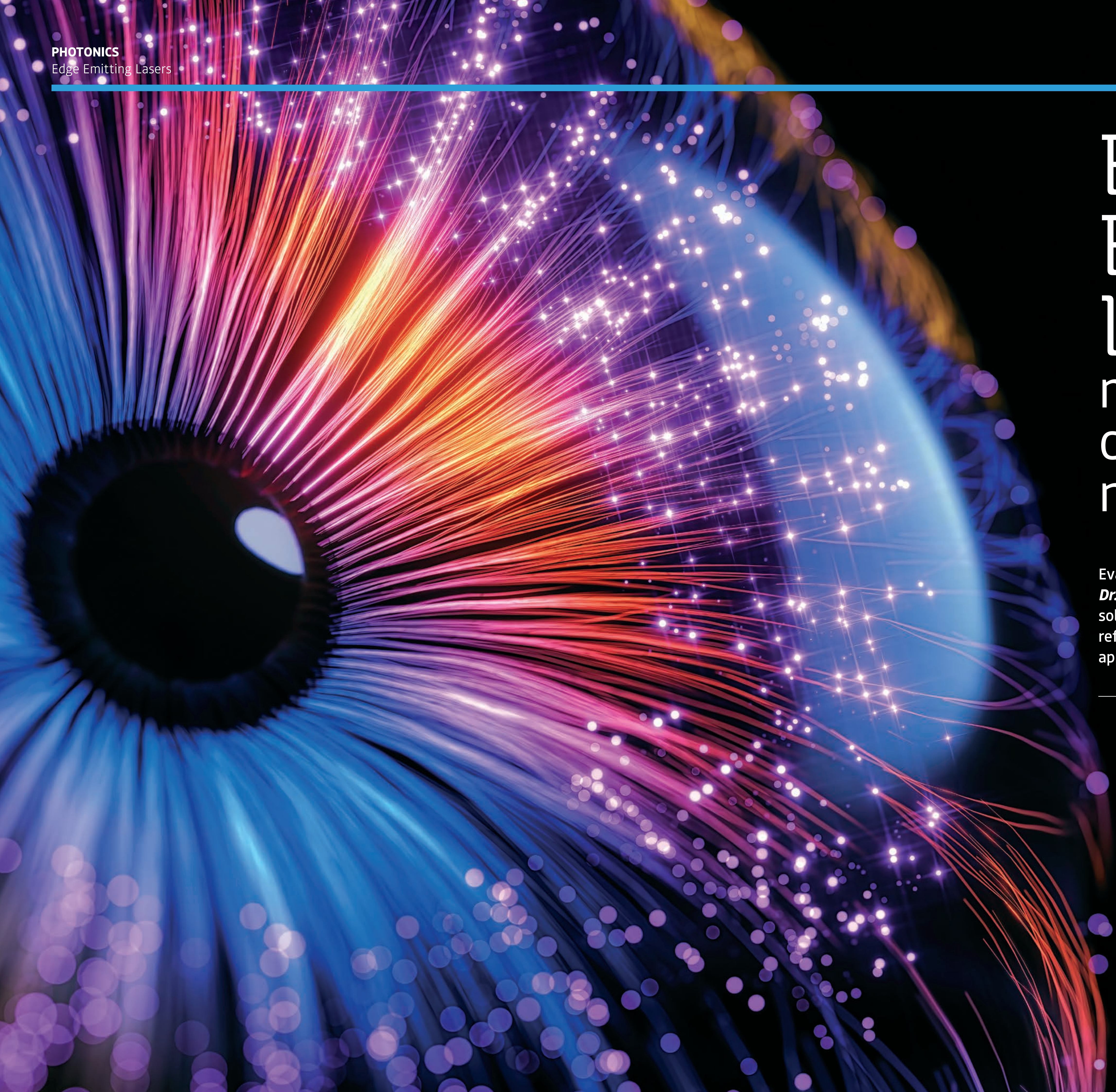

EDGE EMITTING LASERS – manufacturing challenges for new markets

Evatec's Senior Product Marketing Manager, ***Dr. Clau Maissen***, talks about production solutions for the antireflection and high reflectivity coatings needed in emerging applications for Edge Emitting Lasers (EELs).

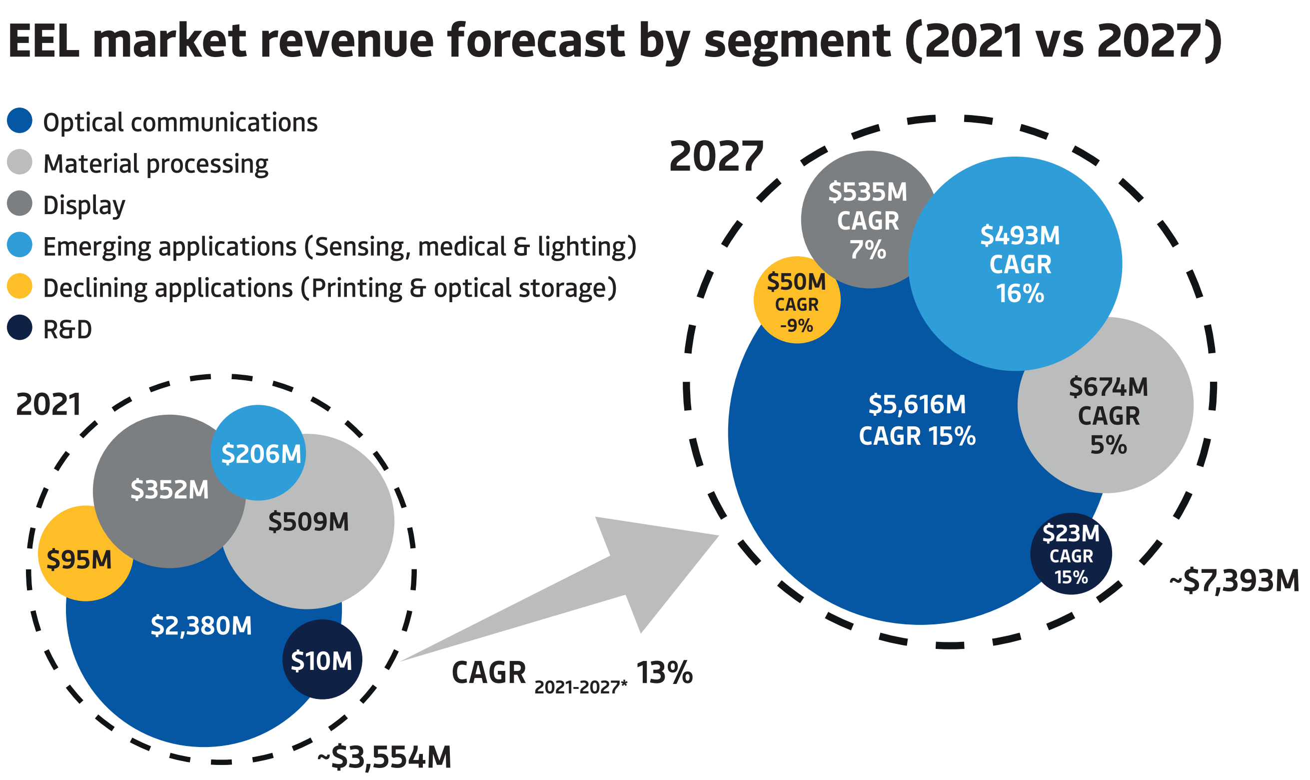

Figure 1: Expected growth of EEL market. Source Edge Emitting Lasers report, Yole Intelligence, 2022

New opportunities in optical communication

With long established applications including optical data storage and material processing, the market for laser diodes may not be new, but opportunities in growth areas like new optical communication applications and autonomous driving are setting manufacturers challenges in delivering effective thin film manufacturing solutions for new diode materials and at much larger volumes (see Figure 1).

How are thin film coatings used?

Figure 2 shows the typical construction of an edge emitting laser where light output from the active region must be maximised using antireflection coatings at the front side, while unwanted output / losses from the backside must be minimised by use of a high performance mirror.

Coatings designs and deposition processes for the required antireflection and high reflectivity layers must be optimised according to laser diode materials and emission wavelengths. Besides the spectral requirements, avoiding damage to the sensitive laser device is key for long device lifetimes as required in optical communication applications. Some example laser diode material combinations and corresponding output wavelength ranges are shown in Figure 3. Applications in optical communication use mainly 1.3µm and wavelengths around 1.55µm to match the low-loss window of silica optical fibers and are built on Indium Phosphide or InGaAs.

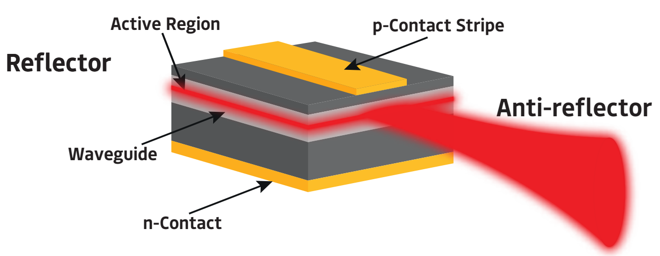

Figure 2: Schematic of an edge emitting laser diode

Optical communications –

Laser diode material (active region / substrate)	Typical emission wavelengths	Typical application
InGaN / GaN, SiC	380, 405, 450, 470 nm	Data storage
AlGalnP / GaAs	635, 650, 670 nm	Laser pointers, DVD players
AlGaAs / GaAs	720-850 nm	CD players, laser printers, pumping solid-state lasers
InGaAs / GaAs	900-1100 nm	Pumping EDFAs and other fiber amplifiers; high-power VECSELs
InGaAsP / InP	1000-1650 nm	Optical fiber communications

Figure 3: Most commonly used laser diode materials

Coating quality and repeatability is key

Laser manufacturing uses complex semiconductor processes for the active light producing layers. For the final laser diode performance the active layers are crucial but no less important are the passive films like high reflector mirror (HR), antireflection (AR) coating or metallization layers.

In a typical manufacturing approach for laser diodes the HR and AR facet coatings are applied before final dicing into individual lasers. These so-called laser bars are stripes of lasers arranged side by side (Figure 4). Multiple laser bars are bundled into special jigs for deposition of the AR and HR films. Vacuum flipping allows us to coat the AR as well as the HR in a single batch without breaking the vacuum. Maintaining consistency of coating quality across all diodes within a single bar, all bars within a coating batch, and then from "batch to batch" is essential.

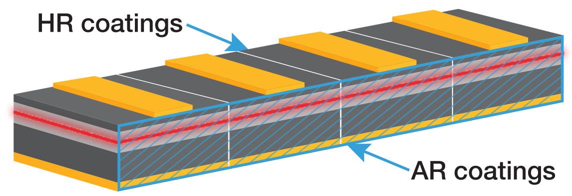

Figure 4: Schematic view of the semiconductor chip of a diode laser bar

Some of the typical coating specifications to consider along with example results for sputter coatings performed on Evatec's CLUSTERLINE® 200 BPM are illustrated below.

1. Optical performance

Laser diodes are being used in optical communication applications in which ever greater distances and higher data rates are required so coating specifications are more demanding. For the diode output for example, antireflection coating specifications may call for levels of reflectivity less than 0.03% over the target wavelength range. Figure 5 shows the performance of an AR coating on InP against customer specifications.

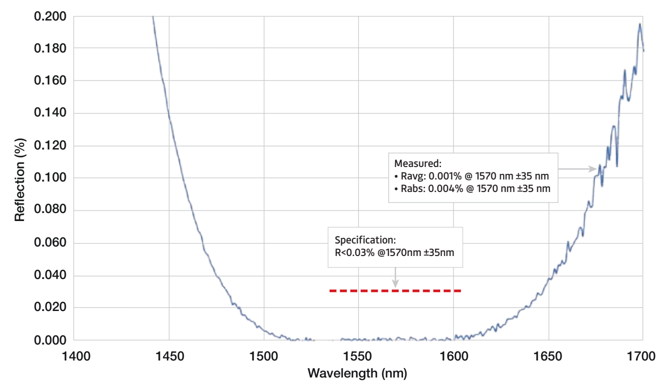

Figure 5: Optical performance of an AR coating on InP

2. Process stability

Such high levels of optical performance are only effective when process stability can be maintained. Figure 6 shows the typical stability levels batch to batch (11 runs in a row) on InP specified for 1270nm. Figure 7 illustrates the stability of coating process from edge to center of coating jigs.

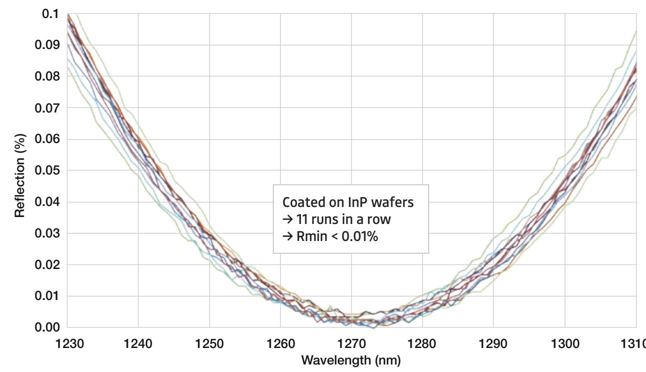

Figure 6: Process repeatability for an AR coating centered at 1270nm

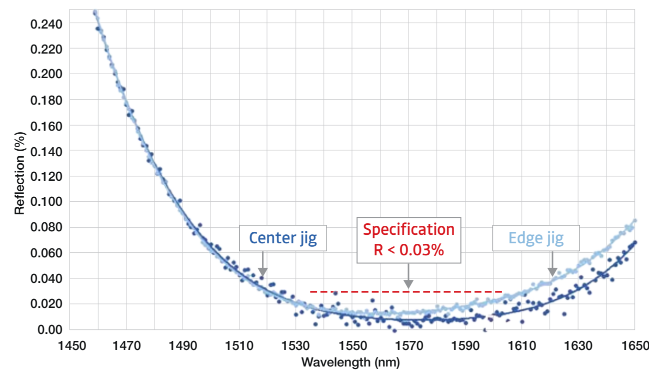

Figure 7: Stability of coating process designed for 1570nm for jigs placed on the center or at the edge of an 8 inch carrier

3. Laser Induced Damage Threshold

ISO 21254-1:2011 defines the Laser induced Damage Thresholds as "the highest quantity of laser radiation incident upon the optical component / material for which the extrapolated probability of damage is zero". But it's a complex parameter to understand with many detailed studies available in the literature to shed light on damage mechanisms. In general however, threshold values reflect, not only the inherent nature of the material itself, but also the "quality" of the deposited coating with influences from both micro or nano defects within a coating (e.g. voids, inclusions) and from coating interface effects (e.g. surface roughness, particles. Figure 8 show the value for a single layer coating of a typical material like SiO_2 measured on Herasil according to ISO norms.

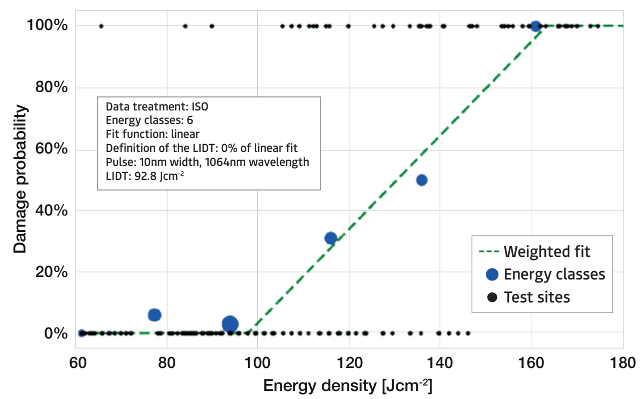

Figure 8: SiO_2 damage probability curve at

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4. Environmental stability

Testing after exposure to depressed or elevated temperatures and higher humidity levels is an accelerated way to predict any deterioration in component performance over product lifetime. Figures 9a and 9b illustrates how layer reflectivity varied against its nominal value with time for typical test parameters in temperature and humidity cycle testing tests respectively.

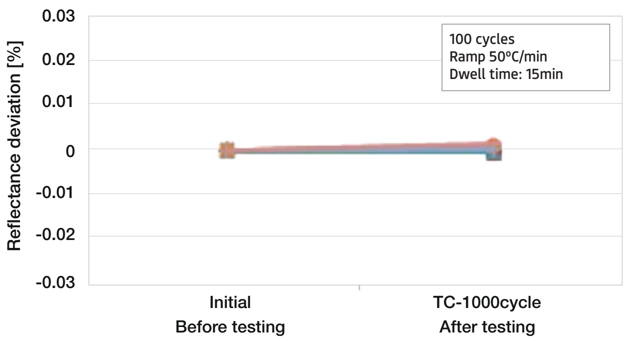


Figure 9a: Temperature cycle test -60°C to 140°C

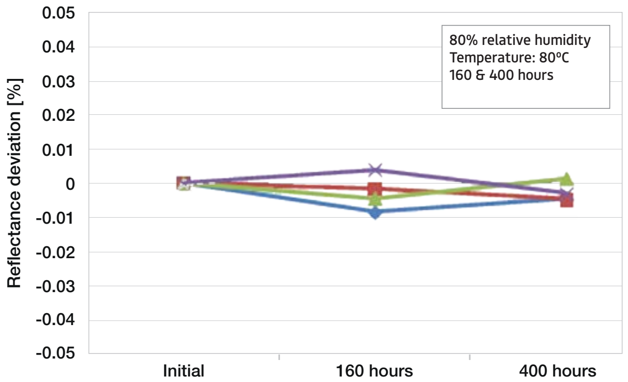


Figure 9b: High temperature, high humidity test

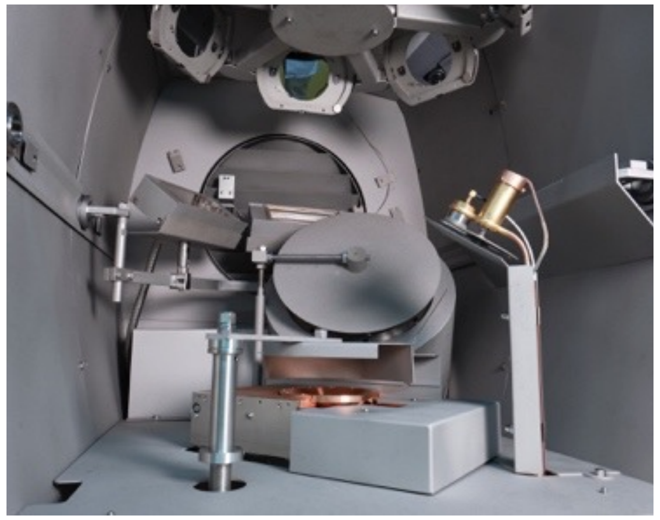


Figure 10: Typical BAK configured with "Flexcalotte"
- ARs
- Reflectors
- Metals

Finding the right production solution

Every manufacturer is unique with their own product specifications and manufacturing fab integration needs. In addition to the antireflection coatings discussed here, there will be metal contact coatings and passivation layers to consider too.

For some manufacturers evaporation technology is the preferred route for deposition of metals, ARs and reflectors. Available in standard and "lift off" configurations, Evatec's BAK family enables integration of the electron beam and plasma sources and custom jig tooling required including flip capability. Solutions like Evatec's "Flexcalotte" (Figure 10) with simultaneous substrate rotation in multiple axes offer the possibility for coating of 3 dimensional mesastructures (Figures 11a & 11b). For others, the way in which sputter lends itself to full cassette to cassette automation more easily is the driver for delivering the lower manufacturing costs they need as volumes ramp up. Process solutions for deposition of metals, reflectors, ARs and passivation layers are also available across products in the CLUSTERLINE® family as seen in Figures 12a & 12b. ◻

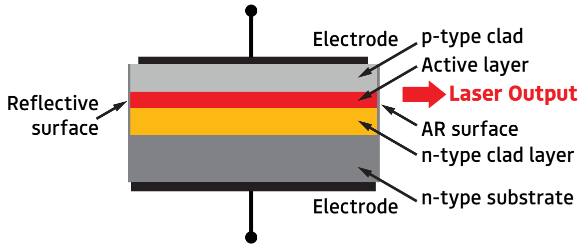


Figure 11a: Typical EEL cross section showing stack construction

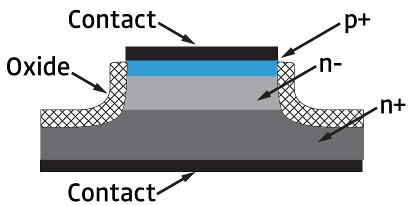
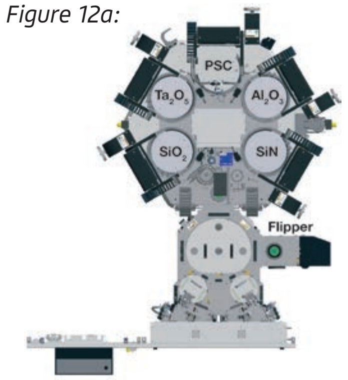


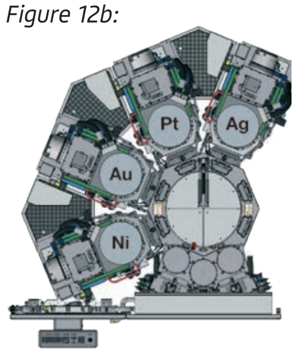
Figure 11b: Typical 3D mesa structures in some EEL

Figure 12a:



CLUSTERLINE® 200 BPM
- ARs
- Reflectors

Figure 12b:



CLUSTERLINE® 200
- Metals
- Passivation

CLUSTERLINE® 200 BPM –
When you need 100 million lasers per year

10 lasers per bar	**24/7** Hours per week	**10** Lasersbars per jig
6 Carriers / hour	**20** Jigs / carrier	**100M** lasers per year on one CLUSTERLINE® 200 BPM

Want to know more?

If you would like to know more about evaporation or sputter solutions for Edge Emitting Lasers or any of the results presented here please contact your local Evatec Sales and Service or complete our web enquiry form at **www.evatecnet.com/about-us/contact-us/**