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Technology Offer

Adaptive Optics Innovations for High Resolution Microscopy and Material Science

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Abstract

This offer presents three cutting-edge technologies for adaptive optics in microscopy, each covered by a distinct patent family: WO2021204663A1, WO2022018002A1, and WO2022223695A1. These innovations utilize spatial light modulators and machine learning, particularly neural networks, to address and correct optical distortions in real-time. They are as well applicable for a broader range of scenarios where precise light delivery is required, and hindered by aberrating conditions, such as for microfabrication and structure writing.

The first technology (WO2021204663A1) improves reflective microscopy by using a neural network, trained on examples of light propagation, and reflection off the sample, which then serves as a model to predict sample aberrations and correct for them with the spatial light modulator. This improves light delivery inside the aberrating samples, significantly reducing image distortions and enhancing clarity and resolution. The second technology (WO2022018002A1) uses physical light propagation model to infer scattering properties of the sample based on measurements of the reflected light. The third technology (WO2022018002A1) applies this idea to fluorescent microscopy, by utilizing intrasample fluorescence. These methods can complement each other and are aimed at improving light delivery to the sample by mitigating possible aberrations and offer a comprehensive solution to the limitations of current laser scanning microscopy techniques, significantly improving image quality and resolution for biological and medical applications.

Advantages

- **Real-time correction of optical distortions:** Neural networks enable dynamic adjustment of light paths, correcting distortions in real-time during imaging.
- **Reduces power loss and improves accuracy** of energy delivery, reducing sample exposure and improving illumination resolution.
- **Enhanced image resolution and clarity:** Significantly reduces image resolution by mitigating sample aberrations.
- **Versatility:** Applicable in both transmission and reflection microscopy, providing flexibility for various microscopy techniques.
- **Reduced need for extensive training datasets:** By utilizing light physics, models are not constrained in prediction to the training dataset only, making the system efficient and quick to deploy.
- **Seamless integration with existing microscopy setups:** These technologies can be incorporated into current optical microscopy systems without extensive modifications.

Potential applications

- **Biological microscopy:** Enhances imaging of biological samples such as tissues and cells, providing clearer and more detailed images for advanced research and diagnostic.
- **Medical Diagnostic:** Improve imaging of tissue samples, leading to more precise and accurate medical diagnostic.
- **Material science:** Facilitates the examination of light-scattering materials, aiding in the understanding of their structure and properties.
- **Microfabrication:** Improves light delivery to the substrate under aberrating conditions for optical microfabrication (photopolymerization/structure writing/ etc.).
- **Optical microscopy:** Enhances image quality across various microscopy types, valuable for researchers and scientists

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Background

In optical microscopy, especially within biological and medical fields, image quality is often degraded by light scattering and aberrations, such as often encountered when investigating partially transparent or scattering materials such as biological tissues. By using a spatial light modulator, one can mitigate these problems, but the challenge lies in determining the particular encountered aberration and calculating the required correction. This is additionally complicated by the microscopy imaging geometry, where it is impossible to directly access and measure focus quality inside the sample, but only observe its effect on the obtained image. Our suite of technologies introduces advanced solutions to aberration sensing and computation of the correction, thus improving light delivery to the sample, and enhancing both image resolution and clarity. These methods are compatible with laser scanning (fluorescent) microscopy, and as well applicable to other scenarios requiring precise light delivery, such as microfabrication and structure writing.

Technology

WO2021204663A1: Method and illumination apparatus of the adaptive optics in reflection microscopy

The technology is based on neural networks to recognize sample aberrations and spatial light modulators (SLMs) to apply corrections in laser-scanning microscopy. The light, backreflected from the sample, serves as input carrying information about the aberration that the neural network is trained to recognize. The method relies on initial recording of the training dataset of the reflected- and transmitted into the sample light. The neural network model is trained with the goal to predict transmission of light (typically inaccessible in microscopy) from the reflected light that can be directly measured.
Once trained, this model can accurately predict the distortions that occur during light propagation in the sample, and compute corresponding corrections that can be applied with the SLM in real time.

WO2022018002A1: Method and illumination device of the adaptive optics in transmission or reflection microscopy

The core of this technology is similarly inference of the transmission properties of the sample based on the light reflected from the sample. However, here we use a physical light propagation model, able to accurately describe the optical system with wave optics, where sample aberration is an unknown parameter. The real sample is probed with few light modulations displayed on the SLM, and the reflected light is recorded. The physical model is then optimized by tuning its aberration parameter to reproduce the same outputs under modulations as observed in the real sample. In the end of this process, the aberration parameter matches the aberration of the sample, and it can be used to compute the correction to apply with the SLM. By using an actual physical model of light propagation, this method is not constrained by training datasets.

WO2022223695A1: Method and illumination apparatus of adaptive optics in reflection microscopy

This technology as well centers around a physical light propagation model however applied to fluorescent samples. Here, fluorescent images are used to infer the aberration that describes the scattering properties of the medium by optimizing a physics model of fluorescent image formation. Fluorescence-capable bodies can be added to the sample, to reveal the aberration when imaged.

Patent Information

WO2021204663A1 and US20230098493A1 pending, DE10202010973B4 granted

WO2022018002A1, US20230273418A1 and DE102020119566A1 pending

WO2022223695A1 and EP4327154A1 pending

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