< Small cracks in the road surface are often the first warning sign of more serious damage. To keep maintenance costs down, any such damage must be identified and repaired as early as possible.

GROUP **MOBILE TERRESTRIAL SCANNING**

A close-up inspection: Detecting cracks in road surfaces

Laser scanners are increasingly being used to measure the evenness of road surfaces. But additional cameras are still used to detect structural damage on a smaller scale. Fraunhofer IPM has now upgraded its Pavement Profile Scanner (PPS) to create the PPS Plus, which provides not just 3D geometric information but also – for the first time – photo-realistic images of the road's surface, showing cracks and other structures down to the millimeter. The 2D images are generated not by a camera but by an additional laser for measuring intensity.

One of the key considerations in road maintenance, alongside the elevation profile, is surface damage such as patching, potholes or fine cracks. Detecting this damage early on can make it possible to prevent more serious and expensive damage. Fraunhofer IPM's original PPS road scanner, on which the new model is based, is the only laser-based measurement system to be approved by the German Federal Highway Research Institute (BASt) for measuring transverse evenness on roads. The device offers cutting-edge levels of precision and resolution for road surface measurements. The scanner is the size of a shoebox and is mounted on a survey vehicle to scan the road surface with an eye-safe laser beam across a width of approximately four meters. The distance to the road surface is determined with sub-millimeter based on phase shift measurement. The laser uses a rotating polygon mirror to scan the surface perpendicular to the direction of travel of the vehicle, generating 800 profiles per second. Each profile consists of as many as 900 measuring points, depending on the measuring frequency selected. This allows the PPS to generate a detailed 3D elevation profile of the road surface. However, at speeds of 80 km/h, the distance between measuring points in the direction of travel is still around 28 mm, while this distance in the perpendicular direction is 4.5 mm. Many types of damage are visible at this resolution – but for detecting cracks merely a few millimeters large, it is not enough.

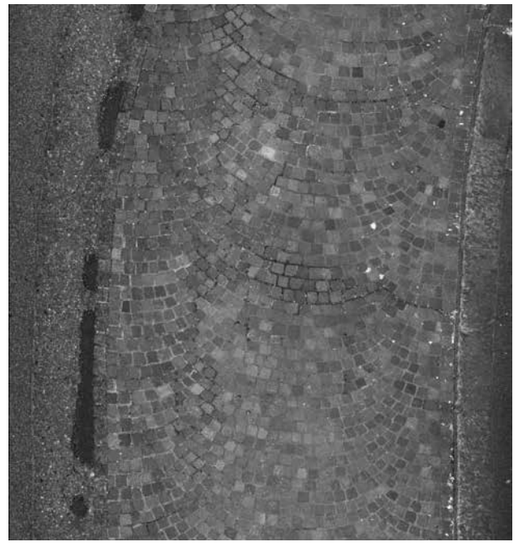
Generating photos without a camera

To detect such small-scale damage, researchers at Fraunhofer IPM have now upgraded the PPS using patented technology. The PPS Plus features an additional laser instead of the cameras usually used for crack detection. It works by measuring the intensity of the backscattered light. This information is used to generate a photo-realistic image with a resolution in the millimeter range capable of showing even minuscule damage. The patented 2D measuring setup includes newly developed optical, mechanical and detection systems which were synchronized with the laser deflection apparatus (polygon mirror), detection lens and detection unit of the 3D laser scanner.

Measuring the intensity of a backscattered laser beam offers a number of advantages over the camera technology conventionally used for crack detection. Cameras require additional active illumination, which means installing bulky equipment on the survey vehicles. The PPS Plus integrates both a distance and an intensity scanner to allow a compact optical setup and flexible system design for mounting on a range of mobile platforms. This means that the system can perform reproducible measurements in moving traffic without the need for road closures. The use of a laser generates uniformly high-resolution images regardless of the ambient light conditions. This is virtually impossible to achieve with cameras since they require additional lighting to balance out light differences along the road, but such uniformity is essential for automated and standardized analysis. And the variety of colors found on the road surface, from the dark asphalt to the light painted markings, is problematic for camera but not for intensity measurements. These measurements eliminate the need to combine individual camera images and then merge scanner and camera data – a time-consuming process.

COMBINED LASER INTENSITY AND DISTANCE MEASUREMENTS: In conventional laser distance measurement, the intensity of the backscattered light is always measured, too. However, the optimal wavelength, measuring frequency and focal spot size are different for distance measurement and intensity measurement. To generate camera-quality gray-level images, the intensity measurements must be performed with a separate laser which allows these parameters to be freely selected. With the PPS Plus, both lasers are deflected using a single scan mirror, ensuring that the geometrical and image data are precisely aligned. This means that the ability to correctly classify spatial characteristics is intrinsic to the system.

The wavelength of the laser used for the intensity measurements was selected to give the optimal image contrast. While the distance scanner's measuring frequency of 1 MHz is sufficiently fast, a measuring frequency of around 4 MHz is needed for the intensity measurements based on a driving speed of 80 km/h. This results in a spatial resolution of around 1 mm over the scanning range of 4 meters. To obtain more detailed measurements also in the direction of travel, the second laser beam is expanded in the direction of travel and measured with multiple detectors at the same time. This increases the resolution in the direction of travel without the need to change the mechanical scanning frequency. Four PPS Plus road surface scanners are already in use and three more are currently being prepared for deployment.



The Pavement Profile Scanner generates photo-realistic images of the road surface which show structural features measuring just a few millimeters.

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