MAX PLANCK INSTITUTE
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Hanieh Fattahi receives ERC Consolidator Grant to advance ‘Label-free microscopy’ research

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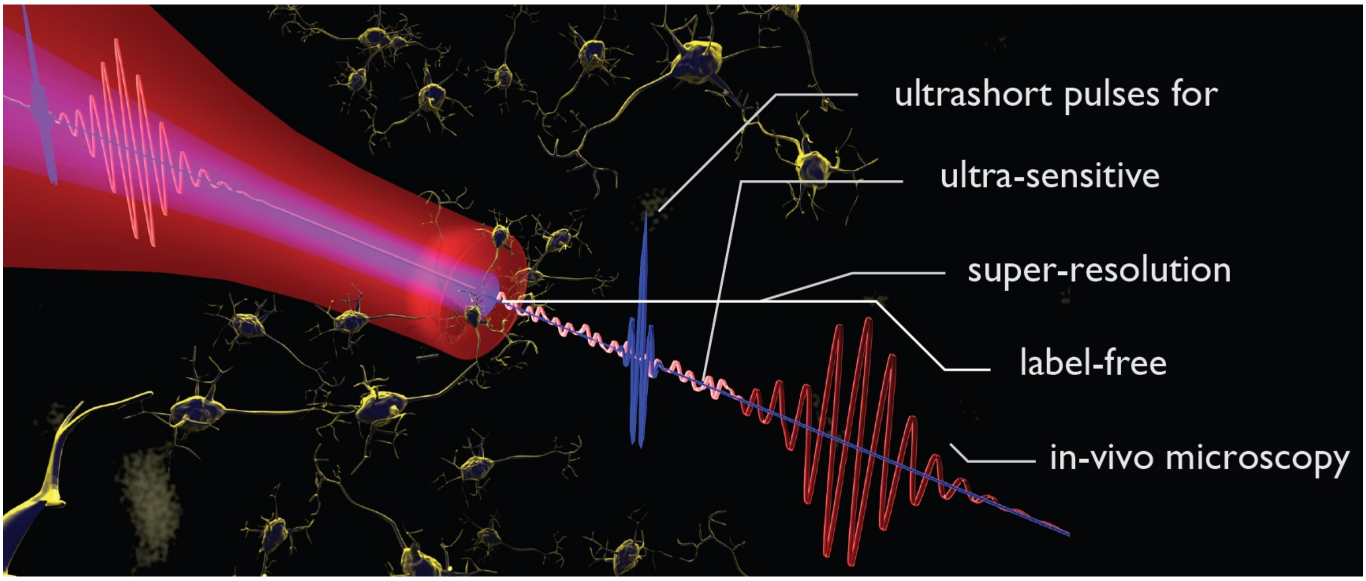
Dr. Hanieh Fattahi from the Max Planck Institute for the Science of Light (MPL) is delighted to have been awarded the prestigious ERC Consolidator Grant and will receive around two million euros in funding over a period of five years. The head of the ›Femtosecond Fieldoscopy‹ research group will advance the next generation of laser-driven biological microscopy with her research project ‘Beyond the visible’. With these innovative microscopes, scientists can use the ‘molecular fingerprint’ directly to investigate the processes of life in a non-invasive manner at high resolution.

The Consolidator Grant, valued at up to two million euros, is intended to support scientists in Europe in their innovative research – the European Research Council selected 308 excellent scientists from over 2,000 researchers. The Consolidator Grant is awarded to researchers who anticipate a promising scientific career. Fattahi receives the grant from the ERC Consolidator call 2023.

More detailed insights into biological fine structures and the dynamics of macromolecules are essential for researchers to gain new insights into life processes. Science already uses a variety of super-resolution imaging techniques. However, the challenge remains not interfering with living systems, for example when labelling with dye, and thereby manipulating processes. This is where the Fattahi team's research project comes in. The ‘Beyond the Visible’ project aims to develop a new generation of laser-driven biological microscopy that leads to a dramatic leap in sensitivity, dynamic range, spatial resolution, and non-invasiveness.



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Conceptual illustration of “beyond the visible”: The microscope delivers label-free, chemically-specific images with sub-100 nm spatial resolution

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The team uses an emergent optical-physical method, Femtosecond Fieldoscopy, which is based on a new type of ambient air field detector. Femtosecond Fieldoscopy in combination with Raman microscopy will be used to analyze the chemical composition in soft matter non-invasively and label-free. The researchers generate the so-called ‘molecular fingerprint’ of the sample and detect it via Fieldoscopy technique. Fattahi's method represents a coherent, realizable imaging technique, with a spatial resolution of less than 0.5 µm, creating new horizons for fundamental studies in science to see ‘Beyond the visible’.

How to get “Beyond the Visible”

Specifically, Raman molecular vibrations are excited coherently and efficiently by using bright, ultra-broadband laser pulses in the femtosecond range at petahertz frequencies. The temporal confinement of the excitation pulses to a few femtoseconds enables temporal filtering of the molecular response and thus a high signal-to-noise ratio and high detection sensitivity. The same laser delivers ultra-short duration optical pulses to directly access and detect the field oscillations of the emitted Raman molecular response.

This novel detection metrology allows for simultaneous and broadband detection of the entire molecular fingerprint and beyond with high dynamic range and sensitivity down to quantum shot noise. Most importantly, due to the near-field imaging in this scheme super-resolution, chemically sensitive images can be constructed without the need for labeling molecules or using structured light. “The advanced near-infrared femtosecond source in combination with the novel field detection technology will enable acquiring the complete fingerprint of complex biological molecules non-invasively to form super-resolution images with attosecond temporal resolution”, says Fattahi. “The technique holds promise to surpass previously demonstrated methods in terms of detection sensitivity and dynamic range”.

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Research at the Max Planck Institute for the Science of Light (MPL) covers a wide range of topics, including nonlinear optics, quantum optics, nanophotonics, photonic crystal fibres, optomechanics, quantum technologies, biophysics, and – in collaboration with the Max-Planck-Zentrum für Physik und Medizin – links between physics and medicine. MPL was founded in 2009 and is one of the over 80 institutes that make up the Max Planck Society, whose mission is to conduct basic research in the service of the general public in the natural sciences, life sciences, social sciences and the humanities.

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