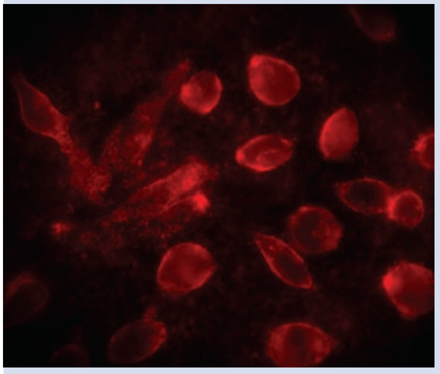
PHOTOLUMINESCENCE IMAGING

A deeper look



Nano Lett. 10.1021/nl802223f (2008)

Fluorescence optical imaging has been the tool of choice in biology and material science because of its high sensitivity and resolution. However, the search for an efficient, cost-effective approach that is capable of *in vivo* and *in vitro* imaging of biological tissue in the near-infrared range is still on. Now, Marcin Nyk and colleagues from the State University of New York at Buffalo have brought this vision a step closer. By using a near-infrared-to-near-infrared (NIR-to-NIR) up-conversion process in nanophosphors doped with rare earth ions, they demonstrate an imaging technique that enables deeper penetration into a sample with higher contrast.

Their approach is different from simultaneous two-photon excitation of organic dyes or quantum dots used for two-photon microscopy in the sense that the sequential up-conversion in rare earth ions does not require high excitation intensity. This enables the use of inexpensive, low-power and readily available continuous-wave laser diodes. The nanophosphors used are aqueous dispersible fluoride nanocrystals, with sizes of 20–30 nm, co-doped with the rare earth ions Tm^{3+} and Yb^{3+}. Under excitation at 975 nm they emit at 800 nm; both wavelengths fall in the NIR range, which is ideal for deep-tissue imaging. High-contrast images in *in vitro* cellular studies and *in vivo* tissue imaging can be achieved thanks to the absence of autofluorescence background and decreased light scattering in the process. The team also confirm the absence of toxicity in the process. They foresee that this approach will lead to three-dimensional imaging systems for advanced whole-body optical imaging.

OPTICAL DELAY

Back and forth

IEEE Photon. Technol. Lett. **20,** 1775–1777 (2008)

Many applications require a large optical delay, in some areas a large delay that can be adjusted very rapidly is desired. Now Steve Yao and colleagues in China and California have exploited the polarization properties of light to devise a scheme that can achieve a signal delay of 72-mm and change it at a rate of 2 kHz, the highest reported rate so far.

A delay or change in delay can be doubled using a Faraday mirror in the fibre. However, previous methods for increasing the delay by bouncing a light signal back and forth have suffered from frequency filtering and a limited range and speed.

In the scheme devised by Yao and colleagues, the signal passes through a polarization beam splitter along a fibre stretcher, before hitting a Faraday mirror. The light reflected by the Faraday mirror is orthogonally polarized with respect to the incident light, so on returning to the polarization beam splitter it is deflected to a second mirror. On reflection from the Faraday mirror for the second time it is transmitted by the polarization beam splitter and directed to the output by an optical circulator.

The researchers tested their system experimentally over a wide range of driving frequencies and voltages. They say that the delay variation rate is sufficient to accommodate applications, such as ophthalmic and dental optical coherence tomography.

PHOTONIC CIRCUITS

Optical integration

Opt. Express **16,** 18203–18214 (2008)

All-optical equivalents of important electronic circuits could one day be used in information processing systems, unburdened by the speed limitations of electronics. Scientists have now fabricated a photonic device that performs the function of one such circuit — the integrator.

An integrator creates a signal that is proportional to the sum over time of an input waveform. In electronics this is simple: a capacitor stores electrical energy, and so the voltage across it is related to the integrated input signal. But storing light in this way is much more difficult. Radan Slavik and colleagues from the Czech Republic and Canada use an optical cavity containing a gain medium, specifically, a doped optical fibre patterned with two Bragg gratings. If the cavity is designed correctly, the intensity of the light that leaks out of the cavity is related to that of an input waveform in just the correct way for integration. This was proven experimentally by inserting pulses of light of varying duration down to 60 ps. The output was a signal with a rise time related to the pulse duration.

One exciting application for devices such as optical integrators is in analog computers. Such computers could potentially solve certain problems much faster than their digital counterparts. Differential equations, for example, could be solved in real time. Such potential is a long way from realization but this work is a notable step forward.

QUANTUM OPTICS

Evolving entanglement

Phys. Rev. Lett. **101,** 170501 (2008)

Entangled states provide fundamental insights into quantum mechanics and are essential for quantum applications, such as in information processing and key distribution. Mark Stevenson and co-workers from Cambridge in the UK now demonstrate states whose quantum correlations evolve over time. These states have classical behaviour as observed using standard measurements, but measurements resolved over time reveal entanglement.

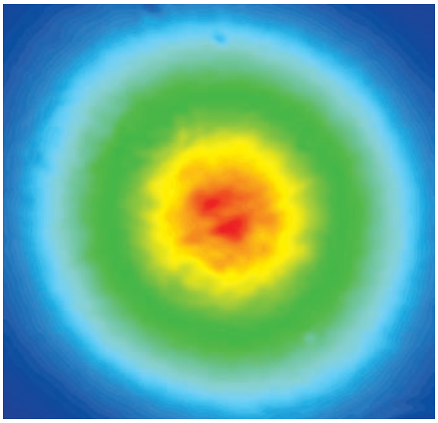
The researchers considered a quantum-dot system, which emits two photons as it decays from a biexciton state by means of one of two intermediate exciton states. The system results in a superposition of orthogonally polarized states that have a phase difference, which is caused by energy splitting of the exciton states and is determined by the delay between emission of the first and second photon. For zero splitting the superposition remains in phase, leading to a well defined entangled state; for finite splitting this phase evolves and, averaging over time, instantaneous superpositions cancel out.

The researchers observed InAs dots and controlled the splitting using a magnetic field. To probe the entanglement as a function of time they measured the fidelity of the system to a zero-splitting state. The time of the delay, hence the phase difference, was selected using a timing gate. The fidelity was observed to oscillate as the delay increased, demonstrating the evolution of the phase.

Direct interactions between qubits entangled in time-delay-dependent states could reveal interesting physics and lead to novel implementations of quantum logic.

LASER MATERIALS

Crystal quality



Opt. Lett. Doc. ID 98893 (2008)

There is a continuing search for gain media for compact laser systems that produce ultrashort pulses and ultrahigh peak power. Now, a collaboration between several research groups in Germany unveils a terawatt-level diode-pumped laser using single-crystalline $Yb:CaF_2$ as the amplifying medium.

Mathias Siebold and colleagues used a chirped pulse amplification process: femtosecond seed pulses stretched to 85 ns were amplified and then recompressed. Cylindrical $Yb:CaF_2$ crystals with a diameter of 28 mm and a length of 20 mm were pumped by two stacks of diode lasers. The team obtain a pulse energy of 197 mJ and a duration of 192 fs after recompression, corresponding to a peak power of 1 TW.

By using longer seed pulses the scheme can also produce nanosecond pulses that have an energy of up to 905 mJ without optical damage. This shows the potential of $Yb:CaF_2$ as a new laser material for high-energy nanosecond lasers.

Despite the low efficiency obtained, which can potentially be overcome by further optimization and scaling-up of the system, the researchers are confident that $Yb:CaF_2$ will be a promising gain medium for future ultrahigh-peak-power diode-pumped lasers.

NONLINEAR OPTICS

Down to size

Opt. Express **16,** 18050–18056 (2008)

Optical parametric oscillators (OPOs) convert laser light into two beams of lower-frequency photons. Harnessing this idea in optical fibres enables compact devices suitable for many diagnostic applications, and OPOs are now a very popular tool in optics laboratories all over the world. Researchers in the USA have now shown that fibre optical parametric oscillators (FOPOs) can be used to generate sub-100-fs pulses.

Key to this achievement was a reduction in the length of the FOPO. The system used by Jay Sharping and co-workers incorporates a fibre just 4.2 cm long. This was made from a commercially available microstructured optical fibre that was modified by reducing the diameter of the core from 5 μm to 4 μm. This shifted the zero-dispersion wavelength. The fibre was placed in a 3-m-long optical cavity and pumped by 370-fs light pulses (wavelength of 1,032 nm) from a fibre laser.

The system's output was a series of pulses just 70 fs long with a centre wavelength of 880 nm. The team see a future investigation of the effects of different set-up parameters — core size and fibre length, for example — as crucial for a better understanding of this potentially very useful device.

FILAMENT PROPAGATION

Polarized apart

Opt. Lett. Doc. ID: 99060 (2008)

Filament propagation describes a beam that passes through a medium without diffraction. The properties of a laser filament — a small diameter and high intensity — are governed by laser-induced optical Kerr self-focusing and plasma defocusing. Now Yanping Chen and colleagues in Quebec, Canada, show how the polarization components of a femtosecond pulse can be separated by a co-propagating filament.

The researchers use 1-kHz, 800-nm, 75-fs (slightly negatively chirped) Ti:sapphire laser pulses: the first generates the filament, and the second is frequency doubled to 400 nm using beta barium borate crystal, for use as a probe. The polarization of the probe beam is analysed with a cube polarizer.

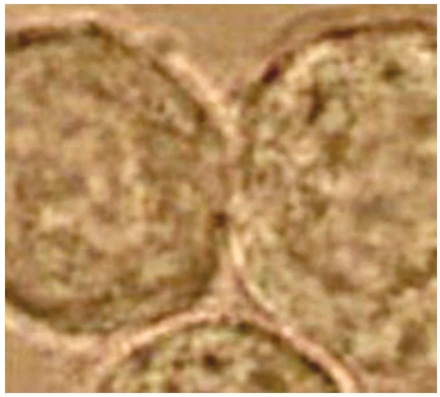
The pump was found to modify the polarization distribution of the probe. The polarization was parallel to the pump at the centre of the probe beam and orthogonally polarized at the periphery. The results were verified using different initial probe polarizations, all resulting in the same polarization distribution.

The mechanism of the polarization separator is explained by the difference in pump-induced nonlinear contributions to the refractive indices along the two orthogonal directions. For the components of the probe polarized parallel to the pump, the pump-induced Kerr self-focusing and plasma defocusing balance. For the orthogonal components they do not balance, so these components are diffracted outwards.

The technique provides a novel broadband femtosecond polarization separator, useful for ultrafast information processing and telecommunications.

BIOPHOTONICS

Femtosecond fusion



Appl. Phys. Lett. **93,** 163901 (2008)

Researchers in Hong Kong have come up with a way of efficiently fusing human cells together using femtosecond light pulses from a fibre laser.

Cell fusion happens naturally, but the ability to do it artificially provides cell biologists with a better understanding of the process. This in turn could lead to developments in genetic techniques and cancer treatments. Previous optics-based fusion techniques, such as the use of nanosecond-long pulses of UV light, have suffered from poor fusion success rates, about 10%, and surrounding cells were damaged by scattered light. Polyethylene glycol was found to improve the efficiency for fusing yeast cells, but it is toxic. The challenge is to improve the efficiency, but at the same time keep the cells alive.

Hao He and co-workers from the Chinese University of Hong Kong take an all-optical approach that does not require any chemicals. Optical tweezers moved two human heptocellular carcinoma cells (HepG2) into contact. Pulses of light 200 fs long, at a wavelength of 1,550 nm were focused onto the contact area for about 10 s. The cells were then incubated for 90 minutes at 37 °C. The fusion was successful in 37.5% of the tests. Thermal effects were limited to the focal volume, reducing disruption to surrounding cells.

The technique was also used to join two different types of cell, HepG2 and human cervical cancer cells, although this was achieved at a much lower efficiency of 10%.