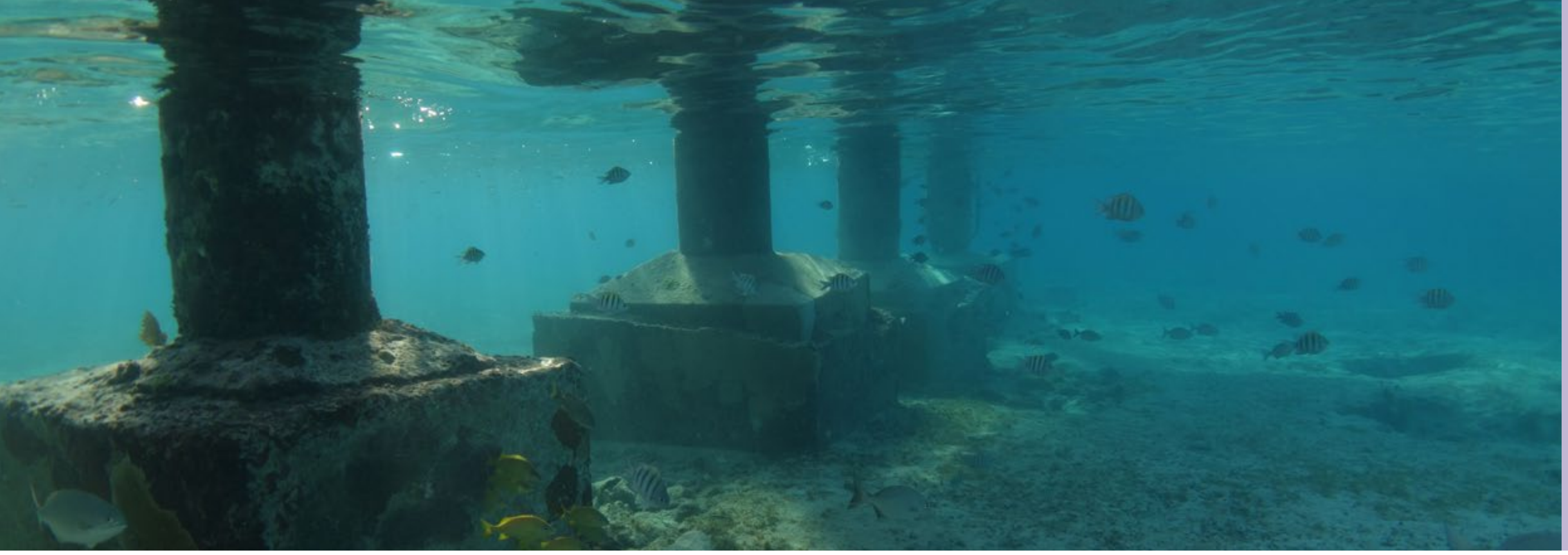


< Inspecting underwater structures is complex and dangerous. The intention is for laser scanners to take on the task of monitoring such constructions in future. They can measure with greater precision and reliability than the systems employed to date.

GROUP **AIRBORNE AND UNDERWATER SCANNING**

Going deep: Underwater laser scanning

At present, underwater structures are generally inspected by divers – sometimes at very great risk. True geometric condition monitoring is virtually non-existent. However, Fraunhofer IPM has now been able to show that 3D measurements can be taken underwater with the help of laser scanners. The long-term goal is to develop a LiDAR-based measurement system for acquiring 3D data on underwater structures.

Throughout 2017, well over a thousand wind turbines spun off the German coasts while some 600 drilling platforms produced crude oil across the globe. Large parts of these structures are submerged in water and are exposed to extremely harsh environmental conditions. The importance of monitoring the condition of such structures was dramatically highlighted by the Deepwater Horizon drilling rig blowout in 2010. Large-scale dams and tidal range power plants pose similarly high risks. Measurement technology can help to make the inspection of such plants accurate, efficient, and cost-effective. The availability of innovative underwater measurement technology is also an advantage where mapping inland waters and shipbuilding are concerned. It allows navigation channels to be surveyed with greater speed and reliability, and ship retrofitting can be planned more efficiently.

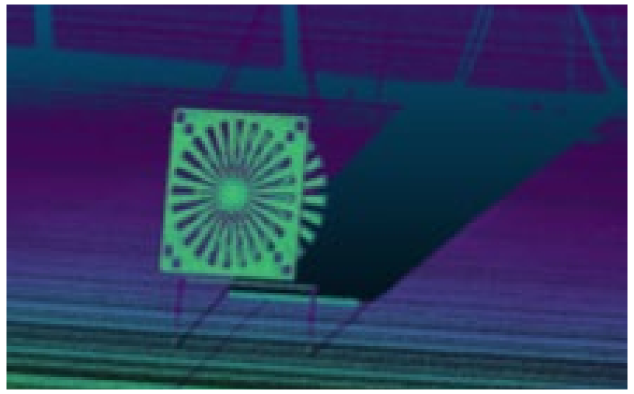
LiDAR outperforms sonar

Typically, underwater structures are monitored using cameras. The images and videos taken support the visual inspections performed by divers. However, the poor light conditions mean that the quality and scope of these images are limited. Images are analyzed manually – a procedure that provides no objective measurement parameters. Geometric dimensions, such as those concerning the topography of ocean floors or those used to determine the position of objects, can only be derived from these images using photogrammetric methods, which are very labor and cost-intensive. Data on large-scale structures are commonly gathered using acoustic measurement systems such as sonar. The disadvantage of this approach is that sonar measurements are comparatively slow and inaccurate. Even at close range, scanning sonar systems only deliver resolutions of a few centimeters. Where condition monitoring is concerned, however, it is necessary to be able to detect deformations down to the millimeter, since these provide early indications of damage. Thanks to their shorter wavelengths and their constant, high propagation velocity, optical techniques achieve fundamentally greater accuracy and measurement speeds than their acoustic counterparts. Here, the time-of-flight method is the most suitable for use underwater. For the DeepInspect project funded by the Fraunhofer-Gesellschaft, Fraunhofer IPM is collaborating with Fraunhofer IGP on an underwater laser scanner that employs this method and that is intended to enable true 3D data capture on submerged structures.

> **UNDERWATER TIME-OF-FLIGHT MEASUREMENT** The time-of-flight method is an extremely accurate optical method for measuring distance. A short laser pulse is emitted, backscattered by the measurement object and picked up by a detector. The distance to the object is given by the propagation delay needed for the pulse to travel from the laser source to the detector. If the laser beam is deflected via a continually oscillating or rotating mirror, 3D pixel information can be deduced from the mirror position and the propagation delay of the light (scanner). In the optically dense medium of water, light travels more slowly than in the atmosphere – which benefits measurement accuracy. At the same time, poor visibility, suspended particles, salinity, and the resulting reflections complicate the measurements.

Digital compensation for light scattering

Performing time-of-flight measurements in turbid water presents scientists with new challenges, since different physical laws apply to the behavior of light underwater than in the atmosphere: Beams of light are very strongly attenuated by water, and scattered particles make it more difficult to interpret the actual measurement signal. It was already clear in the preliminary stages of the project that the problem of light attenuation is solvable, since laser pulses can be adequately reflected over several kilometers where light propagation is undisturbed. A laser range finder, which can measure over a kilometer on land, will still achieve a sufficient signal level even when light is attenuated to one percent over a measurement distance of 100 meters. Such measurement ranges are adequate for the majority of underwater measuring tasks. Overcoming light scattering proves more of a challenge, however: Particles suspended in the water reflect part of the measurement beam. The scattered signal of all objects in the measurement volume reach the detector, although only the signal from the furthermost measurement object is desired. It is therefore necessary to isolate superfluous signals from the object's signal. The key to doing this is signal digitization: Rapid analog-to-digital converters assign a specific propagation delay, and thus a specific range, to the digitized signals. This technology is already employed in terrestrial laser scanners, for instance to eliminate interference from vegetation. Using real-time digitization and subsequent signal processing, the team has now been able to demonstrate that this approach is even successful with continually occurring obstructions.



Under ideal conditions in the testing tank, the underwater laser scanner can measure with an accuracy of approximately four millimeters (a test object is shown here).

A prototype was used to perform successful test measurements in a specially-designed underwater measurement tank. In clear water, a measurement accuracy of four millimeters was achieved over a distance of up to ten meters. The measurement system, which is cased in a watertight pressure housing, will be tested in the sea in spring 2019.

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