CELLULOSE TO SOLAR CELLS: MULTIFOCAL, MULTIMODAL, MULTIPHOTON, PHOTON-COUNTING IMAGING FOR RENEWABLE ENERGY RESEARCH

Eric Chandler, Erich Hoover, Kraig Sheetz, R. Carriles, Wafa Amir, Jeff Squier
Center for Microintegrated Optics for Advanced Biological Imaging, Colorado School of Mines
Golden, CO 80401

We have developed a novel nonlinear optical microscope that is capable of studying a diverse range of specimens – be it photovoltaic materials, algae systems, or cellulosic material for studying biomass chemical conversion processes. The light source is a home-built Yb:KGW laser that produces 250 fs pulses, centered at 1040 nm, at a repetition rate of 56 MHz. The pulses from this laser are directed through an optical multiplexer which interleaves pulses of opposite polarization, and results in a new pulse train which has a repetition rate of 112 MHz. The multiplexed output is directed through an Olympus IX71 microscope. The intensities generated by focusing femtosecond pulses, using even modest numerical aperture objectives (e.g., NA 0.65), are sufficient to excite a number of optical nonlinearities that are then used to generate image contrast. With the optical multiplexer, the imaging system simultaneously images at orthogonal polarizations, or at different focal planes while using only single element detectors for the first time. These detectors, combined with IR excitation wavelengths, enable imaging through thick, scattering media – increasing the application base of this imaging system. In fact, we collect four images simultaneously – two in the forward direction, and two in the epi direction. To produce the final images the signals from the photodetectors are demultiplexed in hardware, accomplished electronically through inexpensive field programmable gate arrays. Either specimen scanning or beam scanning is possible. Lastly, photon counting provides an improvement in signal-to-noise over analog detection schemes.

Figure 1 shows an example of the imaging capability of the system – corn stover is imaged at two different polarizations, at the same focal plane simultaneously. Third harmonic signal (THG) is detected in the forward direction, while second harmonic (SHG) is detected in the epi direction. All four images were acquired simultaneously.

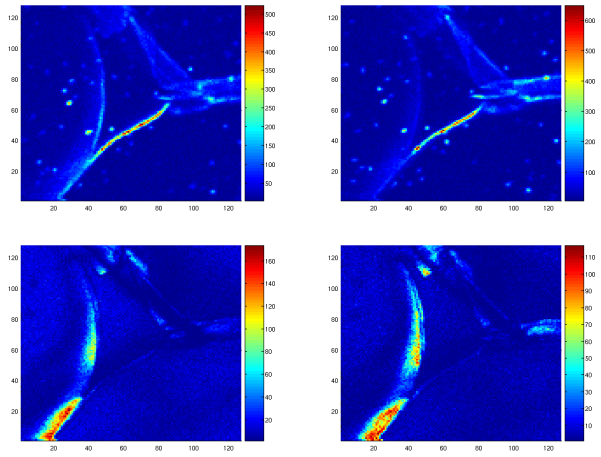

Figure 1: Nonlinear images of a corn stover cell junction. Top row - SHG images at orthogonal polarizations, Bottom row – THG images at orthogonal polarizations. Note the image intensity is quantitative – the color contours represent actual photon counts.