Promotion Modular Optical System

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Abstract / Abstract

In the present project, a modular, cost-effective, reduced-complexity, yet high-resolution microscopy system is developed. Image capture and processing devices, such as smartphones in conjunction with 3D rapid prototyping, significantly reduce production costs.
The modular design allows fast and easy adaptation of the system to the specific requirements of the end user. In combination with intelligent algorithms the use of the microscopy system for single molecule detection (dSTORM) and scanning microscopy (ISM) is also made possible.

The project presented here aims to provide high-resolution, inexpensive microscopes for the general public, educational concepts and scientific special tasks in the form of a democratization of device development. The focus is on field research, for instant microscopic diagnostics, e.g. Malaria, in the S3 laboratory as a "disposable microscope" or also for use in the educational context.

Motivation

There are about 2.3 billion mobile phones in daily use, of which the majority have high-resolution integrated cameras. By modern image analysis techniques enable the observation

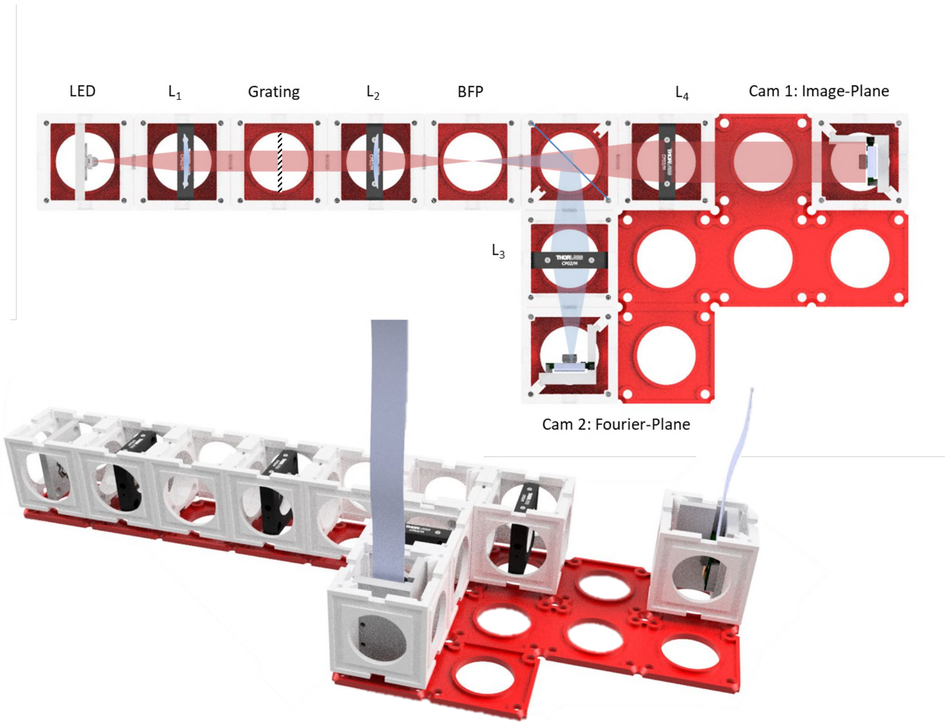

Figure 1 - Exemplary configuration of the Abbe experiment to demonstrate the effect on the optical resolution in the pupillary intervention

of the quality of drinking water in remote or economically weak regions, e.g. in developing countries.
The field of "telemedicine" is one of the first in which the smartphone has long been established as a measuring instrument. In this case, the data acquisition in the field takes place directly at the user and from there, e.g. for analysis in clinics.

For some time, the trend has been towards the modularization and reusability of technical devices. Google's project Ara describes e.g. a modular smartphone concept in which the battery, CPU, camera and other components are interchangeable and thus self-configurable.
project goal

The aim of the proposed project is to transfer this concept of modularization to optical superstructures, especially microscopes. For this purpose, a system in the form of an optical kit is to be developed, which can be dynamically adapted to the task of the users.
In this way, the creativity of the users should be more involved in the development of modules. The function thus no longer results at the moment of the product, but results from the sum of the variable parts in combination with the creativity of the user.

Working Principle

The modular System relies on the well-known principle of Fourier-Optics. This is realized by the letting focal lengths of adjacent lenses follow one another. This makes it very robust to align any given optical setup. It reduces possible aberrations induced by misaligned lenses on the optical axis. Magnets and their corresponding counterparts allow an easy to use alignment system where misalignment is hardly possible. It promotes the easy of playing with different optical modalities and let users get creative.

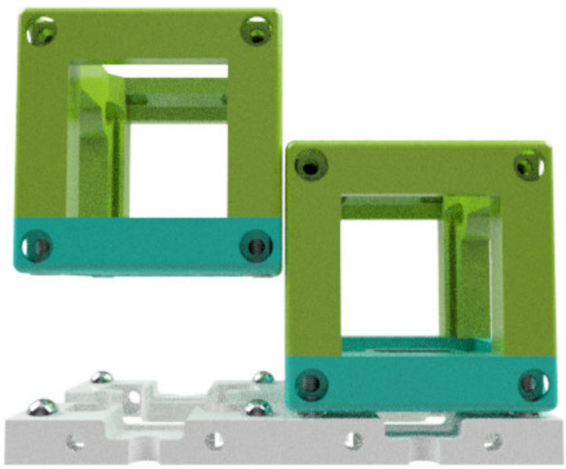

Figure 2 - Two Building Blocks and the magnetic base-plate.

Exploitation

In order to clarify scientific and social relevance, some practical examples – some of which are already in the practical test phase - are shown in figure 1 and 3.

Biolabor

The cost-effective modular basis of the project can have a key impact on biological research. For example, the creation of long-term studies of living cells is a typical challenge in this field. For this purpose, e.g. a fluidchip is currently undergoing testing. This is used in an incubator, which considerably complicates the use of standard laboratory microscopes. On the other hand, the presented portable and modular system can be used directly in the incubator. In addition, the development of a separate incubator module within the framework of the project would also be conceivable in which the sample can be prepared separately and then simply inserted into the microscope.
The modularity in conjunction with the planned software allows the use of more complex microscopy techniques such as localization microscopy (e.g. dSTORM / PALM) or structured illumination microscopy (SIM) for super-resolution in vivo measurements under optimized ambient conditions (temperature, CO2), but this is still in the early project analysis phase.

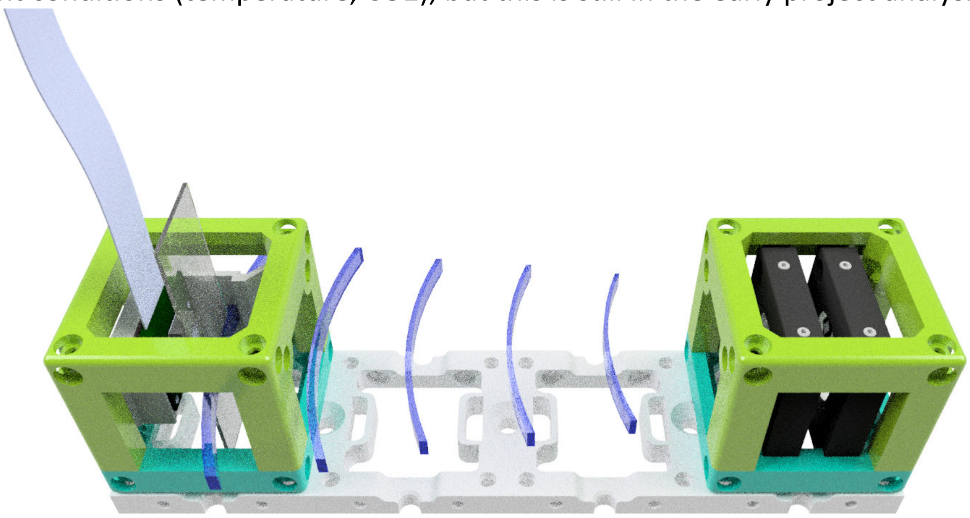

Figure 3 - In-Line Holographical Microscope setup. Right: LED+ Pinhole which produees a spherical wave. The spherical wave hits the transmissive sample which diffracts the wave. The resulting interfernce patter is recorded by the lensless camera from the Raspberry Pi (left). A custom-made reconstruction algorithm reconstructs the image.

After a probable contamination by the sample, the cost-effective assembly can then simply be autoclaved and disposed of according to appropriate safety regulations. Cross-contamination can also be avoided. This aspect can be used in the application of the microscope kit in laboratories from safety class S2. From there the return of devices is in principle still possible, but however with a high expenditure connected and thus often not practicable.

An extension of the label-free investigation by means of digital phase-contrast methods, by means of suitable components such as adapted LEDs and filter sets for fluorescence microscopy, is conceivable.

Education: School and University

Only recently, a report from the OECD shows that interest in the so-called STE(A)M subjects not only in Germany has reached an unprecedented level. Open source systems with an easy-to-understand user interface motivate pupils and students to develop their own modules and

apps within design contests, which in turn increase the range of functions and foster the desire for learning.
This can be accomplished by a series of well documented workshops where one e.g. starts with the basics of optics. Following workshops will then built on top of each other to rise the student's interest in the area of science/engineering and optics especially. Combining the optical building blocks with tailored electronics, makes it possible to introduce students into the world of programming. Creating customized experiments gives students the possibility to develop e.g. the microscopic world of biological specimen.

Relying on off-the-shelf electronic/programming devices, such as Raspberry Pi or Arduino, lowers the entry-level for students to develop own coding examples. A wide variety of different code building blocks is already available which accelerates development significantly.

Computational and imaging resources of cellphones can be used as well.
In this way, the proposed modular and cost-effective optical kit allows students to learn the complex optical contexts. Further, e.g. Measurements and results of samples in the course of biology teaching are first generated and then shared with the group in the digital classroom.