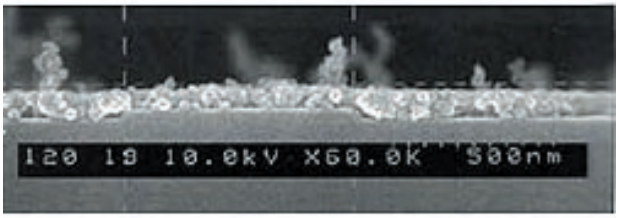
Advanced Optical Components & Technology

Wet-Etched Gratings, Reticles, and Kinoform Optics

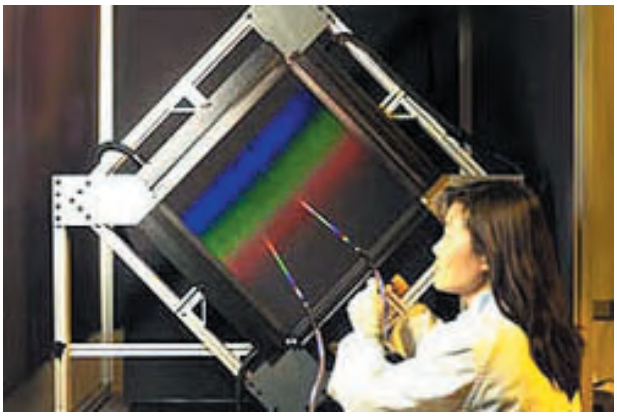
Using both proximity printing and holographic patterning techniques, AOCT designs and fabricates wet-etched, diffractive, binary or kinoform structures on optics having up to one-meter apertures. AOCT has developed a real-time etch-rate monitoring system for etch depth control to ten nanometers, and can execute maskworks of up to one-meter aperture, with submicron pixel placement.

AOCT fabricated the maskworks and the final, four-level wet-etched Fresnel lens in a fused-silica optic for a color-corrected, diffractive telescope application.

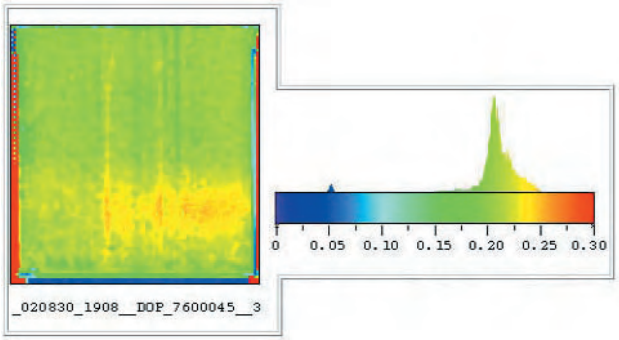
AOCT has designed gratings that transmit ultraviolet (351-nanometer) light with high efficiency while rejecting 532- and 1,053-nm light from the zero-order focus – also with high efficiency.



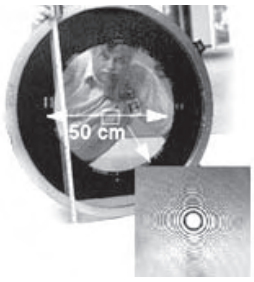
Scanning-electron microscope image of a beam-sampling grating (20-nm modulation) overcoated with a 75-nm-thick, sol-gel Si_{02} antireflective coating applied by spinning.



A holographically-written, focusing sampling grating on a 43-cm-square, fused-silica substrate. Grating grooves are approximately 15 nm deep on one to three micron centers.



Full-aperture, –1 order transmission diffraction efficiency of a 43-cm-square beam-sampling grating. Mean= 0.21% and RMS variation is 5 percent of mean, consistent with ± 1-nm-etch depth control.



A chrome-on-quartz mask for a 50-cm-diameter kinoform Fresnel lens. The smallest linewidths at the perimeter are 20 mm wide.

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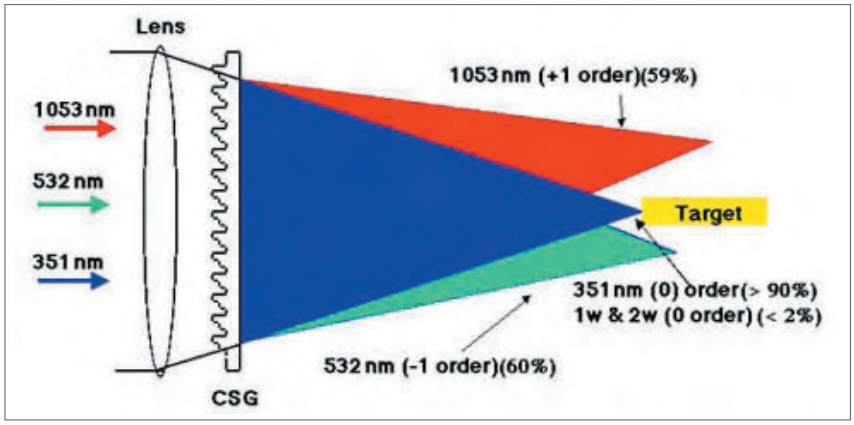
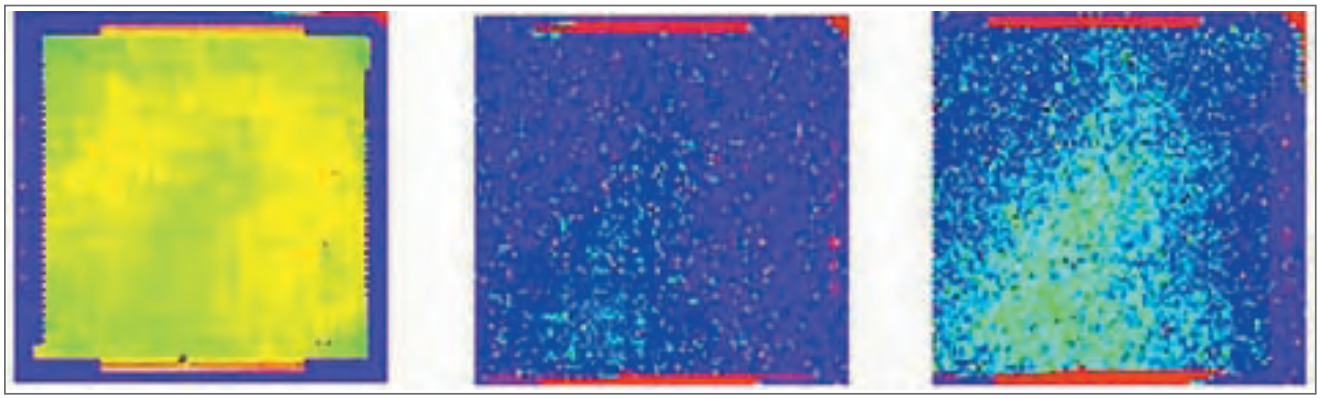
Advanced Optical Components & Technology – Gratings

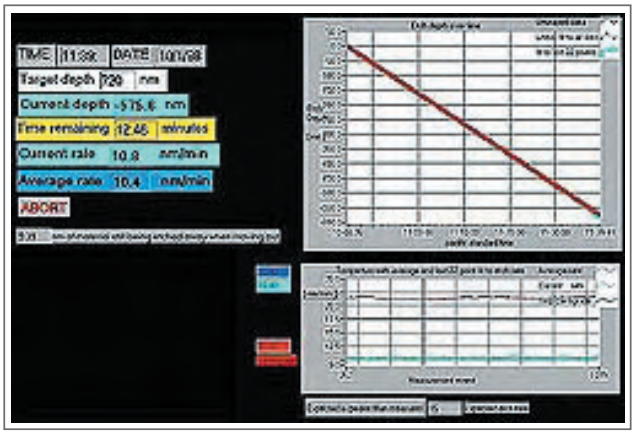
A three-level stairstep (Dammann) grating for high-efficiency color separation of laser-light harmonics is depicted in the figure at right.

The three images below illustrate the measured, zero-order transmission efficiency of color-separation grating (CSG) at 351, 532, and 1,053 nm. The pattern was wet-etched using chrome artwork proximity printing on 40-cm^2 fused-silica panel.





The screenshot at right depicts AOCT's etch-monitoring system's graphical user interface; the program uses differential interferometry and back-side imaging to monitor and control wet-etch rates in real time, to accuracies of ±five nm.



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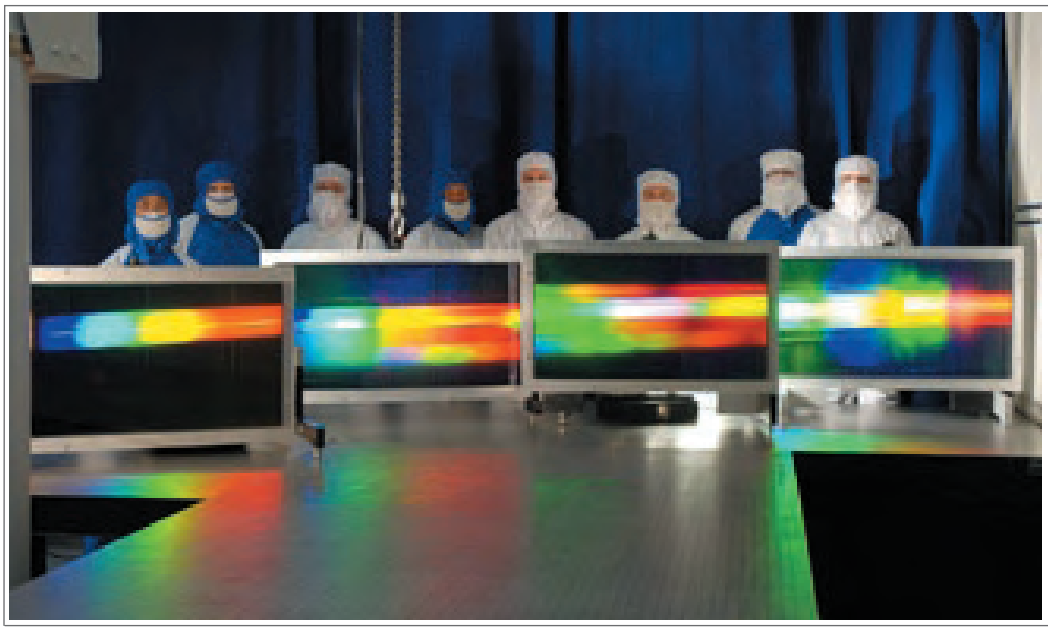
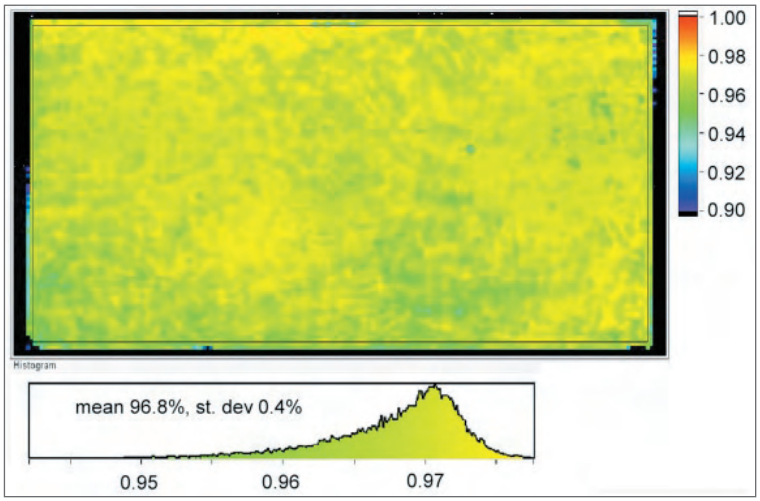
Multilayer Dielectric-Reflection Diffraction Gratings

AOCT designs and manufactures custom multilayer dielectric (MLD) gratings for high-energy Petawatt (10^{15} watt) short pulse laser compression as well as for high average-power applications. These plane gratings are designed to operate in reflection. We have made several square meters of gratings for operation at 1030, 1053, 1064 nm and even broadband Ti:Sapphire systems operating at high rep rate.

In 2008 we began production of 40 meter-scale MLD gratings for the NIF ARC project. These are the largest such gratings ever made. Each of these 4 gratings shown has ~97% average diffraction efficiency at use conditions.



Left to right: Hoang Nguyen, Cindy Larson, Curly Hoaglan, Jim Peterson, Mike Aasen, Tom Carlson, James Nissen, Jerry Britten.



Full aperture diffraction efficiency map of a 910x450 mm MLD grating, 1752 lines/mm, for 1053 nm light into the -1 order at 76.2° incidence, TE polarization. Average diffraction efficiency 96.8%.

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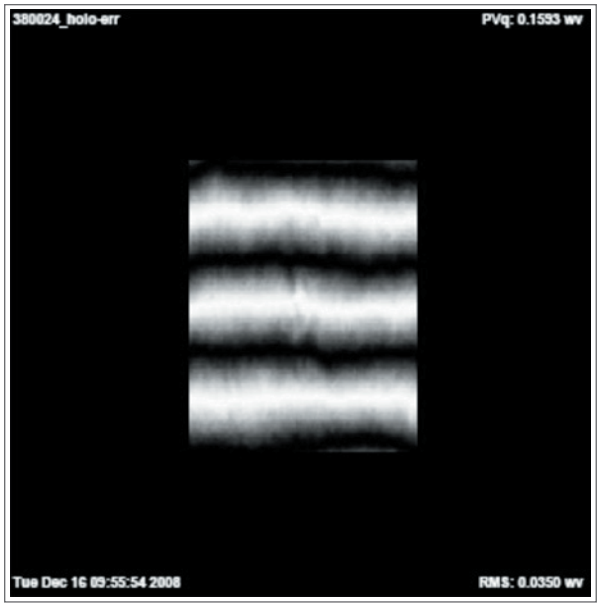
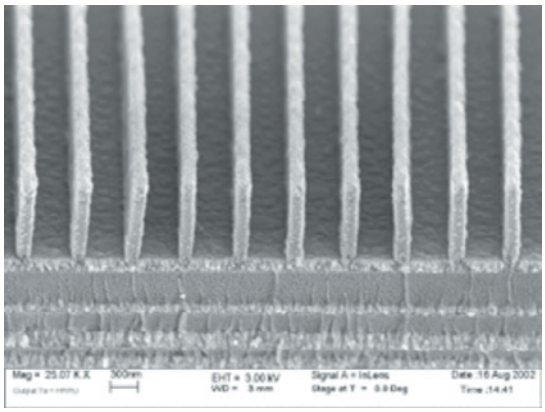
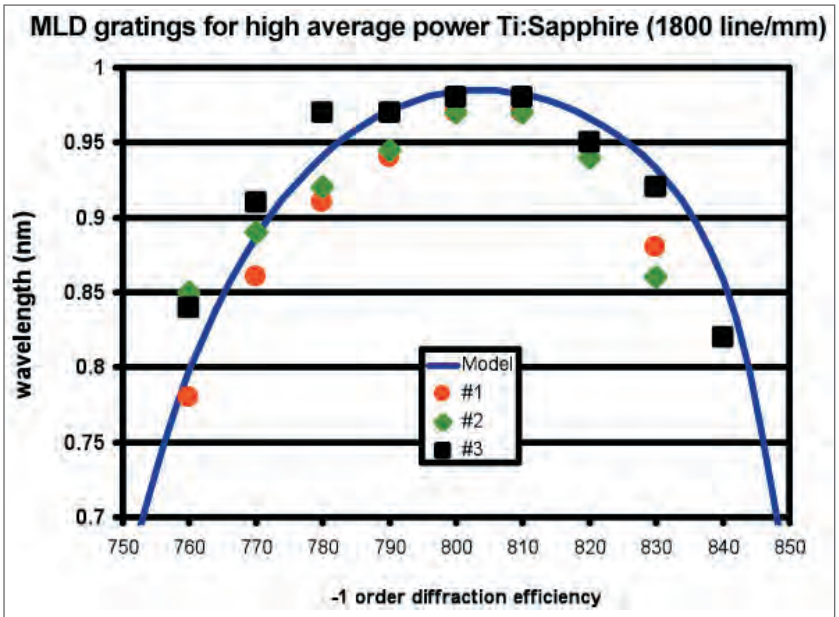
Synthetic fringe map (right) of holographic phase error (wavefront) of 910x450 mm 1752 l/mm grating at the Littrow mount. 0.15 waves peak-to-valley. The flatness of the diffracted wavefront of these optics is currently limited by coating stresses. We are working to get this level down to ~0.2 waves.



Grating Microstructure



Microstructure of a MLD grating. Line spacing is about 550 nm.



Efficiency vs wavelength for 1800 line/mm MLD gratings for high rep-rate Ti:Sapphire lasers.

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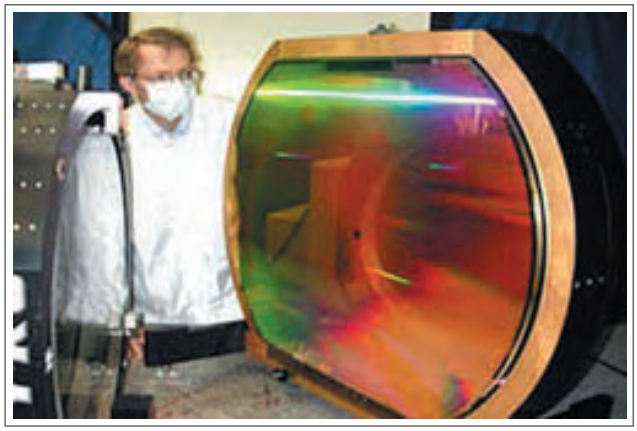
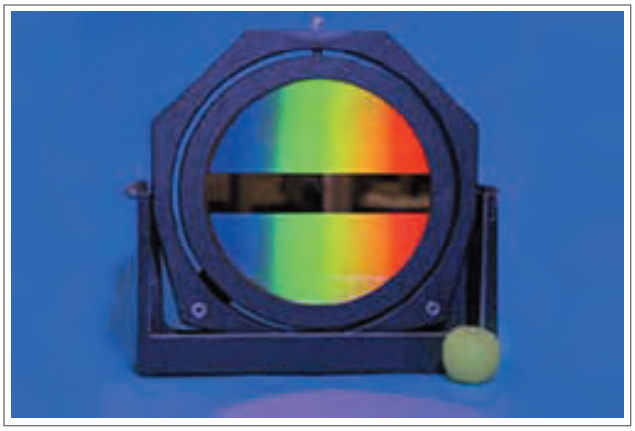
Gratings





Large-Aperture, Gold-Coated Plane Gratings

AOCT designs and manufactures custom, metal-coated plane gratings of up to one meter in diameter, optimized for user wavelength and incidence angles. AOCT's 94-cm-diameter, 1480 l/mm plane grating is used for pulse compression in Rutherford Appleton Laboratory's Vulcan Petawatt Facility.

These gold-overcoated, resist gratings on 500-pound, BK7 substrates are optimized for a diffraction efficiency of greater than 90 percent at 1,053 nm, TM polarization, Littrow angle, and are manufactured entirely at LLNL. The pulse stretcher grating, consisting of two in-phase gratings separated by a high-reflector on the same optical surface, allows for an all-reflective, easy-to-align, reduced-aberration pulse stretcher for ultrashort-pulse laser applications; it was patented by LLNL in 1999.

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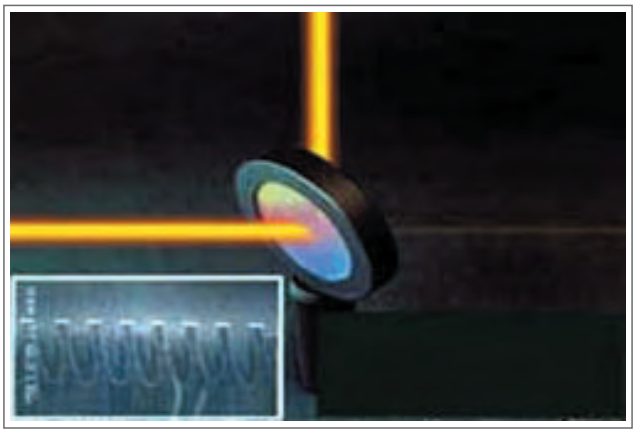
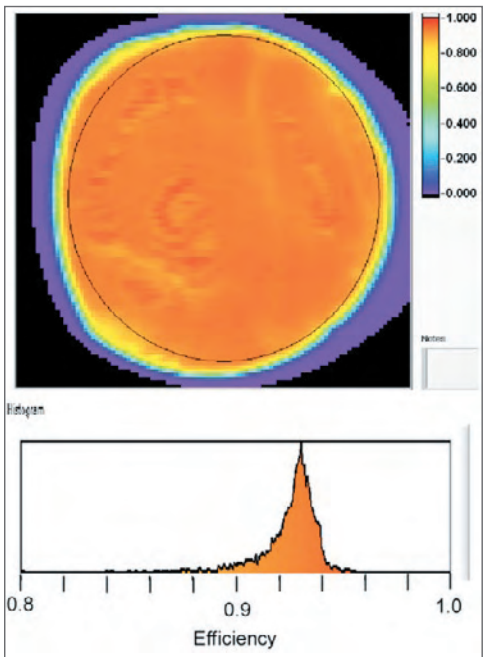
High-Efficiency, Ion-Beam-Etched Transmission Gratings

The grating at right was ion-beam-etched into a fused-silica substrate, and transmits 1,064-nanometer light at 90 degrees with greater than 95 percent efficiency and a 45-degree angle of incidence. The grating's microstructure is shown in the inset. The period is 1,333 l/mm, and the modulation depth is 1.6 microns.



2857 line/mm gratings



–1 order diffraction efficiency in transmission of 532 nm laser light through 100 mm ion-beam etched 2857 line/mm grating.

Gratings in Sapphire

A 1200 line/mm transmission grating etched in Sapphire.

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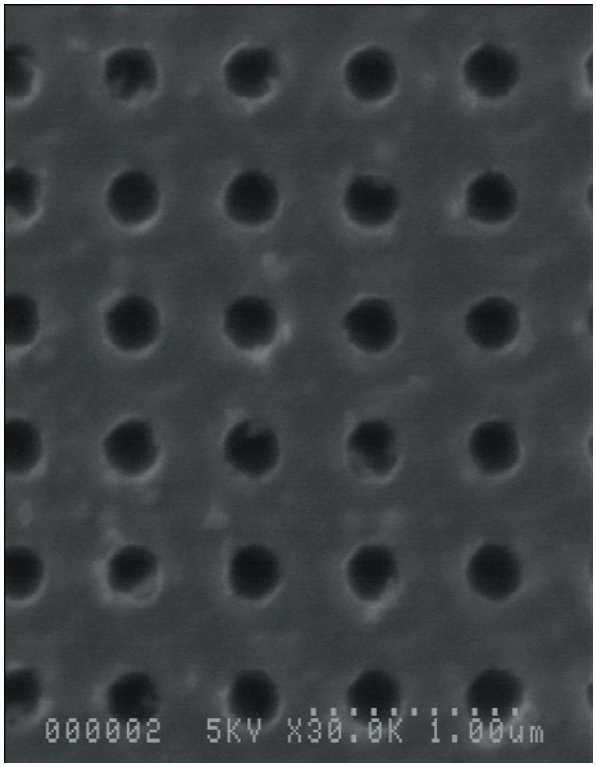
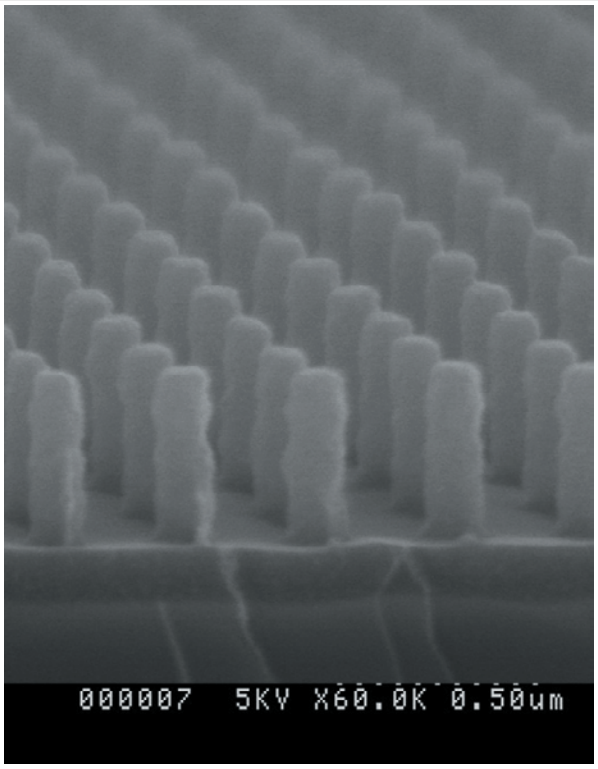
Nano-scale Patterning

AOCT patterns 2-dimensional regular patterns (posts or holes) on a wide variety of substrates at spacings from 300 nm to >1 micron, by laser interference lithography. Uniform fields from millimeter to meter-scale are possible.



2-D hole pattern on Silicon, 575 nm period.



2-D array of photoresist pillars on fused silica, 350 nm period.