AO Commercialization: From building block AO components to turnkey AO enhanced microscope instrumentation

John Taranto[1], Benjamin Potsaid[1], Alex E. Cable[1], Scott Barry[1]

[1]Advanced Imaging Group, Thorlabs, Inc., 435 Route 206 North, Newton, New Jersey (USA)

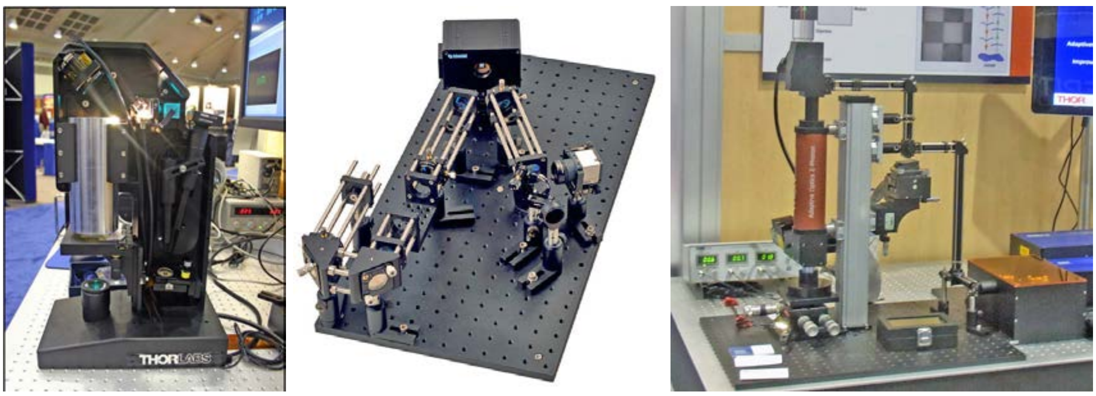
jtaranto@thorlabs.com, bpotsaid@thorlabs.com, acable@thorlabs.com, sbarry@thorlabs.com

Introduction

The recent development and commercialization of low cost MEMS based deformable mirrors, CCD based wavefront sensors, and powerful desktop computers has enabled a new generation of commercially viable and high performance AO enhanced instrumentation. Thorlabs, Inc. was one of the first to introduce full turnkey microscope systems for biomedical and industrial imaging application, along with AO kits for research and education. In this paper, we present of historical review of AO system development at Thorlabs and discuss current AO related R&D activities.

AO Enhanced Imaging Systems and AO Subsystem Components

To address the longstanding limitation of field of view in microscopy, Thorlabs entry into the AO market was with the Adaptive Scanning Optical Microscope (ASOM) [1], shown in Figure 1(A). Using a deformable mirror from Boston Micromachines (BMC) in coordination with a custom designed telecentric scan lens and steering mirror, the adaptive optics enable the ASOM to achieve an order of magnitude increase in field of view while maintaining high resolution. At the same time, Thorlabs realized the cost-of-entry into AO was prohibitive for those considering the integration of AO into their products, as well as to the university labs that would like to use AO in undergraduate or graduate teaching labs. This spurred the development of the AO Kit; a fully function kit with pre-aligned opto-mechanics that offers users nearly out-of-the-box functionality. Of the available microscope imaging modalities, 2-photon microscopy excels at deep tissue and live cell imaging because of reduced photobleaching outside of the focal plane, reduced photodamage, and deep tissue penetration using longer, lower scattering IR wavelengths [2, 3, 4]. However, imaging through tissue introduces optical aberrations that reduce signal strength and compromise axial and lateral resolution. In 2011, Thorlabs introduced the first commercially available adaptive optics 2-photon microscope, which uses a deformable mirror to correct for sample induced optical aberrations to achieve increased signal strength and resolution for demanding deep tissue imaging applications.

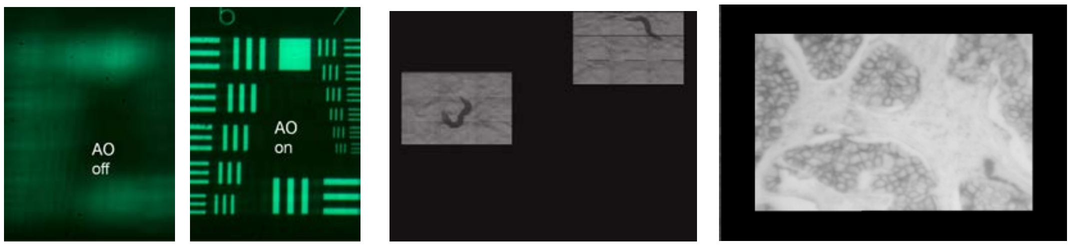


(a) (b) (c)

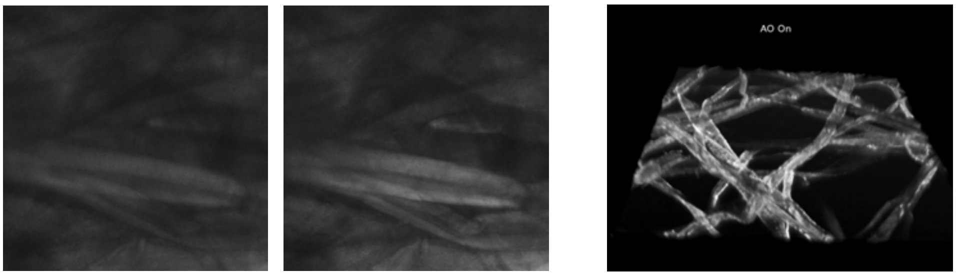
Fig. 1. Thorlabs AO enhanced imaging systems and research kits. (A) Adaptive Scanning Optical Microscope (ASOM). (B) AO kit. (C) Adaptive Optics 2-Photon Microscope (AO-2P).

Results

Figure 2 shows imaging results from the Thorlabs systems. Fig. 2 (a) and (b) show an image of a USAF 1951 calibration target obtained by the ASOM with the AO off and on. Figure 2(c) shows a multiresolution c. elegans worm tracking demonstration [1]. Fig. 2(d) shows high throughput imaging of cancer biopsies using the ASOM. Figure 2 (e) and (f) show imaging of wood fiber with AO off and on, respectively, by the AO-2P. Figure 2 (g) shows a 3D rendering of wood fiber obtained by sectional imaging using the AO-2P.



(a) (b) (c) (d)



(e) (f) (g)

Fig. 2. Imaging results from Thorlabs AO instrumentation. (a) through (d) are images from ASOM. (e) through (g) are from the AO-2P microscope.

Conclusions

Lower cost adaptive optics based on MEMS technology has enabled a new generation of AO enhanced imaging systems with applications in biomedicine and industry. Thorlabs' strategic partnership with BMC has enabled a lower "cost of entry" into AO for many university labs and OEM applications. We present our AO systems in this paper and offer a snapshot into the AO related R&D activities in the Advanced System Technology group at Thorlabs.

References

1. Benjamin Potsaid, Yves Bellouard, and John Wen, "Adaptive Scanning Optical Microscope (ASOM): A multidisciplinary optical microscope design for large field of view and high resolution imaging," Opt. Express **13**, 6504-6518 (2005)

2. Delphine Débarre, Edward J. Botcherby, Tomoko Watanabe, Shankar Srinivas, Martin J. Booth, and Tony Wilson, "Image-based adaptive optics for two-photon microscopy," Opt. Lett. **34**, 2495-2497 (2009)

3. M. J. Booth, A. Kubasik-Thayil, A. Jesacher, D. Debarre, K. Grieve, and T. Wilson, "Adaptive Optics in Biomedical Microscopy," in *Novel Techniques in Microscopy*, OSA Technical Digest (CD) (Optical Society of America, 2009), paper NWA1.

4. P. Marsh, D. Burns, and J. Girkin, "Practical implementation of adaptive optics in multiphoton microscopy," Opt. Express **11**, 1123-1130 (2003)