Distributed laser telemeter for profile measurements

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An innovative time-of-flight distributed telemeter is presented, developed for the installation on train monitoring portals. It is composed of a single transmitter-receiver unit, and of up to six scanning stations, connected to the main unit by fiber optics pairs. The systems operates at 400 kHz, with a measuring range of 0.5-15m, and an uncertainty of ± 3mm.

1 Introduction

Train monitoring portals require very high frequency telemeters to measure the train profile. Commercial phase-shift telemeters were installed in a first experimental portal by our company, but with some drawbacks. The need arose to develop a time-of-flight telemeter with superior performance.

The system specifications required the telemeter to operate at very high frequencies (up to 400 kHz), and the need to contain the costs while installing four units on the portal led to the concept of distributed telemeter, where a single unit containing the transmitter optics, receiver optics and control electronics feeds multiple scanning stations through fibre optics pairs. The use of fibre pairs for transmission and detection allows to place the remote measuring stations at distances of 50-100m from the main unit, which can be positioned in a well-shielded shelter far away from train and environmental disturbances.

2 The optical setup of the telemeter

Fig. 1 shows the overall architecture of the system.

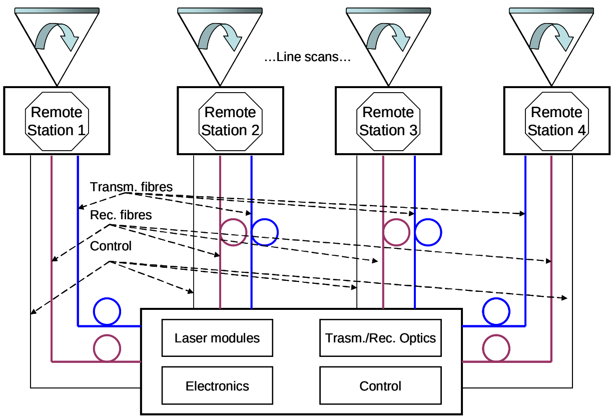

***Fig. 1** overall layout of the telemeter*

The distributed telemeter, in the present assembly, is composed of four measuring stations, although the architecture of the system is rather flexible. The control unit contains the transmitter laser source and the receiver optics and electronics.

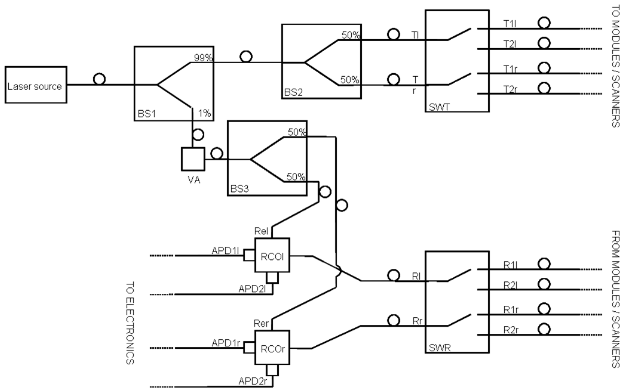

***Fig. 2** Transmitted-receiver optics.*

The transmitter and receiver section is depicted in Fig. 2. A 400kHz, subnanosecond fibre laser is used as the transmitter source. It is coupled to a beam splitter to produce the measurement and reference signals. In turn the measurement signal is further split to produce the signal for the left- and right-side of the wagon. Each signal is finally multiplexed to be addressed to the left or right track.

The optical fibres from the measuring stations are demultiplexed to produce the left-right signals. Each signal is combined to the reference signal through a beam combiner. This, in turn, produces two outputs: the first one contains a 99% signal and 1% reference pulse sequence, the second one the 1% signal, 99% reference pulse sequence. Using either of the two sequences, depending on the receiver signal amplitude, allows to extend the dynamic range up to 40dB at 400kHz.

Fig. 3 shows the schematics of a single scanning station. The mirror rotates at 70 rps, thus allowing the acquisition of the entire half-wagon each 1.4ms. The fibre at the input is collimated by a 25mm lens, and directed to the rotating mirror through the 45° mirror. The light scattered by the target is collected by a 50mm lens.

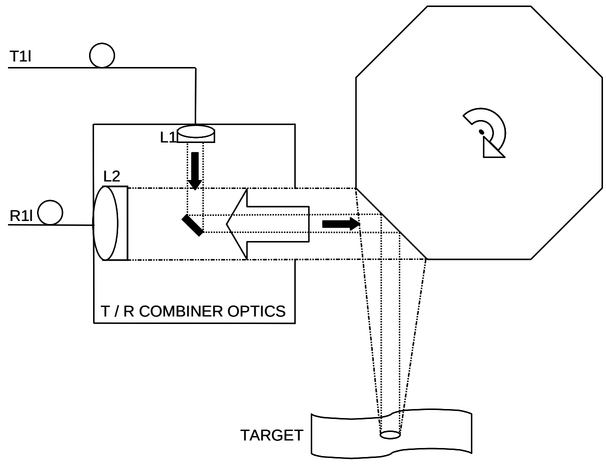

Fig. 3 *The scanning station.*

3 The conditioning electronics

The output signals from the four APDs described in the Receiver section are sent to the system electronics, which is composed of Front-end Electronics, a Constant Fraction discriminator (CFD), a Time-to-Distance converter section, which yields the measured distance. The choice of which signal (higher or lower) should be used is made by means of a peak detector circuit that samples the signal level. All the controls of the electronic unit are made by a control unit based on a FPGA.

4 System performances

In-house tests were performed at various nominal distances, ranging from 0.5m to 20m. The results are shown in Fig. 4 where the measured distance (left scale) and the single shot accuracy (right scale) are plotted *vs.* the nominal distance. The measurement errors are contained within an interval of -5mm - +5mm throughout the nominal distance.

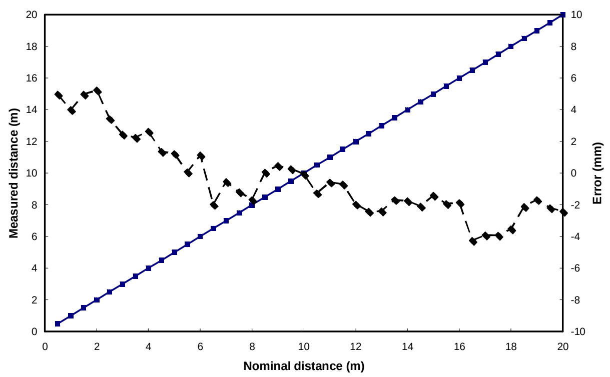

Fig. 4 *: Plot of the measured single-shot, static distance values (squares, left scale) and of the errors (rhombs, right scale) in a range of nominal distances 0.5 to 20m, at 400 kHz.*

The overall Type B uncertainty was tested with the use of a fixed target of known diffusion coefficient (85% reflectance) placed at a nominal 3m distance (measured by means of a high accuracy laser telemeter) from the exit window of the instrument, and at a SNR of 100. The uncertainty resulted of ±3mm.

The distributed telemeter is now installed on a train-monitoring portal located on the Roma-Napoli Railway. The four stations have been mounted so that each scanned a whole half-carriage under an angle of ±36° with trains passing under the portal at circa 200km/h. A complete profile of the left and right side of the carriage is obtained every 1.4ms.

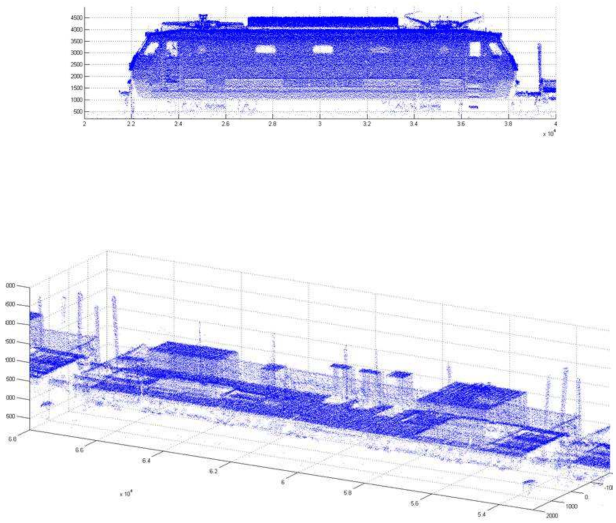

Fig. 5 *3D profiles of a train as obtained by the elaboration of the telemeter measurements. a) profile of the engine, b) profile of an open freight car receiver optics.*

A typical result of a train monitoring process is shown in Fig. 9. The two examples show the point clouds of the train obtained by combining together all profiles obtained from the scanning procedure. The point cloud is shown without filtering or digital processing of the points. Nevertheless, in the figure only very few points are evidently “false”, due to particularly unfavourable target conditions (glass, dirt, etc.).

The results obtained in the monitoring process are extremely positive for the detection of unbalanced loads, open doors, etc. for a train before entering a tunnel.

5 References

[1] L. Fumagalli, P. Tomassini, M. Zanatta and F. Docchio: “A 400kHz, high-accuracy laser telemeter for distributed measurements of 3D profiles” Submitted to IEEE Transaction on Instrumentation and Measurements (2009).

[2] L. Fumagalli, P. Tomassini, M. Zanatta, and F. Docchio, “Laser Telemeter for Distributed measurements of object profiles”. Italian patent (submitted)