< In the future, a novel measurement system will determine the geometry, surface structure and vegetation growth on tunnel constructions simultaneously and at high speed.

GROUP **LASER SCANNING**

Tunnel vision: Sensor determines condition of tunnel structures

In the future, a laser-based multispectral sensor will be able to simultaneously identify the geometry, surface structure, moisture level and vegetation growth of tunnel constructions. This system will determine all relevant parameters in a single measurement run at speeds of up to 80 km/h. As a result, it will be possible to perform inspection and maintenance of tunnels far more efficiently and economically.

Tunnels are critical transit connections for both passenger traffic and goods transportation, particularly in Central Europe. However, they also play an important role in drainage systems and as mine access shafts. In Germany alone, over four hundred road, rail and subway tunnels require regular inspections – and many of these are several decades old. In addition, there are some 250,000 kilometers of tunnel-like structures in the sewer network. Every year, the costs of maintaining and repairing tunnels amount to nearly one billion euros solely in Germany. As part of the IncaS (IntracavityScan) in-house Fraunhofer project, Fraunhofer IPM has developed a multispectral sensor that will significantly reduce the costs of tunnel inspection while improving the quality of measurement data at the same time.

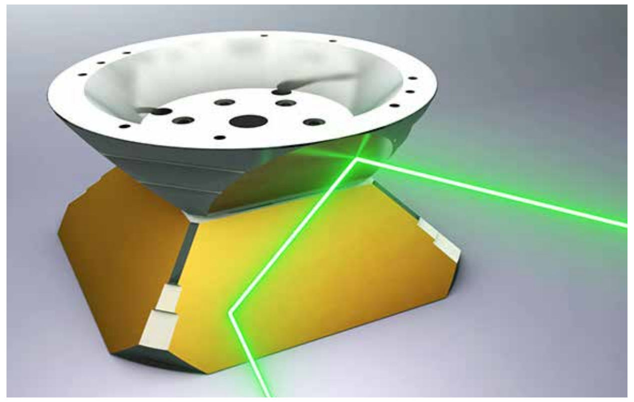
Multiwavelength measurement

The scientists use a novel laser scanner design for performing measurements with multiple wavelengths. The measured data of the different wavelength are then combined. This allows for a seamless and dense detection of 3D geometries, surface structures, moisture levels and vegetation growth on tunnels in a single measurement run. The measurement system operates at high travel speeds meaning that it will no longer be necessary to close routes during surveying. Propagation delays in laser light backscattering are used to survey the geometry of a given structure. Up to two million measuring points per second ensure high resolution. In order to measure surface moisture, two lasers with different wavelengths are used. The laser light is specifically absorbed by water, depending on the respective wavelength of 1.3 and 1.45 µm. An intensity analysis of the two signals gives the moisture value. These data on geometry and moisture allow the researchers to ascertain information on vegetation, such as moss and algae growth. Features of the surface structure are detected based on the intensity of the backscattered light: High spatial resolution is required here in order to generate realistic, photo-like images of cracks in the surface structure measuring just a few millimeters. The laser illuminates the object along a line parallel to the direction of travel. A specially adapted receiver lens forms a planar image of the signals and thus generates a continuous gray-scale picture of the surface. Resolutions of 1.5 mm x 1.5 mm are achieved at travel speeds of up to 80 km/h using this patented technology from Fraunhofer IPM.

CUTTING-EDGE TECHNOLOGY FOR TUNNEL INSPECTION: The geometry, wall surface structure, vegetation growth and wall moisture in tunnels are inspected every five years. Today, static laser scanners positioned at numerous points throughout a tunnel are predominantly used to measure geometries. A small number of systems perform these measurements from mobile platforms, usually on manually-driven inspection cars. Cracks and moisture are detected using cameras, while cavities are identified with a special hammer. All existing methods are time-consuming and labor-intensive, and require full closure of the structure – which has far-reaching economic consequences.

Innovative scanner design for true 360° scanning and multiwavelength measurements

For the first time, a specially developed, square bifrustum-shaped scanning device has made it possible to use laser beams of several different wavelengths synchronously to produce undistorted images (see drawing). This was not possible with the laser scanners available to date, as the light paths could not be clearly isolated. The device also enables true 360° scanning for the first time. Previously, mechanical fixings created shading and made it necessary to perform multiple measurements. Data from several measurements had to be fused to create an unbroken 3D model – an error-prone process that has now been eliminated by the new system. The bifrustum has four facets that cover an angle range of just under 180° each so as to avoid artifacts in edge areas. Thanks to this geometry, the scanning speed is doubled in relation to the speed of rotation, enabling as yet unequalled scanning frequencies. Up to four identical laser systems per frustum and corresponding detection devices can be arranged around the deflection unit in a star shape to guarantee full coverage of all angles. The design ensures perfectly correlated data capture, both in terms of time and space, and enables the use of specially shaped laser beams. The beam propagates along a line to allow planar scanning and guarantee eye safety.



A specially configured deflection unit was designed to meet the requirements of 360° scanning and multiwavelength measurements. This also ensures that all eight laser beams are projected onto the tunnel wall without distortion. This image shows an example of one beam.

This will be the first cavity inspection system to measure all relevant parameters simultaneously, rapidly, and with high levels of resolution. Thanks to its perfect data synchronization, comparisons can be made with previous measurements allowing even small changes in a structure to be identified in good time.

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