
Vibration measurement of a concrete slab under impact test with Ommatidia Q2 laser Doppler vibrometer

Óscar Raúl Enríquez Paz y Puente, Eladio Montoya*, Eduardo Margallo.

Ommatidia Lidar, C/ Faraday, 7. Parque Científico de Madrid Campus de Cantoblanco 28049 Madrid (SPAIN)

*eladio.montoya@ommatidia-lidar.com

Introduction

This Application Note exposes the results of the vibration measurements obtained at the Institute of Structural Mechanics at the Bauhaus-Universität Weimar (<https://www.uni-weimar.de/en/civil-and-environmental-engineering/institute/ism/>) with the Ommatidia Q2 multiple beam laser Doppler vibrometer during an impact test of a concrete slab. The goal of this report is to show the measurement capabilities of Q2, the only LDV in the market able to perform **multiple point simultaneous measurements**.

The Q2 laser Doppler vibrometer

The equipment used for this test was the Ommatidia LiDAR Q2 Laser Doppler vibrometer based on FMCW Laser RADAR technology (*Frequency Modulated Continuous Wave*). The Q2 has two operating modes:

- **Laser Doppler vibrometer mode:** measures the velocity or displacement of a surface without contact.
- **Metrology mode:** measures the distance to the sensor and generates a point cloud

This system features multichannel coherent detection, consisting of **65 simultaneous laser beams** for signal acquisition. Thanks to the use of a dedicated photonic integrated circuit (PICs), the Q2 analyzes multiple optical channels in parallel, enabling the simultaneous three-dimensional measurement of vibrations and displacements.

The main benefits and characteristics of the Q2 are as follows:

- **Ultra-fast acquisition:** between 65 and 25,600 points per second over a 360° sweep.

- **Multi-point vibrometry:** sampling at 40 kHz across 65 simultaneous points, with a velocity range of ± 15.5 mm/s.
- **Integrated accelerometer:** bandwidth of 2,000 Hz, sampling rate of 4,000 Hz, and a noise level of $22.5 \mu\text{g}/\sqrt{\text{Hz}}$.
- **Pointing aid and autofocus:** Full-HD RGB camera (1920 × 1080) with automatic focusing.
- **Robust industrial design:** IP54 protection and atmospheric compensation (pressure, temperature, and humidity).
- **Comprehensive connectivity:** Gigabit Ethernet, GPS synchronization, analog I/O, and digital output.
- **Unified software:** controlled via the Ommatidia Atelier™ platform.
- **Open format data (HDF5)**



Figure 1: Ommatidia's Q2 LDV

Q2 measures 65 aligned points (“channels”) simultaneously (this is what we call “frame”, Figure 2), and performs a full-field of view measurement by scanning the azimuthal angle of the sensor head.



Figure 2: left: field view from Q2. The green dotted line represents the 65 measuring points. Right: by scanning the azimuthal angle, the full-field view measurement is obtained

Experimental set-up

The experiment consisted in exciting a concrete slab (2m x 1m x 0.15m) (h x w x t) with an instrumented hammer (PCB Piezotronics model 086C03). The slab was damaged with a horizontal crack at around 2/3 of its height. The Q2 LDV was around 5m from the slab. Figure 3 shows the experimental setup.



Figure 3: Experimental setup for the concrete slab at the Institute of Structural Mechanics at the Bauhaus-Universität Weimar (<https://www.uni-weimar.de/en/civil-and-environmental-engineering/institute/ism/>). The green dashed line is a superimposed guide to the eye to show how the frames are measured.

The slab was hit repeatedly by the hammer at the top left corner. At each hit, a complete frame was measured. The output signal of the hammer was injected to the Q2 to be used as

a time reference and equalize the phases of all measured points. A signal conditioner (PCB Piezotronics model 480C02) was connected between the hammer and the Q2. The impact test was performed twice to assess the repeatability.

Impact test

Figure 4 shows the hammer signal voltage and time of the peak after the beginning of the measurement. Most peaks are saturated to 3.2V because this is the maximum input voltage of Q2 analog input. Only one hit was missed by the instrument (frame 21, circled in red) due to the manual procedure of hitting the slab.

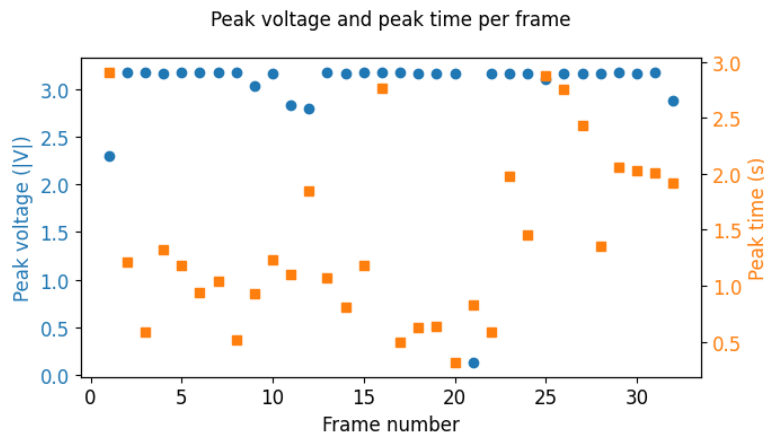


Figure 4: Hammer signal peak voltage and peak time after beginning of the measurement for Impact test 1

Figure 5 shows the average FFT over the whole surface of the concrete slab.

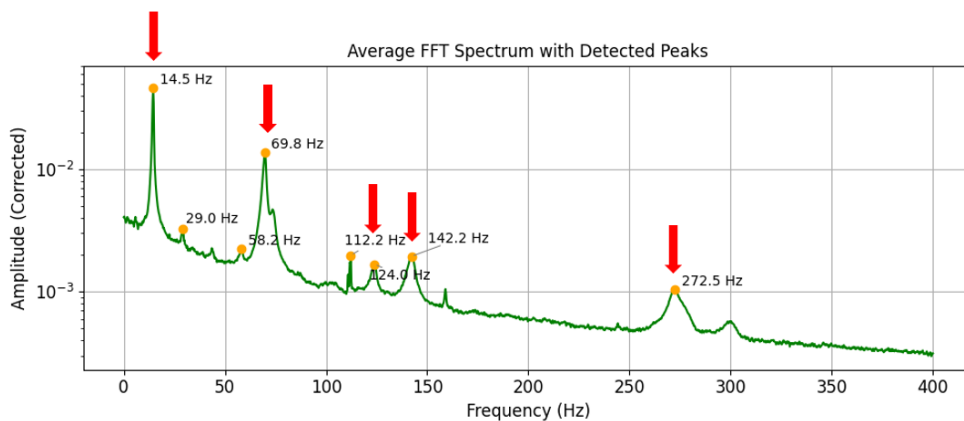


Figure 5: average FFT over the whole surface of the concrete slab for Impact test 1

We have extracted the magnitudes of the velocity of each of the peaks in Figure 5 and depicted them in Figure 6. The dashed line indicates the upper and lower ends of the slab.

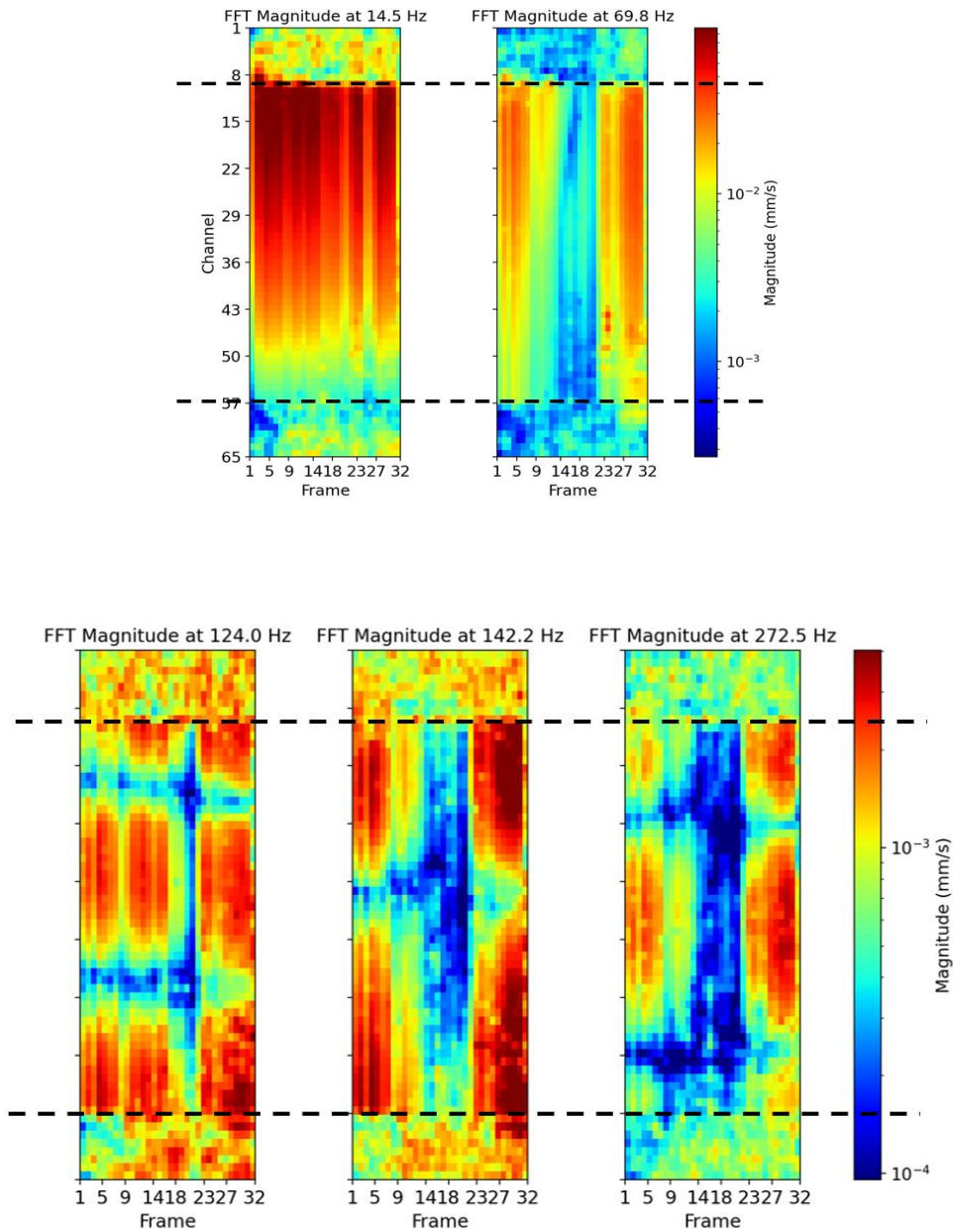


Figure 6: velocity at the peaks in Figure 5

From Figure 6 we can deduce some characteristic vibration modes:

- 14.5Hz: first bending mode
- 69.8Hz: first torsional mode
- 124.0Hz: mixed torsional and bending mode
- 142.2Hz: mixed torsional and bending mode
- 272.5Hz: mixed torsional and bending mode

At 29.0, 58.2 and 112.2 Hz we cannot associate these frequencies with vibration modes. However, these are minor peaks and might be related to the background (frames 1-9) or the base of the slab (frames 57-65).

The attribution of the peaks at 124.0, 142.2 and 272.5Hz is quite complex and would require complete modal analysis. We wonder whether the vertical bands correspond the different vertical slabs that build the block.

Acknowledgements

OMMATIDIA wishes to thank the Institute of Structural Mechanics at the Bauhaus-Universität Weimar (<https://www.uni-weimar.de/en/civil-and-environmental-engineering/institute/ism/>) for their support in these tests.