Executive Summary for:

Noninvasive High-Resolution Imaging through Living Tissue with Single-Shot Synthetic Wavelength Holography

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What is proposed? This proposal seeks to develop a *computational camera* that can *image through dynamic scattering media* with *high resolution*. The camera is primarily proposed for medical imaging applications through living (moving) tissue. The proposed noninvasive technique only uses light in (or close to) the optical wave band and works with standard off-the-shelf camera technology – theoretically even with mobile phone camera sensors. The technique leverages the huge potential of carefully designed optical systems paired with sophisticated algorithms. If successful, the camera could become part of a new wave of computational imaging devices that will represent key technologies in our near future.

Why is this important? Over the last decades the field of medical imaging has spawned several seminal inventions which can be found in every hospital nowadays. Prominent examples include Optical Coherence Tomography (OCT), Computed Tomography (CT), Ultrasound, or Magnet Resonance Imaging (MRI). However, recent years have seen a growing interest in medical imaging techniques which enable to look inside the human body, *but are non-invasive* and can be facilitated in a *small form factor*, i.e., possibly even operated in a hand-guided fashion. In other words: Cameras that allow to image small structures (such as capillaries, lesions, tumors, etc.) through scattering media, such as tissue and bone.

What is the problem? The proposed plan to develop such a camera builds up on the recent publication of the PI's research group, which used "Synthetic Wavelength Holography" (SWH) to image through scattering media and around corners with a demonstrated resolution up to 800µm [1]. However, the current SWH approach relies on the *acquisition of sequentially captured images* (at different optical wavelength) and is *extremely susceptible to motion*. Even the slightest movement of object or scatterer between two captured images leads to a complete loss of information, which makes imaging through living (i.e., moving!) tissue impossible with the current method. Moreover, the current SWH technique relies on expensive modulation/imaging hardware, such as acousto optical modulators and specialized lock-in cameras.

What is the solution? This proposal outlines a solution for the aforementioned problems of the current SWH method. The solution draws inspiration from established optical metrology principles and allows for *single-shot (!)* SWH measurements with the same or similar quality as shown in [1]. This means that all required information can be captured *with one single camera image* in a very short exposure time (<1ms in our preliminary experiments). Moreover, the proposed approach allows to swap expensive and specialized imaging hardware with standard off-the-shelf camera technology that can be found in every smartphone nowadays.

Who cares (impact)? If successful, the proposed technique of "Single-Shot-SWH" could have immense impact on future academic research as well as today's billion-dollar industries. This impact goes far beyond potential applications in medical imaging (e.g., to noninvasively monitor the beating heart through the chest). Potential examples from other industries include self-driving cars that use the technique to analyze hidden scenes around corners or through fog, hand-guided industrial inspection devices that detect defects around corners in confined spaces, novel cameras for first responders that image through smoke or turbid water, or next generation VR/AR headsets that show the user obstacles or hazards which are hidden from his direct view.

Why should this proposal be granted? The proposed technique significantly advances the state-of-the-art and our fundamental understanding of limits. Moreover, the work represents a critical first step to put the PI's long-term research vision into practice and would eventually enable him to apply for follow up funding. Due to the risks involved in the initial "Single-Shot-SWH" demonstration (which would provide the basis for larger multi-year grants) the proposed project may be difficult to be funded from other sources.