A laser made entirely of living cells and materials derived from living organisms

Rendicontazione

Informazioni relative al progetto

LIVINGLASER

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Progetto chiuso

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Final Report Summary - LIVINGLASER (A laser made entirely of living cells and materials derived from living organisms)

Report for "LIVINGLASER" (627274) FP7-PEOPLE-2013-IOF
A laser made entirely of living cells and materials derived from living organisms

The proposed goal of LIVINGLASER was to make a laser composed entirely of living cells and materials derived from living organisms. By using cells producing green fluorescent protein, a laser was proposed that self-assembles, self-heals, self-reproduces, evolves and adapts to the environment. A number of applications are envisioned including research and medical uses.
These goals were reached entirely and even surpassed. Not only we were able to make living lasers, but we have also showed standalone microlasers completely embedded inside single cells. Further, we have also developed biocompatible optical fibers, which can be used to pump these lasers deep within human body or for a variety of medical applications such as diagnosis and treatments.

Lasers inside live cells

In the last few decades, lasers have become an important part of our lives, with applications ranging from laser pointers and CD players to medical and research uses. Fluorescent dyes have also become commonplace by biologists, routinely used in research and diagnostics to identify specific cell and tissue types. Illuminating a fluorescent dye makes it emit light with a distinctive color. The color and intensity are used as a measure, for example, of concentrations of various chemical substances such as DNA and proteins, or to tag cells. The intrinsic disadvantage of fluorescent dyes is that only a few tens of different colors can be distinguished because of the broad emission spectrum. In a combination of the two technologies, it is known know that if a dye is placed in an optical cavity – a device that confines light, such as two mirrors, for example – they can create a laser, which emits very narrow spectrum.
Taking it all a step even further, our research, published in the journal Nature Photonics, shows we can create a miniature laser that can emit light inside a single live cell. We made our lasers out of solid polystyrene beads ten times smaller than the diameter of a human hair. The beads contain a fluorescent dye and the surface of the bead confines light by total reflection, creating an optical cavity. We fed these laser beads to live cells in culture, which eat the lasers within a few hours. After that, we can operate the lasers by illuminating them with external light without any harm to the cells. The lasers can act as very sensitive sensors, because the wavelength of the emitted line depends on their environment, thereby enabling us to better understand cellular processes. For example, by using our lasers inside the cells, we measured the change in the refractive index – the way light travels through the cell – while varying the concentration of salt in the medium surrounding the cells. The refractive index is directly related to the concentration of chemical constituents within the cells, such as DNA, proteins and lipids.
Further, lasers can be used for cell tagging. Each laser within a cell emits light with a slightly different fingerprint that can be easily detected and used as a bar code to tag the cell. Since a laser has a very narrow spectral emission, a huge number of unique bar codes can be produced, something that was impossible before. With careful laser design, up to a trillion cells (1,000,000,000,000) could be uniquely tagged. That's comparable to the total number of cells in the human body. So in principle, it could be possible to individually tag and track every single cell in the human body.
Instead of a solid bead, we have also used a droplet of oil as a laser inside cells. Using a micro pipette, we injected a tiny drop of oil containing fluorescent dyes into a cell. In contrast to the solid bead, forces acting inside the cells can deform the droplets. By analyzing the light emitted by a droplet laser, we can measure that deformation and calculate the force acting on the droplet. It's a way to get a very precise picture of the kinds of mechanical forces exerted within cells by processes such as cellular migration and division.
We have also realized that fat cells already contain lipid droplets that can work as natural lasers. They don't need to eat or be injected with lasers, just supplied with a nontoxic fluorescent dye. That means each

of us already has millions of lasers inside our fat tissue that are just waiting to be activated to produce laser light. Instead of supplying the dye, we have also used cells which produce the dye themselves in the form of green fluorescent protein. Finally, instead of external source of light to excite the lasers, we have used a natural source of light; that is bioluminescence.
Our new cell laser technology will help understanding cellular processes and improve medical diagnosis and therapies. They could eventually provide remote sensing inside the human body without the need for sample collection. In pursue for such applications we have developed a novel super-resolution microscopy based on these microlasers. The method could be particularly useful for deep imaging of biological tissues. Cell lasers also hold promise as a way of deliver laser for therapies, for example, to activate a photosensitive drugs and to kill microbes or cancerous cells.
The news about first laser was published in numerous news media including Nature, Science, Yahoo News, Fox News, Discovery Channel News, Scientific American, New Scientist, Tech Radar, Beta Boston, Tech Times, Horizon Magazine (European Commission), etc. I was interviewed by local newspapers (Primorske Novice) and national newspapers (Delo, Finance, Dnevnik). I had three interviews for TV channels (Slovenia 1, POP TV and Kanal A) including national TV broadcasted in main evening news. I also had numerous interviews on radios (Radio Maribor, Radio Koper) including twice on national radio (VAL 202). Readers and viewers selected me by voting as the Slovenian personality of the week and Personality of the month of Primorska region.

Biocompatible optical waveguides

Advances in photonics have stimulated significant progress in diagnostics, surgery and therapeutics, with many techniques now in routine clinical use. However, the finite depth of light penetration, which is typically less than a few mm’s in tissue, is a serious limitation constraining clinical utility. To address this overriding problem, we have developed implantable light-delivery devices made of polymers that are bio-derived or biocompatible, and biodegradable. In contrast to conventional glass or plastic optical fibres, which must be removed from the body soon after use, the biodegradable and biocompatible waveguides may be used for long-term light delivery and need not be removed as they are gradually resorbed by the tissue. As proof of concept, we demonstrate this paradigm-shifting approach for photochemical tissue bonding for wound closure, leading to faster healing and less scarring. In addition, optical needle arrays have been developed to bring light deeper into the skin, enabling blue light antibacterial therapy, till now only limited to the skin surface. The developed fibres have great potential for wide array of biomedical applications, such as in vivo optical sensing and phototherapy. The work about biodegradable optical waveguides was featured in the TV series “White Rabbit Project” on Netflix (Season 1, Episode 8, December 2016).

Documenti correlati

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