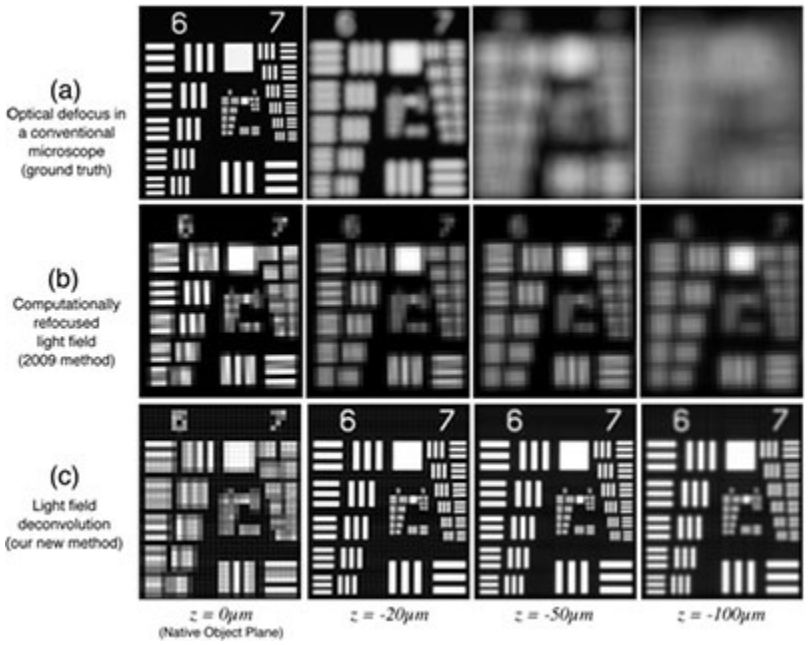
**Docket #:** S13-113

# Super Resolution for Light Field Microscopy

Light field microscopy (LFM) is a new technique for high-speed volumetric imaging of weakly scattering or fluorescent specimens. It employs an array of microlenses to trade off spatial resolution against angular resolution, thereby yielding the information needed to reconstruct a volume from a single photographic exposure. However, this ability to perform scan-less 3-D imaging comes at a cost: the resulting volume reconstruction has considerably lower lateral resolution than a conventional microscope image.

This invention addresses this drawback of conventional light field microscopy. This technique, which draws its inspiration from“super-resolution” methods in computer vision, enables reconstructions of up to 8x higher resolution than previously possible with conventional LFM when reconstructing a planar object, and up to 2-4x higher resolution when reconstructing a sample with complex 3-D structure. This resolution improvement is due in part to a new, more accurate optical model based on wave optics that captures the effects of diffraction in light field microscope images. The GPU accelerated reconstruction algorithm in this implementation also performs 3-D deconvolution, which enhances lateral resolution while also computationally removing out-of-focus light in the volume for better optical sectioning.




*Comparison of conventional (a) and LFM (b and c) imaging of USAF 1951 resolution test target translated to depths up to 100 um from the native object plane (z = 0 um). The wave optics reconstruction algorithm (c) improves lateral resolution up to 8-fold compared to standard LFM imaging (b), except at the z = 0 plane (left image).*

**Stage of Research**

The inventors have validated this technology by measuring lateral resolution on a standard USAF 1951 resolution target. They have demonstrating the ability to resolve higher spatial frequencies in the images reconstructed with the new algorithm with the target placed at a range of different z-depths spanning a range of +/- 200 microns. The technique has been shown to work well with a variety of different microscope objectives. They have also reconstructed images of pollen grain to demonstrate the improved image resolution and optical sectioning capability of a biological specimen.

# Applications

- **Microscopy** - Light Field Microscopy for fast 3-D recording of dynamic phenomenon with end user applications in:
    - biological research
    - clinical pathology
    - quality assurance inspections

## Advantages

- **High resolution 3-D imaging** - 8-fold improved lateral resolution and better optical sectioning compared to standard LFM
- **Improved Optical Model** - the newly developed wave optics model is considerably more accurate when modeling the imaging process at microscopic scales where diffraction plays a key role.

## Publications

- "Wave Optics Theory and 3-D Deconvolution for the Light Field Microscope, Michael Broxton, Logan Grosenick, Samuel Yang, Noy Cohen, Aaron Andalman, Karl Deisseroth, Marc Levoy, *Optics Express*, Vol. 21, Issue 21, pp. 25418-25439 (2013).

## Patents

- Published Application: 2014-263963
- Issued: 9,658,443 (USA)

## Innovators

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