Application Note

Vibrational dynamics of a Morane Saulnier MS.760 Paris aircraft wing using Ommatidia Q2 Laser Radar – Collaboration with ONERA

1. Introduction

Ground Vibration Testing (GVT) and Maintenance, Repair and Operation (MRO) activities are essential processes in the lifecycle of an aircraft. Accurate modal identification and structural validation are required to ensure airworthiness, support structural modifications, and detect early-stage damage. Traditional approaches rely heavily on large accelerometer arrays, complex cabling, and extended setup times, which increase operational cost and limit measurement density.

The Ommatidia Q2 Laser Radar provides a non-contact, easy to deploy alternative capable of capturing full 3D vibrometry and metrology data using a single, mobile unit.

2. Q2 System Concept for Aviation Applications

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 µg/√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

The Q2 Laser Doppler vibrometer mounted on a movable metrology tripod enables a single operator to perform comprehensive 3D vibration measurements across aircraft structures including wings, fuselage, auxiliary power units, and wing–fuselage junctions . Unlike conventional sensor-based systems, the Q2 requires no accelerometer installation, eliminating mass loading effects, cabling and significantly reducing preparation time.

A complete GVT campaign can be performed by repositioning a single Q2 unit at multiple locations around the aircraft. The movable tripod configuration allows rapid relocation while maintaining metrology-grade accuracy. The lightweight design requires no time-consuming installation beyond tripod deployment, enabling streamlined operation in hangar environments.

For large-scale campaigns, additional Q2 units may be deployed to accelerate acquisition and enable simultaneous multi-axis or multi-location measurements. However, even a single unit can complete full GVT coverage sequentially at all required positions.

3. Data Acquisition and Measurement Workflow

The Q2 system collects both 3D vibrometry and high-resolution metrology data during the same acquisition process. Measurement locations can include wing tips, wing roots, fuselage sections, and structural junctions. The integrated RGB camera supports visual referencing of scanned areas, while autofocus and microscan capabilities ensure precise surface targeting and optimal signal quality.

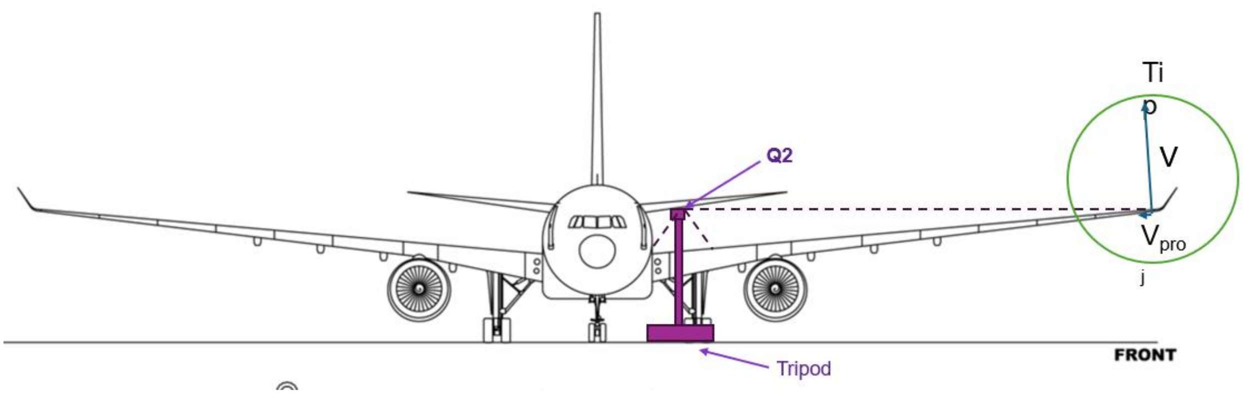

Figure 2: position of Ommatidia Q2 laser Doppler vibrometer relative to the aircraft

The system generates metrology-grade point clouds colorized by vibration amplitude, with displacement sensitivity down to tenths of a micron. This enables accurate reconstruction of modal shapes without physical contact with the structure.

Customizable measurement profiles allow adaptation to specific GVT or MRO requirements. Automated focusing and scanning procedures reduce operator dependency and increase repeatability. A typical full measurement campaign involving multiple aircraft positions can be completed in approximately eight acquisitions of fifteen minutes each, corresponding to roughly four hours of total time around the aircraft.

Figure 3

4. Beam Geometry and Velocity Projection Considerations

When performing laser vibrometry on aircraft wings, the angle between the laser beam and the structural velocity vector must be considered. At the wing tip, the beam–velocity angle may be approximately five degrees, close to the dihedral angle of the wing. In this configuration, the measured velocity is a projected component of the true structural velocity.

For example, a true velocity of 600 mm/s at the tip may appear as 50 mm/s due to geometric compression of approximately 1:12. Closer to the wing surface, where the beam–velocity angle approaches thirty degrees, compression may be approximately 1:2.

The Q2 system automatically compensates for this geometric projection using the acquired 3D scan data. By reconstructing the surface orientation and measurement geometry, the software restores the true velocity magnitude, ensuring accurate modal parameter estimation without manual correction.

5. Aircraft Vibrational Dynamics – MS.760 Paris

The Morane Saulnier MS.760 Paris aircraft was subjected to controlled excitation to investigate structural modal response. Two excitation cases were analysed, corresponding to nominal frequencies of 26 Hz and 10 Hz.

Under 26 Hz excitation, the structure exhibits strong response at the excitation frequency and additional modal participation at higher harmonics and coupled modes. Spatial RMS velocity maps reveal distinct amplitude distributions across the wing and fuselage, highlighting **torsional modal shape** characteristics. Higher-frequency responses indicate the presence of local bending or torsional modes superimposed on global structural deformation.

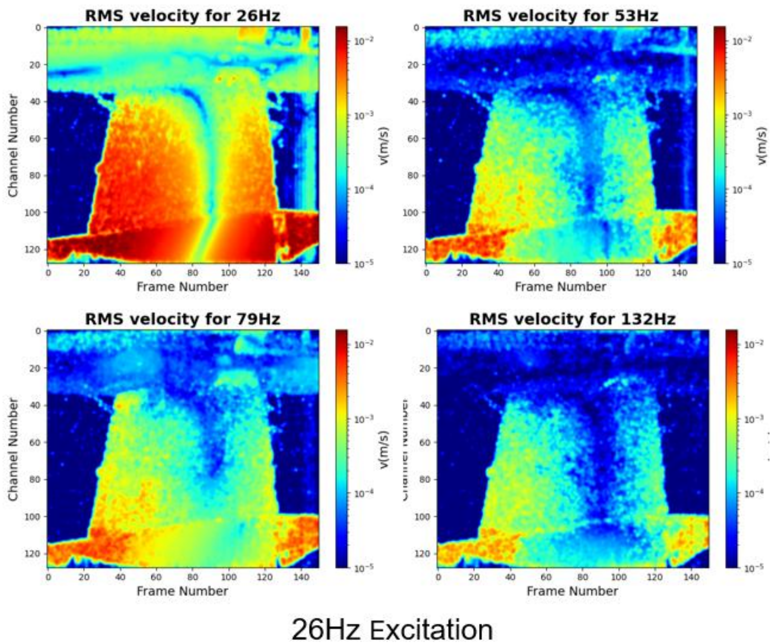

Figure 4: full field vibration map with 26Hz excitation

Under 10 Hz excitation, a different modal profile emerges. The lower frequency excites global bending modes involving larger portions of the airframe. Secondary responses at higher frequencies demonstrate structural coupling and harmonic excitation phenomena. The full-field vibrometry data allow clear visualization of nodal regions and antinodal areas, facilitating accurate modal identification.

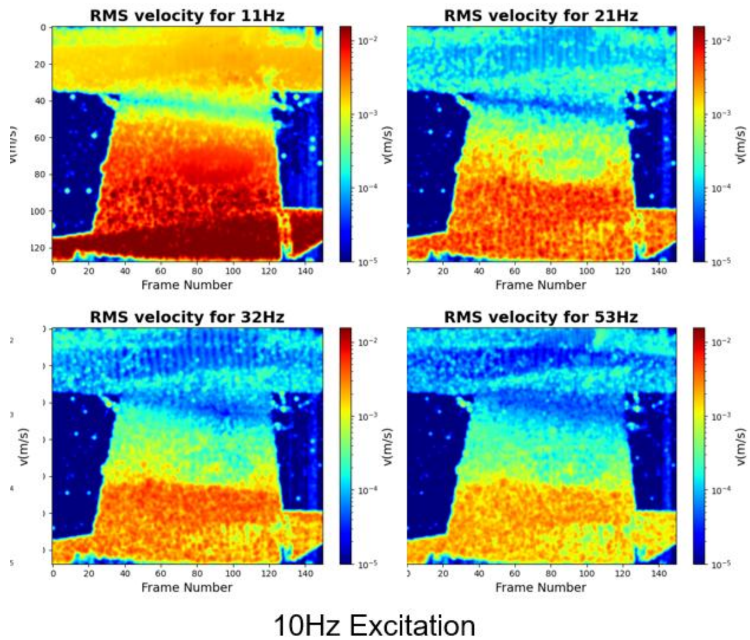

Figure 5: full field vibration map with 10Hz excitation

The combination of frequency-resolved RMS mapping and high-density spatial sampling enables direct comparison of modal shapes under different excitation conditions. This approach supports finite element model correlation and validation, as well as detection of stiffness variations or structural degradation.

6. Implications for GVT and MRO

The Q2 Laser Radar provides a scalable solution for aircraft structural dynamics testing. For GVT applications, the ability to reposition a single instrument around the aircraft reduces logistical complexity while preserving full-field coverage . The absence of wired sensors accelerates setup and minimizes aircraft downtime.

For MRO operations, rapid deployment enables vibration diagnostics during scheduled maintenance windows. The metrology-grade 3D data combined with vibration measurements provide both geometric and dynamic insight, supporting damage detection, repair validation, and structural trend monitoring.

Repeated measurements over time establish a baseline for structural health monitoring. Changes in modal frequency, damping, or spatial amplitude distribution can be identified with high sensitivity, enabling predictive maintenance strategies.

7. Conclusion

The Ommatidia Q2 Laser Radar demonstrates advanced capability for aircraft vibrational dynamics analysis, Ground Vibration Testing, and Maintenance, Repair and Operation applications . Mounted on a movable tripod and operated by a single user, the system captures full 3D vibrometry and metrology data with micron-level sensitivity.

The measurement campaign on the Morane Saulnier MS.760 Paris confirms the effectiveness of non-contact, full-field vibrometry for modal identification and structural health monitoring. By combining rapid deployment, geometric compensation, and high-resolution vibration mapping, the Q2 establishes a new paradigm for efficient and accurate aircraft structural testing.

8. Acknowledgements

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