DATA ACQUISITION, CONTROL, AND ANALYSIS FOR THE ARGONNE ADVANCED ACCELERATOR TEST FACILITY (AATF)

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ABSTRACT

The AATF has been used to study wakefield acceleration and focussing in plasmas and RF structures. A PC-based system is described which incorporates the functions of beamline control and acquisition, storage, and preliminary analysis of video images from luminescent screen beam diagnostics. General features of the offline analysis of wakefield data are also discussed.

INTRODUCTION

The AATF was designed to measure wakefields in conventional and dielectric loaded structures and in plasmas by using a low-intensity electron bunch to integrate the accelerating and deflecting fields induced by a high intensity driver bunch as it passes through a test device. Results from these experiments have been published elsewhere.[1-4] In this report, the emphasis is on the control and data acquisition system used at the facility.

A plan view of the AATF is shown in Fig. 1. Its main function is to split the 22 MeV electron bunches from the ANL chemistry division linac into two bunches, a high intensity (3-4 nC) 22 MeV "driver" bunch and a low intensity 15 MeV "witness" bunch. The witness beam is produced by dE/dx losses of a fraction of the incident electrons which are intercepted by a graphite target. The two bunches are then transported through their respective beamlines, with the temporal separation (delay) between the two bunches varied by adjusting the physical length of the low-energy line with a trombone. After recombination the two bunches pass through the experimental section and then into a spectrometer, which permits simultaneous measurement of the energy change and transverse deflection of the two bunches.

Beam diagnostics are entirely destructive, consisting of phosphor screens and Faraday cups which are inserted and retracted from the beamlines by means of pneumatic actuators. Light from the phosphors is detected using conventional CCTV cameras with the exception of the low-energy portion of the spectrometer focal plane, where a camera equipped with an image intensifier is employed.

SYSTEM OVERVIEW

The control and data acquisition system is based on an IBM PC/XT personal computer, equipped with commercially available interface cards. A block diagram of the system is shown in Fig. 2. Two hard disk drives are used, a 10MB system disk and a 20MB data disk, with a tape backup unit also available for archival storage. The PC screen is dedicated to control and monitor displays, so a Tektronix 4010 terminal connected to a serial port is used for graphics output. The 4010 has the additional advantage of providing higher graphics resolution than the PC display.

Magnet supplies and diagnostic actuators are controlled and monitored through a single-crate CAMAC system. A Kinetic Systems KS-2925 card provides the interface to the PC, and is used in conjunction with a KS-3920 crate controller. The quadrupole magnet supplies were built in-house, and were designed to be set from a CAMAC 24-bit TTL output register. Bending magnet supplies were purchased commercially, and are controlled by analog levels provided by a 12-bit DAC module. Monitor voltages from power supply shunts are read back using a 32 channel 12-bit data logger. Diagnostic actuators are positioned using another output register.

Signals from the video cameras are digitized using a Data Translation DT2803 frame grabber. The digitized video frames have a 256 × 240 spatial resolution, with a 6-bit dynamic range. A certain amount of real-time image enhancement is possible, using output lookup tables to map gray levels into false color. This feature is particularly useful when tuning the low energy line, where the beam intensities involved are small. Camera selection is done using a DT2859 video multiplexer. The multiplexer has two output channels, which allow simultaneous display of the raw video signal as well as the processed signal through the frame grabber.

The low energy line trombone is positioned by means of a stepping motor controlled by a Compumotor PC21 indexer card. Finally, the Faraday cup currents are measured using a Keithley 480 digital picoammeter, which is read out by the PC through a Metrabyte MBC-488 GPIB interface card.

ONLINE SOFTWARE

P1 is the online program for the AATF. The software is written primarily in FORTRAN, with some low-level functions handled by assembly language routines. Beamline tuning features implemented include control of magnet power supplies, both individually and in groups. The software also has the capability of storing and recalling tunes from disk files. A display of the set and readback current values for all magnets is provided, with the readback values continuously updated. Diagnostic positioning and camera selection are also performed by the program.

In addition to beam tuning, P1 is also used to control the data acquisition process, i.e. the measurement of the longitudinal and transverse wakefields induced by the beam in the device under test. The procedure used is known as a "delay scan". The experimenter selects the camera which views the witness beam spot at the spectrometer focal plane, then specifies the delay increment and total number of delay values desired. P1 then proceeds to move the trombone by the specified delay increment, digitizes a frame, and reads the beam current from the picoammeter. At this point the entire frame or (more usually) an area-of-interest (AOI) surrounding the beam spot is saved to disk, along with the delay and beam current information. The process is repeated until the desired number of delay values is reached.

Insofar as the experimental data consists primarily of digitized video frames, a number of image processing operations are implemented in P1, in addition to the real time enhancement mentioned previously. Possible frame manipulations include frame sums and differences, scalar multiplication, and filtering (convolution with a user-supplied 3 × 3 array). Crosshairs may be displayed and positioned to select a single pixel or AOI. Frame dissection features include plots of vertical and horizontal profiles through a given pixel, projections of the AOI, contour plots, and gray-level histogramming. These plots are displayed on the graphics screen, using a FORTRAN callable graphics package (PSTEK) developed for this purpose. Previously acquired data frame sequences may be played back and analyzed, with the online wakefield analysis algorithm essentially the same as the offline procedure described in the next section.

WAKEFIELD DATA ANALYSIS

Once the data has been taken, the next step is to extract the wakefields (or more properly the wake potentials) from the delay scans. For the offline analysis, the data is transferred to a VAX using KERMIT or a similar communication program.

Since the witness beam intensity is several orders of magnitude smaller than that of the driver, a significant background of low energy electrons is present which results from scraping of the driver beam in the test section and spectrometer. While a simple subtraction of a single witness-off frame is adequate in some cases, in general the large frame to frame background fluctuations require a separate background to be obtained for each frame. A satisfactory solution is obtained by approximating the background locally as a plane in (x,y,gray level) space, and fitting to the pixels in a border (typically 5-6 pixels wide) around the AOI in each data frame.

The bend and nonbend view witness beam centroids are then computed for each background-subtracted frame, and plotted as a function of witness delay to yield the longitudinal and transverse wake potentials. Errors are estimated from the spread in the measurements for the non-causal part of the wake. Conversions from pixel to energy and position units are 10.4 keV/px and 0.75 mm/px respectively. An example of a longitudinal wake potential measured at the AATF is shown in Fig. 3 for a dielectric wakefield device.

The ideal probe of the wakefields would be a single electron, or at least a very short witness pulse with small transverse dimensions. The method used here for producing the witness beam yields bunches with dimensions similar to those of the driving bunch. The wake potential calculated from witness centroids is thus an average over the longitudinal and transverse dimensions of the bunch, which must be unfolded to obtain the true wake potential. In actual practice, when comparing the experimental results to theory, the theoretical predictions are smeared by the appropriate witness dimensions.

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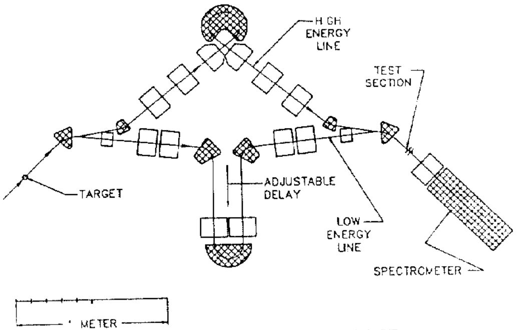

Fig. 1. Plan view of the AATF

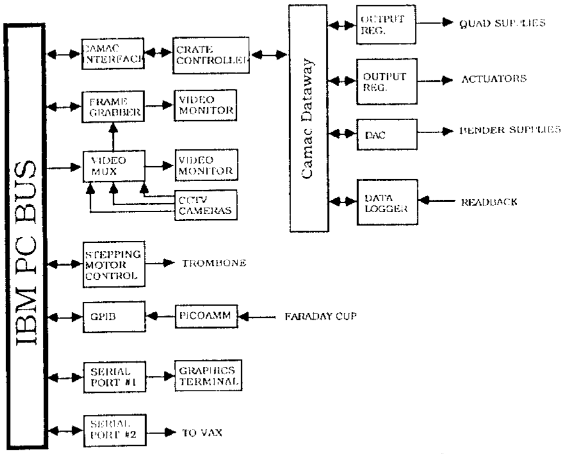

Fig. 2. Block diagram showing the essential features of the AATF control and data acquisition system.

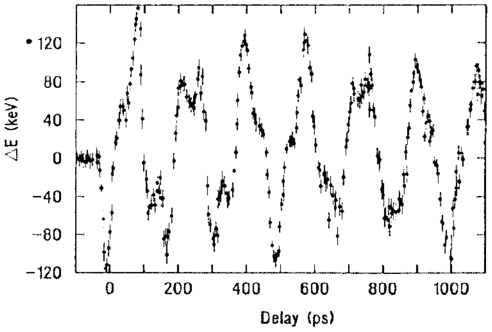

Fig. 3. Example of a longitudinal wake potential measured for a dielectric device (Cherenkov Wakefield Accelerator).