Fast laser pulses with power VCSEL arrays

Practically speckle-free, nanosecond laser light sources for industrial, research and medical applications

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By combining optimized assembly and packaging technology with integrated drivers accurately defined light pulses can be generated with nanosecond precision using power VCSEL arrays. Unlike the edge emitters commonly used power VCSEL or vertical-cavity surface-emitting laser arrays consist of many hundred to thousand single emitters. They are therefore practically speckle free and can be easily mounted thanks to their special design. Their round beam profile permits simple optics to be used for subsequent beam shaping. As they have a planar structure, as on integrated circuits, with the beam exit perpendicular to the chip's surface, they can be easily mounted on a circuit board. This makes VCSEL arrays a generally interesting prospect for use as fast, pulsed light sources in sensors or as a source of light for 3D cameras.

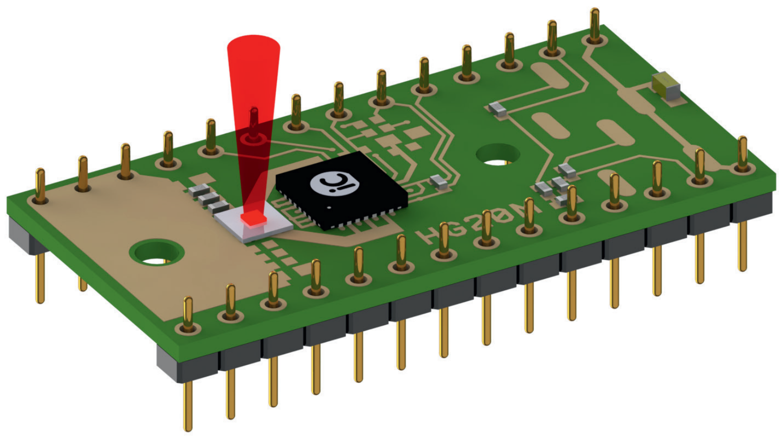

Figure 1: VCSEL array module with an iC-HG driver IC

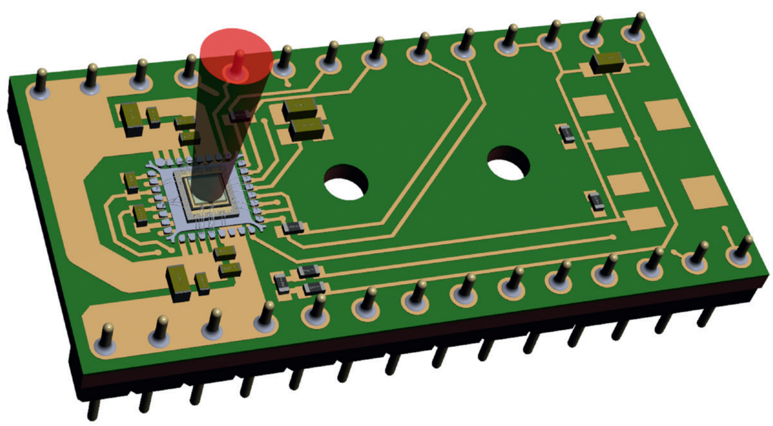

Figure 2: VCSEL array and driver in an optoQFN package (without glob top)

Generating fast nanosecond pulses

Creating driver circuits for short laser pulses with nanosecond precision is a huge challenge for circuit designers and assembly and packaging technology engineers. This applies equally to edge-emitting laser diodes and VCSEL arrays. Fast switching is usually counteracted by the inductance in the laser current path which prevents a correspondingly fast change in current. According to the equation di/dt = u/L (with i current, t time, u switching voltage and L inductance), this can only be achieved with high switching voltages and/or a suitably low inductance in the laser circuit.

To this end, in discrete driver circuits a capacitor with a high voltage of up to 50 V is usually simply charged and then discharged into the laser diode with a fast transistor switch. Here, the energy stored in the capacitor determines the intensity of the light pulse, the shape of which is largely undefined, however.

Integrated driver circuits demonstrate much better switching properties here. Using these, defined pulse currents of almost 10 A can be generated in the single-figure nanosecond range with voltages of 10 V. The lower switching voltage also reduces the level of power dissipation in the driver.

The quality of switch used is critical to the laser diode's lifetime. When switched off, standard transistor switches generate rises in current due to parasitic Miller capacitance which can damage the laser diode or VCSEL array. Integrated circuits permit these increases in current to be practically eliminated.

Compact driver ICs in modern QFN or quad-flat no-lead packages also simplify the board layout and improve heat dissipation. The driver IC can be placed close to the VCSEL array in order to keep the parasitic line inductance as low as possible **(figure 1)**.

The layout of the circuit board is a vital for good heat dissipation and low line

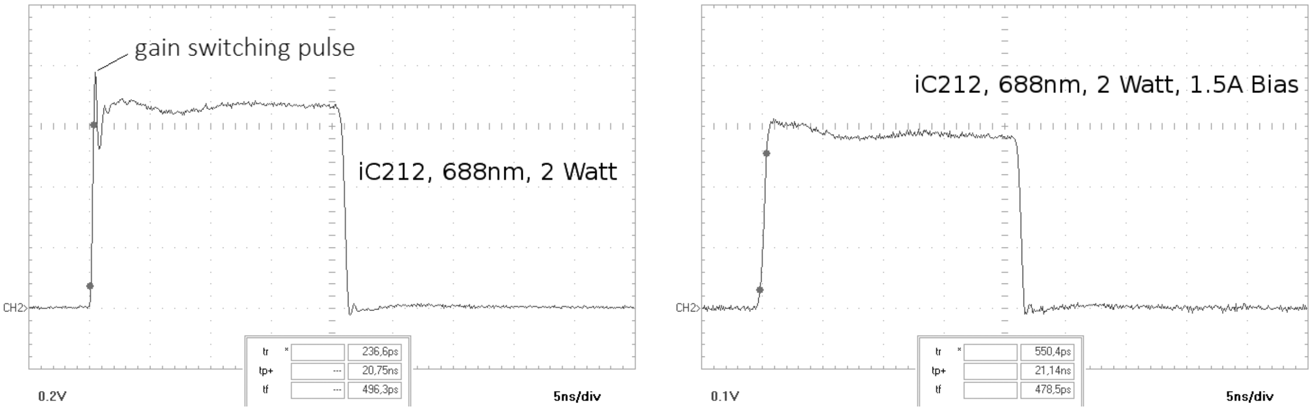

Figure 3: 2 W pulse from 5 V with (right) and without (left) bias current

inductance. Here, through connections known as vias are made between the top and underside for the purpose of heat dissipation. In order to keep the inductance in the laser circuit low on a four-layer circuit board, as many micro-vias as possible must be used in parallel between the different wiring levels. In this manner a driver module as shown in **figure 1** can readily achieve substantial switching speeds using standard components and SMD (surface-mounted device) technology.

Using this setup a heat resistance of approximately 4 K/W from the chip to the underside of the circuit board can be obtained. In this way both VCSEL arrays and driver ICs can be cooled relatively easily. This assembly is thus specially suitable for applications with larger duty cycles (such as 3D camera lighting, for instance).

Chip-on-chip assembly

Further integration is possible with planar VCSEL arrays when these are mounted directly onto a suitably prepared laser driver. This 'sandwich' assembly enables drivers and VCSEL arrays with short bonding wires to be connected both to one another and to the chip substrate. The special driver and VCSEL array can then either be mounted onto a PCB (printed circuit board) using chip-on-board technology or packaged in what's known as an optoQFN housing. Packages such as these are already used in optical sensor integration. **Figure 2** shows a driver module like the above as a sandwich assembly with an integrated iC-HV laser driver and VCSEL array.

iC-HV switches up to 3 A of continuous wave current and 9 A of pulse current spike free at a typical 600 ps. Depending on the VCSEL array, this is equivalent to pulse powers of up to 10 W. Integration results in a compact component with uncritical connections as the switched current paths are connected up within the device. All that has to be fed in are the supply voltage for the driver and VCSEL array, the switching signals and the control voltage to set the current. In doing so the demands made of the circuit board layout are more or less singled down to the need for optimum heat dissipation.

Optimizing nanosecond pulses

Optimum conditions for the generation of pulses with nanosecond precision are created with a VCSEL driver module as represented in figure 2. With this light pulses of 2 W and more can be produced from just 5 V driver voltage at switching speeds of less than 100 ps. Here, the gain switching pulse accelerates the rising edge of the laser light as shown in **Figure 3** on the left.

The familiar gain switching effect in edge-emitting laser diodes also occurs in VCSEL arrays and is produced when the diode or array is switched on. When the laser threshold is exceeded, the charge carriers generated thus far are suddenly discharged and there is a flash of light.

The gain switching effect can be suppressed by injecting a bias current. With a DC current just above the laser threshold the gain switching effect no longer occurs. The right-hand diagram in **figure 3** depicts a pulse such as this [1].

The generated light pulse then closely matches the current curve and thus the actual switching speed of the driver IC. As the line inductance in the driver circuit has been practically eliminated by use of a sandwich assembly, the VCSEL current switching speeds are almost as high as the driver IC chip technology allows. The fast laser pulses in the nanosecond range generated at a supply voltage of just 5 V can be reproduced, their shape independent of the pulse length and height.

Conclusion

Where systematically integrated driver devices are combined with optimized assembly and packaging technology, very fast, easily reproducible and well-defined light pulses with nanosecond precision can be generated using power VCSEL arrays. Compact, practically speckle-free, nanosecond light sources such as these can cover a great number of applications in industry, research and medical technology, such as lights for 3D cameras, light sources for optical sensors and sources of light in endoscopes.

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[1] Design and testing of fast laser driver circuits (iC-Haus White Paper)