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IMAGE PROCESSING AND COMPUTER CONTROLS FOR VIDEO PROFILE DIAGNOSTIC SYSTEM IN THE GROUND TEST ACCELERATOR(GTA)*

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Abstract

This paper describes the application of video image processing to beam profile measurements on the Ground Test Accelerator (GTA). A diagnostic was needed to measure beam profiles in the intermediate matching section (IMS) between the radio-frequency quadrupole (RFQ) and the drift tube linac (DTL). Beam profiles are measured by injecting puffs of gas into the beam. The light emitted from the beam-gas interaction is captured and processed by a video image processing system, generating the beam profile data. A general purpose, modular and flexible video image processing system, *imagetool*, was used for the GTA image profile measurement. The development of both software and hardware for *imagetool* and its integration with the GTA control system (GTACS) will be discussed. The software includes specialized algorithms for analyzing data and calibrating the system. The underlying design philosophy of *imagetool* was tested by the experience of building and using the system, pointing the way for future improvements. The current status of the system will be illustrated by samples of experimental data.

Video Profile Monitor (VPM) Overview

The purpose of the video profile monitor is to measure horizontal and vertical beam profiles in GTA.[1,2] A secondary goal is to measure horizontal and vertical beam positions. The measurement takes place in the Intermediate Matching Section (IMS) located between the Radio Frequency Quadrapole (RFQ) and the Drift Tube Linac (DTL). The video system uses intensified video (TV) cameras to look at beam activated gas fluorescence. Basically we want to insert a camera in the beam line and take a picture from which we'll measure the beam's location and size. Since the amount of light produced is in relation to the number of particles interacting with the gas, this technique should be able to provide physical measurements of the beam as to size and shape. The concept seems simple but the implementation is not quite so straight forward.

Video System Configuration

The video system equipment configuration is shown in figure 1. It is located in three main places: the accelerator beam line, the racks, and the control room. Its use for diagnostics is described more fully in [2].

The accelerator beam line equipment consists of two computer controlled video cameras. Each camera has a controllable image intensifier and a motorized lens system which allows computer control of its focus, iris and zoom. They are pointed at a calibration light emitting diode(led). There is one camera situated to obtain images of vertical beam profiles and another situated to obtain images of horizontal beam profiles. A piezo electric valve is used to inject gas into the accelerator.

The racks contain electronics that interface the equipment on the accelerator to the computer control system. Video monitors, a video oscilloscope and manual controls are

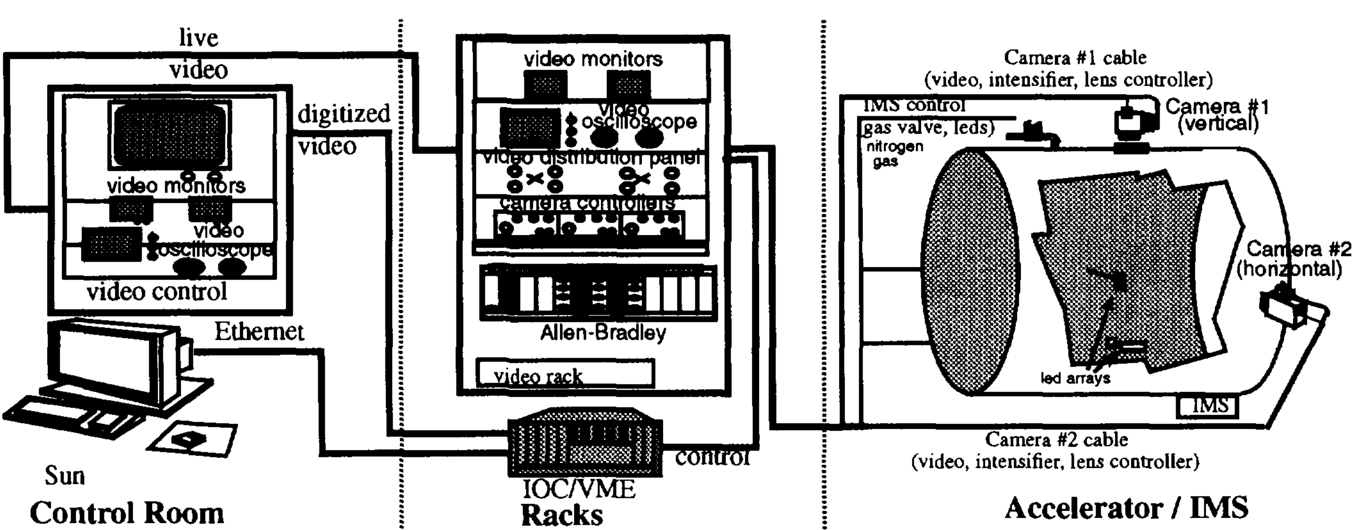

Fig. 1 Video Profile Monitor System

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available for off-line testing of the equipment. An Allen Bradley interface and a VME based input output controller (IOC) supply the actual computer interfaces. In the VME crate are two video digitizers, two video memories and a video display unit all purchased from Datacube.

The control room uses Sun workstations as operator interfaces. These are connected to the rack equipment via ethernet. A display of the digitized video image is brought into the control room from the VME crate over a fiber optic link. Two video monitors display the analog data from each camera. A video oscilloscope is also available.

Video System Software

The video system software can be broken down into a number of distinct parts: basic hardware controls; video controls; real time plotting and analysis; and off-line analysis.

The software is distributed between the Sun and the IOC. The operator interface and off-line analysis execute on the Sun using OpenWindows and the Unix operating system. The control programs and real time programs for plotting and analysis execute on the IOC using the VxWorks (real time Unix) operating system. VxWorks executable subroutines to support the video hardware are provided by Datacube.

Off-line analysis is accomplished through a program, *imagetool* [3], which displays images and allows user written analysis codes to be invoked through menus. Initially *imagetool* also provided a menu driven operator interface which passed commands to VxWorks, via a remote shell interface, to invoke Datacube video subroutines. Figure 2 shows a typical image and plot generated by *imagetool.*

The GTA Control System (GTACS)[4] is used for control of the basic hardware including auxiliary video controls such as lens control, intensifier control, gas valve controls and video timing. GTACS applications are built with a set of control system building tools which require very little programming. These tools worked very well for the simple controls and operator interface involved. Figure 3 shows the main video control screen generated by GTA.

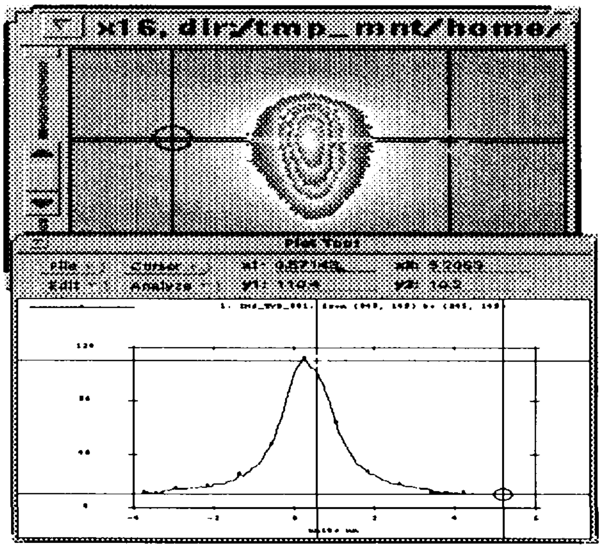
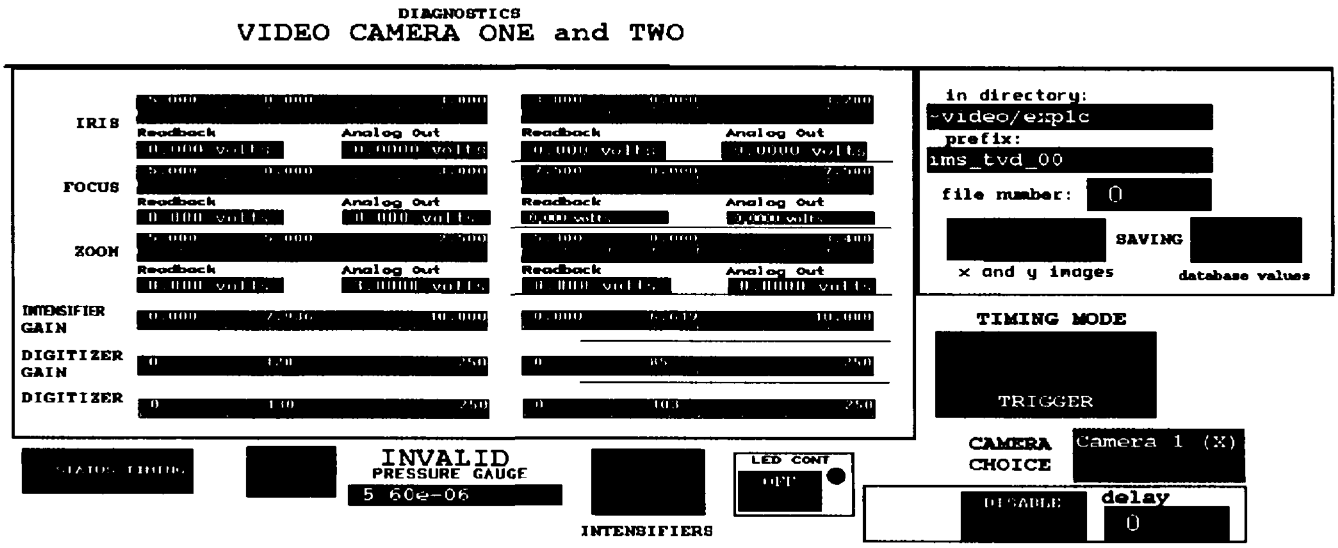


Fig 2 Image and plot of image profile

The video controls themselves were more challenging, They were initially developed independently from GTACS. After the video controls were working well they were integrated with GTACS. This was done by using GTACS subroutine records and sequences to call datacube subroutines. The *imagetool* menus used for control were replaced by standard GTA operator screens.

The implementation of the real time plotting and analysis utilizes a hardware graphics overlay. This is used to plot a line or a column of image data which can be updated at



INVALID
PRESSURE GAUGE
5 60e-06

in directory:
~video/explc

prefix:
ims_tvd_00

file number: 0

TIMING MODE: TRIGGER

CAMERA CHOICE: Camera 1 (X)

delay: 0

Fig 3. GTACS Video Control Screen

a rate of up to10 Hz. In addition, measurements such as full width half maximum may be printed on the plots.

Experience with System

It took some time before its operational characteristics were known. During this time of uncertainty, helium was used as the injected gas rather than nitrogen to prevent ice formation on the cryogenic RFQ. We are still learning about the system but some of the experiences to date are outlined below.

The first challenge was to find and correct major system problems that would prevent operation of the system. As an example of the problems encountered, an illegal set point caused the GTACS timing unit to generate a series of small pulses instead of one single pulse. Since this particular channel was connected to the gas valve, it repeatedly opened the valve causing a tank of gas to be emptied into the accelerator vacuum. To prevent recurrence of incidents of this type we now use a small reservoir to limit the amount of gas that can be dumped into the vacuum at one time. The GTACS system was also modified so that it would not respond disastrously to bad set points.

The first data collected indicated that the beam width was approximately the width of the accelerator beam pipe just up stream of the video profile monitor station. This beam width is much larger than expected. At this point we were confident that the gas valve subsystem was working correctly and we started using nitrogen as the injected gas. We also gated the image intensifier to integrate over no more than the duration of one macro pulse. After these adjustments were implemented the data began to give results which were closer to what was expected. A careful examination of the data led us to the hypothesis that the data was the sum of a broad low amplitude Gaussian and a narrower, high amplitude Gaussian. We have written software to fit two Gaussians of this type to the data. When the low amplitude fitted Gaussian is subtracted from the original data the resulting signal appears to be a reasonable representation of the beam with much flatter tails that the original.

Calibrating the system was also difficult. To obtain spatial calibrations a face plate with two columns of 4 holes each was put over an LED in the field of view of the camera. The exact location of the upper left hole was then measured. The idea was to turn on the LED and automatically find the position of each hole in the image. A simple code was written to find these points of light and calculate their centroids. In practice it was very difficult to take an image that would give sufficient contrast between the lights and the background. The light points were frequently of different intensities. To add to the problem, the focus of the lens was set to the beam position which was approximately 5 mm in front of the LEDs. As a result the points of light were out of focus. Despite the above problems, calibrations were successfully run and plots were made of the center of the lights to check the calibrations. Data was then taken with the calibration lights on to visually verify that the calibrations were being correctly applied to the beam data.

Future Directions

We shall continue to refine our data collection and analysis techniques so as to obtain useful data. As we gain experience we are discovering how best to operate the equipment. This will lead to more complete automation of the system for equipment operation as well as data collection.

Another improvement would provide calibrations that are more reliable and more easily obtained. This is still the hardest part of the process. The calibration procedure depends on automatically finding the calibration lights. If it fails to find the lights, it is not readily apparent to the operator what adjustments should be made to insure a better calibration. This is an open ended problem at present.

The final task is to integrate the results of the video profile monitor with the rest of the accelerator diagnostic data. When this is done the system will cease to be an interesting experiment and turn into a useful diagnostic.

Conclusions

We have successfully designed and implemented the controls for a video diagnostic system to measure beam profiles. Experience has shown us that even though the system is not straight forward to use, it is not too difficult to achieve reasonable results. In the future we hope to achieve a turnkey operation and demonstrate the usefulness of the diagnostic.

References

[1] Gilpatrick, Power, "RFQ and IMS Permanent Diagnostics", LA - UR # LA-CP-91-168 (Dec. 1990)

[2] D.P. Sandoval, R.C. Garcia, J.D. Gilpatrick, M.A. Shinas, R. Wright, V. Yuan and M.E. Zander, "Video Profile Diagnostic System for GTA", This Conference.

[3}]Mark E. Zander, "Imagetool: Image Processing on the Sun Work-station", SPIE Conference on Applications of Digital Image Processing 14, Vol. 1567, 9 (1991)

[4] A.J. Kozubal, D.M. Kerstiens, J.O. Hill and L.R. Dalesio ,"Run-time environment and application for the ground test accelerator control system", Nucl. Instr and Meth. 292 (1990)