SEMICONDUCTORS & PHOTONICS
ULTRAFAST LASER TECHNOLOGIES

University of Arizona researchers develop compact and high-performance ultrafast fiber laser systems for applications that include high resolution 3D imaging, precision metrology, and 3D micro- and nanofabrication.

Ultrafast fiber lasers emit pulses on the order of pico- to femtoseconds (10^{-12} to 10^{-15} s). Ultrashort durations enable light-matter interaction effects such as harmonic generation, multiphoton absorption and material ablation with minimal thermal damage. The periodic nature of the laser's output can be used in accurate optical clocks and highly sensitive spectroscopic setups.

The team develops ultrafast fiber laser systems that are compact, low cost and field deployable. Applications include metrology, semiconductor manufacturing, imaging and sensing.

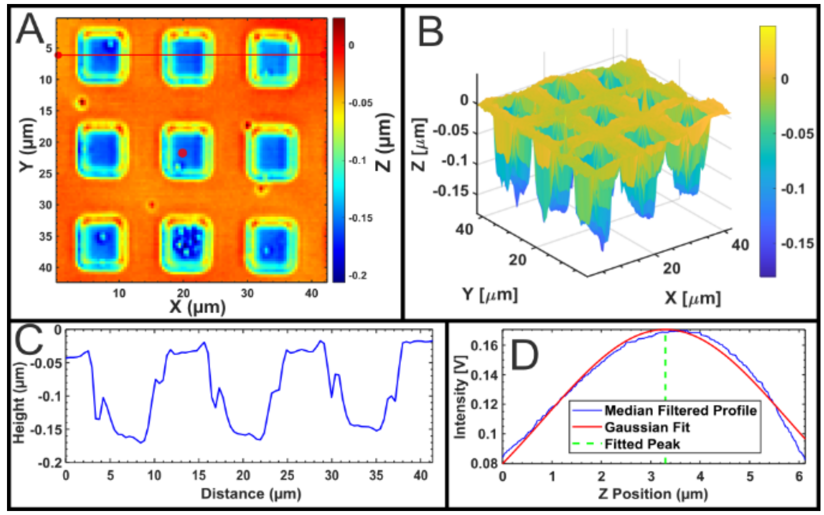

Figure 1: Surface profiling with third harmonic generation. (**A**) AFM calibration sample; (**B**) surface profile rendering showing sub-10 nm sensitivity; (**C**) cross-section of the surface profile; (**D**) fitting model for each pixel.

3D imaging and precision metrology

The team builds custom multiphoton microscopes that can be used to image samples in 3D, from biological tissues to electronic and photonic devices. Laser scanning multiphoton microscopy (MPM) has applications in a growing number of fields for label-free, non-destructive, high resolution 3D imaging. The application of MPM for metrology in semiconductor manufacturing is new and has potential uses that include surface profiling, defect detection to device characterization.

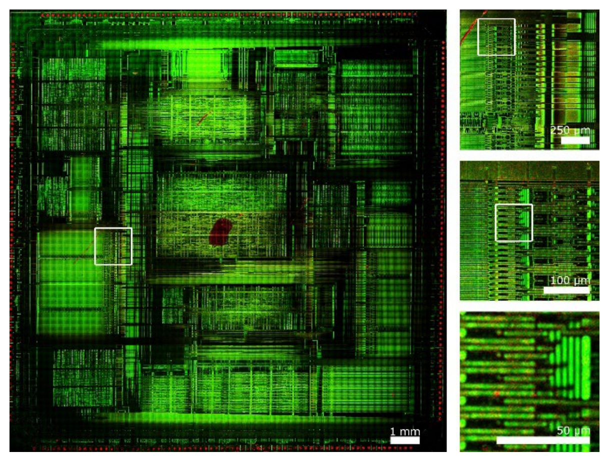

Figure 2: Multiphoton image of a computer chip. Right panel: Mosaic of the whole chip. Scale bar at bottom-right is 50 μm. **Left panel:** Zoom-in sections. Green is third harmonic signal, red is second harmonic.

Femtosecond laser materials processing

Laser materials processing is an indispensable tool in semiconductor manufacturing. Lasers are used to cut, drill and locally remove and/or deposit materials at strategic locations throughout an electronic chip's fabrication process. The use of femtosecond lasers has many advantageous compared to continuous wave or nanosecond lasers. The most important aspect is the capability of non-thermal ablation of any materials (dielectrics, semiconductors and metals) with extremely high precision. The net result is a clean cut (or processed area) that has minimal thermal damage, removing the need for postprocessing. The team has the capability to process materials with sub-micron precision in all three x, y and z dimensions.

Sensitive magnetic field sensors

One new direction is the development of sensitive magnetic sensors based on nitrogen vacancy (NV) centers in diamond. This platform may allow us to establish the map of electrical current flow through a live chip with high resolution. The team has successfully demonstrated optically detected magnetic resonance (ODMR) using NV centers in diamond.

More information: B. Amirsolaimani et al., All-reflective multiphoton microscope. *Optics Express* (2017). doi: 10.1364/OE.25.023399.

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Khanh leads the Ultrafast Fiber Lasers and Nonlinear Optics Group. He works on ultra-fast lasers, nonlinear optics, and optical imaging. He is particularly interested in optical fiber technologies such as fiber lasers, fiber optical sensors, nonlinear effects and devices in waveguiding structures.