TUPP30

Non-Invasive Dispersion Function Measurement during Light Source Operations

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IBIC '20 International Beam Instrumentation Conference

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NATIONAL SYNCHROTRON LIGHT SOURCE II

Abstract: We implemented a completely parasitic measurement of lattice dispersion functions in both horizontal and vertical planes, which is fully compatible with light source user operations. The measurement is performed by applying principle component analysis (PCA) and adaptive filtering to very small residual orbit noise components introduced by the RF system and detected in the beam orbit data, sampled at 10 kHz. No changes in RF frequency are required. The measurement, presently performed about once a minute, was shown to be robust and immune to changes in the beam current, residual orbit noise amplitude and frequency content as well as other factors. At low current it was shown to provide similar accuracy to the traditional method (which shifts the 500 MHz RF frequency by +/-500 Hz). In this paper we will explain our measurement technique and present typical dispersion function stability achieved during NSLS-II operations.

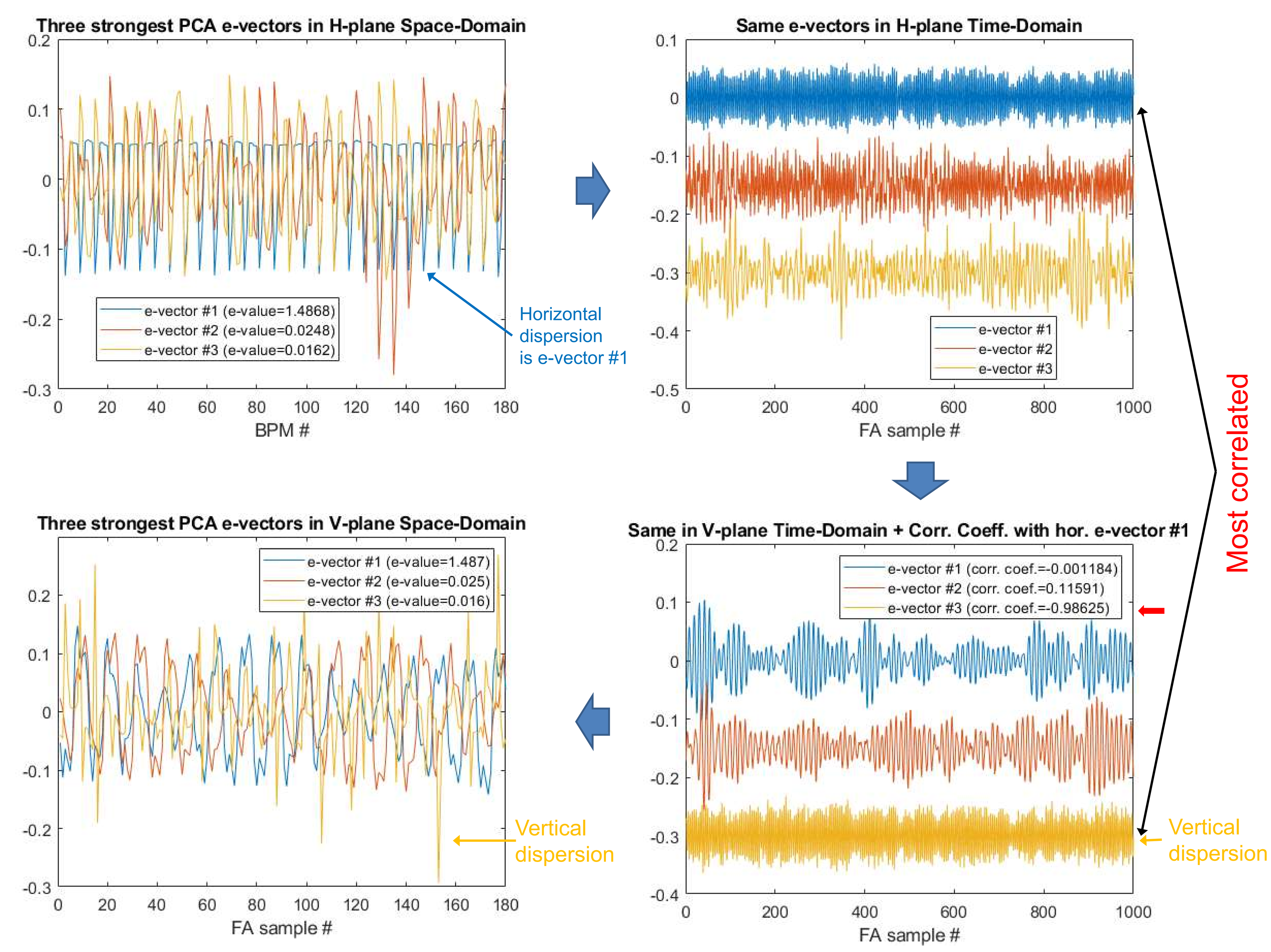
Main Idea and Major Steps

- Maintaining beam stability, including beam size, is paramount to light source operations. Therefore, lattice functions need to be monitored, preferably by non-invasive methods. Standard dispersion measurement is too disruptive, so we implemented a new, PCA-based method.
- During NSLS-II user operations, ~every minute, all 180 "regular" BPMs are triggered, and 10-second buffer of synchronized fast acquisition (FA, 10kHz) data is acquired.
- We take these buffered data and apply high-pass or a band-pass filter, >500 Hz. Details are not critical, as long as the synchrotron frequency, f_s, (typically, 2-3 kHz) remains in the filtered signal.
- We then apply PCA to get space- and time-domain eigen-vectors (e-vectors) separately in H and V planes.
- One of the strongest components in the H-plane (usually corresponding to the fist eigenvalue) is the dispersion. It is easily recognizable by its 30-peak shape (NSLS-II has 30-period DBA lattice), and f_s-dominated noise in freq. domain.
- Dispersion identification is less simple for the V-plane, because dispersive-like motion is by far not the strongest eigen-motion (usually V-dispersion e-vectors could be number 3 to 15, depending on the filter and the orbit noise, and their spatial shape is irregular).
- Our method: find the V-plane time-domain PCA e-vector with the highest correlation coefficient with the time-domain H-plane e-vector for the horizontal dispersion. The corresponding space-domain e-vector is the vertical dispersion.
- PCA provides normalized e-vectors. To get the dispersion function in meters, we 1) scale the horizontal dispersion e-vector to best match the model (at dispersive BPMs only); 2) apply the same scale for the vertical dispersion e-vector, multiplied by the ratio of the eigen-values.

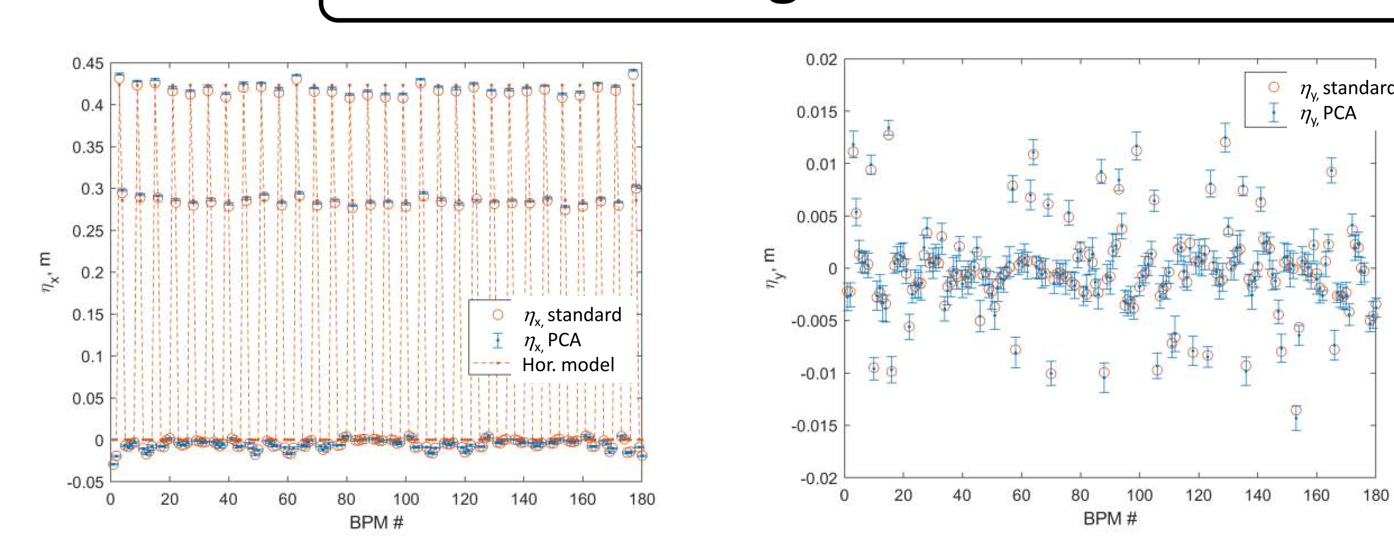
Implementation, Findings and Operational Experience

- All steps are automated in Orbit Monitor Input-Output Controller (IOC).
- Measured dispersion functions are available as EPICS PVs.
- The new method was cross-checked with the traditional one, which shifts the 500 MHz RF frequency by +/-500 Hz, which would cause unacceptable orbit motions during user operations. The methods agree very well, as long as the data is taken at the same beam current.
- Some variation of vertical dispersion with beam current was noted due to collective effects.
- Over 24-hour periods of user operations, dispersion, measured every minute, was very stable. Over longer timescales, some variation was noted, therefore monitoring during operations is worthwhile.
- The measurement was running during operations for almost one year. It is reliable and robust to changes in RF voltage, beam current, and orbit motion noise and provides useful information about machine setup and stability.

Dispersion Measurement by Means of PCA

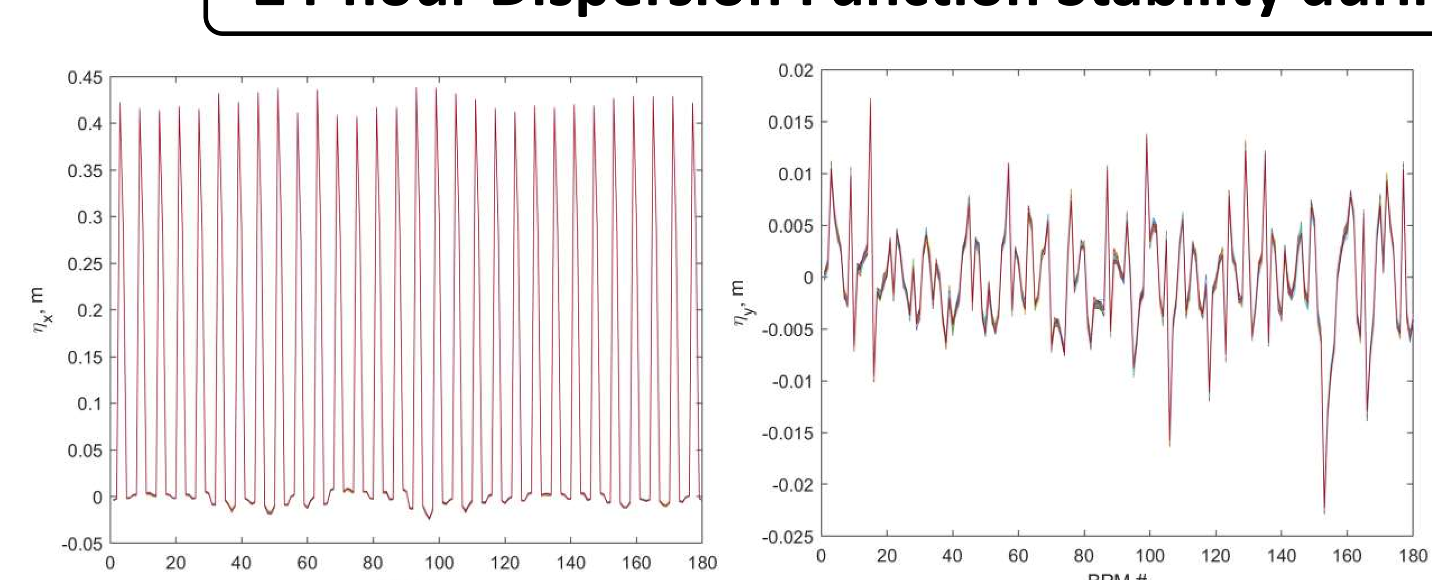


Cross-Checking with Traditional Method

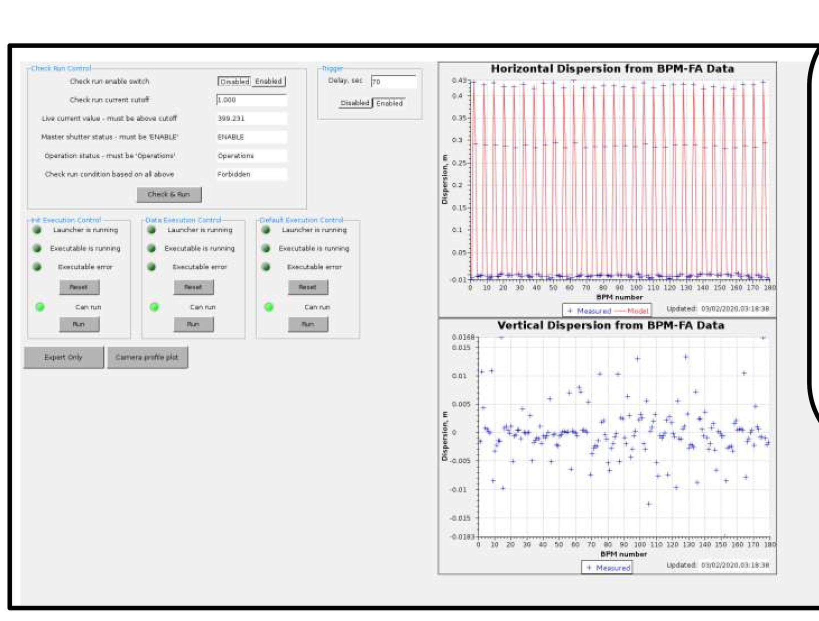


- Data taken 15 sec apart
- Studies at 10 mA beam current
- Traditional method: +/- 500 Hz change in RF frequency

24-hour Dispersion Function Stability during Operations



- Data for March 8, 2019
- 400 mA user operations
- 1323 consecutive measurements plotted
- Dispersion is very stable



Control System Studio panel for Orbit Monitor IOC with real-time display of measured dispersion functions

Acknowledgements

We are thankful to Anton Derbenev and Kiman Ha for implementing Orbit Monitor IOC as well as to Robert Rainer for CSS Control Panels

Work supported by U.S. DOE under Contract No. DE-SC0012704.