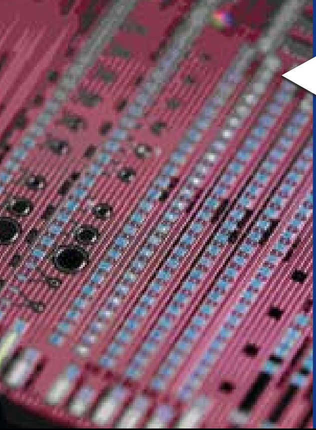

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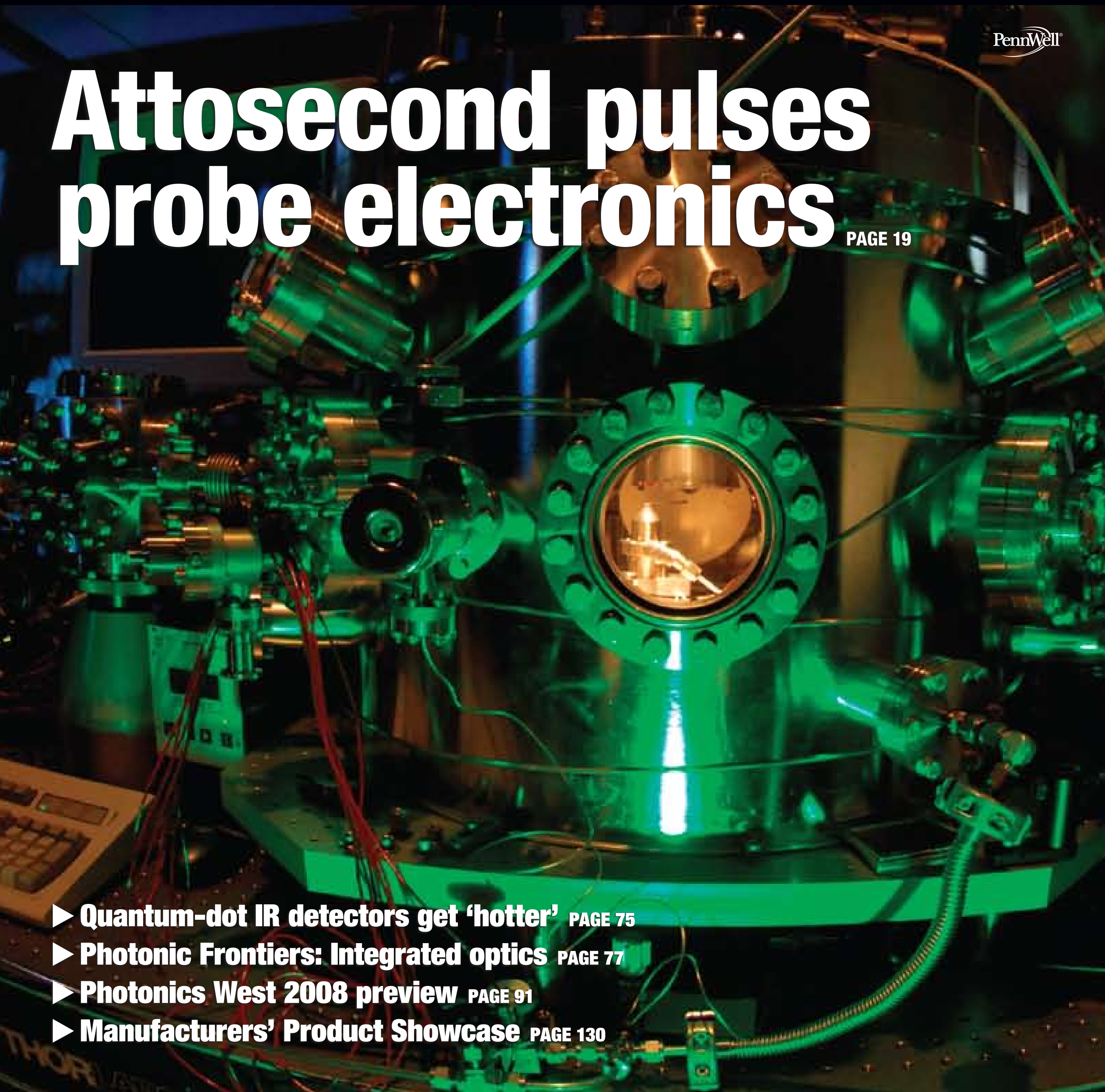

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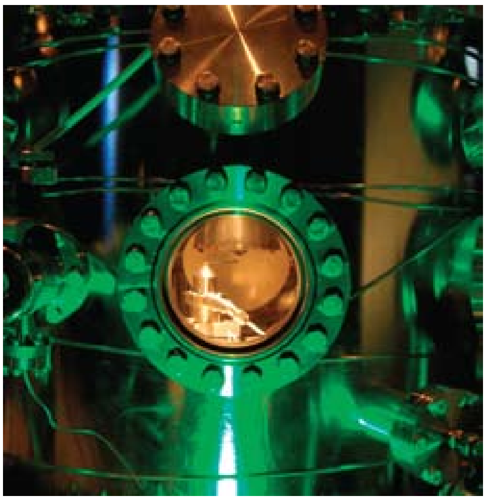
Attosecond pulses probe electronics PAGE 19

ATTOSECOND METROLOGY

Attosecond electron measurement probes ultrahigh-speed electronics

Understanding the motions of electrons inside solids is the basis for future technological developments in computing speed, ultrahigh-speed communications, and remote surgery, among other possibilities. Such advances depend on detection and measurement of the atomic-scale motion of electrons, which take mere attoseconds to travel from atom to atom in a solid (1 attosecond = 10^{-18} s).



The attosecond-scale measurement scheme uses a commercial Ti:sapphire laser to deliver waveform-controlled few-cycle, 5 fs near-infrared (750 nm) laser pulses at a repetition rate of 4 kHz. The laser pulses produce isolated coincident 300-attosecond EUV pulses used for real-time observation of rapid electron motion inside atoms, molecules, and solids. (*Courtesy of Max-Planck-Institut für Quantenoptik/Thorsten Naeser*)

In April, physicists announced the attosecond-scale real-time measurement of the electron tunneling speed in neon gas using ultrashort light-pulse generation and control (see www.laserfocusworld.com/articles/294633). Now, the attosecond envelope has again expanded with the measurement of the electron transport in a condensed-matter system—the first of its kind in a solid, according to an international research team led by Ferenc Krausz, professor of physics at the Ludwig Maximillians University in Munich, and director of the Max-Planck-Institut für Quantenoptik (Garching, Germany).[1]

Measuring photoelectron wave packets in condensed matter can be more complicated than single-atom setups because electrons are released from energy bands containing many distinct states. The researchers chose to probe tungsten, which features localized 4*f* core states that are deeply bound and fully populated, meaning the emission is less complicated.

Using a 400 μJ Ti:sapphire laser system, the Max-Planck team focused 300-attosecond extreme-ultraviolet (EUV) pulses onto the (110) surface of a tungsten single crystal to trigger photoemission. A coincident, waveform-controlled near-infrared pulse at 750 nm probed the freed electrons of two types: loosely bound electrons responsible for conduction and tightly bound 4*f* electrons from the cores of the tungsten atoms.

An attosecond transient recorder used in previous gas-phase experiments showed that the conduction-band atoms were emitted approximately 110 as before the localized 4*f* core electrons, even though the emission is stimulated simultaneously by the same EUV pulse. The tiny delay between the emission of the two electrons indicates that the excited conduction electrons travel nearly twice as fast as the excited core electrons over a distance of several atomic layers inside the tungsten crystal.

Such a demonstration sheds new light on electronic charge transport across surfaces and in condensed matter. "The major significance of the measurement lies not so much in the acquisition of some revolutionary new finding," says Krausz, "but more in the demonstration of the feasibility of observing electron transport dynamics across atomic layers in a solid in real time."

Measuring the time required for an electron to travel between neighboring atoms represents perhaps the smallest possible length scale for electronic processes like channeling and switching signals. "This technical capability is a prerequisite for advancing electronics to its ultimate speed limits, expected to be in the petahertz regime," says Krausz.

Valerie C. Coffey

REFERENCES

1. A.L. Cavalieri et al., *Nature 449*(7165), 1029 (Oct. 25, 2007).