

# Show Cave Lighting Systems

**Alexander Chrapko and Vladimir Vashkevich** of Cave Lighting CL GmbH & Co. KG explain how lighting for show caves has changed significantly in recent years. This, in turn, has improved the visitor experience as well as providing environmental benefits.

Alexander Chrapko was 13 years old and had joined the Sparta caving group at the House of Youth in Kiev, Ukraine. The youth group went on expeditions to unexplored, wild caves in various republics of the former Soviet Union. They started with smaller caves, followed by larger caves and extensive expeditions. Among the greatest achievements were the expeditions to the Arabicskaia cave system in the mountains of the Caucasus.

An original project, and later, the company Cave Lighting, was born out of this passion for caves. It was precisely out of this love of caves that the founders began to focus on show caves, most of which were in a poor condition and very badly lit. The aim of Cave Lighting was, and still is, to make dilapidated show caves accessible to the general public with new technologies and the philosophy of a caving enthusiast.

## The Early Days

In the beginning, we had no idea about show caves, guided tours, electrical systems or lighting design. We quickly realised that we first needed to develop a lighting system uniquely suitable for caves. As nothing was available on the market, we developed it ourselves based on the technological requirements.

In 2008, we had completed hardware for the first luminaires and control units. We then began our first projects. We realised that the point of view of the cave explorer is very different from that of professionals such as electricians, specialist planners, architects, lighting designers and scenographers. If you're not familiar with the latter word, it's someone who develops the appearance of a stage design, TV or movie set, gaming environment, trade fair exhibition, or a museum experience. A major problem was that normal electrical companies had no idea about the cave environment but had, nevertheless, carried out the installations in show caves. Although these were usually correct electrically, they were often horrible for the cave. They destroyed the cave environment, they had no aesthetics, the lighting was boring, and cables and cable ducts were visible everywhere.

After our first encounters with these inappropriate lighting systems, we realised that we needed to consider two aspects. First was the technology and engineering, and second was the aesthetics of the lighting in order to put the show caves in the right light, quite literally. Therefore, the basic technical requirements for a cave lighting system were formulated, because lighting is not only light. And so the development of our unique solution began.

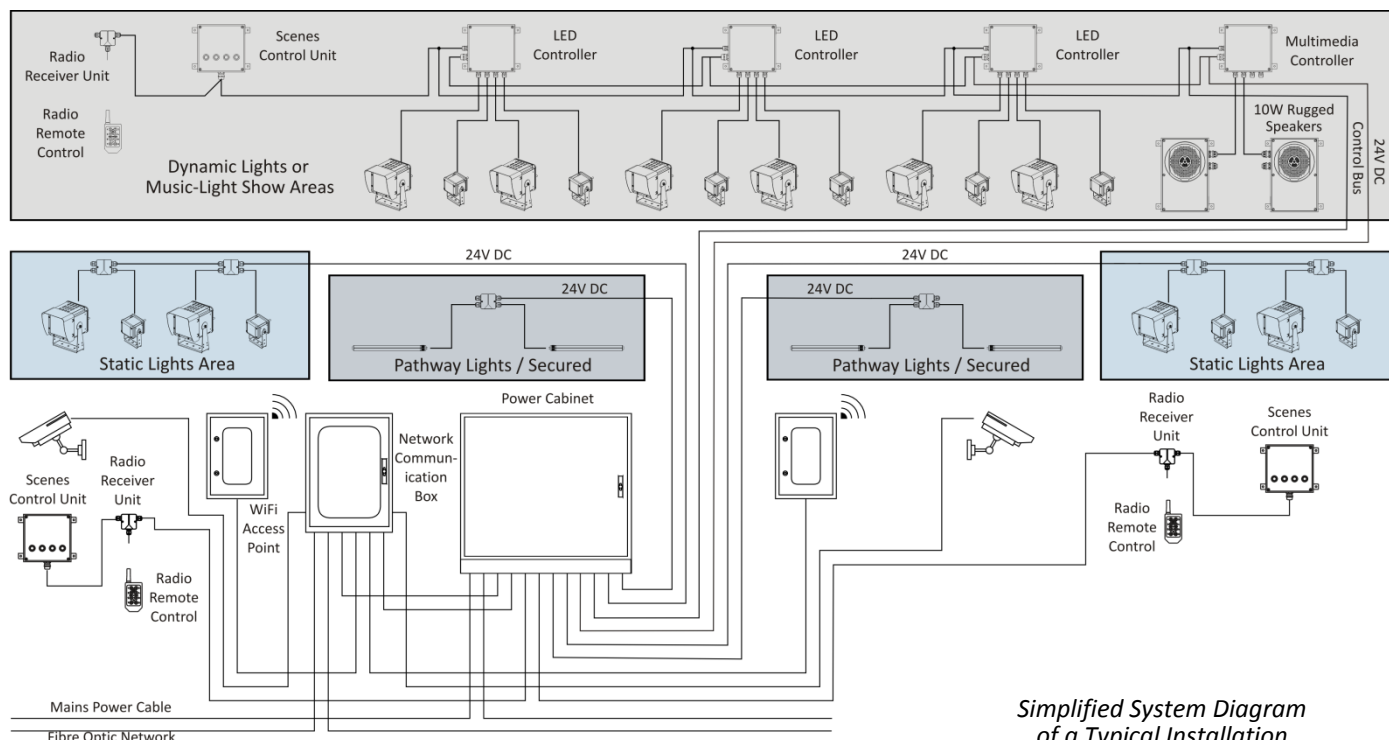
## Principles and Priorities

Several basic principles and priorities have been defined and applied in our projects. Included here are the following:

- Visitor safety comes first.
- The lamps themselves, and all installed equipment, must be suitable for the harsh, damp environment.
- A lot of light is unnecessary. A combination of diffuse and directed light with topical focus suffices.
- Lights and all parts of the electrical installation should have only the most minimal negative ecological impact. They should be installed in such a way that they are practically invisible.
- There should be minimal impact on the cave ecosystem, ("lamp flora" – vegetation growing around lamps, bats, insects, etc.), both during installation and in operation.
- Light exposure should be minimised to exclude "lamp flora". Various control algorithms can be used for this.
- Controllable light should intensify the emotional effects.
- Shadows and background highlights should be provided, avoiding frontal flood light.
- Blinding and glare effects should be minimised.
- The combination of small lamps at different angles for accent lighting intensifies the impression of depth.



*These gour pools, in Grottes de Thouzon in Le Thor, France, have been illuminated with cool white light to preserve the natural colours.*



*Simplified System Diagram  
of a Typical Installation*

- Using mostly cold (6000 K) and neutral (5000 K) LEDs alters the appearance of a show cave considerably. Daylight lends a unique individuality to formations and the wall structure. This compares with warm white light (3000K), which had mostly been used previously, that cannot reproduce the actual colours of the underground objects, especially white speleothems.
- central, local or remote controls,
- multimedia system (with static or dynamic light scenes),
- electrical power supply and distribution,
- other options: WiFi, VoIP, CCTV and etc.

The current trend in the installation of show caves is the implementation of modern intelligent solutions. Included here is IoT and industrial automation based on fibre optic IP networks, central control, complex algorithms of light and guide control, monitoring of the cave microclimate, and guide visualisation. The latter feature allows guide locations and the current state of the lighting to be visible on-screen in the office.

The use of modern technologies also has an impact on the operating conditions of show caves. Communication solutions for 2.4GHz (WiFi, Bluetooth, ZigBee) do not always work well and can be unreliable.

An important element is the functionality of a central control and monitoring system that not only monitors the technical status (battery status, emergency power supply, fuses and emergency control). It is also necessary to monitor the management in order to avoid potential management conflicts between groups.

### Luminaries

The brightness of the lighting system should not be too high, but the lighting must ensure safe and comfortable movement for visitors. For this reason, luminaires with a low output of 1 to 17W

are ideal for use in show caves. The basic principle is not to use too much light, but to properly direct and control the light to adapt to the theme of the tour. The reduction in lamp power is useful in the design of IPX8 waterproof units and helps to avoid the “heat pump” effect as the lamps heat up and cool down.

An especially important design feature of the lamps is the use of non-corrosive materials. The front cover is made of treated polycarbonate and the outer parts of the housing are made of stainless steel. A deeply anodised outer aluminium heat sink was used originally, but was then replaced by an epoxy polyurethane coating with high thermal conductivity. The contact between different metals is, therefore, completely eliminated to prevent galvanic corrosion of the individual elements.

The light is connected via a built-in cable. The screw connection is also sealed from the inside. The individual ends of the wires are further protected with a sealing compound to prevent water from flowing between the wires inside the cable.

The built-in driver is designed for low voltage only, 24VDC or 30VDC. Thanks to carefully selected electronic components, the lamps are protected against switching faults, overvoltage and overheating.

The lamp housing is not designed for disassembly and repair on site. The units are manufactured and packaged in such a way that residual moisture is excluded. The water tightness of the luminaires is tested at a pressure of 3 bars. All lamps are subjected to mandatory MTBF tests.

## The Cave Lighting System

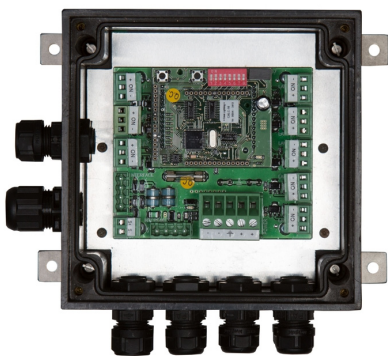
The Cave Lighting system includes the following parts or subsystems:

- artistic or general lighting,
- emergency or safety lighting,





*DMX Controllable RGBW Luminary*



*Inside of Light Controller*



*IP65 Waterproof Speaker*

A wide range of settings and options allows a flexible and versatile cave lighting system to be created. Included here are:

- Power consumption: 3W, 7W, 12W, 17W (RGBW)
- Light output: 240lm, 500lm, 1200lm, 1000lm (RGBW)
- Light options: cool, neutral, and warm white, RGB, RGBW, CWA
- Beam angle: Narrow Spot (10°), Medium spot (20°), Wide spot (40°) Flood (70°, 120°)
- Supply voltage: 18 - 36 VDC
- Electrical connection: integrated cable
- IP code: IP68
- Control options: DMX/RDM, PW.

## Control Units

One of the advantages of an LED lighting system is that it is relatively easy to control the lighting. The lighting should only be switched on when visitors are actually in the illuminated area, unless they are taking part in a light show. Otherwise, it should remain switched off.

The most effective way to protect the cave from the growth of "lamp flora" is to reduce the light exposure to a minimum. The use of lighting control also improves the visitor's emotional experience.

In addition to the levels of physical control, the cave is divided into zones of logical control. During a tour, control can be transferred from one zone to another, and each zone can have its own control scenario. In general, the basic principle is arrive – switch on – depart – switch off.

When designing a control system, various options can be used depending on the specific requirements of a particular object. These include simple relay control, brightness control, dynamic or static lighting and light show. By technical means, any combination of these options can be used. The choice of control system depends primarily on the characteristics of the cave and the concept of the tour. The cave guide can control the lighting with a remote control or work autonomously by activating motion sensors.

There are 3 basic types of control unit: (1) lamp control unit, (2) keypad or scene control unit, (3) multimedia control unit.

The devices are encased in a protective housing made of moulded rubber, and have protection class IP67. The electronic components of the devices are coated with a special lacquer and protected against overvoltage and connection errors. The control system also supports other additional devices such as DMX splitters, receivers, adapters and other remote controls.

## Installation Components and Installation Principles

Only high-quality components and cables should be used for the electrical installation in show caves. The system should be watertight from the distribution cabinet to the last luminaire. Therefore, only tested components from trusted manufacturers should be used.

The most difficult factors to consider, when installing underground, are 100% humidity, dripping water and aggressive alkaline conditions. This places special demands on the planning and use of lighting technology.

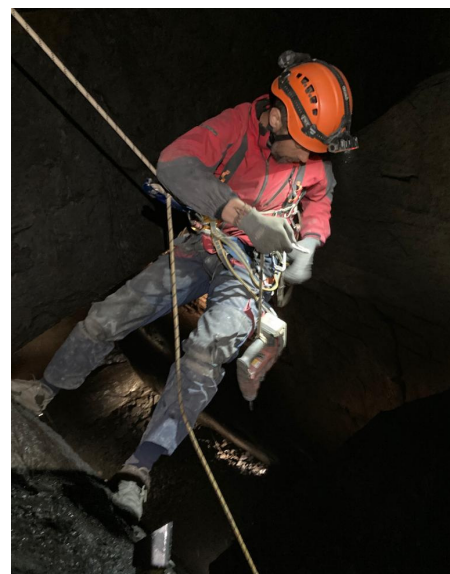
These requirements are:

- Protect all electrical connections with suitable sealants.
- Protect electronic components using waterproof varnishes and coatings.
- Ensuring that water does not enter lamps and control units when laying and connecting cables.
- Minimise the number of electrical connections.
- Make sure that the ends of the connected cables do not remain open for a long time.
- Fill the inside of the lamps with silicone or polyurethane foam if necessary.
- Control the climatic conditions in electrical cabinets.
- Use only non-corrosive materials, e.g. stainless steel.
- Completely seal all electrical connections using a sealant such as Tyco Gurosil Gel.

## Lighting Design

Solutions are now available that nobody would have thought of just a few years ago. Show caves are increasingly digital and multimedia-based. To enhance the visitor's aesthetic experience, lighting is complemented by dynamic colour shows. These can be synchronised with sound and music, video mapping on walls and natural formations, multilingual audio guidance, and 3D laser shows. One trend is the provision of selfie points – well-lit places where visitors can take photos and immediately post them on social networks.

It is very important to find an appropriate balance between natural objects and installed devices, between the cave and the people in the cave.



*Installation in Haut Martelange*



*Giant Ice Cave, Dachstein, Austria*

If the safety of visitors to the show cave is guaranteed, various lighting concepts can be implemented. Lighting design in caves can be used in different ways. For example, it's possible to create a concept with a story and use the lighting to tell that story. In any case, it is very important in underground projects not to over-light or use saturated colors so as not to overwhelm visitors with content. Therefore, the balance of lighting is very important. For all projects, we try to work predominantly with white light and not to exceed the maximum illuminance of 200 lux.

Cave Lighting has undertaken more than 110 projects in the last 18 years. The company thrives on collaboration and synergy with experts from various fields. We have successfully worked on numerous projects with electrical designers, lighting designers, architects and theatre designers.

### **Giant Ice Cave, Obertraun (Dachstein) Austria**

It's time to introduce you to one of our projects that we have realised in very successful collaboration with set designers and lighting designers.

One of our most extreme projects was the new staging of the Giant Ice Cave on the

Dachstein in Austria, which was installed in 2017 and 2018.

The Giant Ice Cave is one of the few high alpine show caves. The entrance to the cave is located at an altitude of 1,421 meters above sea level. The length of the show cave section is approximately 800 meters, with a height difference of about 70 meters between the entrance and the exit. The show cave is divided into two parts: a lower part with ambient temperatures of up to 3°C, and an upper part with ice formations and a maximum ambient temperatures of ~0°C.

A local design company was responsible for the project. The

company specialises in integrated tourism projects that combine tourism, ecology, architecture, landscape planning, art, education, design, crafts and graphics. Cave Lighting took on the task of lighting design and electrical planning for the show cave.

A design company developed a concept to transform the show cave into a Disneyland. However, our experts saw the situation differently. After many discussions and tests on site, they agreed to a combination of natural and authentic lighting with several multimedia areas including light and music shows, colour lighting and dynamic content.

The cave is equipped with a PLC-controlled automation network and is divided into nine guided zones. The first four zones are ice-free and are illuminated in white with a correlated colour temperature from 6000K to 4500K.

The second part of the show cave is a real ice cave with thick layers of ice, ice figures and special shapes. A combination of cool white and RGBW lighting was used here. In the five zones of the ice cave, five light and sound shows were created in collaboration with the set designer to thematically support the main script.

Cave Lighting products were predominantly used for the installation in the cave. 1W, 30lm CL-LMT lamps with a colour temperature of 5000K were used to illuminate the pathways. 3.5W, 250lm, 4500K to 6200K CL-LSQ2 luminaires and 12.5W, 1200lm, 4500K to 6200K CL-LQP2 luminaires were used for the accent lighting. The RGBW light and music shows were equipped with luminaires developed by Cave Lighting for the entertainment industry. These were 17W, 700lm 4-die LED matrix, either RGBWc (Red, Green, Blue, Cool White) or RGBWn (Red, Green, Blue, Neutral White). The luminaires are controlled via the DMX protocol.

What was special about this project? First of all, the installation began in February 2018, with temperatures of -25°C on the mountain and -12°C at the cave entrance. So we had to work on and in the ice and not only design the lighting, i.e. finding places for the lamps and creating lighting scenes, but also drilling holes, lay cables and electrical connections and programming them.

Many new installation techniques had to be learned, such as forming cable channels in the ice using thermal cables or protecting the devices from the slow movement of the ice. In addition, the equipment and materials for the installation were delivered by helicopter.

The second problem was the open location of the cave and the very poor protection of the power grid against lightning strikes and surges. We very quickly realised that the show cave was not adequately protected against surges. It was therefore necessary to develop and install a special lightning protection system comprising around 50 individual lightning protection devices (SPDs).

### **Summary**

The main purpose of the lighting system in a show cave is to ensure the safety of visitors while ensuring maximum aesthetic effect and minimum impact on the ecology of the cave. The LED lighting should remain invisible in the cave, but be protected from the conditions in the cave. The use of modern technologies and specialized technical solutions is changing the world of underground attraction lighting, which seemed so simple just a few years ago. When planning and installing modern lighting systems, a number of important requirements must be met as described.

We are always open to any opportunities and suggestions. You can contact us at [www.cavelighting.de](http://www.cavelighting.de).

