Nature's Ingenuity Shows the Way

FusionOptics™ - The New Dimension of Stereomicroscopy

Anja Schué, Leica Microsystems GmbH

Up to 80 percent of our experience of our visual environment takes place via our visual perception. Without spatial vision, we would hardly be able to stay oriented. In recent decades, the neurosciences have gained many insights into the complex processes by which our brain's visual cortex and cerebral cortex do the fascinating job of processing the signals originating from the eyes into an image. A study carried out jointly by Leica Microsystems and the Institute of Neuroinformatics at the University of Zurich and Swiss Federal Institute of Technology showed how flexible and powerfull our brain joins visual signals to create an optimal spatial image. The results provided the basis for an innovation in stereomicroscopy which, in terms of resolution and focus depth, has broken through limits that were previously impossible to overcome.

Stereomicroscopy enables us to view microstructures in 3D with the help of two separate beam paths—which, in principle, work like our two eyes. Ever since their discovery by Horatio S. Greenough, stereomicroscopes have worked according to the optical principles based primarily on Ernst Abbe's work. For over a century, optics designers have worked to push magnification, resolution and image quality to the limit permitted by optics. These limits are determined by the correlation between resolution, convergence angle and working distance. The higher the microscope resolution, the higher the convergence angle between the left and right beam paths and the lower the available working distance. However, increasing the distance between the optical axes would cause the three-dimensional image seen by the observer to become distorted; a cube in the object would then appear as a tall tower. A greater zoom range alone is of little use, since with increasing magnification, there is not an attendant increase in optical resolution. The result is what is known as empty magnification.

Limits are made to be broken

Scientific studies about visual perception and vision problems have shown that the brain can selectively process information from individual eyes and that it is very much capable of compensating for differences in the visual acuity of the two eyes. This gave the development engineers at Leica Microsystems a simple but ingenious idea. Why not make use of this ability of the brain and use each beam path of the microscope for different information? One image channel provides high resolution, the other focus depth. The two very different images are merged to a single, optimal spatial image by the brain. This completely new optical approach—applied for patent under the name FusionOptics™—brings with it two distinct advantages. Compared to existing stereomicroscopes, the resolution can be increased drastically and the focus depth can be improved significantly. Furthermore, the resolution can be increased without increasing the convergence angle between the two beam paths.

Scientific study confirms new approach

However, the feasability of this design first had to be reviewed in light of neurophysiology—whether the brain can process signals that differ greatly between the two eyes into correct three-dimensional images. Earlier studies were primarily concerned with two-dimensional images. Leica Microsystems presented the idea to Dr. Daniel Kiper of the Institute of Neuroinformatics at the University of Zurich and Swiss Federal Institute of Technology, who specializes in researching signal processing in primate brains, which agreed to carry out corresponding studies. Kiper, along with Graduate Assistant Cornelia Schulthess and Dr. Harald Schnitzler of Leica Microsystems, designed a study. 36 test subjects with normal visual acuity underwent psychophysical tests that investigated the binocular combination of visual signals. Of particular interest was whether an interocular signal suppression takes place when both eyes are exposed to different stimuli. The result of this would be that the image of the suppressed eye would be perceived only partially or not at all.

During the experiments, the test subjects observed patches arranged around a central fixation point. The fields either had grating or were uniform (Fig. 1). To create differences in the spatial perception of both eyes, binocular disparity is required—both eyes must be exposed to different stimuli. This is done using special stereo glasses with which separate test images can be projected to each eye. In a series of trials, the test subjects saw changing arrangements of the grid patches in various depth planes. After each image that was visible for 1000 msec, the subjects reported where they saw the grid patches, and whether they appeared in front of or behind the central fixation point..

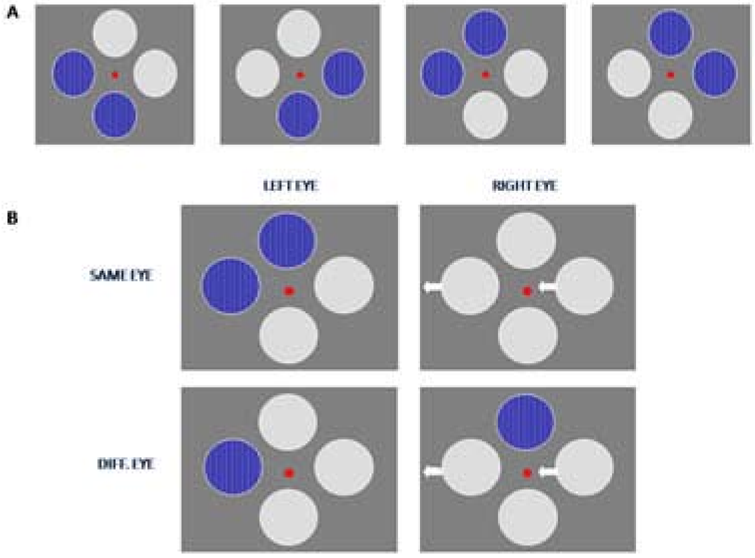

Fig. 1: Schematic depiction of the visual stimuli. A: The four possible perceptions of the test images. The test subjects specified where the grids appeared and whether they appeared in front of or behind the fixation point. B: An example from the test series for different binocular stimulation (corresponds to percept image 3 from A). The grids were presented to either the same eye or different eyes. A few patches were also shown shifted in one eye (white arrows).

The evaluation of the correct/incorrect answers for the position of the grid patches and the spatial resolution in various spatial planes showed no significant differences. No evidence of signal suppression was observed in any of the tests. This means that the human brain is capable of using the best information from both eyes in order to compose an optimal spatial image. This is true regardless of whether the images are acquired using both eyes or each eye provides entirely different information. The results prove once again how adaptable and powerful our brains are in processing visual impressions.

FusionOptics™ provides one-of-a-kind 3D images

On the theoretical basis provided by the study, Leica Microsystems was able to implement the FusionOptics™ concept in a completely new stereomicroscope: The Leica M205 C is the world's first stereomicroscope with a zoom range of 20.5:1 and a resolution of up to 525 lp/mm (Fig. 2). This corresponds to a resolved structure size of 952 nm. When appropriately configured, this can be increased to up to 1050 lp/mm (structure size of 476 nm). Up until now, optical attachments could only achieve a maximum zoom range of 16:1 or a magnification increase without an increase in resolution (empty magnification)..

Fig. 2: The new Leica M205 C high-performance stereomicroscope, based on FusionOptics™

The significant performance increase attained by FusionOptics™ is highly valuable for everyday work at the microscope. The large working distance of the new objective generation allows convenient freedom of movement for examining specimens on the microscope table. Whether in natural sciences or medicine, semiconductor technology, plastics development, materials testing, criminology, or earth sciences—the Leica M205 C opens up frontiers that had previously been unattainable in conventional stereomicroscopy.

Integrated LED Illumination for Stereomicroscopes

Identifying ultra-fine structures in incident light quickly and accurately—these tasks require more than a high-performance stereomicroscope and trained eyes. Optimum illumination is the key to even more details and the best possible results. With the new Leica LED5000 RL and Leica LED5000 MCI™ LED illumination modules, material samples appear in a new light..

Fig. 3: Integrated illumination Leica LED 5000 MCI.

The new LED modules are integral components of the Leica M-series. They can also be controlled by computer using the Leica Application Suite (LAS) software. If a Leica camera is used, all illumination settings can be saved along with the acquired image and reproduced at the touch of a button for recurring experiments.

Save time and costs

Gone are the days in which the external light source had to be readjusted by hand when scanning specimens. Latest-generation LEDs provide constant, daylight-like conditions. With a life of over 25,000 hours, lamp replacement is unnecessary. The specimen is not heated, and with an energy saving of 90% compared to a 150-watt halogen lamp, the LEDs help to protect the environment. An additional benefit is that the workstation remains neat and tidy—without cables and power supplies for the external light sources.

The ring illuminator sheds the best light on the specimen

The Leica LED5000 RL ring illuminator illuminates a specimen with up to 48 LEDs and provides a very bright, uniform light. Various illumination perspectives and scenarios can be realised by switching quarter-circular or semicircular segments differently. In addition, using LAS, you can define how quickly to toggle between scenarios.

The oblique light for the correct angle

The Leica LED5000 MCI™ developed by Leica Microsystems for "Multi Contrast Illumination" specialises in flexible oblique illumination. Three illuminator arcs contain three power LEDs each, which can be activated differently. The specimens can be illuminated in an angle between 15° and 40° to make more details visible by means of changes in contrast. Furthermore, the two outer arcs can be moved as desired on the guide rail and form an angle of up to 90°, allowing you to discover even the smallest details. .

Fig. 4: Zebrafish embryos – Images taken with the Leica M205 C.

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Seydelstr. 28 · 10117 Berlin
info@chemie.de · Tel: +49 (0)30 20 45 68 - 0