

to originate from separate spatial locations, but in reality all signals can come from any location in the cell. As seen in the energy level diagrams, the SHG signal is enhanced when the energy of two photons in the laser field is similar to the separation between the two electronic states of the molecule. Similarly, THG is enhanced when three photons of the laser field are equal to the energy difference between states. Exploiting resonances is a general property of nonlinear interactions³, and it also holds true for FWM. As shown in Fig. 1, independent recording of the three

signals is aided by the fact that they are spectrally distinct and can therefore be separately measured using a spectrally resolved detector or dichroic mirrors and colour filters.

The apparatus described by Selm *et al.* provides high-quality images capable of discriminating between different materials by simultaneously recording signals from multiple nonlinear microscopy techniques. The simplicity, stability and effectiveness of the device ensure that it will be attractive for widespread use in biological and biochemical imaging. □

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ACOUSTICS

Fibre-optic pickup

Guitars and violins may soon sound better than ever thanks to photonic technology. Researchers in Italy and Canada have developed a fibre-optic pickup that is capable of converting acoustic vibrations from a musical instrument to an electronic signal with a claimed distortion-free dynamic range of 50 dB for frequencies ranging from 8 Hz to 30 kHz (*Opt. Express* **19**, 25057–25065; 2011).

Saverio Avino and co-workers from Istituto Nazionale di Ottica in Italy and Queen's University and Ryerson University in Canada say that their photonic pickup is compact, lightweight and can be easily attached to vintage musical instruments. They also say that their device reproduces lower frequencies more accurately than conventional piezoelectric pickups, thereby providing a broader acoustic bandwidth and producing a more natural sound.

The pickup is based on a fibre Fabry–Pérot cavity comprising two high-quality (transmission extinction ratio of 23 dB) fibre Bragg gratings spaced 2 cm apart. The cavity can be used as an acoustic transducer because its length — and therefore the spectral position of its transmission fringes — changes with the applied strain.

Piezoelectric-based pickups have traditionally been used for amplifying or recording musical instruments, but they have a limited acoustic response. Although fibre-optic pickups have a greater frequency response than piezoelectric pickups, they have previously suffered from absorption losses and optical noise arising from uncontrollable fluctuations in the laser emission and



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detector response. Avino and co-workers have now overcome these problems by adopting an interrogation method that locks the frequency of the probe laser tightly to the audio-modulated reflections.

The transmission fringes of the Fabry–Pérot cavity had a narrow linewidth of around 25 MHz, which was essential for locking the distributed feedback laser and for detecting small strain modulations. The researchers attached the cavity to the guitar body and locked the distributed feedback laser, with a linewidth of 5 MHz at 1,549 nm, to the peak of a cavity fringe using Pound–Drever–Hall laser stabilization — a well-known technique for demanding tasks such as the interferometric detection of gravity

waves. They extracted the error signal from the reflected cavity field by mixing the detector signal with the modulation signal applied to the laser. They then fed the error signal to a proportional-integral servo amplifier whose output was fed back to the distributed feedback laser current.

The researchers say that their fibre-optic pickup system is largely immune to optical noise sources. They captured distortion-free audio recordings of guitars with a frequency response from the infrasound (around 8 Hz) to 30 kHz, with a 50 dB dynamic range in acoustic power. It should be noted that the upper limit of the acoustic frequency range (30 kHz) was determined by the speed of the servo loop — not by the cavity finesse — and that further improvements in dynamic range and frequency response may therefore be possible.

The cost and complexity of the photonic pickup system must be reduced before it can be adopted by guitar manufacturers and musicians, but Avino and co-workers are confident that this can be achieved.

“All components are off-the-shelf electronic and optical parts, and the laser driver can be easily replaced by a home-built current source,” comment the authors in their paper. “We estimate that a dedicated sensor system may be built from components costing US\$1,000 or less. This is comparable to the cost of a studio-quality ribbon microphone.”

The photonic guitar is currently being exhibited at the Canada Science and Technology Museum in Ottawa until April 2012.

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