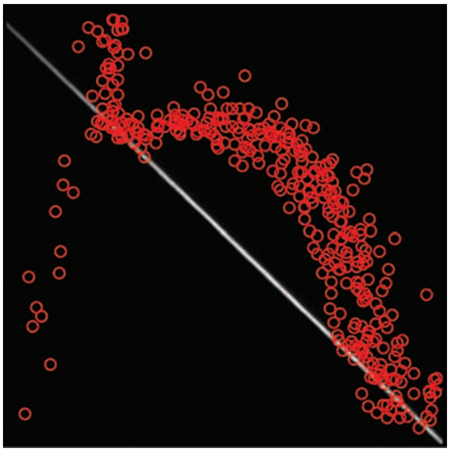
OPTICAL MANIPULATION

The photonic trampoline

Appl. Phys. Lett. **101,** 131115 (2012)



Researchers in Germany have shown that a sheet of intense laser light can act as a trampoline for small droplets of ink. Michael Esseling and co-workers from Westfälische Wilhelms-Universität Münster observed the trajectory of strongly absorbing 50-μm-diameter particles of liquid ink falling vertically through a sheet of green laser light. When the light was sufficiently intense — a peak intensity of more than 100 μW μm^{-2} — the falling droplets were repelled from the sheet when in close proximity. The mechanism for the interaction is thought to be the photophoretic force — a force resulting from a light-induced thermal gradient on an object's surface that pushes it away from regions of high light intensity. Because the direction of the force depends on the intensity distribution of the light field, the researchers were able to alter the droplet trajectories by using a cylindrical lens to change the angular orientation of the light sheet. The interaction was also not limited to a single event; the researchers observed up to three bounces for a single drop. The ability to control liquid droplets in this manner may prove useful in the fields of optofluidics, biomedicine and chemistry. *OG*

SOLAR CELLS

Efficient recombination

Nature Nanotechnol. http://dx.doi.org/10.1038/nnano.2012.166 (2012)

Although photovoltaic devices based on silicon nanostructures are expected to provide excellent power-conversion efficiencies, they have not yet been able to out-perform conventional cells. This shortcoming is due partly to a lack of understanding regarding the mechanisms involved in the charge recombination processes. Jihun Oh and researchers from Colorado in the USA have now demonstrated an 18.2%-efficiency 'black silicon' nanostructured cell that not only absorbs a high percentage of incident light but also suppresses unwanted recombination processes. By varying the diffusion time of a phosphorus dopant, the researchers identified two parallel charge recombination channels that dominated under different conditions. They found that the Auger recombination channel dominated under high doping, whereas the surface recombination channel dominated under low doping. Between these two levels, both channels contributed to photocarrier recombination. The researchers report that, contrary to popular belief, it is the Auger recombination process that limits the efficiency of most nanostructured silicon solar cells. *SA*

METAMATERIALS

Negative in two bands

J. Opt. Soc. Am. B **29,** 2839–2847 (2012)

The past decade has seen several impressive demonstrations of metamaterials that exhibit negative refractive indices. Such studies were originally performed in the microwave region, and there have been relatively few demonstrations in the important visible region of the electromagnetic spectrum. Scientists from the USA and Pakistan have now proposed a metamaterial that simultaneously exhibits a negative refractive index in two different regions of the visible spectrum. Their design — a modified version of the established fishnet structure — involves adding a metal layer to form a four-functional-layer structure. The additional layer extends the plasma frequency deep into the visible range, slightly above the second-order magnetic resonance. This leads to two negative refractive index bands: one in the green, at around 550 THz, and the second one in the red, at around 450 THz. Moreover, the operation is independent of the polarization of the incident light. The researchers report that by incorporating additional metal layers and higher-order magnetic resonances, it may be possible to develop a metamaterial that exhibits an even greater number of multiple negative-index bands. *SA*

TERAHERTZ IMAGING

Birefringence in one take

Opt. Express **20,** 23025–23035 (2012)

By employing terahertz waves and a polarization-sensitive detector, Stefan Katletz and colleagues from Austria and Germany have efficiently determined the birefringence and orientation of the optical axis of a thick sample. Their sample was a glass-fibre-reinforced polymer that was opaque to electromagnetic waves in the visible. By employing circularly polarized light, the researchers were able to measure the phase difference introduced by the slow and fast optical axes of the sample in a single measurement. Using linearly polarized light, in contrast, requires two measurements — one for each axis. This breakthrough allowed the researchers to extract information about the birefringence and optical axis of

EXTREME-ULTRAVIOLET SOURCES

Sub-10-nm success

Appl. Phys. B **108,** 743-747 (2012)

Sho Amano and Tomoaki Inoue from the University of Hyogo in Japan claim to have created the first extreme-ultraviolet source that can generate radiation continuously at a wavelength of 6.7 nm and is potentially scalable to industrially relevant powers. This wavelength is of particular interest for performing next-generation extreme-ultraviolet lithography. Their device is a laser plasma X-ray source that uses radiation from a high-energy-density plasma produced by laser irradiation of a target. The target is a drum-shaped copper surface, cryogenically cooled with liquid nitrogen, onto which xenon gas is blown to form a solid xenon layer. The researchers rotated the position of the drum to ensure that a fresh area of xenon on the target surface is available for each shot from their Q-switched Nd:YAG laser. Maximum emission at 6.7 nm was obtained with irradiation at a wavelength of 1,064 nm. Emission with a narrow spectral bandwidth of 0.6% — which is particularly desirable for lithography applications — was enabled by using La/B_4C mirrors instead of the usual Mo/Si structures, although this came at the cost of reduced power. They achieved an average emitted power of 80 mW (at a repetition rate of 320 Hz and an average pump power of 100 W), which is well below the ~100 W needed for industrial mass-production applications. However, the researchers report that in principle up to 120 W can be obtained if the average pumping laser power is increased to 80 kW. A repetition rate of 100 kHz may be possible by enlarging the drum diameter from 10 cm to 50 cm, thereby providing a greater amount of xenon target. *DP*