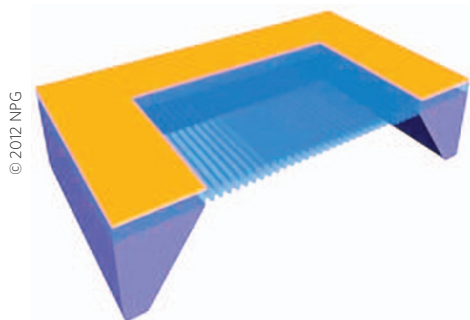


master clock laser used in the experiment is reportedly the most stable clock laser at NICT, whereas the 698 nm slave clock laser, being based on a  $^{87}\text{Sr}$  transition, is inherently less stable. The researchers used an optical frequency comb generated by a Ti:sapphire laser to bridge the frequency gap between the two lasers and applied a feedback-signal driven acoustic optical modulator to correct for fluctuations in the frequency of the slave laser. They measured a factor of two improvement in stability (from  $4.4 \times 10^{-15}$  to  $1.9 \times 10^{-15}$ ) for the phase-locked slave laser. The researchers are now attempting to reduce thermal noise and improve the inherent stability of the slave laser by cooling pure-silicon optical cavities to temperatures of around 120 K. OG

## NANOPHOTONICS

### Circuit design

*Nature Mater.* **11**, 208–212 (2012)



Electronic elements such as resistors, inductors and capacitors are commonly used as building blocks to control and manipulate radiofrequency signals in electronic circuits. Nader Engheta and co-workers previously proposed that optical nanostructures, if properly designed and judiciously arranged, could behave as analogous nanoscale circuit elements for use at optical frequencies. The researchers have now experimentally verified their predictions by using arrays of nanorods to build a two-dimensional optical nanocircuit that operates at mid-infrared wavelengths. The researchers designed and fabricated arrays of  $\text{Si}_3\text{N}_4$  nanorods and then quantitatively evaluated the equivalent impedance of these nanostructures in the mid-infrared regime. Using Fourier transform infrared spectroscopy, they showed that the nanostructures can indeed function as two-dimensional optical circuit elements. In addition, the connections between the nanocircuit elements, in particular whether they function in a series or parallel arrangement, can be controlled through the polarization of the

optical control signals. The researchers say that introducing optical nonlinearity into such optical circuits could provide a platform for mixing multiplexing optical signals with different incidence angles and polarizations. JB

## QUANTUM CASCADE LASERS

### Chasing room temperature

*Opt. Express* **20**, 3866–3876 (2012)

Research is continuing in the quest to demonstrate room-temperature terahertz quantum cascade lasers (THz QCL). The main problem is that the gain of a THz QCL depends on the product between population inversion and oscillator strength, which are difficult to optimize simultaneously. Saeed Fathololoumi and co-workers from the National Research Council of Canada, the University of Waterloo, the Massachusetts Institute of Technology, Technische Universität München and Shanghai Jiao Tong University have now used a density matrix approach to maximize the gain of a THz QCL and achieve lasing at a temperature of 199.5 K. The THz QCL was based on  $\text{GaAs}/\text{Al}_{0.15}\text{Ga}_{0.85}\text{As}$  and had a three-well structure. The active region thickness, ridge width and length of the device were 10  $\mu\text{m}$ , 144  $\mu\text{m}$  and 1 mm, respectively. The researchers reduced the waveguide loss within the QCL by fabricating a Cu–Cu double-metal waveguide without a top  $n^+$  contact layer. The device produced single-mode emission at a wavelength of 3.22 THz when electrically driven with a pulse duration of 300 ns at a repetition rate of 300 Hz. The researchers measured a threshold current of around 1.92 kA  $\text{cm}^{-2}$ . NH

## QUANTUM COMMUNICATION

### Frequency conversion

*Phys. Rev. A* **85**, 013845 (2012)

Quantum communication networks rely on optical devices such as quantum light sources, optical fibres, quantum memories and photodetectors. Unfortunately, each type of device has its own optimal wavelength of operation; 1,550 nm for optical fibre, 800 nm for quantum memories using rubidium vapour, and visible light for a silicon-based photodetector. Quantum frequency converters, which can change the wavelength of a photon while preserving its indistinguishability, single-photon character and entangled state, are therefore extremely important tools. Sven Ramelow and co-workers from the University of Vienna, the Austrian Academy of Sciences and the Austrian Institute of Technology have

now demonstrated a quantum frequency-conversion scheme based on sum-frequency generation. First, the researchers generated polarization-entangled photon pairs at a wavelength of 810 nm by spontaneous parametric downconversion in a periodically poled  $\text{KTiOPO}_4$  crystal. They were then combined this signal beam with 1,550 nm pump beams in two orthogonally oriented  $\text{KTiOPO}_4$  crystals. The horizontally and vertically polarized components of the signal beam were converted to 532 nm beams in the first and second crystals, respectively. To render the output photons indistinguishable, the researchers used a pair of birefringent calcite wedges to compensate for the temporal walk-off of 1.8 ps between the orthogonal polarization components. This resulted in the successful transfer of entanglement between the 810 nm and 532 nm photons. NH

## OPTOMECHANICS

### Quantum motion

*Phys. Rev. Lett.* **108**, 033602 (2012)



Amir Safavi-Naeini and colleagues at the California Institute of Technology in the USA have used lasers to cool a mesoscopic optomechanical resonator down to a phonon occupancy of just  $2.6 \pm 0.2$  — a level that allows characteristics associated with quantum zero-point fluctuations to be observed. The team used a silicon microbeam patterned with air voids that forms a Bragg cavity at the centre of the beam for both the photonic modes and the acoustic mode. The photonic modes at 1,545 nm and 1,460 nm were used for readout and optical cooling, respectively. The in-plane breathing mechanical mode, which had a frequency of around 4 GHz, was coupled to the optical modes by radiation pressure. Although photon cooling to the single-phonon level has already been achieved in related systems, the researchers say the performance of their set-up (with a minimum observed phonon number of 2–3) is currently limited by the power of the cooling laser and is therefore open to improvement. They also noted that the results deviate from ideal predictions due to optical absorption, which causes power-dependent variations in the parameters. DP

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