A TOOL FOR REAL TIME ACQUISITIONS AND CORRELATION STUDIES AT FERMI*

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Abstract

In this work we report the recent implementation of a Matlab-based acquisition program that, exploiting the real time capabilities of the TANGO control system, can be used at FERMI for acquiring various machine parameter and electron beam properties together with most FEL signals on a shot-by-shot basis. Analysis of the saved datafiles is performed with a second code that can retrieve correlations and study dependence of FEL properties on machine parameters. An overview of the two codes is reported.

THE REAL TIME CAPABILITIES AT FERMI

The control system of FERMI uses the Tango [1] toolkit to provide an effective integration of technical systems and the software controlling them. A distributed real-time framework is integrated into the control system and provides the capability to measure the seed laser, electron and FEL output photon properties on a pulse-to-pulse basis [2]. With this framework, a unique "bunch number" time-stamp is distributed to all of the low level computers. Most of the measurement system detectors (e.g., electron and photon diagnostics) and actuators (e.g., power supplies) are synchronized with the bunch trigger and can have the "bunch number" associated to their measurements.

Using the Tango bindings, the FERMI control system allows interfacing the accelerator instrumentation to Matlab. This capability has been used to develop various scripting procedures and GUIs to permit user interaction with the machine and has been extensively used for the commissioning of both FEL-1 [3] and FEL-2 [4].

THE ACQUISITION PROGRAM

In this section we describe the MATLAB code implemented at FERMI for real time acquisition of relevant machine and FEL output signals. A brief description of the main features and components of the code will be presented.

Acquisitions are first setup from the RT MATLAB graphical user interface (GUI) (see Fig. 1) that allows the user to define the type of acquisition and select some of the device signals to be acquired. Before the main acquisition begins, a one shot record of the most important machine parameters (e.g., undulator gap settings, dipole and quadrupole magnet currents, lasers

intensities, …) is acquired to provide a snapshot of the machine and FEL configuration. This information is stored and saved in the final achival data file. The predefined list of the acquired devices in principle saves all the relevant information that will allow reconstruction of the linac and FEL state during the data analysis phase. When needed, the list of saved signals can be changed on a case-by-case basis via a user-defined configuration file.
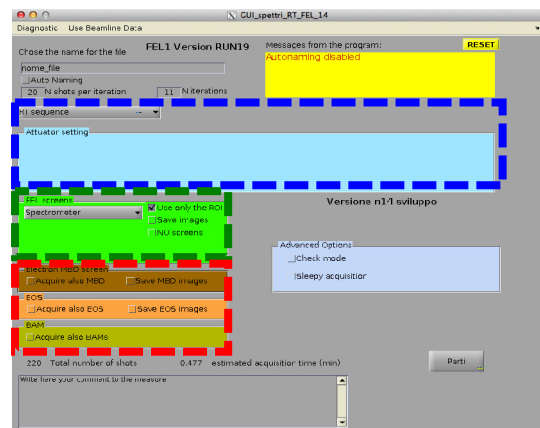

Figure 1: Graphical user interface for RT acquisition of FERMI machine instruments.

Types of Acquisition

The region highlighted in blue in Fig. 1 is used to select the type of acquisition. At present three possible acquisition types are available: "RT sequence" and "actuator scan" and "script scan".

The **RT sequence** is the standard acquisition of the specified list of the machine devices, without any linac or FEL parameter being purposefully changed (i.e., "scanned"). The type of sequence is normally used to collect large quantities of data for statistical studies (e.g. correlations). The user can decide the length of the acquisition by deciding the number of shots acquired.

The **actuator scan** allows the user to actively change a particular machine parameter (e.g., the seed laser power or a dispersion section magnet strength) in order to map the response of the FEL. The parameter is selected from a predefined list as shown in Fig. 2.
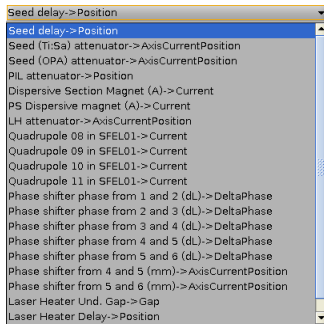
Figure 2: List of available machine parameters that can be used for a scan.

Further options for defining the parameters of the scan (number of shots per individual scan parameter value acquired, the total range and number of parameters values scanned, accuracy, …) are also available to the user (see Fig. 3). At present standard actuator scans involve a linear change of actuator value.
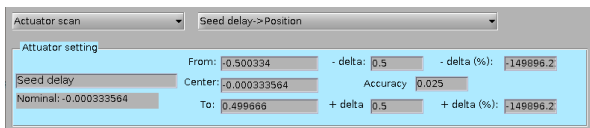

Figure 3: Details of the scan settings section of the data acquisition GUI.

A MATLAB-based **script scan** can be used in those cases where a simple scan cannot be defined with a single actuator or a simple linear value change. With the script scan option it is possible to use an external MATLAB script that controls the changes of one or more machine parameters during the data scan. One commonly used scan using this option measures the FEL gain curve by acquiring the FEL intensity as the number of on-resonance undulators is changed one-by-one.

Data Acquired During Scans

During the acquisition, the program reads data from the machine devices contained in a predefined list. This second list only accounts for devices that can be acquired on a shot-to-shot basis and will have the associated "bunch number" tag. The list of acquired instruments is defined in an external text file and is highly inclusive in order to have available in the final achival file all the possible information that might be useful to study possible correlation between the FEL intensity and other parameters. Examples of such measured quantities are the electron beam charge both before and after the undulator, the beam compressor pyrometer signals, transverse beam position monitor signals at a large number of locations both before, in, and beyond the undulators.

In addition to the predefined list of machine parameters the user can add to the acquisition few more instruments that may be of interest depending on the purposes of the measure. This includes the possibility to add data from one or more CCD cameras at various locations in the machine (see the green highlighted region in Fig. 1). The CDDs image either an intercepting LINAC e-beam screen

or an FEL diagnostics (e.g.: photon spectrometer). The acquisition can be limited to only the projections (1D vectors) or include the full 2D matrix. Additional special devices can be acquired in synchronization with all the other diagnostics for those case they are needed and are made available (see the red highlighted region in Fig. 1). This includes the bunch arrival monitors (BAMs), electro-optical sampling (EOS) station and the main electron beam dump.

After the acquisition is started, both messages about the scan's progress are reported on the dedicated space in the GUI and selected data are shown within a dedicated figure. After acquisition is concluded, a logbook-ready image is displayed together with a summary of the acquisition, showing a small subset of the acquired data. An example is reported in Fig. 4 where the FEL intensity and the FEL spectra are plotted as a function of the actuator used during the acquisition (in this case the seed laser delay). The plot also reports the name of the file that is saved at the end of the acquisition.
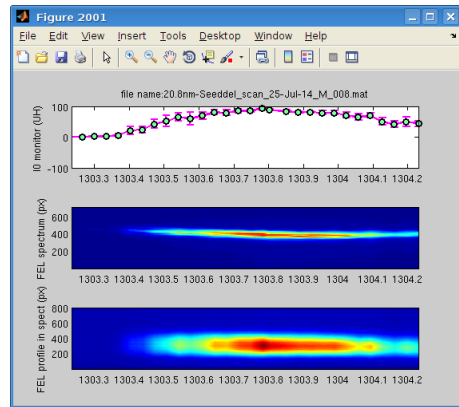

Figure 4: Details of the scan settings section of the data acquisition GUI.

The data file is saved in a MATLAB format, which allows a reasonably good compression, and contains all the acquired data as well as additional information such as the version of the code used, an optional user-defined comment to the acquisitions that can be inserted from the dedicated panel in the GUI, and the time of the acquisition.

THE ANALYSIS PROGRAM

After the data is taken and stored, a separate MATLAB-based program (Fig.5) is available to analyse the information.
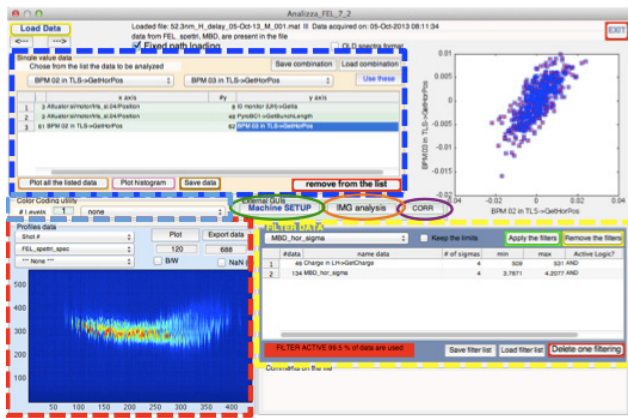
Figure 5: Details of the scan settings section of the data acquisition GUI.

Data Selection

After a file is loaded, all the acquired "single value" devices present in file are recognized and listed in the two tab-listed region highlighted in blue in Fig. 5. The two tab-lists allow the user tp select an x-y combination whose preview is then shown in the side image. When the chosen x-y pair is considered acceptable, the user can add it to a table below. The data listed in the table is then considered for the final plotting, statistics computation and data exporting according to the user's interests.

Vector-like quantities (e.g., spectra profiles) are listed in a separate tab (the red highlighted region in Fig. 5) and are visualized as false colors images. The vertical axis corresponds to 1D vector coordinate of each single profile while the horizontal direction corresponds to the different acquired bunches. A preview plot can also be done either by ordering bunches with time or according to the settings of a third device. This option is very useful for identifying correlation between the FEL spectra and other machine parameters as shown in Fig. 6.
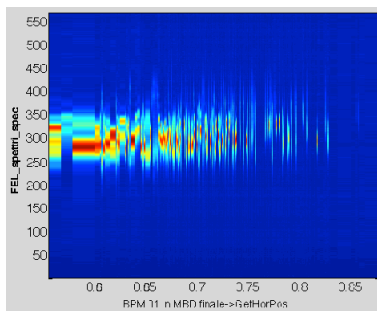

Figure 6: FEL spectral profiles ordered as a function of the transverse electron beam position in a dispersive region.

Data Filtering

Filter tools are available to improve the effective S/N ratios and to weed out bad shots. The user can define filter parameters by mean of the dedicated panel (yellow highlighted region in Fig. 5). The tab-list allows the user to select any of the acquired "single value" data and use it for filtering bad shots. In the particular case shown in

Fig. 5 the charge at the beginning of the LINAC and the position at the last e-beam screen are considered. The acceptance filter can be set by specifying extremes or by defining number of RMS sigmas. The program indicates to the user the amount of data that are rejected both in totla and from each individual filter. Once the user has defined a filter configuration, it can be applied resulting in only the good shots will be used for all further analysis and plots. In in the graphs generated by the code, a label is inserted to emphasize the use of the filter and the percentage of used data (Figs. 7,8,10).

Data Analysis and Plot

The data selected and listed in the table can be visualized in separate MATLAB figures. Various plots are generated depending on the type of acquisition and the user's particular interests. In case of an "actuator scan" acquisition, if the actuator is selected for horizontal axis independent variable, an average and error bar are also calculated and plotted (Fig. 7).
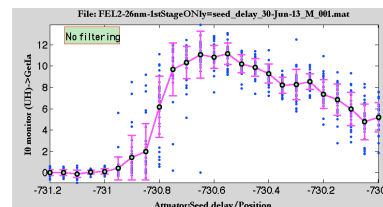

Figure 7: Plot generated for a scan acquisition.

Because the acquired data are synchronized by bunch number, they can be used to visualize correlations between different parameters. This can be done by plotting as an example, the FEL intensity as a function of electron beam parameters. It can also be exploited to show the correlation in FEL-2 between the first stage emission and the second stage emission (Fig. 8).
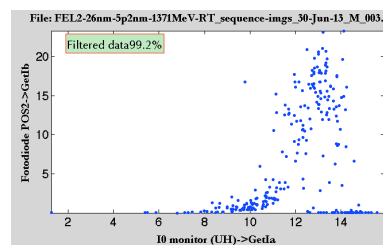

Figure 8: Intensity of second stage vs the first stage emission from FEL-2 operated at 5nm.

A visualization of the correlation between three separate machine parameters is also possible by using the dedicated "color coding" panel (the light blue highlighted region in Fig. 5). An example is shown in Fig. 9
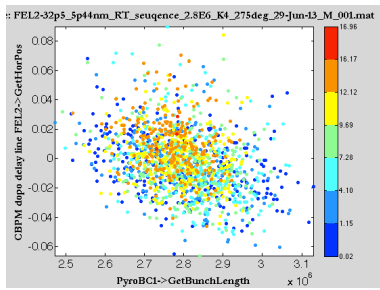
Figure 9: FEL intensity in color code as a function of the beam compression and position signals.

A statistical analysis of the selected data is also possible and the distribution of the variable values can be plotted together with the calculated average and standard deviation values (Fig. 10).
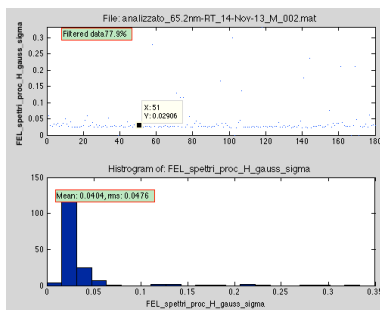

Figure 10: Histogram distribution of the data selected.

The plotting of the profiles (1D vectors) is handled by the Profile Viewer utility (red highlighted region in Fig. 5). A typical image showing the analyzed FEL spectrum as a function of on scanned parameter (dispersive section) together with the trend of the FEL intensity is shown in Fig. 11.
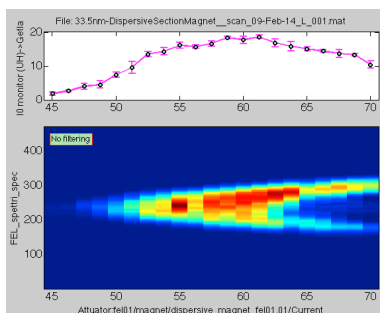

Figure 11: Plot generated for a scan acquisition.

If needed the data selected and listed in the table can be exported in ascii format for further analysis or processing with external programs.

Image Analysis

For those data files where diagnostic screen data were taken with images or profiles, an external program can be used by means of the dedicated button (orange circle in Fig.5) to determine various quantities such as the centroid and RMS size in the two transverse planes. For files with spectra, Gaussian fits to the output are used to determine

bandwidth and central wavelength. These quantities can then be added to the list of "single value" data and correlated against individual machine signals in the case of RT sequences or against the scan parameter in actuator scans.

Machine Setup

The machine configuration snapshot produced by the acquisition program at the moment of the acquisition can be easily visualized by using a dedicated tool that is launched from the main GUI (green circle in Fig.5). The tool automatically recognizes the devices and produces a user-friendly table with their names and corresponding values divided by machine sectors as shown in Fig. 12.
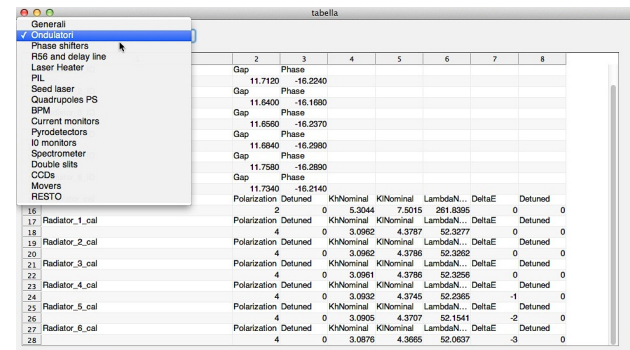

Figure 12: Tool to visualize the machine snapshot showing the setting for the FEL undulators at the moment of the acquisition.

CONCLUSION

Over the past two years we have steadily improved the acquisition and analysis programs. Currently, more than half of all FERMI commissioning data is taken with them. Moreover, many scientific users on FERMI are also using the acquisition program (or specially modified versions) for their studies. Since the acquired data is archived and is more-or-less self-describing in terms of contents, as the analysis program is improved, we are able to extract additional information from older data runs.

ACKNOWLEDGMENT

REFERENCES

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