



DOI:10.29013/AJT-26-3.4-234-238



MODULAR INTEGRATION SOLUTIONS FOR ELECTRONIC SYSTEMS. (Electronic system modules, including laser diode components, featuring an intensive cooling system utilizing diamond – copper composite materials)

Prykhodko Ostap Volodymyrovych¹

¹ Director of LLC “Ukrainian Holding of Construction Projects” Kyiv, Ukraine

Cite: Prykhodko O.V. (2026). *Modular Integration Solutions for Electronic Systems. (Electronic system modules, including laser diode components, featuring an intensive cooling system utilizing diamond - copper composite materials). Austrian Journal of Technical and Natural Sciences 2026, No 3 – 4.* <https://doi.org/10.29013/AJT-26-3.4-234-238>

Abstract

This article examines one of the key engineering challenges of modern electronics – the provision of reliable and efficient thermal management in the development of complex electronic devices, particularly those incorporating laser diodes and high-intensity lighting components. The critical importance of effective heat dissipation for maintaining operational stability, extending service life, and preserving the performance characteristics of thermally sensitive electronic and optoelectronic systems is emphasized. Particular attention is devoted to the analysis and substantiation of integrative technical solutions aimed at improving cooling efficiency while minimizing energy losses and eliminating the need for additional structural cooling elements or separate energy-consuming thermal regulation systems. The article investigates modern approaches to passive and integrative heat dissipation, including structural and material-based solutions that ensure effective thermal conductivity and heat removal directly through the functional architecture of the device. It is demonstrated that the implementation of advanced integrative cooling solutions significantly improves thermal regulation efficiency, reduces structural system complexity, minimizes parasitic energy consumption, and enhances the overall energy efficiency of high-performance electronic and lighting devices. The article concludes that the development and integration of innovative thermal management architectures constitute a strategically important direction in the advancement of next-generation electronic and optoelectronic systems, particularly for applications requiring high power density, compact design, and enhanced energy efficiency.

Keywords: *Integrative modules, Electronic systems, Laser diodes, Optical power, Diamond spheres, Ductile material, Composite material, Pseudo-porous structure, Optical cable, Laser radiation, Flat-emitter lamp*

Introduction:

In order to eliminate energy losses and increase output efficiency, particularly in various lighting systems, there is an active search for integrative technical solutions that enable performance improvement without the use of additional structural elements or additional energy consumption for cooling.

In parallel, research and development efforts are focused on identifying and refining technical solutions that, through a concise and simplified design, allow for an increase in the output optical power of lighting devices while maintaining relatively low power input and, consequently, low energy consumption.

The author of this publication considers the most effective approach to be comprehensive integrative solutions, as presented in the scientific and technological publications and books of Oleksandr Sylyaiev, a recognized innovator in this field.

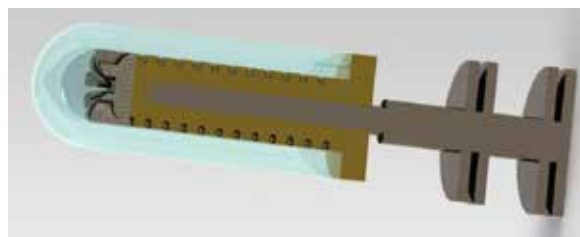
What fundamentally distinguishes Oleksandr Sylyaiev's proposals and developments from those of other authors is the extensive platform for experimental computer modeling, made possible by his broad and in-depth expertise in system-based and combinatorial modeling methods applied across related innovative processes, including at the intersections of fundamental scientific disciplines.

In analyzing the innovative technologies presented in his publications, Oleksandr Sylyaiev advances a critically important concept for addressing the problem: the combinatorial structure of each solution – that is, the harmonious integration and mutual complementarity between conventional technologies and materials and innovative technologies and materials, primarily composite-based.

Moreover, among Oleksandr Sylyaiev's contributions, particular importance is attributed to the principle of integration and comprehensive adaptation of new materials and technological approaches within the framework of existing, proven technologies and materials, which are prepared for transformation and enhancement at a new, innovative level.

The following image presents an axial cross-section of such a device, providing a more detailed and convenient view for analysis.

Figure 1.



As can be seen from the design of the innovative lamp, the functions of several fundamental structural elements are integrated into a single system.

The lamp holder incorporates a vortex-type heat sink, the axis and discs of which are made of a diamond–copper composite, serving as a key component of the lamp's cooling system.

Each element of this system is multifunctional: in addition to heat transfer and heat accumulation, the structure of these components – formed from numerous composite micro-globules – also performs a critical function of dissipating thermal flows. This is achieved due to the pseudo-porous structure of the composite.

Let us consider the innovative structure of the diamond – copper composite (Appendix 1).

The original manufacturing process of the composite globules begins with the formation of diamond spheres from synthetic diamond, with a diameter of 5–7 microns (this size may vary depending on the geometry of the component and operating conditions).

Subsequently, these spheres are coated with copper using specialized equipment and an original innovative technology (Appendix 2).

The coating thickness is selected such that, during the molding of the lamp component, a sufficient amount of ductile material is present on the diamond spheres to ensure metal flow and complete filling of the interstitial spaces between the synthetic diamond spheres.

As a result, a pseudo-porous structure is formed, in which diamond spheres – characterized by exceptional thermal conductivity and complete electrical insulation – are uniformly distributed.

Such a structure enables instantaneous heat dissipation and uniform distribution across the cross-sectional area of the heat sink discs.

Optical fiber is placed within spiral grooves in the lamp housing, through which laser radiation from the laser module is transmitted. The optical fiber is coiled in a spiral and positioned within the grooves at a diameter that induces uniform emission along the entire cylindrical surface, which is significantly more efficient than emission from the fiber end.

In order to separate the laser radiation from the output light of the lamp, a phosphor layer is applied to the optical fiber, designed to produce a specific emission spectrum.

As a result, the final light output of the lamp is non-toxic, and due to the emission area being several orders of magnitude larger than that of the fiber end, a laser diode with a power of 1–2 W can achieve an equivalent output corresponding to a 60–75 W conventional lamp.

The presented models demonstrate that, based on the general principles of innovative design proposed by Oleksandr Sylyaiev, it is possible – within conventional forms and structures, such as ion-exchange filters – to achieve near-ideal results using natural and entirely safe materials, with unique performance characteristics:

- complete absence of chemical reagents in the process;
- utilization of natural ion-exchange properties;
- exceptionally high exchange capacity, including for the purification of liquid contaminated with radioactive substances.

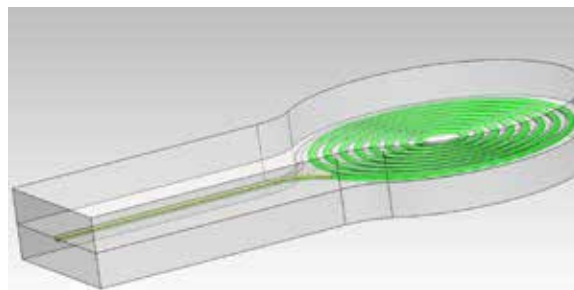
Figure 2.



The following image shows a miniature lamp in which a phosphor mixture is applied to the end of an optical fiber according to a defined geometry in a three-dimensional coordinate system, enabling emission in the white spectral range.

The diameter of the optical fiber is only 120 microns, allowing for the creation of micro-miniature light sources suitable for use in highly compact optoelectronic systems.

Figure 3.

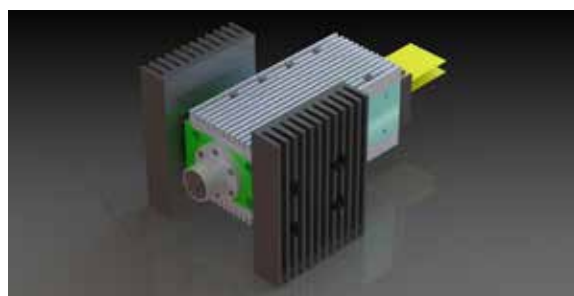


The following image shows a lamp with a flat emitter connected to a single optical fiber.

In addition to overall energy efficiency, such a system makes it possible to achieve the required level of illumination over a specified area with minimal cost and maximum design simplicity.

This configuration also allows the application of virtually any combination or mixture of phosphors onto the spiral (planar spiral) section at the end of the optical fiber, enabling the desired light emission parameters to be obtained.

Figure 4.



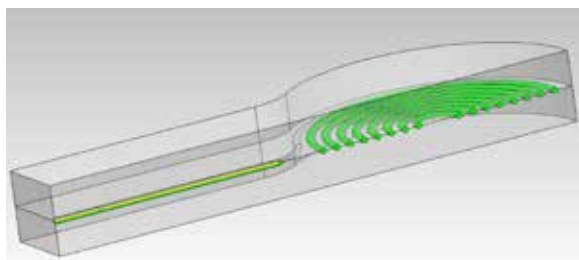
The following image shows a laser diode module designed based on the principles of active cooling utilizing a heat dissipation effect in components made of a pseudo-porous diamond–copper composite.

One of the key innovative integrative features of the presented design is the use of thermoelectric coolers in combination with heat-conducting and heat-dissipating structural elements of the module housing.

The thermoelectric coolers are positioned between the external heat sinks and the module housing. Heat-conducting elements of the structure transfer thermal flows from the printed circuit board to the housing walls, on which the thermoelectric coolers are mounted. In turn, the base surfaces of the heat sinks are pressed against the coolers, and additional components of the module requiring continuous cooling can be mounted on these heat sinks as needed.

Practical application has demonstrated that reliable cooling enables maximum stabilization of the output parameters of laser radiation. This, in turn, significantly expands the range of output configurations of the module and, when necessary, allows the laser radiation to be distributed among multiple optical fibers, each supplying a separate lighting device.

Figure 5.



The image shows models of such devices.

Figure 6.

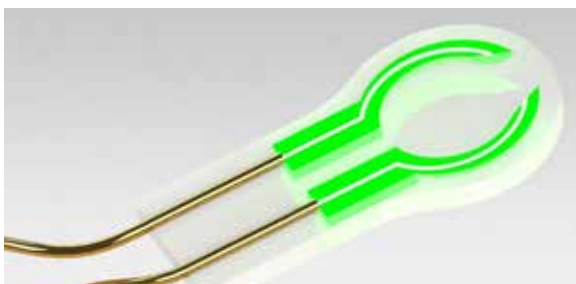
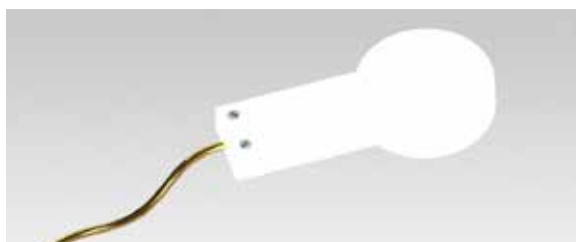


Figure 7.



The most critical aspect remains the primary heat removal directly from the laser diode.

The presented three-dimensional models illustrate heat-conducting elements that simultaneously serve as structural mounting bases for the laser diode within the module housing.

As can be seen from the models, despite their simplicity and manufacturability, the support disk of the laser diode (highlighted in red in the models) effectively protects the diode from overheating due to a combination of factors. As noted above, this significantly enhances the operational stability of the module and reduces energy consumption for lighting.

The models also include a coding and decoding system that enables identification of optical fibers connected to the module along with their associated lighting devices.

In addition to core operational functions, such a system provides a platform for implementing and controlling various computational models for energy management and distribution.

These functions are highly dependent on the intended application and operating conditions of the module. Of particular importance for further development is the capability to integrate software components directly into the most critical parts of the system.

Furthermore, this fundamentally new approach to the application of advanced composite materials in novel configurations with unique properties and characteristics enables the creation of new lighting devices and instruments that meet the requirements of modern technologies.

It is also important to note that, alongside advanced composite materials, nature offers exceptionally valuable natural materials. The application of the design principles outlined in Oleksandr Sylyaiev's publications makes it possible to achieve a harmonious integration of well-known natural materials with extensively proven engineering and technological approaches.

The conceptual solutions proposed by Oleksandr Sylyaiev also enable further development, for example, of carbon-carbon composites in textile form into compressed solid components with entirely new properties,

thereby opening up innovative possibilities in lighting technology and related processes.

As can be seen from the image, all other housing and cooling system components of the laser module are manufactured from standard profiles and materials and do not require any specialized materials or dedicated technological equipment. All components are produced using standard machining and measuring tools. This can be considered an

example of the integration and combination of innovative solutions for the efficient and safe conversion of laser diode radiation into safe and high-intensity phosphor emission, with virtually complete heat dissipation and minimal thermal and optical losses.

All key output parameters of this integrated lighting system fully comply with current standards and safety regulations.

References

- United States Patent Application No. 20120040166 (A1). *Composite Material, Method of Manufacturing and Device for Moldable Calibration*. Published: February 16, 2012.
- United States Patent Application No. 20100224497 (A1). *Device and Method for the Extraction of Metals from Liquids*. Published: September 9, 2010.

submitted 28.03.2026;
accepted for publication 12.04.2026;
published 30.04.2026
© Prykhodko O. V.
Contact: alexsilyaev@gmail.com