

As the name suggests, liquid crystals (LC) are substances that can exhibit characteristic features of both isotropic liquids (ability to flow) and crystalline solids (anisotropy of properties). They constitute a basis for many modern devices encountered in our everyday life, e.g., in various types of displays (TV, tablets, mobile phones), optical sensors, modulators and switchers, as well as LC thermometers and smart window curtains. In LC, the molecules are anisometric and their arrangement displays some orientational order. At different temperatures different types of such arrangements or LC phases have been observed and in the LC classification apart from the well-known nematic, smectic and cholesteric LC phases, there is also a separate highly self-assembled category called the 'blue phase' (BP). Blue phases typically occur within a narrow temperature range between the low-temperature cholesteric phase and the high-temperature isotropic liquid phase. Their origin has been ascribed to a competition between an intermolecular twist induced by chirality and the necessity of molecules to fill the space. This competition results in the molecules self-organizing into a complicated helical architecture – double twisted cylindrical structures, known as blue phase I, II and III. In BPI and BPII, the packing of double twist cylinders gives rise to three-dimensional periodic crystal-like cubic symmetry structures. The lattice periods for BPI and BPII are very large, and of order of the wavelength of visible light (i.e. hundreds of nanometers or about 10^7 molecules in the unit cell) which give rise to selective (color) Bragg reflections (which inspired the 'BP' name). BPIII is considered to be an amorphous structure of double twist cylinders. For more than 100 years the blue phase was regarded as an exotic liquid crystal state without any possibility of finding practical applications, mainly due to their narrow thermal stability range (a temperature range of ca. 1K). About 15 years ago there started to be an increased interest in blue phases after the discovery of ways to considerably widen their stability temperature range. Several methods of achieving this were found (involving e.g., the formation of a polymeric or nanoparticles skeleton), which enabled an extension of the temperature range of blue phases to tens of degrees. This has opened up the wide prospect of new practically useful directions of exploration. In comparison to conventional LC materials the blue phases have many advantages e.g., a lack of birefringence or requirement of layer alignment (which simplifies the manufacturing processes) and the electro-optic response times are lower than 1 ms. Thus, today BPs have great potential for applications in a wide variety of fields (e.g., sub-millisecond response displays, mirror-less lasers, tunable lenses, in photonics) and remain one of the most fascinating and challenging systems to understand from a fundamental point of view.

Many of the BP investigations are at the exploratory and laboratory stage and there are several key issues which are intensively being investigated in the ongoing research, which includes: the operating voltage, the transmittance, the widening of BP stability range, hysteresis and residual birefringence effects. Recent reports indicate that many of these issues can involve or are related to the elastic properties. However our knowledge of elasticity of BPs is very limited and remains practically untackled. Sophisticated mechanical measurements have shown that the shear modulus of a BPI polycrystalline sample is roughly 6-orders of magnitude smaller than that found for typical atomic or molecular crystals – thus, the BPs are elastically very difficult to study and fragile materials. Also, recent theoretical and experimental results have demonstrated the great importance of elastic constants of the host nematic (forming BPs). Because of the unique 3D structure (symmetry of cubic crystals), BPs single crystal exhibit elastic behaviour characterized by three elastic constants, or macroscopic elastic moduli in the case of a polycrystalline sample. In the complex relationship between the *stability range*, *electro-optic response*, *structure* and *material parameters* the lack of sufficient investigations of these elastic properties of BPs constitutes a serious and outstanding problem.

The aim of the project is to undertake a systematic research which would fill this identified gap: to (a) develop a framework for determining the single crystal elastic constants and macroscopic elastic moduli of the BPs, and (b) to establish the relationship between the elastic properties, stability range, structural changes and electro-optical properties. In our approach to determine elastic properties of BPs we propose to exploit visible light. In particular the framework combines: the diffraction elastic constants scheme, determination of the selective light Bragg reflections (in analogy with X-ray experiments for solid crystals) with and without applied stress and micromechanical modeling to describe the elastic behaviour of a polycrystalline material in terms of the single crystal elastic constants. To obtain the desired relationship a number of experimental methods will be used to obtain the key quantities for structure changes, stability range and electro-optical behaviour. These include: the helical pitch, dielectric anisotropy, Kerr constant, birefringence, and the accurate temperature range of the LC phase sequence. In the context of elastic constants, the issue of strong slit-geometry confinement (used in most LC experiments) and totally unknown auxetic behaviour of BPs will also be investigated.