

## **Exploring the Potential of a New Nematic Twist-Bend Ferroelectric Phase and Liquid Crystalline Luminescent Dyes in Lasing and Nonlinear Optical Applications**

Liquid crystals (LC) belong to the class of soft matter that combines properties typical of both crystals and liquids. The combination of fluidity and long-range orientational order allows for easy tuning of their properties under the influence of optical, magnetic, and electric fields. The original concept of a liquid crystal laser was presented by Goldberg and Schnur in 1973, but the first experimental demonstration was conducted 25 years later by Kopp. Since then, much research has focused on utilizing LC in light amplification phenomena.

Nematic liquid crystals (NLC), known for their simple molecular alignment and widespread use in optoelectronics, have remained unmodified for over a century. In 2017, a unique polar phase, the ferroelectric nematic (NF), was confirmed. In 2024, the revolutionary spontaneous mirror symmetry breaking of the ferroelectric twist-bend nematic chiral structures (NTBF phase) was demonstrated. NLCs are widely used as optically active matrices for luminescent dyes to tune emission properties through external fields. However, research on the newly discovered NTBF phase has not yet been conducted. Liquid crystalline systems, particularly those utilizing the ferroelectric twist-bend phase, are very promising candidates for a new generation of photonic devices due to their unique optical properties and tunability.

The collaboration between Wrocław University of Technology and the Military University of Technology focuses on the synthesis, preparation, and fundamental research of nonlinear optical, luminescent, and laser properties of entirely new organic compounds. The main task of this research project is to characterize nematic phases (ranging from the classical nematic phase and its chiral, helical counterpart, through the apolar phase, twisted nematic phase (Ntb), to polar nematic phases) and completely new liquid crystal fluorescent emitters (LCFE) exhibiting light generation. We will test the hypothesis of whether and to what extent it is possible to obtain new hybrid materials (in the form of molecules, thin films, or LC cells) that exhibit very good second and third-order nonlinear optical properties comparable to inorganic materials while allowing for light-stimulated emission (amplified spontaneous emission (ASE), distributed feedback (DFB), random lasing (RL)).

The novelty of this project is to investigate the possibility of laser light emission via a completely new matrix (ferroelectric twist-bend nematic) and LCFE emitters that not only exhibit fluorescence but also possess liquid crystalline properties. The range of applications where photoactive materials in the form of molecules or LC cells made from LCFE can be utilized includes Li-Fi technology, organic light-emitting devices (OLED), display technology, optical logic gates, and other nanophotonic elements.