New research by several UK institutions, including Imperial College London in collaboration with Durham University and the University of Sheffield, may offer a ubiquitous, inexpensive way to secure documents based on microscopic surface imperfections.

Naturally occurring randomness in the physical properties of materials provides a means of ascribing a unique “fingerprint” to that material, which can be probed easily using the optical phenomenon of laser speckle. James Buchanan from Imperial College London and his research team examined the fine structure of different surfaces using the diffuse scattering of a focused laser. Speckle, which can hinder other optical techniques used in homeland security applications, is commonly used for determining surface roughness, identifying small deformations on metal, and visualizing blood flow in the medical industry.

By focusing a laser beam across a sheet of standard white paper and continuously recording the reflected intensity from four different angles using photodetectors, the team was able to differentiate the random fluctuations from different types of paper. Similar results were also obtained between other types of material, including plastic credit cards and identity cards. They found that even after the object had been handled roughly, recognition was good. For paper this included screwing it into a tight ball, submerging it in water, scoraching the surface, scribbling over the scanned area with ink, and scrubbing it with an abrasive cleaning pad. Comparing the amplitude of the cross correlation peak, it was possible to determine the probability of two objects sharing indistinguishable fingerprints. For the two different types of paper, the correlation was $10^{-72}$.

With the 200–500 bytes of storage space that each fingerprint provides and the ability to use a low-cost portable laser scanner, researchers hope that this technique will provide a new approach to authentication and tracking, offering a complementary method for existing fraud protection techniques. Indeed, the group has already spun out a company, Ingenia Technology Ltd. (London), to commercialize their findings. Regarding the method’s ability to differentiate between different types of paper, Russell Cowburn, group leader and co-author, explains, “We obtain a unique signature for every note; the paper type is largely irrelevant. We can uniquely differentiate every single dollar bill from every other dollar bill. It works equally well on dollars, euros, and pounds.”

The range of applications for this technique is considered to be vast, including preventing grey-market trafficking of...
Researchers at the Institute of Molecular Science (Okazaki, Japan) have developed a microchip laser using a saturable Q-switch capable of producing 1.7 MW.

Diode-pumped, solid-state lasers (DPSSL), including microchip lasers, have much to recommend them. Not only are they compact and highly efficient, but they also offer a long life compared to flash-lamp pumped, gas and dye lasers. But for the purposes of Takunori Taira’s research, DPSSLs high beam quality and accumulation of energy are perhaps the most significant source characteristics. “Our objective with the project was to increase the pulse brightness in a microchip configuration,” Taira says.

The team picked a passive Q-switched laser because it needs neither high voltage nor high-frequency power supplies, Taira says, making the system safer to handle. In addition, its advantages include compact size, low cost, and portability.

Taira’s team used a diode end-pumped high-brightness Nd³⁺:YAG microchip laser that was passively switched by a Cr⁴⁺:YAG saturable absorber (SA). Taira’s research revealed that SAs do not reach complete saturation; instead, there is a residual loss, which Taira accounts for by assigning $T_o$ to the initial transmission before saturation and $T_f$ to the final transmission when the laser oscillation is completed in the SA.

“In order to investigate the key parameters that determine the characteristics of the laser,” Taira says, “we calculated the rate equations of the passively Q-switched laser. As a result, we found that the pulse energy increases when the reflectivity of the output coupler decreases, when the initial transmission of SA decreases, and when the effective area of the resonator mode at the laser medium increases.”

As noted above, the team started with a diode end-pumped passively Q-switched Nd³⁺:YAG laser. The cavity was formed between the end face of the laser medium—which was a 5-mm-long Nd³⁺:YAG crystal (1.4 at %)—and the output coupler—a flat mirror with 56% reflectivity. The SA was constituted by Cr⁴⁺:YAG crystals with initial transmission $T_o$ of 30%, 65%, and 80%, with a 30-µm Microchip continued on page 8