

with evidence for a bridle, and it all suggests horses were being ridden,” says Sandra Olsen, an archaeologist at the University of Kansas, Lawrence, who was not part of either study.

Not long after, the Xiongnu emerged. They translated their skills on horseback into a sophisticated means of waging war and organizing an empire over vast distances. Starting in about 200 B.C.E., the Xiongnu marshalled nomadic tribes from across Eurasia into a formidable force, turning the steppes into a political center rivaling neighboring China. “The Xiongnu have been a source of constant worry and harm to China,” one contemporary Chinese historian wrote. “They move about in search of water and pasture and have no walled cities or fixed dwellings, nor do they engage in any kind of agriculture.”

Jeong’s study of DNA from 60 human skeletons from the Xiongnu’s 300-year-run shows how the region was transformed into a multiethnic empire. After more than 1000 years in which three distinct, stable human populations lived side by side on the Mongolian steppe, genetic diversity rose sharply around 200 B.C.E. Populations from western and eastern Mongolia mixed with each other and with people carrying genes from as far away as present-day Iran and Central Asia. Such wide-ranging mixing has “never been seen before at that scale,” Jeong says. “You can see the entire Eurasian genetic profile in the Xiongnu people.”

The results suggest mastery of the horse made possible stunning long-distance voyages on Central Asia’s sea of grass. Archaeological finds in the graves of Xiongnu elites, such as Roman glass, Persian textiles, and Greek silver, had suggested distant connections. But the genetic evidence suggests something more than trade. Eleven Xiongnu-period skeletons showed genetic signatures similar to those of the Sarmatians, nomad warriors who dominated the region north of the Black Sea, 2000 kilometers across the open steppe from Mongolia.

“There’s no written evidence of [Xiongnu] contact with Sarmatians, and it’s not well-attested archaeologically. It’s really surprising they’re mixing over these long distances,” says Tsagaan Turbat, an archaeologist at the Mongolian Academy of Sciences’ Institute of Archaeology. “This kind of information is really a game changer.”

In the future, researchers hope the genomes will help reveal how the mysterious nomad empire worked. The Xiongnu are “doing the things that empires do—forcing or enticing people to move,” says University of Michigan, Ann Arbor, archaeologist Bryan Miller. “Are people sent out to rule, or are local elites allowed to continue?” he asks. “Only genetics could answer that.” ■

TECHNOLOGY

New chip-based lasers promise practical terahertz imaging

Semiconductor lasers work with small coolers, enabling medical imaging and contraband detection

By Robert F. Service

Compact, chip-based lasers have conquered much of the electromagnetic spectrum, from ultraviolet to infrared, enabling technologies from digital communications and barcode readers to laser pointers and printers. But one key region of the spectrum remained untamed: the terahertz band, which lies between infrared light and microwaves. Engineers hankered for a ready source of terahertz radiation, which can penetrate opaque objects and probe chemical fingerprints inside. But compact terahertz lasers have only worked at ultralow temperatures, limiting them mostly to laboratory settings.

No longer. In this week’s issue of *Nature Photonics*, researchers report creating a grain-of-rice-size terahertz laser on a chip that operates at 250 K, or -23°C , a temperature reachable with a plug-in cooler the size of a cracker.

“This is a great achievement,” says Miriam Vitiello, a condensed matter physicist at the Nanoscience Institute of Italy’s National Research Council. “It has been a long-term goal in the community

to push up the temperature of terahertz lasers,” she adds. “There is now a plethora of applications that can be done,” from medical imaging to explosives detection at airports.

Standard chip-based lasers generate photons when electrons fall into electron vacancies within a semiconductor alloy, whose makeup determines the color. Gallium nitride, for example, emits blue light, whereas gallium arsenide emits red. No semiconductor alloys emit photons in the terahertz range. (“Terahertz” refers to the light’s frequency: trillions of cycles per second.) In 1994, however, researchers at AT&T Bell Labs created a new kind of laser in which the semiconductor’s structure, not just its chemistry, determined the wavelength. Called a quantum cascade laser (QCL), it contained hundreds of layers of semiconductors of precise thicknesses. Electrons

injected into the structure cascade down hundreds of energy steps, shedding a photon at each one. Those photons were infrared in the first QCL, but in 2002 researchers in Italy and the United Kingdom created QCL lasers that emitted terahertz photons.

Those devices needed to be chilled to 50 K, but last year, researchers led by physicist Jérôme Faist at ETH Zurich unveiled a terahertz QCL made up of hundreds of alternating layers of gallium arsenide and aluminum gallium arsenide (AlGaAs) that works at 210 K. It still required bulky and expensive cryogenic coolers, however.

At higher temperature the electrons become unruly, leaping barriers between layers rather than cascading through the structure one step at a time. “Over-the-barrier electron leakage was the killer,” says Qing Hu, an electrical engineer at the Massachusetts Institute of Technology. So Hu and colleagues added more aluminum to the AlGaAs barriers to better confine the electrons. Hu’s team also had to prevent electrons from interacting in a way that caused them to leak through the AlGaAs barriers.

Now, the researchers have shown that by tailoring the

layered structure even more precisely—some layers were just seven atoms thick—they could make electrons behave at temperatures warm enough to be reached with standard compact thermoelectric coolers. What’s more, Hu says, the same strategy should enable the team to eventually make room temperature terahertz lasers.

Room temperature terahertz sources could be paired with terahertz detectors that also work at room temperature, which Vitiello and other researchers are now developing. That marriage could lead to technologies such as terahertz imagers able to distinguish skin cancer from normal tissue without a biopsy or watch airline passengers and cargo for hidden explosives, illegal drugs, and even pharmaceutical fakes. Faist says: “We have hoped for this for a very long time.” ■



A terahertz laser sits on top of a small cooler.

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