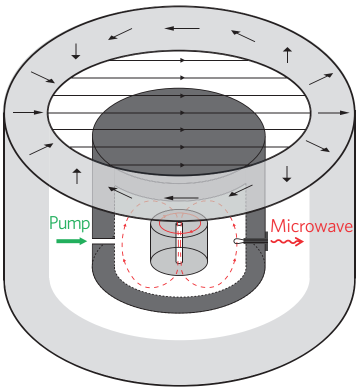
MICROWAVE TECHNOLOGY

Diamond maser

Nature Commun. **6,** 8251 (2015)



NPG

Applications for masers, the microwave predecessor to the laser, are hindered by the need to operate such devices under conditions or either low temperature or high vacuum. A solid-state maser that operates at room temperature is thus highly desirable. Although a room-temperature pulsed version was reported in 2012, scientists are still seeking a device that will support continuous-wave operation. Now, Liang Jin and co-workers from the Chinese University of Hong Kong in China and the University of Stuttgart in Germany have theoretically proposed that it could be feasible to make such a device from diamond. Their idea is to use an ensemble of nitrogen–vacancy (NV) centre spins in diamond resonantly coupled to a high-quality ($Q \sim 10^5$) microwave sapphire resonator cavity. The Chinese and German scientists considered a $3 \times 3 \times 0.5$ mm^3 diamond crystal with an NV centre concentration of 2 ppm located inside a cylindrical sapphire dielectric resonator (radius of 15 mm) loaded in a coaxial cylindrical cavity (radius of 40 mm). The set-up was exposed to a magnetic field of 2,100 G such that the transition frequency between the ground and excitation states was resonant with the cavity mode frequency around 3 GHz. The scientists calculated the spin inversion, the microwave output power gain and the noise temperature and found that the threshold of 532 nm pump power for masing was 4.3 W. For the pump power less than 10 W, a maser output power greater than 10 nW was predicted with a coherence time of minutes. *NH*

QUANTUM COMMUNICATIONS

Long-distance teleportation

Optica **2,** 832–835 (2015)

Quantum teleportation over optical fibre is less efficient than over free space, due to the relatively low detection efficiency of typical single-photon detectors that operate at the 1.5 μm low-loss window of optical fibre. Now, Hiroki Takesue and co-workers from NTT Cooperation in Japan and the National Institute of Standards and Technology in the USA have developed MoSi-based superconducting nanowire single-photon detectors (SNSPDs) and used them to demonstrate quantum teleportation over 102 km of optical fibre — four times further than the previous record of 25 km. Time-bin entangled photon pairs were prepared from signal photons (1,546.3 nm) generated through the spontaneous parametric down-conversion process from a periodically poled $LiNbO_3$ waveguide and detected by two SNSPDs. The idler photons (1,555.9 nm) were transmitted over 102 km of dispersion-shifted fibre and detected by another two SNSPDs. The system detection efficiencies of the SNSPDs were 80–86%. The Japanese and American scientists prepared six distinct quantum states for input photons and implemented quantum state tomography on the teleported states. The averaged fidelity for each input state was 83.7%, which relates to a violation of the classical limit by more than eight standard deviations. *NH*

HIGH-HARMONIC GENERATION

Vacuum effect

Phys. Rev. A **92,** 032115 (2015)

Light propagation through vacuum can be modified due to the polarizability of virtual electron–positron pairs. By using numerical simulations and analytically solving modified Maxwell and wave equations, Patrick Böhl and Hartmut Ruhl from Ludwig-Maximilians-Universität München, together with Ben King from Plymouth University, have studied the effects of vacuum interactions on a plane probe pulse propagating through a strong electromagnetic field. Specifically, a pump–probe set-up is used with a linearly polarized oscillating plane wave (probe) counterpropagating through a stronger plane wave background (pump). Taking virtual electron–positron pair creation into account, their numerical simulations suggest that a shock wave can arise from vacuum high-harmonic generation. The team has identified a nonlinear shock parameter of $\nu \approx 1$, which indicates when the self-interaction of the probe due to the polarized vacuum becomes important and can be consistently described using a probe-dependent vacuum refractive index. The findings will be of importance for studies of X-ray pulsars and highly magnetized neutron stars or 'magnetars'. *RW*

OPTICAL COMMUNICATIONS

Underwater link

Opt. Express **23,** 23302–23309 (2015)

A high-speed underwater optical communications link that operates at a data rate of 4.8 Gbits s^{-1} over a distance of 5.4 m has been demonstrated by scientists in Saudi Arabia and Taiwan. The link is the result of work by Hassan Oubei and co-workers from King Abdullah University of Science and Technology (KAUST), National Taiwan University and National Chiao Tung University. It makes use of a 15 mW blue laser diode with a wavelength of 450 nm to transmit light pulses in the blue-green low-absorption window of seawater, which are then detected by a silicon avalanche photodiode-based receiver. A 16-QAM-OFDM modulation and multiplexing format is used to optimize the link's signal-to-noise ratio (15.63 dB) and bit error rate (2.6×10^{-3}). Such high-speed underwater communication links are expected to be useful for providing data connections to sensor networks and remotely operated vehicles. *OG*

X-RAY PHOTONICS

Atomic laser

Nature **524,** 446–449 (2015)

X-ray lasers based on atomic transitions are challenging to realize due to the difficulty in creating a population inversion between levels separated by the required large energy gaps. Although there has been a lot of progress in creating lasers operating at shorter and shorter soft X-ray wavelengths, for example using neon to produce a 14.6 Å laser in 2012, a hard X-ray version has remained elusive. Now, Hitoki Yoneda and colleagues from Japan have demonstrated a 1.5 Å laser that makes use of the inner-shell atomic levels of copper. They used the SACLA free-electron laser to pump the absorption edge of K-shell electrons in Cu atoms with intense 1.4 Å wavelength pulses, which resulted in 1.54 Å laser emission. The 7 fs duration pump pulses were focused to a 120-nm-wide spot that was scanned across a 20-μm-thick Cu foil. Scanning helped to avoid damage due to the extreme pump intensity of $\sim 6 \times 10^{19}$ W cm^{-2} — each shot impacted on a fresh region of target surface. *DP*

Written by Oliver Graydon, Noriaki Horiuchi, David Pile and Rachel Won