Tissue-integrated microlasers used to measure contraction in beating heart of zebrafish

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Researchers have shown that tiny lasers integrated into heart muscle cells or tissue can be used to acquire high-resolution measurements of contractility in heart muscle cells, live zebrafish and living heart tissue at locations several times deeper than other light-based techniques. The ability to characterize the contractile properties of single cells in the beating heart could improve our understanding of heart diseases and help advance new therapies.

Marcel Schubert from the University of St. Andrews, UK will present the research at the all-virtual 2021 OSA Biophotonics Congress: Optics in the Life Sciences to be held 12-16 April.

"Microscopic lasers can reveal biophysical signals deep within tissue where imaging methods can't be applied," said Schubert. "In the future, this technique could help to overcome the increasing burden of cardiovascular diseases by guiding the development of artificial cardiac tissue and regenerative cardiac therapies."

Using light to analyze or image the beating heart is challenging because the tissue is constantly moving and the dense muscle fibers in the heart tend to strongly scatter and absorb light. Although advanced microscopy techniques such as multiphoton imaging can image at depths of up to 1 mm in the brain, the challenging environment of the heart limits functional imaging to about 100 microns.

In the new work, the researchers use spherical microlasers that are just 15 microns in diameter. Because of their unique emission characteristics, these lasers work well for applications that require high signal strength and short acquisition times.

The researchers found that the microlasers can be internalized by neonatal mouse heart muscle cells. Once inside the cell, the microlaser stays in direct contact with myofibrils—the contractile filaments that form the muscle fiber. When the cell contracts, it changes the refractive index of the myofibrils touching the laser, creating detectable pulse-shaped perturbations in lasing wavelength. These changes in refractive index are directly correlated with contractility.

The researchers also injected the microlasers into the outer wall of the heart of a zebrafish embryo and then recorded detailed contraction profiles. The results showed that the technique is not affected by the fast movements of the heart. The new approach also worked in thick sections of heart tissues, which could be used for drug screening or testing regenerative cardiac therapies. In these tissue sections, the microlaser signals and heart contraction could be measured through tissue that was up to 400 microns thick.

"Our study shows that microlasers can be used as versatile sensors to reliably characterize contractile properties of cells without any complex image reconstruction or tissue stabilization processes," said Schubert. "In the future, this approach could be used to study transplanted cells and engineered cardiac tissue."

A next step in the research will be to decrease the size of the microlasers, improving their biocompatibility. More importantly, by switching to multiphoton excitation or infra-red emitting lasers, light penetration could be increased drastically, allowing to sense contractions deep within the beating heart.

More information: The presentation is scheduled for Wednesday, 14 April at 11:30 PDT (UTC-07:00).

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