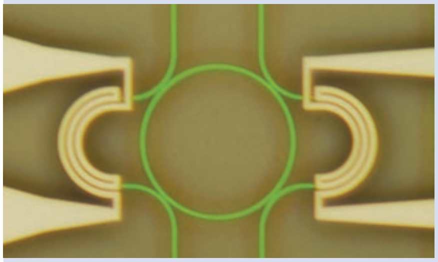
SILICON PHOTONICS

Tiny and tunable



Opt. Lett. **32,** 3361–3363 (2007)

Long Chen and colleagues at Cornell University have come up with a new design of microring resonator that is both compact and bandwidth-tunable. The device could be useful for applications involving optical communication and information processing. In integrated optical signal processing, for example, reconfigurable channel selectors tune the bandwidth of an add–drop filter to accommodate one or more channels within a single resonance and enable easy switching between them.

The bandwidth of a resonator describes the range of wavelengths or frequencies over which its resonances exist. A narrow bandwidth is better suited to certain purposes (such as lasing and sensing), but for other applications a wide bandwidth is preferable. Resonator bandwidth is determined by the intrinsic loss and the coupling to input or output ports.

The Cornell team fabricated a microring resonator on a silicon-on-insulator substrate with a continuously tunable bandwidth of between 0.1 nm and 0.7 nm. The key to the tunability is the use of interferometric couplers that dynamically alter the coupling between the resonator and the input and output ports using thermo–optic effects. By tuning both the input and output coupling coefficients, the bandwidth can be varied while maintaining a high extinction ratio of more than 23 dB. This is all achieved in a device with a footprint of less than 0.001 mm^2. With improved coupling design and fabrication processing, the researchers say that a tuning range from 0.01 nm to a few nanometres will be possible.

LASER PROJECTION

The right image

Opt. Lett. **32,** 3281–3283 (2007)

Phase-only modulation is a promising technique for projecting images using laser light. Researchers in Denmark have now demonstrated that a technique known as generalized phase contrast can achieve this while wasting very little of the laser light.

One of the major challenges in phase-only modulation is to determine the particular phase pattern that yields the desired output intensity. In generalized phase contrast, a phase-modulated light beam is broken down into its Fourier components using a lens. A small non-absorbing phase-contrast filter is then used to shift the phase of the lowest frequency waves relative to the higher-frequency ones, and interference between the various recombined frequency components yields the desired intensity spectrum.

Jesper Glückstad and co-workers at the Technical University of Denmark use generalized phase contrast to construct a greyscale photographic image with an efficiency of 74%. By using an arbitrary phase-shift filter, they avoid the need for high-frequency modulation and conjugate-phase encoding, and can use existing dynamic spatial light modulators instead. As a result, the device performance needed to achieve the projection can be relaxed, which makes the scheme easier to implement in practice. This generalized-phase-contrast approach could benefit a range of applications that rely on efficient projection of laser beams, for example: laser imaging for the patterning of material surfaces; phase-only encryption and data storage in optical information systems; or light control in all-optical lab-on-a-chip devices.

HOLOGRAPHY

DNA stripes

Opt. Express **15,** 15268–15273 (2007)

The potential applications of DNA in photonics and molecular electronics are increasingly attracting attention. Although DNA itself is optically passive, a group of scientists from France and the USA have shown that adding functional groups to DNA creates a medium that can be inscribed by a holographic grating and may be useful for optical data storage.

The authors prepared a complex of DNA and CTMA — a surfactant that has previously been shown to improve the temperature resilience of the DNA's double-helical structure. The complex was then functionalized using DR1, a chromophore derived from azobenzene, and spun into a thin film. Two interfering laser-beam pulses were used to record a diffraction grating on the film and a continuous-wave laser was used to monitor the grating formation. Thin films of polymethylmethacrylate and poly(9-vinylcarbazole) were also functionalized with DR1 and similarly inscribed with a diffraction pattern for comparison.

Grating patterns were successfully inscribed on both the functionalized DNA–CTMA complex and polymethylmethacrylate. However the inscription process was fastest for the DNA–CTMA complex, which was also found to undergo observable relaxation when the inscribing pulses were removed. In addition the DNA–CTMA complex was most sensitive to the polarization of the inscribing beams; when the two inscribing beams had opposite polarizations, no diffraction pattern was observed.

The results indicate that DNA–CTMA has potential for applications in dynamic holography, a promising avenue for optical storage.

ATOMIC OPTICS

Moving in time

Phys. Rev. Lett. **99,** 213601 (2007)

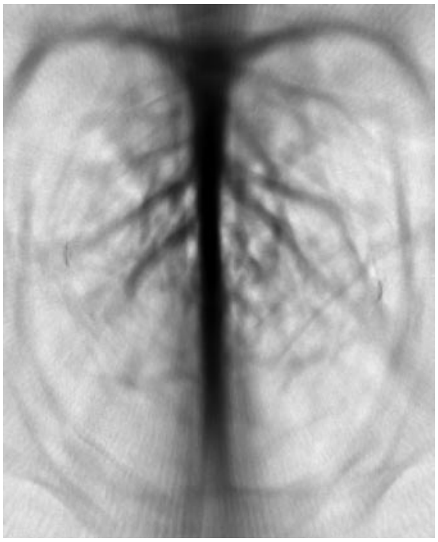
Intense light can radically alter the optical properties of a material. It would be useful, however, to achieve the same optical phenomena at much lower field intensities, even at levels where only a few photons are present. Subhadeep Gupta and co-workers from the University of California, Berkeley, and the Lawrence Berkeley National Laboratory have now seen nonlinear optical effects using light with a photon number less than one.

To make a material's response to a weak optical field similar to the response to intense pulses, it is necessary to increase the strength of the interaction between light and matter. A tried and tested method for this is to use tiny optical cavities. Gupta *et al.* trap cold rubidium atoms inside a cavity and exploit coherent collective motion of the atoms to create optical nonlinearity. The optical force exerted by the photons is enough to displace the atoms, changing the effective refractive index of the system — so-called Kerr nonlinearity. The nonlinearity was observed by measuring the transmission of light as its wavelength is swept through the cavity resonance. The team observed a different response depending on the direction in which the probe wavelength was swept — an important nonlinear effect.

Nonlinear optical effects at very low light levels will probably have important implications for optical communication, particularly in the quantum regime.

BIOIMAGING

Designer cages



Nano Lett. doi:10.1021/nl072349r (2007)

Photoacoustic tomography is an imaging technique that measures the ultrasonic waves that result from the thermoelastic expansion of body tissue due to the absorption of incident irradiation. Recently, gold nanoshells have been successfully used as a contrast agent for photoacoustic scans. Now a collaboration of scientists from the USA and China has demonstrated that gold nanocages may be a better choice.

The nanocages were prepared through a simple replacement reaction between $HAuCl_4$ and silver nanocubes. The peak in the optical absorption of the resulting cages is controlled by the amount of $HAuCl_4$ used in the reaction. The team prepared structures with a peak at 820 nm, a wavelength at which the blood's attenuation of light is low.

The nanocages were injected into two rats with different dosages, and their cerebral cortices were then scanned over several hours to capture photoacoustic images. Comparison with anatomical photographs of the rats' brains showed good agreement. The nanocages were found to enhance the optical absorption peak in the blood by 81%, compared with 63% using nanoshells.

PHOTONIC CRYSTALS

Perfectly flawed

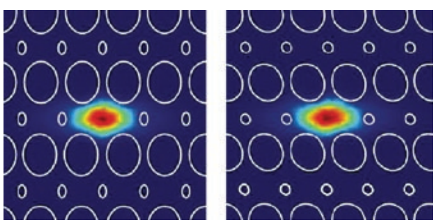
Appl. Phys. Lett. **91,** 201102 (2007)

Whether you are working with diamonds or photonic-bandgap structures, the aim is often to produce a flawless crystal. But work by Juraj Topolancik and colleagues at Harvard University and Cornell University show that perfection is not always necessary.

Photonic crystals exploit multiple reflections from periodic surfaces to prevent the propagation of light in a specific band of wavelengths. This effect can be used to create waveguides and cavities that can guide and confine light within dimensions on the scale of the wavelength. Such structures are often created by perforating a thin layer of high-refractive-index material with an array of circular holes. Topolancik *et al.* show that if disorder is introduced into the design, then it is possible to create high-performance optical cavities capable of confining light in a very small volume. The team replaced the circular holes with pentagons, some of which were rotated by 24°. They then measured the cavity's quality factor — a measure of its optical confinement and the length of time that it can hold onto light. As would be expected in random structures, the quality factor varied from device to device, but the authors measured a maximum of approximately 150,000. This figure is just an order of magnitude smaller than record values in 'perfect' crystals where extreme care has been taken to eliminate any imperfections.

PHOTONIC-CRYSTAL FIBRE

Breaking the symmetry



Jpn. J. Appl. Phys. **46,** L1048–L1051 (2007)

Photonic-crystal fibre with high birefringence is of interest because it is able to reduce polarization-mode dispersion — an unwanted pulse-spreading effect that degrades the performance of optical-communication systems. Now, according to a report by Taiwanese researchers, the birefringence of a photonic-crystal fibre can be improved to a value of approximately 10^{-2} at a wavelength of 1,550 nm, without incurring loss in the fibre's structural integrity. Yuan-Fong Chau and colleagues simulated the performance of a photonic-crystal fibre consisting of a solid silica core and photonic-crystal cladding made of elliptical air holes of two different sizes. Whereas previous structures used air holes of only one size, the two-size approach increases the gaps between holes, strengthening the fibre.

Numerical models of the fundamental mode of the fibre confirm a significant enhancement in the birefringence and show the importance of the orientation of the ellipses. When oriented at 40° to the photonic-crystal lattice, a maximum value of 1.0837×10^{-2} — at least one order of magnitude higher than that of other photonic-crystal-fibre structures — is predicted at the wavelength of 1,550 nm. The researchers have the opinion that breaking the symmetry of the structure is key to enhancing the fibre's birefringence.

TERAHERTZ SOURCES

All together now

Science **91,** 1291–1293 (2007)

Although it is difficult to fabricate efficient light sources in the region of 0.5 THz to 1.5 THz based on semiconductors, superconductors are good emitters of light in this range. Now, Lütfi Özyüzer and colleagues in an international collaboration have shown how to get the most out of these materials.

Josephson junctions are a key element in superconductor science. They are made by separating two superconducting electrodes by a thin insulating material. The application of a direct-current voltage across the junction creates a small amount of terahertz light. More light is made available by stacking many such junctions together; however, each junction emits independently, so the output is not as useful as it could be. This is the problem tackled by Özyüzer *et al.* using $Bi_2Sr_2CaCu_2O_8$ (BSCCO), a high-temperature semiconductor that naturally forms a high-density stack of Josephson junctions. The approach they take to synchronize the emission of all of these junctions is very similar to that applied in lasers — use a cavity to set up a standing electromagnetic wave. The BSCCO is formed into mesa structures 1 μm high and 300 μm long. The peak output frequency is determined by the width of the mesa: a 40-μm wide mesa emits at 0.85 THz. The researchers made more than 500 junctions oscillate in phase to produce 0.5 μW of output power. What's more, the devices operate at temperatures up to 50 K.