UniversitätsSpital Zürich

Klinik für Neonatologie

Prof. Dr. Martin Wolf
Leiter des Forschungslabors Biomedizinische Optik

Klinik für Neonatologie
Frauenklinikstrasse 10
CH-8091 Zürich

Telefon 044/255 53 46
Email: martin.wolf@usz.ch

To whom it may concern

Report for the doctoral thesis "Microscopy behind Turbid Media" submitted by Archana Malavalli Sudarshan

The thesis of Archana Malavalli Sudarshan is about different approaches to focus light and image through a scattering layer. I would like to point out that this is an important topic in particular in biomedical research, because tissue intrinsically scatters light strongly. This limits many imaging approaches based on light such as e.g. optical coherence tomography, or microscopy to address only superficial tissue layers, even though it would be highly relevant for biomedical research to image deeper layers of tissue. The thesis works on different approaches to refocus light through a scattering medium in order to be able to image deeper tissue at high spatial resolution. This is certainly highly relevant and seminal work.

In the introduction Ms. Malavalli describes the basics of microscopy, light interaction with tissue and in particular the light scattering and closes with a section on imaging despite scattering.

In the second chapter the focusing of light in turbid media is addressed. This includes the experimental setups, the different options to refocus light, the algorithms used, the sample preparations and finally a thorough overview of the theory behind all this. Finally, the intriguing concept of the "scattering lens" is introduced, i.e. the idea that a layer of scattering can be used as a lens, if the wavefront of the light is shaped appropriately. A set of representative experimental examples is introduced. The outlook is also impressive describing approaches of focusing and options to address dynamic scattering.

Chapters 3 and 4 are somewhat connected, i.e. chapter 3 lays the foundation for chapter 4. In chapter 3 Ms. Malavalli describes phase mask generation to enable a structured illumination of layers behind a turbid medium. This chapter introduces first the theory and examples of setups. It presents experimental setups how to validate this approach. The results show that indeed a structured illumination behind a turbid layer is possible.

In chapter 4 such patterns are employed for structured illumination microscopy, to obtain super resolution, i.e. spatial resolution below the diffraction limit. The chapter starts again with an introduction into the theory, in this canse on how it is possible to obtain super resolution. The theory also describes how to obtain such super resolution behind a turbid medium. The developed algorithms are tested in experiments based on fluorescent beads. As expected from the theory, Ms. Malavalli is able to increase the spatial resolution by a factor 2. This is an excellent achievement. This will enhance microscopy in biomedical research tremendously.

Chapter 5 contains a well written conclusion and outlook.

In her thesis, Ms. Malavalli's achieves relevant advances in imaging in turbid media. The approach is methodologically sound, first describing the relevant theoretical background and then confirming the new approaches in experiments. The thesis certainly relevantly advances microscopy for biomedical tissues. Obtaining a spatial resolution, which is a factor 2 beyond the diffraction limit is an outstanding result for scattering media.

In general, the thesis itself is well written, concise and comprehensible. The thesis will result in 3 scientific publications. One was already published in Optics Express, one of the top journals in the field of optics. The thesis contains several relevant advances and innovations over the state of the art. Excellent results were achieved. Therefore, I recommend accepting the thesis of Ms. Malavalli without any reservation.

M. Wolf

Prof. Dr. sc. techn. ETH Martin Wolf
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