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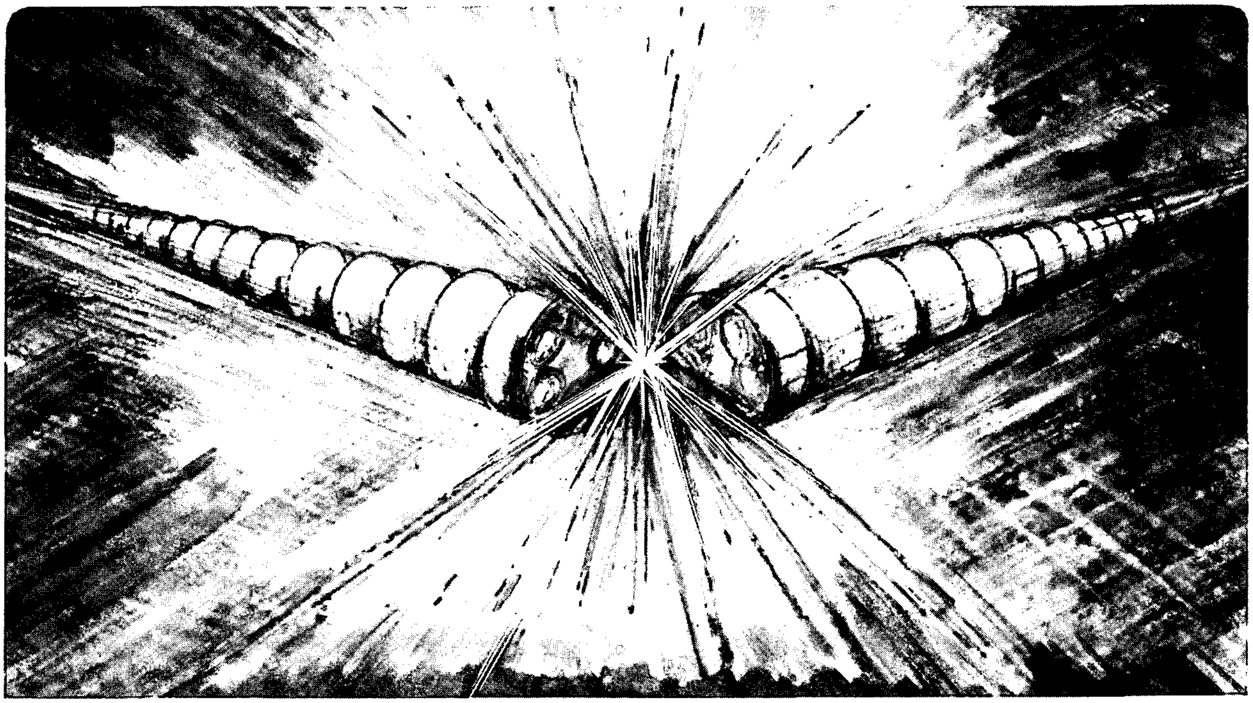

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AUTOMATED TUNE MEASUREMENTS IN THE ADVANCED LIGHT SOURCE STORAGE RING USING A LABVIEW APPLICATION*

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Automated Tune Measurements in the Advanced Light Source Storage Ring Using a LabVIEW Application*

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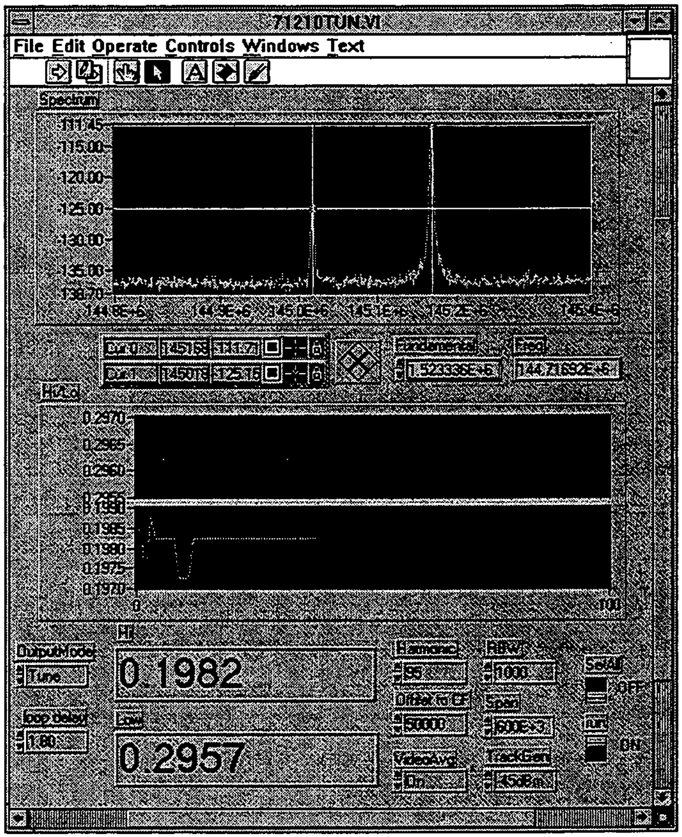
Abstract

Horizontal and vertical betatron tunes and the synchrotron tune are measured frequently during storage ring commissioning. The measurements are tedious and subject to human errors. Automating this kind of repetitive measurement is underway using LabVIEW for Windows, a software application supplied by National Instruments Corporation, that provides acquisition, graphing, and analysis of data as well as instrument control through the General Purpose Interface Bus (GPIB). We have added LabVIEW access to the Advanced Light Source (ALS) data base and control system. LabVIEW is a fast and efficient tool for accelerator commissioning and beam physics studies. Hardware used to perform tune measurements include a tracking generator (or a white noise generator), strip line electrodes for external excitation of the beam, button monitors, and a spectrum analyzer. All three tunes are displayed simultaneously on the spectrum analyzer. Our program automatically identifies three tunes by applying and analyzing small variations and reports the results. This routine can be encapsulated in other applications, for instance, in a chromaticity measurement and correction program.

1. INTRODUCTION

Operators, engineers and physicists access and control ALS accelerator systems and instrumentation via control room computers running a wide variety of commercial software tools. These include Borland C++, Microsoft Visual C, Visual Basic, Excel, Micrografx Designer, and Asymetrix ToolBook. All of these general purpose tools work well for generating a graphic user interface (GUI) based display, but they usually require 3rd party add-ons to provide data-acquisition and control properties such as instrument interface and scientific analysis tools. LabView has been used on the ALS since mid 1993. It was chosen because of its GUI generation, and its data-acquisition, control, and analysis capabilities. In this paper we describe in detail the ALS tune measurement system as it is currently configured using LabVIEW. We also mention other applications for which LabVIEW is useful at the ALS.

2. ALS LabVIEW VIRTUAL INSTRUMENTS



Fundamental 1.523336E+6
Freq 144.71692E+6
OutputMode Tune
loop delay 1.80
Hi 0.1982
Low 0.2957
Harmonic 95
RBW 1000
Offset to CF 50000
Span 600E+3
VideoAvg On
TrackGen -45dBm

Figure 1 Tune measurement virtual instrument.

LabVIEW was first used as an operations-interface to the storage ring Errant Photon Beam Interlock (EPBI) system. This was a "crash" project that needed to be finished before the ALS could safely run large beam currents with small undulator gaps. The Instruments Section installed the EPBI electronic instrumentation and additionally provided the LabView virtual instruments (VIs) for testing and operation of the hardware. These VIs have proved sufficiently "user-friendly" and functionally complete that they are still in regular use by operations staff. Since then, LabView has been used for tune measurements, beam lifetime measurements, and fluorescent screen control.

The LabVIEW system for tune measurement has three main sections; a GUI front panel VI, the tune measurement

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hardware, and a data interface to the ALS Control System database. Fig. 1 is a front panel snapshot of an actual tune measurement and setting run.

The upper waveform in Fig. 1 is the spectrum waveform from the HP 71210C spectrum analyzer. The two peaks are ν_x and ν_y tune lines. The vertical scale is in dBm, and the horizontal scale is in Hz. The two lockable cursors are handy for observing how the tune lines change in response to machine magnet settings. Just below the spectrum waveform on the right are two digital displays. **Fundamental** is a control that the user sets equal to the storage ring beam rotation frequency, and **Freq** is an indicator showing the frequency corresponding to the actual beam rotation harmonic (in this example the 95th). The **Hi/Lo** chart in the middle of the front panel is a history of ν_x and ν_y fractional tune. At the bottom left, **OutputMode** is a mode control that allows **Hi** and **Low** to display in units of tune, absolute frequency or difference from rotation harmonic frequency.

The six digital controls at bottom right of Fig. 1 configure the 71210 via the GPIB. **Harmonic** and **Offset to CF** set which rotation harmonic to view and analyze. **RBW** sets the resolution bandwidth of the spectrum analyzer, while **Span** sets the width of the frequency sweep. The VI makes use of the 71210's peak-search capabilities to find the tunes by assuming that the two highest displayed peaks are the target frequencies. Therefore, the user must restrict the **Span** and **Offset to CF** so that the correct peaks are displayed in the spectrum. The **VideoAvg** control allows different options to tradeoff update rate versus noise reduction. Typically this is set to 20 video averages. **TrackGen** controls the tracking generator output power and is set as low as possible (usually -35dBm) to minimize disturbance to the stored beam and its users.

The two resulting tune measurements of the VI are computed on a dedicated instrumentation PC; providing an interface to the ALS Control System database allows for other control room PC consoles and programs to use these measurements. This interface is provided by a 3rd party product called "DownShift" from Viewpoint (Rochester, NY). DownShift is a set of LabView VIs based on National Instrument's Code Interface Nodes (CIN). CINs allow the LabView user to create VIs that are custom C-derived computing blocks. In DownShift's case, they are simply interfaces to Dynamic Link Libraries (DLLs). Since the ALS Control System database software interface is based on DLLs, connecting these together was simple. Implementing a DLL call simply requires "filling in the blanks" to the CIN.

3. TUNE MEASUREMENT EQUIPMENT

Betatron and synchrotron tunes in the ALS storage ring are measured with a variety of equipment. Beam position monitors (BPMs) and real-time spectrum analyzers permit analysis of transient tune conditions. The BPMs have single-turn measurement capability. Fourier analysis of beam position data from any of the 96 BPMs reveals betatron tune if the data are taken while injection orbit instabilities exist or when sustained betatron oscillations occur at high beam currents. Normally the beam is stable, and no betatron oscillations exist. In that case the beam must be excited horizontally and vertically for fractional betatron tune measurements to be made. Fig. 2 illustrates the measurement system.

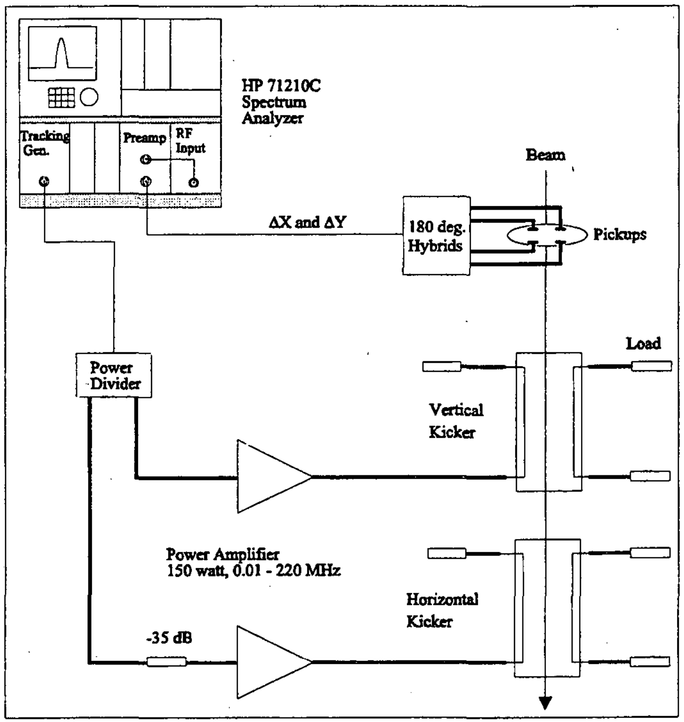


Fig. 2 Block diagram of fractional tune measurement system.

The heart of the system is an HP 71210C microwave spectrum analyzer. It is fitted with a tracking generator and a low-noise preamplifier. The tracking generator drives a power splitter which in turn feeds the inputs of two, 150 watt amplifiers. These amplifiers are connected to one plate of the horizontal and vertical kickers. The kickers were installed for the transverse beam damping system which will be commissioned this year.

The transverse kickers are two sets of strip lines installed in the RF straight section of the storage ring. They are 300 mm in length and have maximum longitudinal impedance at 250 MHz. Maximum transverse impedance, 10 kΩ, occurs at 0 Hz. The transverse impedance falls to zero at 500 MHz. The amplifiers have frequency response from 0.01 MHz to 220 MHz. The pickups, modified LEP BPM electrodes, act as high pass filters to beam signals. The -3 dB cutoff frequency for these pickups is about 300 MHz. Their shunt impedance is approximately 1 ohm with a centered beam. The LEP pickup signals are processed in four Anzac H9, 180 degree hybrids. The ΔX and ΔY signals are summed in the output hybrid and sent to the analyzer preamp input. With consideration of the frequency response of all elements in the system, we routinely make tune measurements at about 144 MHz, the 95th harmonic of the ring revolution frequency.

Depending on accelerator tune and chromaticity settings, the power required to excite the beam and obtain a measurable response can vary greatly. Vertical tune can be almost impossible to measure. During normal operations a measurable horizontal response is obtained with only -11 dBm applied to the kicker. The vertical axis requires 24 dBm. Under these circumstances the synchrotron light users detect no transverse beam motion.

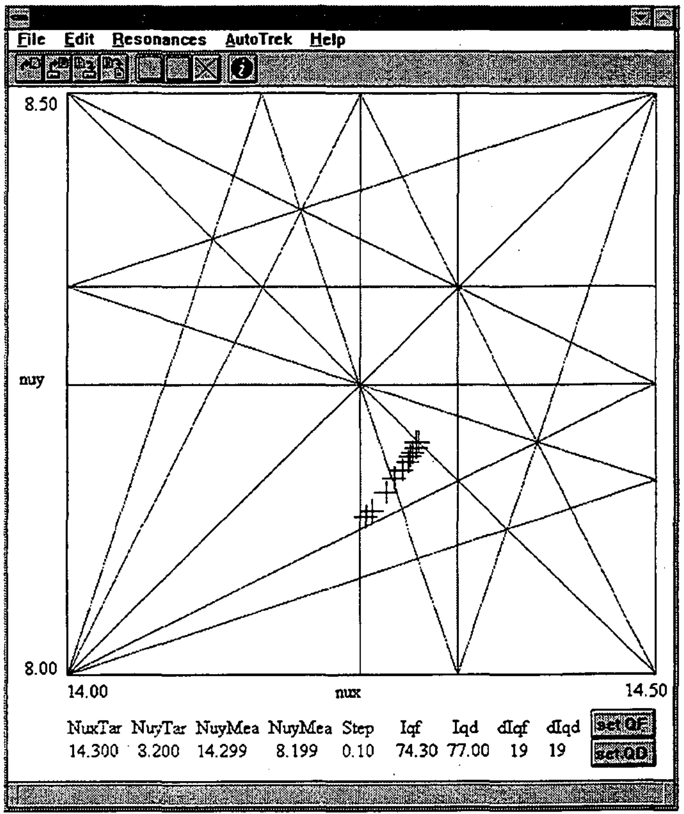
4. AUTOMATIC TUNE SETTING

The tune-measurement system described above was used successfully, for instance, in horizontal-to-vertical coupling measurements, in chromaticity measurements, and in automated tune-setting operations. The last example is described to some detail in this section. It is a Borland C++ application which uses a feedback technique for setting the storage ring tunes to the desired values. Tune setting is not easy because of the hysteresis effect of the magnet cores. In a static operation of the storage ring, where all the magnet settings are static, we first bring all the magnets including the quadrupole families, QF and QD, to the maximum strength near saturation and then reduce them along the hysteresis curve to the correct values. For small changes of the excitation currents the variations of the tunes depend linearly on the current increments:

$$\begin{pmatrix} d\nu_x \\ d\nu_y \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} dI_{QF} \\ dI_{QD} \end{pmatrix} \qquad (1)$$

In a dynamic operating environment the strengths of the magnets vary constantly, such as in the case of energy ramping or an undulator gap scan. Equation (1) still holds except that the matrix elements vary with time and must be measured dynamically. This was done by performing the following sequence of events: first the required current changes in the quadrupole (QFs and QDs) excitation currents were calculated by inverting equation (1); correction for QF (a fraction typically about 50 % of dI_{QF}) was applied first and the new tunes were measured after a specified period of time; matrix elements a_{11}, a_{21} were calculated; correction for QDs (a fraction of dI_{QD}) was applied next and the new tunes were measured after a specified period of time; finally matrix elements a_{12}, a_{22} were calculated. Measurements of the matrix elements were a natural by-product of the steps in this way, in the sense that no additional number of changes of magnet strengths are necessary. The matrix elements vary the most when the direction of the variation changes, as can be expected from the hysteresis effects.

Fig. 3 illustrates the graphic user interface and typical data. At the beginning of the run the storage ring tunes were: $\nu_x = 14.25$ and $\nu_y = 8.125$. The program was asked to set the tunes to $\nu_x = 14.3$ and $\nu_y = 8.2$ with 10 % of the full corrections for each step. The tune converged in about 8 steps as shown.



NuxTar	NuyTar	NuyMea	NuyMea	Step	Iqf	Iqd	dIqf	dIqd
14.300	3.200	14.299	8.199	0.10	74.30	77.00	19	19

Fig. 3 Tune correction program graphic user interface.

Available menus are: the **File** drop-down menu which saves the present data or recalls an old data set for analysis. We can change the target tunes, step size, and the tune display ranges using the **Edit** menu. We can change the order, symmetry, and slope of the displayed resonance lines using the **Resonances** menu. Fig. 3 shows resonances up to the 4-th order with the super-periodicity of 1. The **AutoTrek** menu enables us to set the length of the waiting period for each step and start/stop of the automatic tune-tracking mode. In the manual mode of operation the operator can look at the pertinent numbers at the bottom of the window and decide upon the next sequence of actions.

5. CONCLUSION

The rapid growth of desktop computing power has been reflected by the proliferation of increasingly powerful programming tools. Inexpensive computing hardware along with commercial software packages promise to make improvements for instrumentation, data-acquisition, and control available to a wide audience. These trends will enable the engineer and physicist to deliver a total system solution.

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