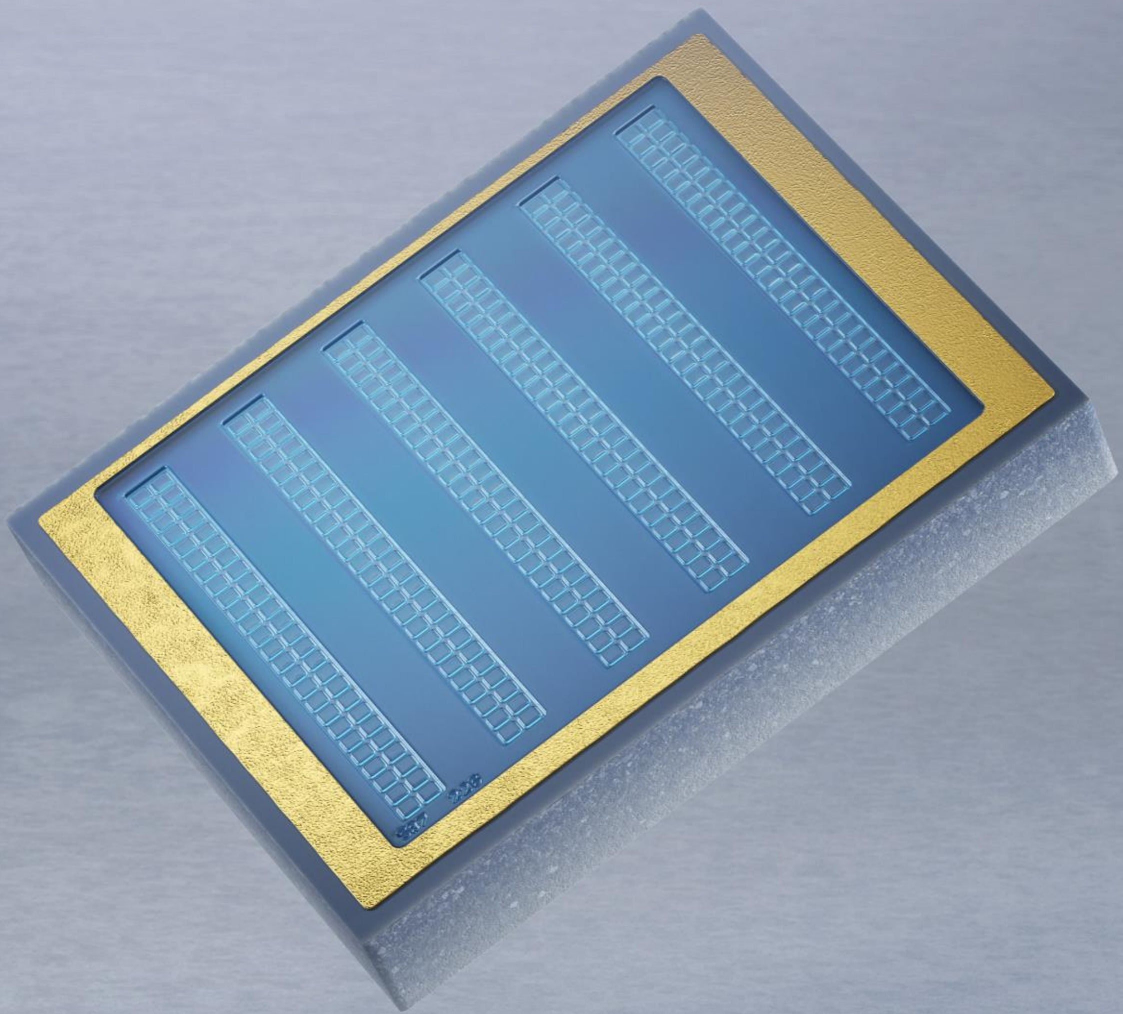

White Paper

Product platform ViBO –
VCSEL with Integrated Backside Optics

Contents

Your contact person for inquiries

Anne-Kathrin Hotz
Marketing Communication Manager

TRUMPF Photonic Components GmbH
Lise-Meinter Straße 13
89081 Ulm
Germany

Phone: +49 731 5501940
E-Mail: photonic.components@trumpf.com

Abstract

The new product platform **ViBO*** revolutionizes the VCSEL technology and offers superior performance as well as cost advantages compared to standard VCSEL devices that are combined with external optics.

The technology behind is that lenses are directly etched into the GaAs substrate. This enables a breakthrough in miniaturization. The monolithically integrated optics on wafer level is irremovable what guarantees life-long laser safety and renounce additional interfaces. Furthermore, the **ViBO** product platform allows tailored illumination profiles: uniform flood illumination is possible as well as multi-spot illumination for consumer or automotive applications such as LiDAR. Addressability of multiple zones on a chip is implemented for enhanced illumination and sensing schemes.

This Whitepaper is explaining the new, unique and leading-edge technology platform of **ViBO** by giving some insights, that are highlighting its performance.

**ViBO stand for VCSEL with integrated Backside Optics*

How VCSELs are used today

Standard VCSEL top emitters:

VCSELs are the ideal source for infrared illumination in 3D sensing. They have a narrow and stable spectrum, perform from -40°C up to more than 125°C and allow very fast switching. Short pulses enable high resolution 3D distance maps.

Applications range from user-facing cameras in smartphones, over world-facing systems in phones, tablets and robots, up to the high-power levels needed in automotive and industrial heating processes.

Bare VCSEL chips are fitted towards the application needs by packaging them with optics, connections and safety means. The optics transforms the genuine beam of the VCSEL into the desired illumination pattern for the scene. Correct and properly assembled optics are a must have to ensure eye-safety.

The volume of such packages is much larger than the original VCSEL chip. The initial advantage of wafer-level production and testing is relativized by assembly and additional interfaces. Today‘s VCSELs in a separate package do not yet exploit the full potential of the semiconductor production technology.

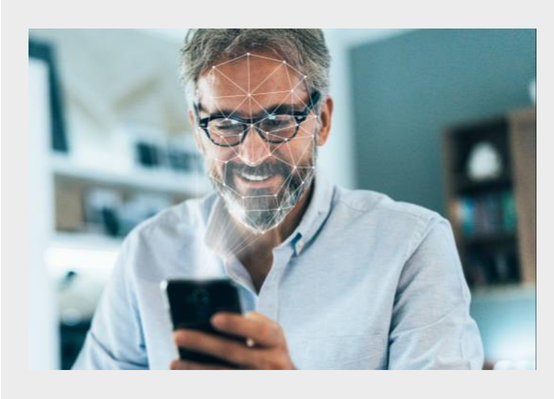

Figure 1: Application of VCSEL in a smartphone

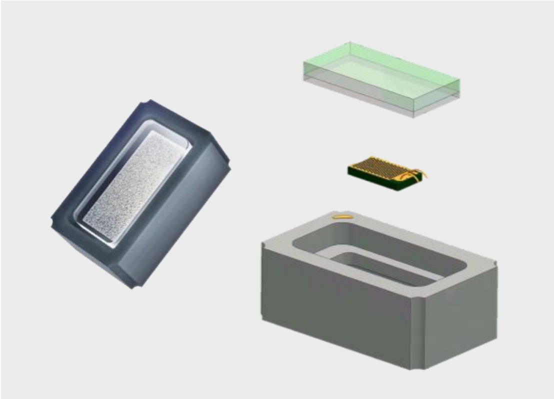

Figure 2: State of the art VCSEL package assembled with components

Principle of ViBO

The challenge

The target is to reduce the footprint and to get very small and compact components that allow way more freedom in design when integrating them for example in consumer devices. Furthermore, the elimination of additional interfaces compared to packaged solutions is considered by optimizing the VCSEL design.

Idea of ViBO

The **ViBO** technology is based on the idea to integrate all the functions, provided nowadays by an extra package, directly into the VCSEL chip.

The principle of ViBO

A first step is to flip the direction of the light emission, no longer out of the surface of the chip, where all the processing and contacting happens, but through the backside of the substrate. Rather than being just a mechanical interface this backside can now be valuable: lenses are directly etched into the GaAs, providing an optical function. And these lenses enabling extraordinary freedom of design for every optical designer. The high refractive index of n=3.5 allows much more freedom than the usual 1.5-2 of plastic and glass.

The processed surface of the chip no longer has to spare out regions where the light comes out. The full surface is available for electrical, thermal and mechanical functions thus optimizing heat removal and electrical contacts. These contacts can be made large, enabling direct soldering of the chips on electronic boards. Or the contacts can be realized as slim copper pillars. A large number of such contacts enables individual addressability and therefore new functionality of the VCSEL chip.

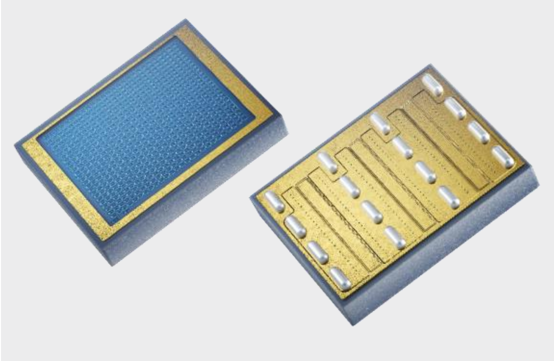

Figure 3: Left: ViBO optics side Right: ViBO contact side for easy SMD mounting to the board or driver

Principle of ViBO

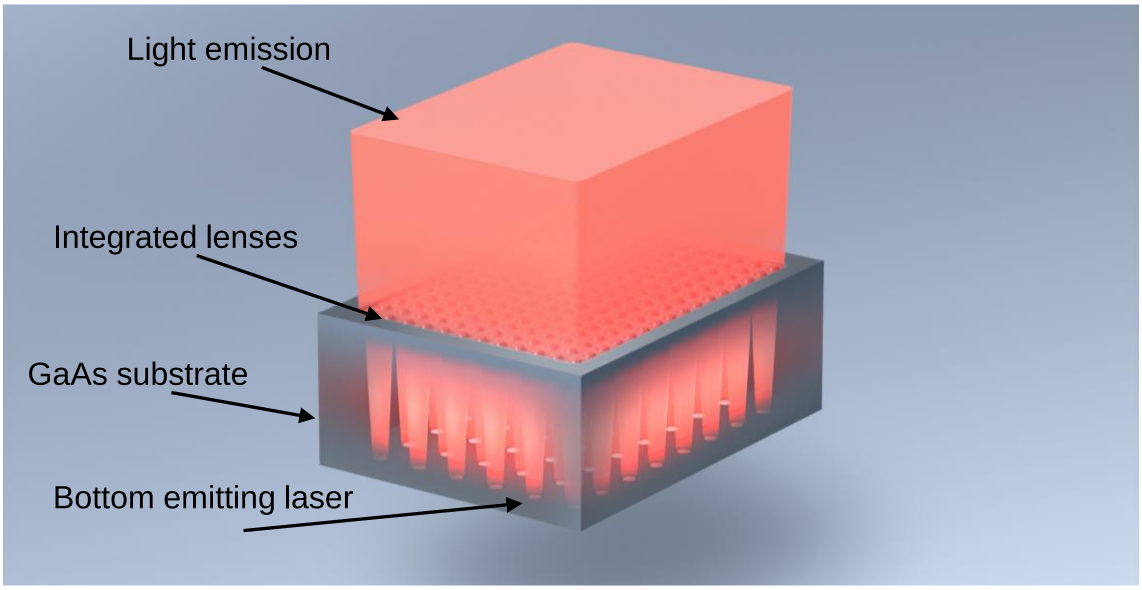

Figure 4:
ViBO principle:
A VCSEL array at the bottom of the chip emits through the substrate. Lenses on top of the substrate are used to shape the beam.

Benefits of ViBO

In the first place the **ViBO** chip offers the same functionality than the VCSEL in a packaged solution. But on the same hand **ViBO** offers benefits, which can revolutionize smart sensing systems due to the following unique aspects:

- The footprint of **ViBO** is 5 – 10 times smaller and in addition the height is reduced by a similar factor. The several mm thick package is replaced by an only 150 µm thick chip. Miniaturization is key in consumer electronics like smartphones. And therefore, the design of the entire sensing system becomes easier with smaller **ViBO** components.
- An inherently eye-safe system during the product lifetime is enabled due to optics being an irremovable part of the chip. No more worries about safety hazards by delaminating or malfunctioning optics.
- The GaAs optics is more powerful, enabling new designs with better efficiency.
- New functionalities are possible, as more contacts are on the chip, enabling addressable segments. These contacts are underneath the surface, so the footprint remains small.
- Longer product lifetime, as additional interfaces are eliminated. No more unreliable glue interfaces that could cause problems during product lifetime.
- The **ViBO** chip is designed very similar to high performance microelectronics. It integrates seamlessly with CMOS electronics.

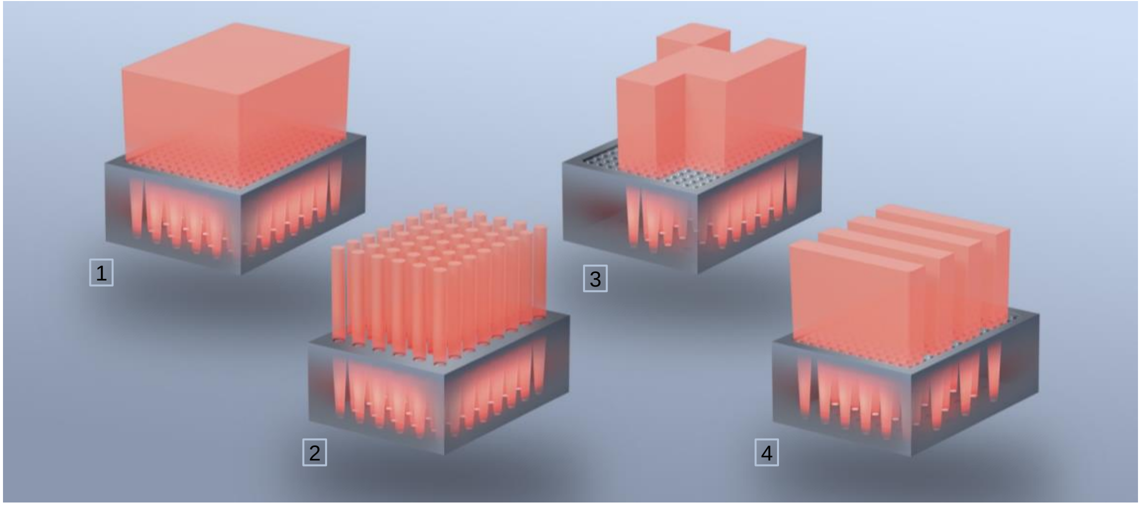

Figure 5:
With ViBO advanced illumination profiles can be generated, such as
1: flood
2: spot
3: individual field of interest
4: addressable lines

Technology of ViBO

ViBO technology is based on well established mass manufacturing processes in the semiconductor industry. The lens pattern is defined with grey-tone lithography using a wafer stepper. The high accuracy of this approach enables millions of lenses to be aligned on wafer level rather than in subsequent production steps.

Figure 6 shows a regular lens pattern designed for a uniform illumination of a field of view on a scene. No further optics are needed. Illumination fields can be narrow as e.g. 20x20° or all the way up to angles >100°. The intensity distribution within such field can be tailored by the shape of the lenses. E.g. more light can be directed towards the notoriously dark corners.

Bonding with copper pillars is common in the semiconductor industry, see for instance the densely packed connections of a microprocessor. **ViBO** uses a similar approach as illustrated in Figure 7. On top of the copper pillar there is a solder depot, facilitating the assembly of the chip on e.g. ceramic or silicon interposers and drivers. Fine pitch patterns support designs with many addressable zones. The shape of the pillar can be adjusted to the specific needs as the pattern is defined by lithography.

Zones on the chip can be addressed individually. Figure 8 shows an electron microscope picture of the chip during processing. Many individual VCSELs are grouped into a zone to provide the desired level of power. Theoretically even individual VCSELs could be addressed, although the amount of contacts might not be practical.

The arrangement of the VCSELs and the contacts is independent and may overlap. This gives more freedom for specific, e.g. interlaced, addressing schemes. For the electronic designer it may be interesting to note that both contacts are available for addressing, e.g. a common anode can be used in the driver. This helps to reduce driver size and power consumption. Especially in applications with short pulses at high current the driver takes a significant part of the budgets: size, cost and heat.

Flip-chip assembly back to back to the driver allows the shortest connection between the two. This is essential to reduce system impedance and to enable shortest rise and fall times.

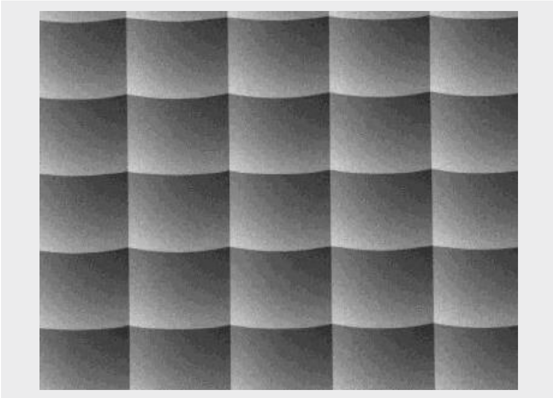

Figure 6: Electron microscope picture of lenses etched into GaAs

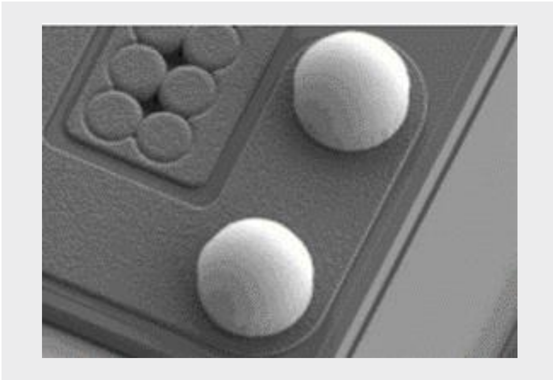

Figure 7: Copper pillars with solder bumps next to the VCSELs

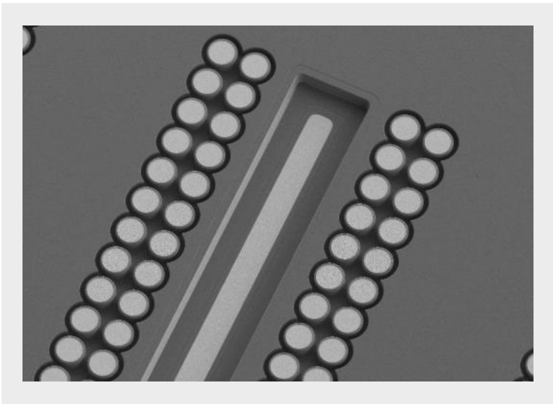

Figure 8: VCSEL chip with individually addressable zones (during processing i.e. not the final chip)

ViBO Use Cases

VCSELs with separate optics mounted in a package (see figure 2) are used to illuminate the field of view of the 3D camera in a smartphone. The optics spreads out the light („diffusor") towards the edges and is a mandatory part to comply with Laser Safety Class 1.

ViBO does not only replace the complete package, but it also allows a much better shaping of the light distribution, for example high irradiation level up to the corners and minimum light outside (see technical background paragraph).

Figure 9 shows a typical distribution with a significantly higher efficiency than possible with separate diffusor elements. **ViBO** provides inherent laser safety. Unlike separate optics it cannot be removed or rendered inefficient. Even wetting with liquids or glue does not destroy the effect of the GaAs lenses thanks to their high refractive index.

Uniform illumination of the scene is great, but sometimes the action happens only in the center. In this case **ViBO** allows to address individual parts of the VCSEL chip, thus illuminating individual zones on the scene and switching off what is not needed (figure 10). **ViBO** is not only optically more efficient but helps to safe scarce battery power and keep the total system cool.

ViBO with addressable zones can also replace mechanical beam scanners which are used in automotive LiDAR (the huge dome on top of the autonomous car). Figure 11 illustrates the principle and shows a demo chip. **ViBO** works all solid state without any moving parts. It is more compact and more reliable. Larger LiDAR systems for longer range may comprise several **ViBO** chips for increased power and resolution.

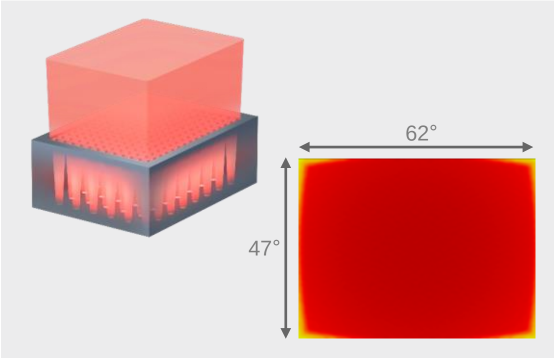

Figure 9: Light distribution on a typical field of view in a smartphone application. 88% of the total light output are inside the box.

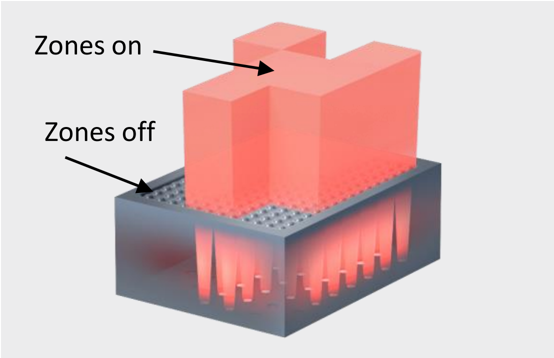

Figure 10: Addressable pattern with only zones of interest

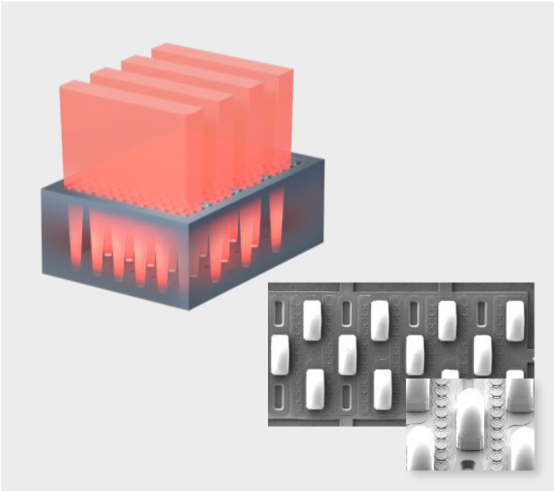

Figure 11: Scanning line system made with an addressable stripe pattern. The electron microscope pictures show details of the contact side of the chip.

Conclusion

ViBO simplifies the way VCSELs are used. With the new product platform, 3D sensing systems can be safer, more compact and more cost-efficient. **ViBO** will replace assembled VCSEL modules and expand the application scope of VCSELs with new possibilities.

Planar integration and the use of lithographic methods as well as fine pitch connectors bring VCSEL production closer to mainstream semiconductors made of silicon.

ViBO takes care of the light generation, silicon serves as sensor and electronic driver. These developments fuel the growth in VCSELs in the smartphone and in automotive applications.

You can find more information about the ViBO product platform at www.trumpf.com/s/vibo

Acknowledgement
This work has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 826600. The JU receives support from the European Union's Horizon 2020 research and innovation programme of France, Sweden, Greece, Spain, United Kingdom, Germany, Luxembourg, Latvia, Hungary.

TRUMPF Photonic Components GmbH
Lise-Meitner-Straße 13, 89081 Ulm, Germany
Publ. 11/2021