Blue Laser Diodes
One milestone closer to mobile laser scanning projection

The story of GaN-lasers started in 1995 with first demonstration of laser operation in the near UV. In 2000 the commercialization started with laser for optical data storage and Blu-ray Disc with emission wavelength of 405 nm. It took another several years to come from a 405 nm near UV emission spectrum to today’s 450 nm. The technological challenges for true blue 450 nm GaN laser diodes are based on the MOVPE-growth of In-rich InGaN-Quantum wells with high material quality and optimized AlGaN wave guiding layer designs with adopted strain management. With only 3.2 mm height an optimized TO-38 Icut assembly meets the demands for an ultra compact package in embedded laser scanning projection systems.

A blue semiconductor laser diode with an emission wavelength of 450 nm opens up a fully new area of projection applications that was not accessible before.

Laser Based Mobile Projection Systems

With feature rich phones capable of recording and handling of high resolution content like pictures and movies there is the need of a high resolution display. Since the size of the mobile device (Figure 1) is limited the most promising solution is a projector, either as attachable device (companion projector) or directly integrated into the mobile device itself (embedded projector).

The projector can be realized either by traditional micro-display technology or laser scanning technology. If a traditional micro-display approach is used, the imager is sequentially illuminated by three LEDs or low beam quality laser sources and the monochromatic picture (color by color) is projected through an optical system (Figure 2). Although the image quality is good it comes with lower system efficiency, complex optics for homogeneous illumination and a trade off between resolution and overall projector size. Since form factor and system efficiency are the most critical factors for mobile projectors the scanning beam technology seems to be the approach of choice. But it also puts specific requirements on the lasers with regards to perfect beam quality and high modulation rate of 10 to 100 MHz.

A laser scanning projector is a projector that modulates a laser beam in order to project a raster-based image. The system works by scanning the entire picture a pixel at a time and modulating the laser directly at high frequency, much like the electron beams in a cathode ray tube. The scanning itself is done by a small MEMS technology based mirror. When correctly implemented, this technology produces the broadest practical color gamut available in display equipment today due to the fact that lasers produce truly monochromatic primary colors. It also provides the best possible contrast ratio since the laser is turned off at pixels with no light. Due to the fact, that a laser scanning projector does not need any projection optics it has a virtually indefinite depth of focus, which is especially for mobile projectors a key advantage when no fixed projection screen is readily available.

Blue laser diodes that are suitable for that type of application must fulfill certain requirements. Primarily for good visibility the wavelength range needs to be in the range of 450 nm with an output power of roughly 50 mW, depending on the design of the projector. The size of the package needs to be as small as possible without compromising its ability to provide proper thermal conductiv-
A modified TO-38 package, with a height of only 3.2 mm seems to be the best fit today. It provides the smallest possible form factor with a thermal resistance close to a standard TO-56 package. A low threshold, a high slope efficiency and a low forward voltage contribute to the lasers efficiency and its suitability to work in a battery powered environment. Important is, that the laser has an outstanding beam quality in order to project nicely shaped pixels and to allow the use of only small collimation optics.

Head-Up Displays

Another family of projection applications, where lasers provide a revolutionary approach are head-up displays, or HUDs (Figure 3). They can be helmet mounted displays and windshield mounted displays and are of increasing importance in both aerospace and automotive environments. The term „HUD“ refers to a display which superimposes visual information (usually data, but may also be natural scenes) on the normal ambient scene.

The first application for HUDs was in avionics setting, where head-up displays present valuable information to pilots by superposing virtual images of data information over the pilot’s normal field of vision, usually focused at infinity. The flight parameters of the aircraft, navigational displays or any other relevant information may be viewed without the pilot moving his/her head or changing the focusing distance, thereby generally improving flight performance and safety. Today HUDs are also finding increased usage within the car industry, with windshield displays becoming popular in many vehicles.

HUD systems that are currently used in vehicles have a several disadvantage. They lack high light efficiency, do not provide high contrast and therefore can not project haze-free images. With its genuine high contrast and high system efficiency a laser scanning system has the potential to provide improvements in all these areas. Additionally a scanning system is able to more easily electronically pre-warp the projected picture, eliminating complex projection optics. The laser performance requirements are identical to requirements for mobile projection systems. Lifetime and temperature requirements may be increased though.

Industrial and Bio/Medical Applications

Blue semiconductor laser diodes are suitable for a wide range of industrial and bio/medical applications. They can be either used as direct light source or according to the instrument’s requirements integrated into modules that provide further stabilization or control. Applications range from confocal microscopes over particle size measurement to flow cytometry or cell sorting.

Flow cytometry is an application where the blue laser diode’s 450 nm wavelength and 50 mW output is a good fit. The very narrow spectral light is used to point on a focused stream of fluid. Cells in the stream either scatter the light or when marked with particular dyes emit light with a different wavelength. When recording scatter data and fluorescence signals simultaneously, biologists receive comprehensive information about their examined specimen. Shape, size and type of cell are analyzed automatically. Detection limits are very low, even sub-micron-sized particles with just a few attached dyes can be recognized in modern systems.

Lasers and mercury or xenon lamps are commonly used light sources in today’s flow cytometers. Arc lamps are less expensive than lasers. They exploit the color emissions of an ignited gas within a sealed tube. However, this produces unstable incoherent light of a mixture of wavelengths that needs subsequent optical filtering. On the other hand lasers emit already coherent and narrow spectral light. A 450 nm laser diode additionally removes the hassle of dealing with traditional solid state lasers like output stability and temperature control.

Technology of blue laser

Mobile laser scanning projection applications have specific requirements to the blue laser diodes. Although the requirements like wavelength, beam quality, low threshold and high slope efficiency are directly related to the design of the laser chip itself only the first two will be explained here in more detail.
The laser diodes are based on the (Al-Ga)N-III-V-material system using MOVPE epitaxial growth of thin layers on GaN substrates with low defect density. Since the start of InGaN laser diode development in the 1990s, the wavelength could be continuously shifted towards longer wavelengths. By increasing the indium content in the InGaN/GaN quantum wells (light generating active layers within the chip) and by optimizing the epitaxial structure today's 450 nm could be reached.

For an almost perfect beam quality the laser light generated within the chip needs to be confined within a vertical and horizontal wave guide structure. Horizontally this is achieved by using the Ridge Waveguide Technology (RWG). For a gaussian beam shape the TEM00 mode needs optimized lateral wave guiding and sufficient suppression of higher order modes. This is realized by etching of a narrow ridge into the upper epitaxial layer of the chip with typical ridge widths of 2 µm and the use of the appropriate insulating surrounding material with lower refractive index as the semiconductor material itself (see Figure 4).

For vertical wave guiding the epitaxial structure design is based on AlGaN-cladding layers around the light generating active InGaN/GaN-based layers. Due to the lower refractive index of the surrounding AlGaN-cladding material relative to the InGaN/GaN-material the optical wave is perfectly guided within the cladding layers.

Conclusion

The blue InGaN-RWG-Laser in an ultra compact TO-38 i-cut package is perfect for laser scanning projection. It represents the next milestone in the evolution of mobile devices with integrated projection modules. Users will appreciate the extremely low power requirements and compact dimensions offered by laser scanning projection units. This will permit manufacturers of mobile phones, e.g. to incorporate micro-projector capability without sacrificing the slim and compact form factor their customers expect.