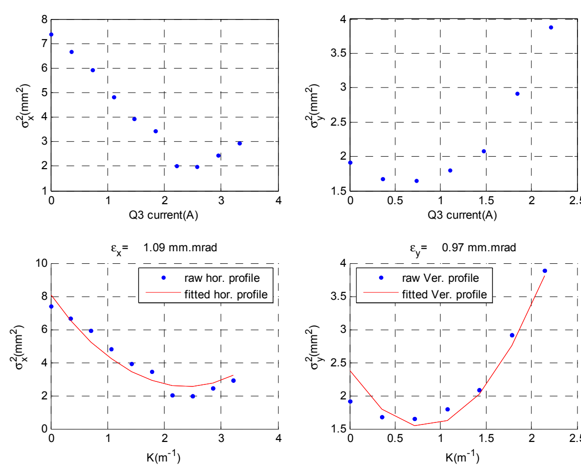

Figure 6: Measured horizontal and vertical emittance of the 50 MeV lianc by quadrupole scan method. The fitted normized emittance is ε_x = 1.09 mm-mrad and $\boldsymbol{\varepsilon_y}$ = 0.97 mm-mrad in the horizontal and vertical respectively.

EXPERIENCES OF IEEE-1394 AND GbE VISION CAMERA FOR BEAM DIAGNOSTIC APPLICATION

Both of IEEE-1394 cameras and GigE Vision cameras were tested and applied for several diagnostics for the TLS. Some of the experience is summarized in the following paragraphs.

Control System Integration

To simplify the control system integration, a PC/ running Windows/XP was adopted for FireWire camera server as well as GigE Vision camera. There are few drivers supporting both kinds of interface. The standard DCAM camera driver with LabVIEW and other COTS softwares are supported for FireWire camera. The GigE standard camera driver is being developing now. We use non-standard windows XP/Linux camera driver in this report. User interface was written by LabVIEW. The user interface was developed by LabVIEW and Matlab to support various experiments and remote controls.

Cabling

Maximum copper cable length in the FireWire is around 10 meters with full speed. Hub is essential to extend the length of links. For long haul transmission, IEEE-1394B fibre link can be used. This fibre link is also useful for hostile EMI environment near the kickers. The connection for GigE Vision camera can be CAT5e or CAT6 Ethernet cables with RJ-45 connectors up to 100 meters. Gigabit Ethernet provides high performance camera interface to convey control and image data up to 100 meters long using inexpensive CAT5e or CAT6 cabling. Such long cable lengths are not generally possible with other kinds of interface. For the hostile EMI environment, this kind of connection sometimes will deteriorate the camera reliability. Remote power reset is still essential for these cases.

Operation Performance

Performance of the IEEE-1394 and GigE Vision camera seems not bad. Exposure condition can be controlled remotely and as a consequence, it is very helpful for diagnostic applications with various beam conditions. Image quality is good and irrelevant to the distance of links.

Reliability and Measure

Reliability of FireWire camera and GigE Vision camera seems no big difference. The FireWire primary problem is resulted from the rigidity of the connectors and power supply problem between several layers hub. At the initial stage, the unreliability is mainly come from the bugs of the device driver. After problem solved, the reliability seems not bad. However, there is a micro-controller inside. If unintentional high field noise due to a fault of the grounding of kickers causes camera hanging, it is no way to recovery without power reset [3]. To remedy this disadvantage, a remote power on/off control was implemented.

Radiation Damage

The FireWire cameras have been operated over two years, there are no severe damages observed. Similarly, the GigE Vision cameras have been operated over 6 months, no observable radiation damage was observed. So, the radiation damage is similar with the analogue camera.

SUMMARY

FireWire camera and GigE Vision cameras are tested at TLS for several diagnostic applications. Their setup allowed images to be transmitted digitally, removing the request from cumbersome frame grabbers and coax switches. Furthermore, the simplicity of triggered acquisition made this mode be a standard rather than a special case. Both FireWire cameras and GigE Vision cameras with the TLS control system allow seamless integration with control room displays and are easy to access image for various machine studies. Experiences gain form these experiments and image quality are excellent. Varying exposure time is very helpful to increase the dynamic range. The only shortage is less reliable than the analogy camera. This can be modified by the aid of reset power reset. Both kinds of interfaces will be suitable for the newly proposed in the 3 GeV Taiwan Photon Source.

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