RECENT UPGRADE AND OPERATIONAL EXPERIENCE OF THE VIBRATION MONITORING SYSTEM AT TPS

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Abstract

In late 2024, the vibration monitoring system at the Taiwan Photon Source (TPS) was upgraded to enhance stability and usability. The system now includes beamline-floor measurement points and a central measurement center for station management, data export, automated reporting, and web-based access to real-time vibration levels and spectra. During more than a year of routine operation, issues such as abnormal sensor signals, DAQ faults, and station instability were encountered and resolved. The upgrade improves monitoring reliability and enhances the capability to record vibration behavior during events such as earthquakes and typhoons. This paper presents the upgraded system architecture, new analysis functions, operational experience, and examples of post-event vibration analysis.

INTRODUCTION

For the low-emittance and high-stability Taiwan Photon Source (TPS), vibration effects on the electron beam have been studied for many years. Ground vibration measurements were performed at the NSRRC site before the construction of TPS [1]. However, the vibration characteristics may change with environmental variations and the installation of utility systems such as cooling water systems and air handling units.

A vibration monitoring system was previously developed to continuously observe the vibration status of the TPS storage ring [2]. However, the previous system stored data independently at each station, provided only integrated vibration levels, and did not preserve raw data completely. These limitations made cross-station comparison and event tracing inefficient.

In late 2024, the system was upgraded to improve stability and usability. This paper presents the upgraded architecture, new analysis functions, and operational experience during more than a year of routine operation.

SYSTEM UPGRADE AND CONFIGURATION

System Overview

The key upgrade is the implementation of a central measurement center and the addition of beamline-floor measurement points. The upgraded system, shown in Fig. 1, consists of sensors, data acquisition (DAQ) sites, and a central measurement center for control, data processing, and web services.

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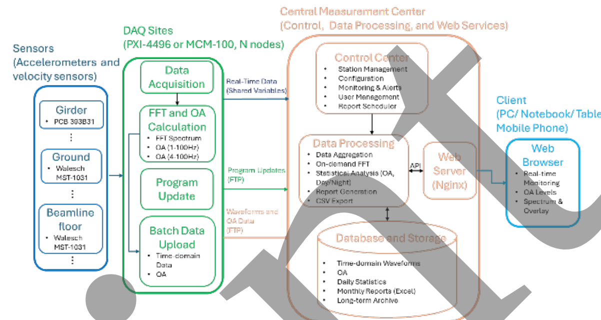

Figure 1: Architecture of the upgraded vibration monitoring system at TPS.

Vibration signals are acquired at the DAQ sites and processed in real time. The real-time data are transmitted within the vibration monitoring system by shared variables, while time-domain waveforms and overall vibration level (OA) values are uploaded to the central measurement center through FTP.

Sensors and Measurement Points

The system uses PCB 393B31 accelerometers on girders and Walesch MST-1031 tri-axial velocity sensors on the ground and beamline floor. Figure 2 shows one of the newly added beamline-floor measurement points.

Figure 2: Beamline-floor measurement point with a Walesch MST-1031 tri-axial velocity sensor.

The measurement points are categorized as girder, ground, and beamline floor. The X, Y, and Z directions correspond to horizontal transverse, vertical, and longitudinal directions, respectively.

DAQ Sites and Data Processing

Each DAQ site is based on either a PXI-4496 or an MCM-100 system. At each DAQ site, fast Fourier transform (FFT) spectra and OA values are calculated in real time. In this work, OA is defined as the root-mean-square displacement obtained by integrating the displacement power spectral density over a specified frequency range. Two frequency bands are used: 1–100 Hz and 4–100 Hz. Signals measured by accelerometers or velocity sensors are converted to displacement spectra in the frequency domain, and all OA values are expressed in nm RMS.

Program updates can be distributed from the central measurement center to both PXI-4496 and MCM-100 DAQ sites, reducing the maintenance effort for distributed stations.

Central Measurement Center

The central measurement center integrates station configuration, data processing, data storage, report generation, and web services. Station and channel parameters, including sensor type, sensitivity, engineering unit, installation group, and measurement direction, can be centrally managed, which simplifies sensor replacement and future channel expansion. The data processing module performs data aggregation, OA statistics, report generation, and CSV export. Abnormal channels can be flagged and excluded from statistical reports, reducing the influence of sensor or connection faults on long-term trend analysis.

Advanced analysis tools are also implemented in the central measurement center. Users can select a specific frequency and compare the corresponding vibration amplitudes across multiple measurement points, as shown in Fig. 3. Waterfall and colormap displays are available to visualize spectral variations across channels, as shown in Fig. 4.

These functions improve the capability of locating vibration sources and understanding frequency-dependent behavior.

Figure 3: Comparison of vibration amplitudes at a selected frequency across multiple measurement points.

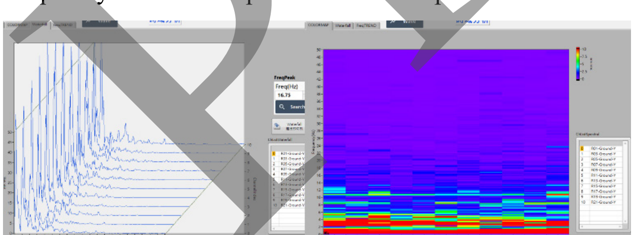

Figure 4: Waterfall and colormap displays of vibration spectra.

Time-domain waveforms, OA values (nm RMS), daily statistics, and monthly reports are stored in the vibration system's central database for long-term historical analysis. FFT spectra for historical data are calculated on demand from selected time-domain waveforms. An example of an automatically generated monthly report is shown in Fig. 5.

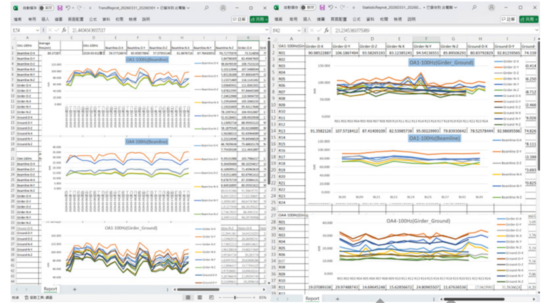

Figure 5: Example of an automatically generated monthly report showing day/night averaged OA trends.

Web Interface

The Nginx web server provides web-based access to real-time monitoring data. Users can observe OA levels, as shown in Fig. 6, and compare FFT spectra with the overlay function, as shown in Fig. 7.

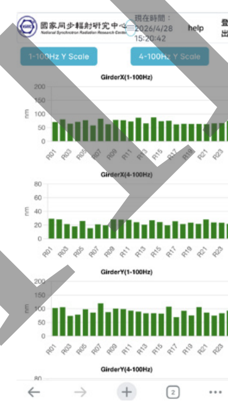

Figure 6: Mobile web interface showing real-time OA levels.

Figure 7: Web interface for FFT spectra and spectrum overlay comparison.

The system has three main data flows: real-time data through shared variables, time-domain waveforms and OA data through FTP upload, and program updates through FTP distribution. This architecture supports real-time OA monitoring, spectral comparison among multiple stations, raw-data export for post-processing, day/night statistical reports, and identification of dominant vibration locations at selected frequencies.

OPERATIONAL EXPERIENCE

During more than a year of operation, abnormal sensor signals, DAQ faults, and station instability were encountered and resolved.

Sensor and Signal Issues

Abnormal high or low vibration values were observed at several measurement points. The main causes were loose or degraded connectors, damaged BNC adaptors, insufficient power supply for velocity sensors, and sensor malfunction, as shown in Fig. 8. These issues were resolved by replacing cables, connectors, power supplies, or sensors.

Figure 8: Examples of sensor and connection issues, including a degraded connector and a damaged BNC adaptor.

DAQ and Hardware Issues

Some DAQ modules showed bias errors or calibration failures and were sent back to the manufacturer for recalibration. Several station crashes were also traced to aging SSD storage devices. After SSD replacement, system stability was improved.

Data Transmission and Software Issues

Several software-related issues were also observed during operation. For newly added stations, the daily day/night OA statistics and charts were not generated correctly at first because newly added measurement points were not completely included in the report-generation process. The station and point-list update logic was then modified.

In addition, the scheduled day/night average calculation sometimes did not start after the system had been idle for a long time. This was related to memory overload in the central processing program. By optimizing memory usage and reducing the loading of the data host, both the scheduled calculation and web data update became stable.

A problem was also found when exporting raw data and spectra across different time periods. The first 10 min segment of exported CSV data was sometimes filled with zero values. This was caused by the raw-data file searching logic and was resolved by correcting the time-interval selection logic.

Event Recording

The upgraded system recorded external disturbance events, including the M7.7 Mandalay, Burma (Myanmar), earthquake in March 2025 and Typhoon Podul in August 2025. The post-event comparison between vibration data and beam position monitor (BPM) readings for the Mandalay earthquake is shown in Fig. 9, and the comparison for Typhoon Podul is shown in Fig. 10. The BPM readings were retrieved separately from a web-based database of accelerator operation data. Although the vibration and BPM data were acquired by independent systems, these comparisons help examine the relationship between external disturbances, structural vibration, and beam position response. These examples demonstrate the capability of the upgraded system for event recording and post-event analysis.

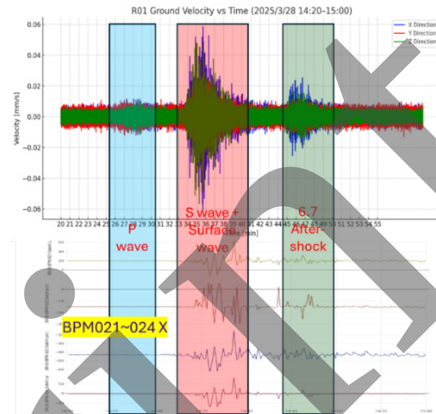

Figure 9: Post-event comparison of ground velocity and BPM readings during the M7.7 Mandalay earthquake in March 2025.

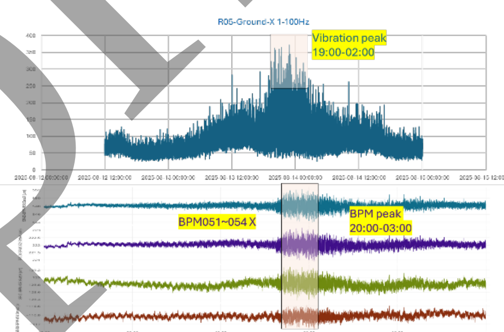

Figure 10: Post-event comparison of vibration OA levels and BPM readings during Typhoon Podul in August 2025.

CONCLUSION

The vibration monitoring system at TPS was upgraded with beamline-floor measurement points and a central measurement center. The upgrade enhances data integration, real-time monitoring, spectral analysis, and automated reporting.

Operational experience shows that most issues are related to sensors, DAQ hardware, storage devices, or software logic, and can be resolved through systematic maintenance. The upgraded system improves monitoring reliability and strengthens event recording during earthquakes and typhoons.

Future improvements include integrating vibration data into the web-based accelerator operation database to facilitate synchronized comparison with BPM readings and other machine parameters, AI-based anomaly detection, spectrum comparison across multiple time periods, and further analysis of environmental effects on vibration.

REFERENCES

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