Railway Safety and Maintenance Using Fiber Optic Sensing and Analytics

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Rail Condition Insights via Fiber Optic Sensing

Fiber Optic Sensing (FOS) enables continuous, real-time monitoring using standard optical fibers along the track. As trains pass, they act as a natural stimulus, exciting the track structure. The resulting vibrations are captured with high spatial resolution and analyzed for mechanical anomalies.

This poster highlights recent applications of FOS for rail condition monitoring. Field data show how characteristic signal patterns reveal rail surface defects, faulty switches, and subsurface issues such as soft soil zones.

Experimental work

Train-induced vibrations are transmitted through the trackbed and subsoil and are detected by a fiber optic cable running alongside the railway. Using Distributed Acoustic Sensing (DAS), these signals are processed into spatially resolved acoustic features, allowing for continuous monitoring of the structural and geotechnical condition of the railway infrastructure [1]. A conventional telecom fiber was employed as sensing medium, demonstrating that existing communication infrastructure can be repurposed for real-time condition monitoring without physical trackside modifications.

Figure 1. Train-induced vibrations along the sensor.

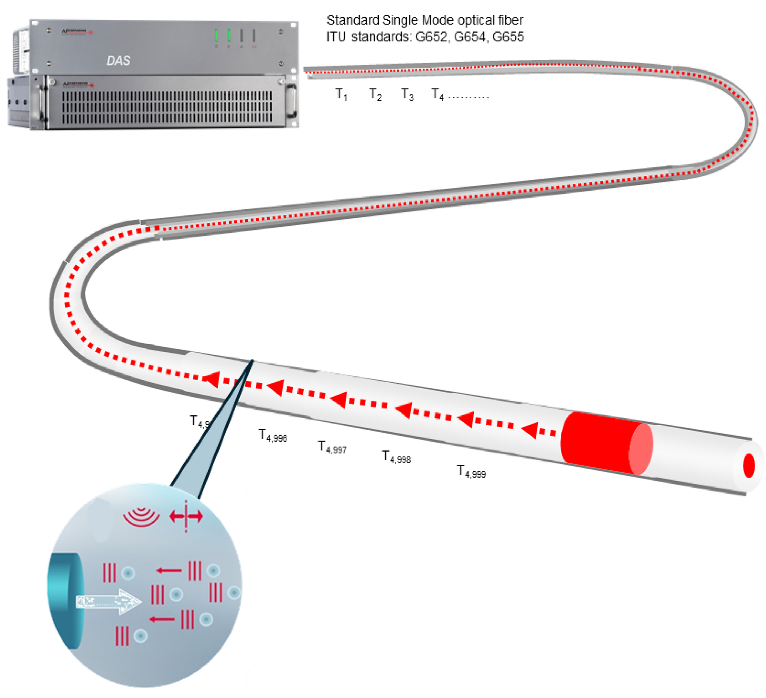

Figure 2. Acoustic-induced strain modulates light backscatter in the fiber, enabling spatially resolved vibration monitoring along the track.

Results

Field data collected on a Swiss railway line confirm that Fiber Optic Sensing (FOS) enables detection of mechanical anomalies along the rail and substructure with high spatial and spectral resolution. Trend-based feature analysis reveals deviations from historical baselines, supporting early-stage damage detection.

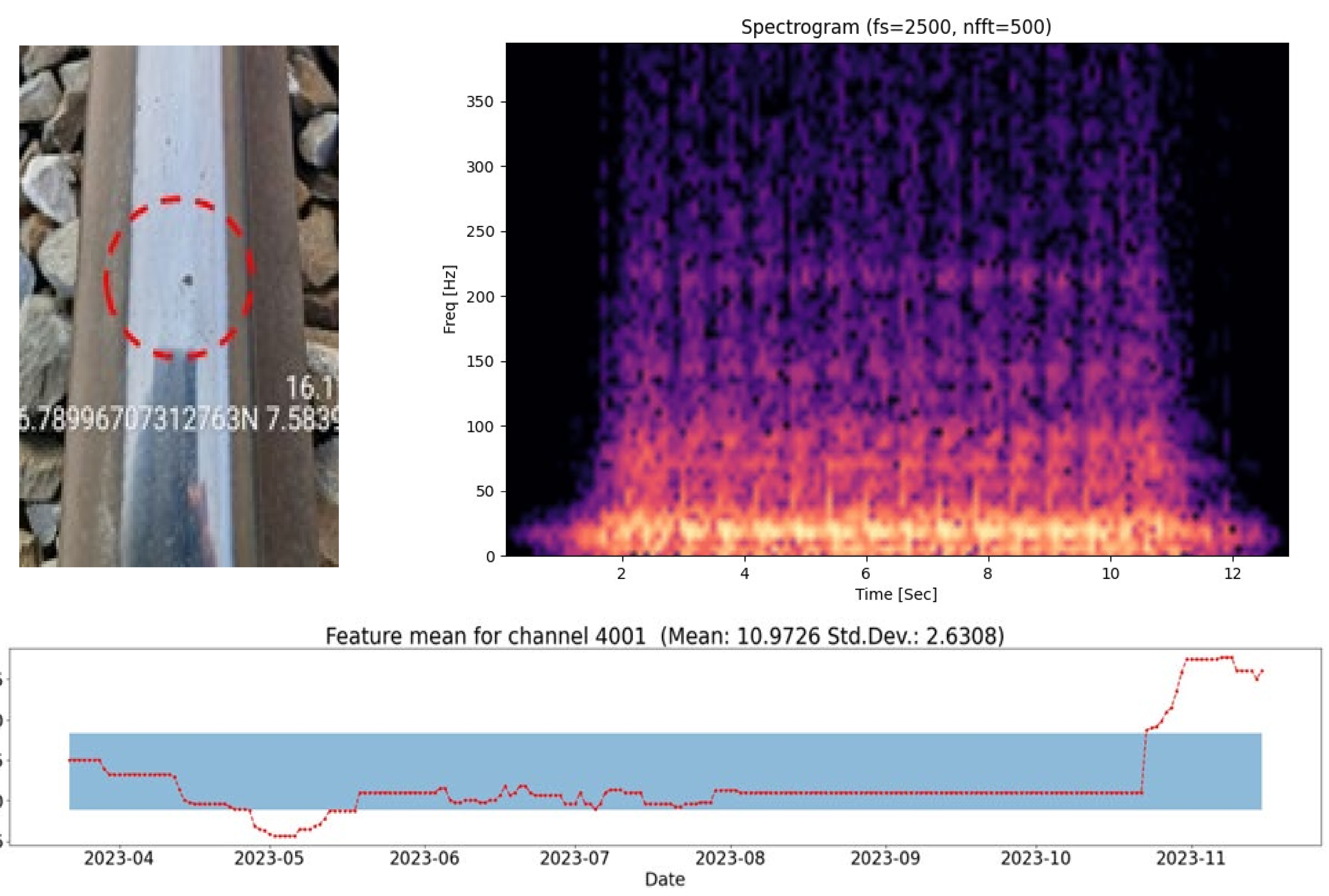

Figure 3: FOS-based detection of a defect via spectral anomaly and temporal feature evolution. Deviation from baseline indicates onset of the damage.

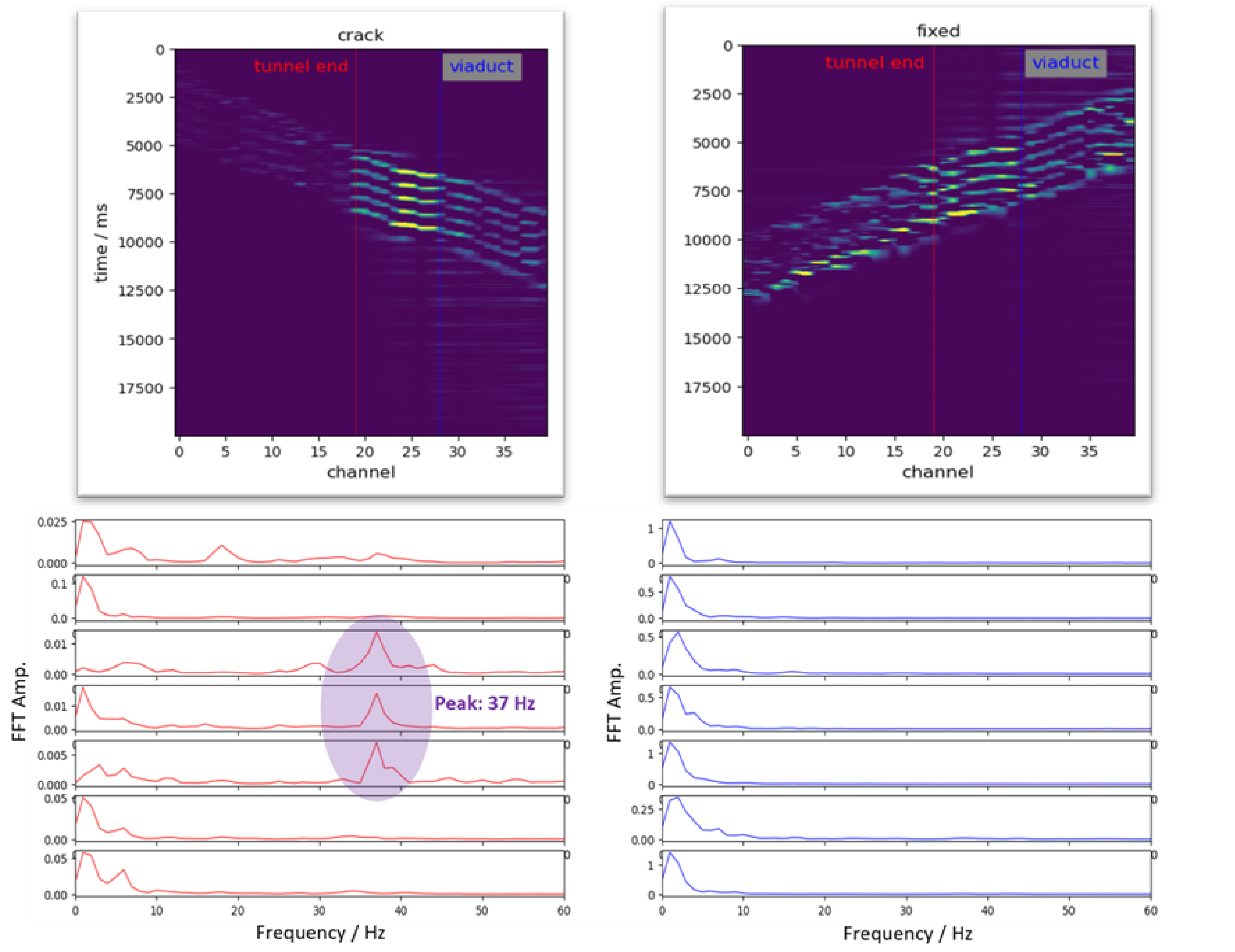

Figure 4. FOS-based vibration and frequency response of a train passing over an unwelded rail joint (left) versus welded state (right). Localized spectral peak at 37 Hz serves as a diagnostic marker for structural discontinuity.

Signal anomalies at rail joints or in disturbed track sections are clearly observed. Characteristic frequency peaks (e.g., 37 Hz) indicate rail surface defects such as squats.

By applying dispersion analysis and inversion modelling, shear wave velocity profiles are derived—allowing identification of weak subsoil layers and other geotechnical risk zones [2], in collaboration with Sercel.

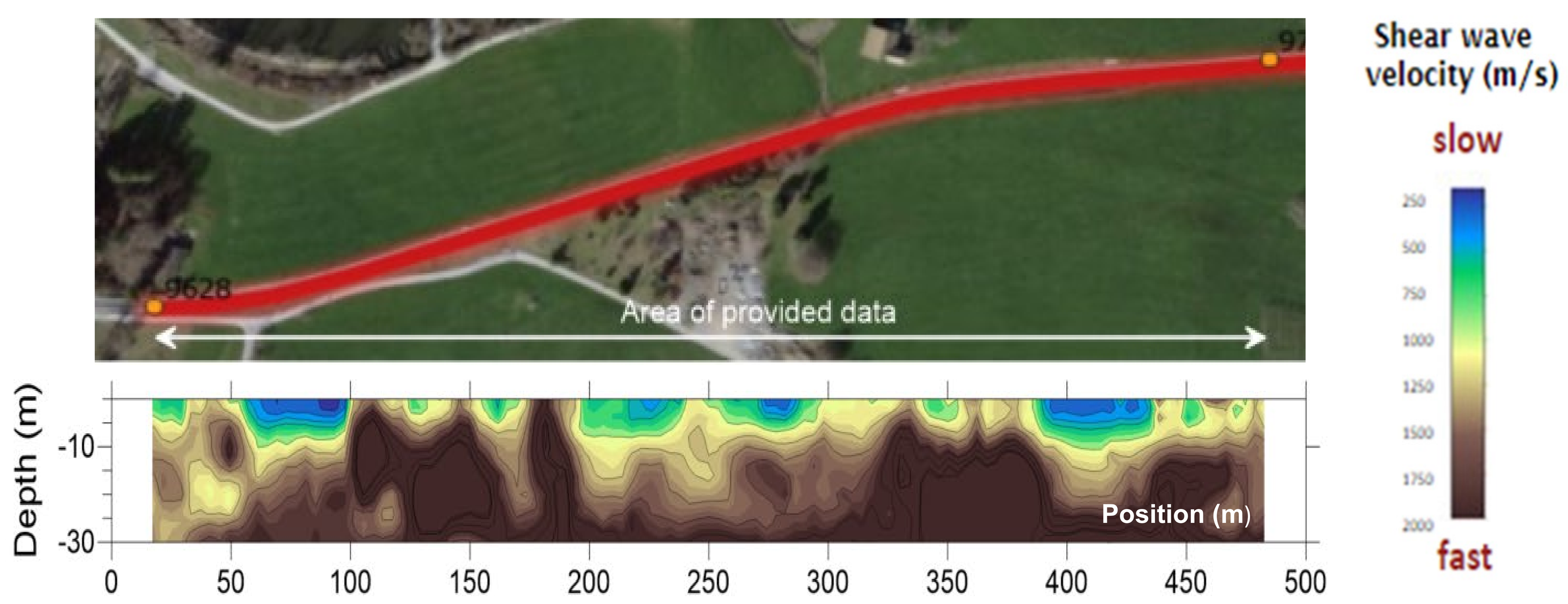

Figure 4. Shear wave velocity profile from DAS data highlights weak layers and geotechnical risk zones beneath the track.

Conclusions

FOS combined with signal analytics offers a scalable solution for continuous, non-intrusive monitoring of railway infrastructure. Structural and geotechnical issues—such as squats, faulty welds, or soft soil—can be detected early using existing telecom fibers. This supports predictive maintenance strategies and improves safety and asset availability.

References

[1] Hartog, A.H.: An Introduction to distributed optical fibre sensors, p 161 ff, CRC Press, ISBN 978-1-4822-5957-5.
[2] Valishin, O., Innovative geophysical investigations of railroad infrastructure using discrete sensors and fiber optics, EAGE 2214-4609, 2023, p 1-5.

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	1	Pleasant to look at. Pleasing use of colors, text, and graphics
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	2	Explicit numbering, column bars, row bars, etc.
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	1	Present, but not explicit. Buried at end of "Introduction", Background", etc.
	2	Explicit. This includes headings of "Objectives", "Aims", "Goals", etc.
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