OPS technology provides new wavelengths that benefit forensics

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Tests at a leading UK crime research lab have shown that newly available yellow (577 nm) and blue (460 nm) multi-watt lasers can find otherwise hidden fingerprints and trace evidence.

OPSLs (optically pumped semiconductor lasers) are the first solid state lasers that can be tailored to produce milliwatt to multiwatt CW output at any arbitrary wavelength in the visible spectrum. This enables a better match with the needs of specific applications than is possible with the limited wavelength selection of conventional laser sources (e.g. 514 nm, 532 nm). This article looks at two new wavelengths that are being introduced to the forensic and crime scene investigation marketplace: a 577 nm yellow laser and a 460 nm blue laser. The advantages of these laser wavelengths have been revealed in a case study at one of the UK’s leading crime research labs.

OPSL technology

In an OPSL, a large area VCSEL (vertical cavity surface emitting laser) is pumped by one or more diodes or diode arrays – see figure 1. The active region is typically made from layers of InGaAs or InGaAsP with varying content of indium, gallium, arsenide and phosphide. The quantum layers are ing content of indium, gallium, arsenide and phosphide. The quantum layers are

to a submount, and the temporary substrate is removed. The output wavelength is determined by the characteristics of the quantum wells in the VCSEL structure and can be optimized for any wavelength in the near-infrared. For example, InGaAs-based OPSLs can emit from 700–1200 nm. Efficient intracavity doubling enables the final output to be set anywhere throughout the visible spectrum, typically 350–600 nm with InGaAs gain region.

OPSLs don’t suffer from so-called green-noise that plagues multi-mode DPSS (diode pumped solid state) lasers. That’s because the VCSELs active medium has a very short upper state lifetime: 5 ns versus 100 µs for Nd:YVO₄. Thus, the mode structure is stable and, therefore, so is the doubling efficiency. As a result, most applications can be well-supported with a simple cavity without etalons using just a birefringent filter (BRF) to narrow the lasing action to a handful of longitudinal modes, lowering implementation and assembly costs. A BRF is a “zero-loss” filter, usually operated at Brewster’s angle, that transmits light in a series of sharp, widely spaced wavelength bands. It consists of a series of alternating layers of polarizing films and plates cut from a birefringent crystal. The transmission bands are smoothly tuned by rotating the BRF around the optical axis.

Advantages and limitations

From an applications viewpoint, the most important benefit of OPS technology is the ability to readily customize it over a wide range of output wavelengths, simply by changing the quantum well structure of the VCSEL. This enables OPSLs to be designed to fit the application instead of vice versa, e.g. in DNA sequencing, confocal microscopy, flow cytometry, ophthalmic procedures, as well as light shows and displays.

Another OPS advantage is the ease of power scaling. A key to this is the lack of thermal lensing in the thin VCSEL, unlike a DPSS laser where thermal lensing in the neodymium-doped laser rod is a major concern. The reason is that the VCSEL structure is thin enough to be efficiently cooled without developing a significant temperature gradient perpendicular to the optical axis. It is cooled from the rear – the principal thermal gradient is therefore front to rear not radial as in a rod.

OPSL technology also benefits from a VCSEL’s broad absorption bandwidth. Unlike crystalline materials such as Nd:YAG or Nd:YVO₄, this substantially relaxes the specification on pump diode wavelength, thus reducing diode cost. Additionally, this eliminates the cost and complexity associated with tight temperature control of the pump diodes, since thermoelectric cooling of the pump diodes is a major component in the total electrical power budget, for example in a DPSS laser.

Finally, OPSLs are simpler to assemble without the manual adjustment typically required when building DPSS and other lasers. Thus, OPSLs lend themselves to automated, robotic production methods with their related economies of scale and high unit-to-unit consistency.
Lasers reveal hidden fingerprints

Lasers have long been known as highly effective sources for examining forensic evidence and for revealing latent (hidden) fingerprints and trace evidence (e.g., bodily fluids) at crime scenes. Here the laser is used primarily to excite fluorescence in the organic component(s) of the print, blood/semens stain or other trace evidence. The laser is typically used via a zoom handpiece that projects a spot of laser light of several centimetres in diameter. The illuminated area is viewed through coloured glass filters that block scattered laser light while passing the Stokes-shifted (longer wavelength) fluorescence light. The superior brightness and monochromaticity of lasers means they produce significantly better results than spectrally-filtered and fibre-coupled incandescent lamps. In these so-called alternative light source (ALS) systems, much of the original lamp output power is wasted due to filtering and fibre-coupling losses.

Prior to OPSLs, this market was serviced by argon ion lasers with blue (488 nm) and green (514 nm) output. But the high capital and operating costs of these lasers, together with their operational complexity, large size, power and cooling requirements, plus their overall weight, limited their use mainly to laboratories at well-funded agencies and larger police departments. This situation improved with the advent of green DPSS forensic lasers emitting at 532 nm. This wavelength is ideal for fingerprints and other evidence treated with DFO (1,8-Diazafluoren-9-one). And these lasers are operationally simpler and more reliable than ion lasers, with simpler power supply and cooling requirements. Yet they proved still too bulky and heavy to support wide-spread field-work, so these lasers were also limited to labs. Moreover, these DPSS lasers were not cost-competitive to ALS systems which therefore continued to dominate the forensic market in spite of delivering inferior results.

The situation finally changed with the advent of affordable, portable, green lasers based on OPSL technology. Emitting at 532 nm, these systems are well suited as forensic tools, being comparatively small and lightweight, and not requiring external water cooling. As a result, a complete 5 W forensic green laser system weighs about 18 kg, only, including the laser head, power supply, umbilical cable and handpiece. Portability is a major advantage in sweeping large areas with limited access. The high electrical efficiency of OPSLs means that they can even be operated from an integrated rechargeable battery.

OPSL technology allows for the design of forensic laser systems for any visible wavelength, not just 514 nm or 532 nm. As a result, Coherent released a yellow (577 nm) and a deep-blue (460 nm) forensic laser (TracER series).

Application within forensics

The Home Office in the United Kingdom is a government department for immigration and passports, drugs policy, counter-terrorism and police (www.homeoffice.gov.uk). Within the Home Office Scientific Development Branch (HOSDB), the Fingerprint & Footwear Forensic (FFF) Group is a lab-based department charged with evaluating and developing techniques for the detection of fingerprints [2] and footwear marks – which are then disseminated to crime labs throughout the UK.

In an FFF Group project managed by Vaughn Sears, the two most recent OPSL wavelengths have been evaluated, comparing these lasers’ performance to both a green laser and a lamp system: Specifically, a 2 W 460 nm laser (deep-blue), a 3 W 577 nm laser (yellow), a 5 W 532 nm laser (green) and a 1000 W incandescent lamp source [1] have been examined. Fifty-six items were randomly chosen for this study, including plastic bags and bottles, glass, plastic and cardboard packaging. These items were then examined for latent fingerprints with all four systems.

While literature may provide the optimum wavelength for fluorescence excitation of pure organic compounds, the problem about fingerprints is that they are extremely complex and varied chemical entities, not just because of the mix of organic chemicals produced by a human body. Surface contact is a two-way street, thus fingers also pick up chemicals from the surfaces touched. It is impossible to predict the chemical composition of a fingerprint, and therefore its optimum visualization technique. Typically, a large number of comparative tests has to be carried out to be certain about a development process.

Table 1 summarizes the results of the FFF group. The new yellow laser performed the best in these tests, visualizing more fingerprints than any other light source in the comparison, and finding eight prints which were not detected by any other source – see figure 2. The green laser found three

<table>
<thead>
<tr>
<th>Items Examined</th>
<th>Yellow Laser (3 W @ 577 nm)</th>
<th>Green Laser (5 W @ 532 nm)</th>
<th>Lamp source (G and G/Y)*</th>
<th>Blue Laser (2 W @ 460 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fingerprints Found</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>Unique Fingerprints Found</td>
<td>20</td>
<td>15</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1: Total number of fingerprints found by each light source, and those detected only by that source (* The incandescent lamp source was used both with the green (1% bandpass 473–548 nm) and green/yellow (1% bandpass 503–587 nm) filter sets supplied by the manufacturer) [1]
unique fingerprints, and while the incandescent lamp source found no unique fingerprints, it did visualize many of the prints seen by the lasers – see figure 3. The yellow laser also proved to be extremely effective at visualizing fingerprints on adhesive tapes treated with Basic Violet 3 (BV3, a non-phenolic version of the gentian violet dye). The FFF group recommends that all adhesive surfaces from serious crimes be treated with BV3 after either being processed with powder suspensions or superglue, since they had found that BV3 will detect extra fingerprints not made visible by other development processes. In addition there are a couple of important issues that must be considered when using these new yellow lasers. For safety and visualization reasons, the operator must wear red goggles, e.g. RG610 Schott or equivalent. Since the human eye is not particularly sensitive to red light, the eyes must be dark adapted for 20–30 minutes, e.g. while searching at shorter wavelengths where the eye is more sensitive. Also, it’s sometimes necessary to manually adjust the f-stop in a digital camera to avoid over-exposed images, because CMOS and CCD sensors are more sensitive to red light. What about the blue 460 nm laser? Although it was the least successful at finding latent fingerprints, it proved an effective wavelength in other FFF tests for visualizing a wider range of forensic evidence, in particular stains and fibres.

**Conclusion**

Optically pumped semiconductor lasers (OPSLs) offer a relatively simple and cost-effective route to compact CW lasers with emission at any visible wavelength and scalable power. They enable to improve applications that were previously limited by the fixed wavelengths of other laser technologies. After the bio-medical instrumentation and entertainment markets, it now appears that forensics will be the next segment to benefit from tailored OPSL specifications beyond green (532 nm) excitation. Independent testing confirms that new OPSL wavelengths can produce unique results, enabling investigators to reveal the full spectrum of latent evidence that is present.

**Literature:**


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**Figure 3:** Some fingerprints can be developed by all these laser sources. This print was on a yellow “post-it” note and was treated with DFO before visualization with (a) ALS illumination, (b) 532 nm laser illumination, and (c) 577 nm laser illumination [1]

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