Multiphoton microscopy is being used to study the dynamics of quantum dots - important future constituents in high-efficiency photovoltaics. New technology has been developed to quantitatively assess quantum dots, including a multifocal, multiphoton imaging system. The two-photon excitation fluorescence (TPF) characteristics of the dots are quite different, as compared to traditional fluorophores. The quantum dots used for this study are CdSe/ZnS core/shell dots. The figure on the left shows quantum dot fluorescence emission. The fluorescence increases as a function of time under two-photon excitation. The vertical axis for both plots is fluorescence intensity, and the horizontal axis is time. Each different color trace represents a different excitation pulse shape. The increase in fluorescence emission is quite distinctive compared to traditional fluorophores, often organic, that bleach. This is illustrated quite dramatically in the center figure where the center area of drop cast quantum dots is pretreated with the femtosecond laser, and images significantly brighter when the entire area is scanned.

In addition to fluorescence characteristics of quantum dots, this new imaging technology has enabled us to study how the shape of the excitation laser pulse impacts fluorescence emission in general. For the quantum dots in the left most figure, differences in pulse shape translate into differences in luminescence efficiency and rate of change of the intensity. Traditional fluorophores similarly can measurably benefit from an optimization of the excitation pulse shape. The right most figure shows improvement of two-photon excitation fluorescence signal by shaping the excitation pulse in epidermal cells of a maize plant expressing the Gossypid protein tagged with mRFP. Images were taken with (a) unshaped (INP) and (b) shaped (OBJ) pulses respectively. In the OBJ image, the arrow points to mRFP concentration near the nucleus, while the arrowheads indicate cytoplasmic fibers in the cell. The figure shows that even using more traditional labels (as opposed to quantum dots) images can be made much brighter through the proper choice of shape for the excitation pulse. These results have been submitted for publication to Nature Methods.