Cascade lasers hint at last-mile television link

Researchers at Bell Labs in the US have sent a free-space video transmission using mid-infrared quantum cascade lasers. The links could be used instead of cable, in low-cost, temporary video connections set up to cover major events, such as the Olympics.

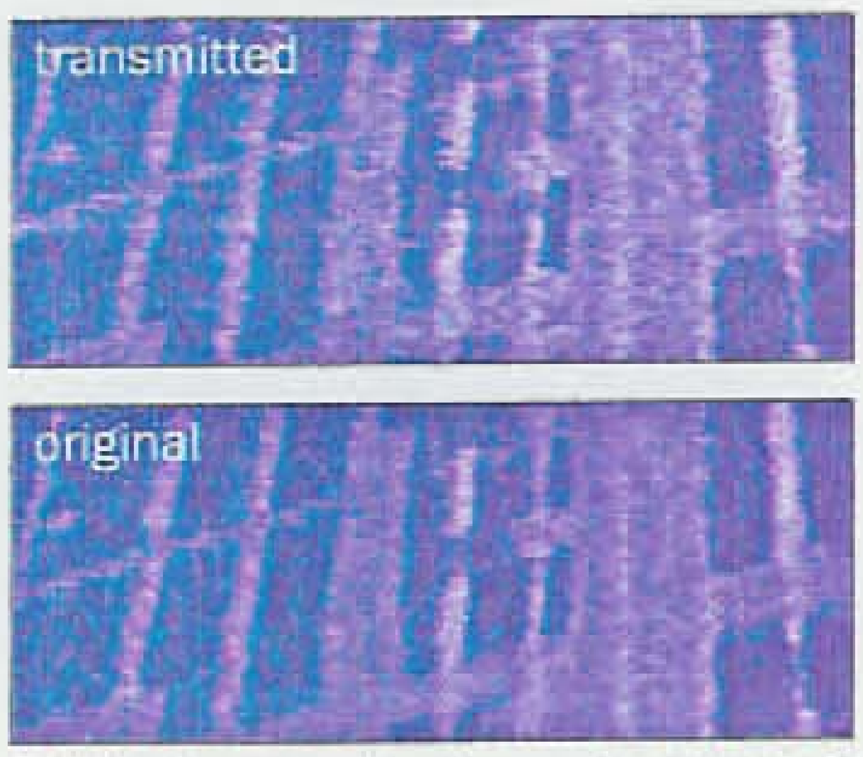
Federico Capasso's team collaborated with Ed Whittaker at the Stevens Institute of Technology. They used quantum cascade lasers (QCLs) emitting near 8 µm to send a video image over a 70 m free-space path in a laboratory. The link ran continuously and stably for more than 8 h.

"The high bandwidth allows users to send large volumes of data in real time through bad weather," said Capasso.

The first applications to emerge could be military. For example, a ship could send data to a ground station during a storm.

Other applications could be the establishment of wireless video links in countries where the local terrain is not suited to conventional fibre-optic installation.

The mid-infrared spectrum has two major advantages over conventional free-space optical links that operate at the same near-infrared frequencies that are used in fibre-optic transmission.



A video image can be transmitted through free space using quantum cascade lasers.

First, the 8 to 13 µm region provides a window where common atmospheric gases do not absorb. Second, interference from Rayleigh and Mie scattering is less significant at longer wavelengths. This means that, theoretically, the mid-infrared sources are superior to existing 1.3 and 1.5 µm optical wireless links (see p25), especially in fog and snow, which increase scattering.

Altogether, losses in the 8 to 13 µm region work out at one-hundredth of the losses experienced in the near-infrared of conventional instrumentation.

The QCLs' robust nature and freedom from the heating effects of non-radiative recombination suggest that they should also be extremely reliable.

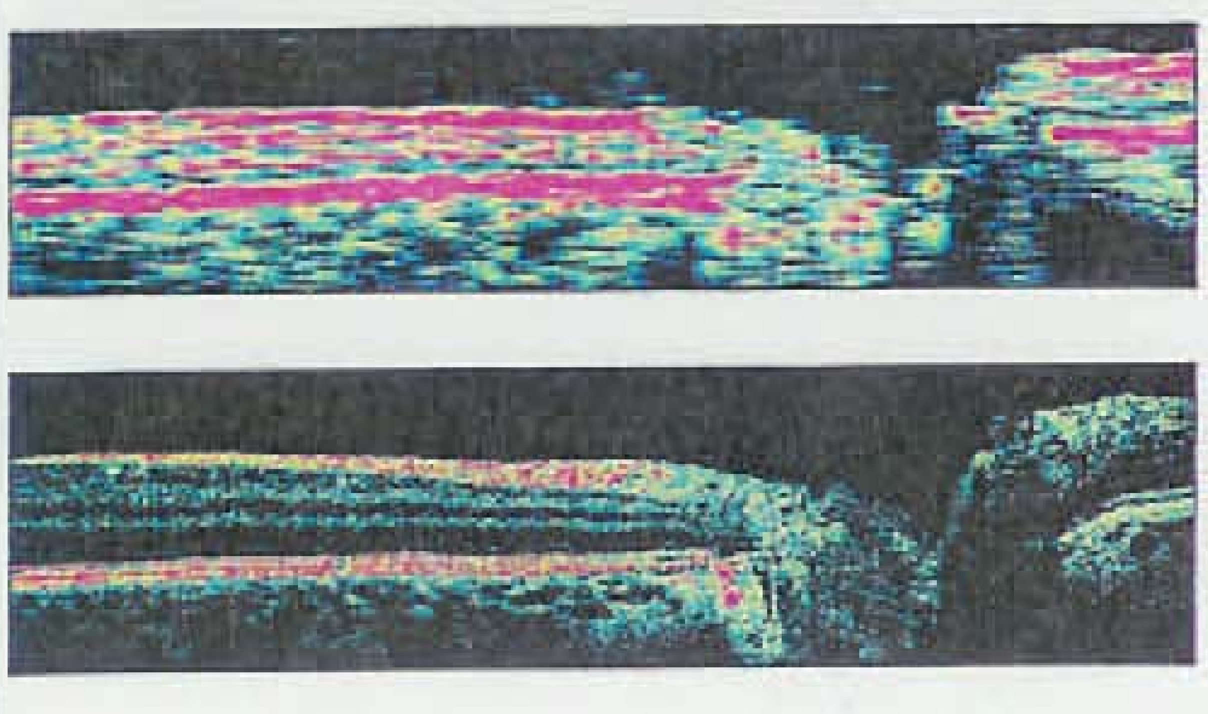
Recombination can also limit the potential bandwidth of the devices. In theory QCLs can send data at several hundred gigahertz. In the current work, Rainer Martini's devices operate at about 2 GHz when cooled to 80 K, and have an average power of 10 mW at a wavelength of 7.35 µm.

Capasso says that the bottleneck to commercial deployment will be finding suitable mid-infrared detectors. The likely candidates look to be quantum well infrared photodetectors.

Another problem is designing suitable optics to collimate the beam for long-range links. "The basic design that we need to use is in the textbooks. In addition, the reduced scintillation effects at the longer wavelength means that there is no need to use adaptive optics," said Capasso.

The team now plans to transmit images across a distance of several hundred metres, between buildings (*Elec. Letts* **37(3)** 191).

Ultrafast source eyes up tomography


Images of a human retina taken using commercially available optical coherence tomography equipment (top) and (bottom) with the new Ti:sapphire laser (resolution 2–3 µm).

Pulses that are shorter than two optical cycles and with bandwidths of more than 500 nm have been generated directly from a Ti:sapphire laser. A research group from the universities of Karlsruhe and Darmstadt, Germany, and Massachusetts Institute of Technology (MIT) in the US made the source.

They believe that this is the shortest pulse and broadest spectrum ever generated directly by a laser oscillator. It has already been used for the *in vivo* optical coherence tomography (OCT) of the human eye and it should enable progress in metrology and phase-dependent non-linear optics.

Karlsruhe's Uwe Morgner told *OLE*: "Other groups have generated 4.5 fs pulses using a laser and a pulse compressor. However, our 5 fs pulses are the first ever that have been obtained directly from the laser oscillator."

To broaden the generated spectrum, the group introduced double-chirped mirror pairs (DCMPs) into a dispersion-managed Kerr-lens mode-locked Ti:sapphire laser.

The 64-layer DCMPs allow for dispersion compensation from 600 to 1200 nm while being highly reflective over the full octave. They are designed so that the dispersion ripple of one mirror cancels that of the second.

Jim Fujimoto from MIT has used the ultrafast source for ophthalmic OCT with an ultrahigh depth resolution of 2 to 3 µm. In conventional instruments the depth resolution lies between 10 and 15 µm (submitted to *Optics Letters* and *Nature Medicine*).

IN BRIEF

Photorefractive quantum wells that are sensitive at 1064 nm have been made by scientists at Japan's Institute of Industrial Science in Tokyo. S Iwamoto tailored the excitonic transition in InGaAs multiple quantum wells by increasing the indium fraction to 0.2. The resulting large lattice mismatch with the GaAs substrate was overcome by using "strain-relief" buffer layers (*Opt. Letts* **26(1)** 22).

Corning researchers have developed what is thought to be the first efficient glass-ceramic fibre laser. Bryce Samson and co-workers doped optical fibres with 0.05% NdF_3, then heat-treated the material to create high local concentrations of neodymium. When pumped with a Ti:sapphire source, the fibre's lasing spectrum was much narrower than that of a normal glass fibre. The slope efficiency was 30% and the maximum output was 40 mW (*Opt. Letts* **26(3)** 145).

A hollow-glass waveguide (HGW) system can deliver an infrared free-electron laser (FEL) emission via an optical fibre. Jin Shen and Karen Joos of Vanderbilt University, US, and James Harrington of Rutgers University, developed the silver-iodide-coated waveguide, which has calcium fluoride optics. The 530-µm-diameter HGW can withstand 24 mJ of 6.45 µm emission, which is equivalent to a power density of 7.2×10^8 W/cm^2 (*Appl. Opt.* **40(4)** 583).

Time-resolved reflectance spectroscopy can assess the bulk properties of fruit. A Spain/Italy collaboration led by Rinaldo Cubeddu at the Politecnico di Milano, Italy, used fibre-delivered, mode-locked Ti:sapphire and dye lasers to assess the 650–1000 nm reflectance of tomatoes, kiwi fruit, peaches and apples. The team is now trying to correlate these optical properties with fruit quality (*Appl. Opt.* **40(4)** 538).