The spread of wearable devices is pushing the need for ***miniaturized photonic elements*** with advanced functions, including light-controlled ones.

Photonic crystals (PCs) are periodic nanostructures that can modulate the properties of light due to their specific structure. A well-known example of such a structure are the wings of butterflies producing iridescent colors. The nanostructure of the scales of butterfly wings reflects light in a particular way and this effect would not occurr if the scales were larger.

However, the creation of such photonic nanostructures in the laboratory is not trivial. Various strategies are being developed to produce these types of materials to obtain one-(1D), two- (2D) or three-dimensional (3D) photonic crystals. The production of **3D photonic crystals** is very complex due to the extremely high criteria for technological requirements leading to a reasonably sized photonic crystals of uniform structure. For this reason, innovative approaches are needed to produce materials for future photonic applications.

Our proposal for the creation of macroscopic photonic structures is based on the use of ***self-assembling materials*** (SAM). The molecules of the SAM medium combine with each other forming complex structures with appealing properties. One example of SAM forming macroscopic structures are liquid crystals (LC).

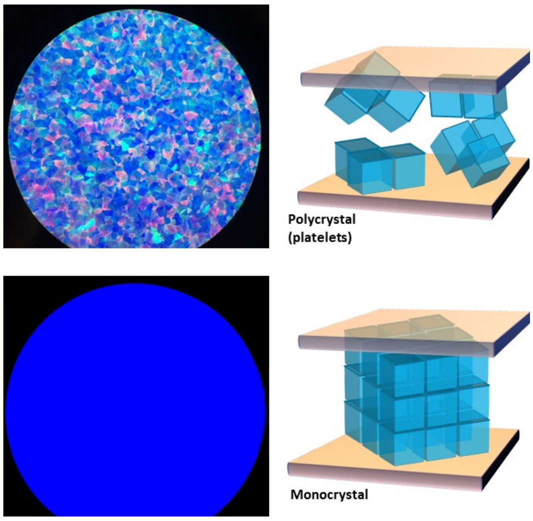

Fig 1. - Example of two Blue Phase crystals: polycrystal and monocrystal

LCs are ubiquitous – used mainly in LCD displays. Their properties place them between solids and liquids.

There is a special type of liquid crystal, though, called **Blue Phase**, that can actually organize itself in **ordered 3D structures with a nanometer scale periodicity**. This 3D organization is achieved by the self-assembly of the LC molecules into cubic structures. Since the crystal size is in the nanometer range, they can be considered **3D photonic crystals**: they produce similar effects to PCs, like, for instance, selective light reflections. However, the fabrication of Blue Phase monocrystals in with controlled orientation still remains a challenge. Currently produced BP structures are often polycrystalline, the size of a single crystallite is usually very limited (of the order of micrometers – Fig. 1).

The aim of the proposed project is to obtain and study macroscopic ***3D photonic crystals based on Blue Phases,*** where the spatial orientation of the structure and its parameters, determining the photonic properties, are controlled. The obtained photonic single crystals will have specific properties designed for the implementation of a **microlaser** with topologically protected spatial distribution of radiation (when doped with emitters), a **light-controlled optical switch** (when doped with an active photomaterial) and a **holographic transducer** (as part of a holographic system).

Emissive materials, such as laser dyes or quantum dots, can be introduced into periodic BP structures for inducing a laser emission. Since the BP crystal is a highly organized nanostructure, the light from the implemented emissive materials is multidirectional and its spatial distribution is topologically protected by the structure of the BP photonic crystal. During the project, we intend to confirm that BP structures are an excellent basis for the design of topologically defined **microlasers**.

As part of the proposed project, partners from the Czech Republic will synthesize new chemical compounds called **photoactive dopants** (PDs). PDs belong to a group of compounds that can alter the conformation of a molecule as a result of the interaction with specific light. The addition of these compounds to BPs will result in the formation of a BP photonic crystal susceptible to changes of properties on demand, such as the size of the lattice constants, the selective reflection band and the dimensions of the laser microstructure. These components can be easily implemented as an energy-efficient optical photoswitch, as they would be controlled by light without the need for implementation of expensive electrodes (contact-less).

What's more, the produced photonic crystals will be tested in **a holographic** system and inside a functional, structured microcavity. In addition, due to their unique optical properties, components using BP-based photonic crystals can be tested as holographic fibers, phase modulators and construction in holographic projection systems.

The research on the proposed photonic crystals is intended to create new ways of producing functional tunable photonic devices. The fruitful results of the proposed research could lead to novel applications that can be implemented in various technologies including optoelectronics, integrated photonics, optical communication, detection and biosensing and biomedical diagnostic tools.