

Liquid crystals are a remarkable form of matter that we all interact with daily—they are the magic behind the screens of our smartphones, laptops, and televisions. They combine the properties of a liquid (fluidity) and a crystal (molecular order), allowing for the precise control of light. Today, we stand on the cusp of a new technological revolution, where miniature and intelligent optical systems based on liquid crystals will be key to the development of augmented reality (AR), autonomous vehicles (LiDAR), and super-fast telecommunications. However, there is a barrier: to create such advanced devices, we must learn to arrange liquid crystal molecules with a precision a thousand times smaller than the width of a human hair. Current methods are like trying to draw a microprocessor with a thick paintbrush—they are simply not accurate enough.

The impetus for this project was a serendipitous discovery. During routine studies in a transmission electron microscope—a powerful tool that allows us to peer deep into matter—we noticed that the electron beam, intended only for observation, began to controllably alter the structure of the liquid crystal. We realized that the microscope could be not just an eye, but also a hand. Our project aims to use this beam as a nanoscale "thermal stylus," which locally heats the material and allows us to "draw" any desired patterns with unprecedented resolution.

Our research will proceed in four stages. First, we need to thoroughly investigate and understand the physics of this phenomenon—to determine how the beam's energy affects different types of liquid crystals, creating a precise user manual for our "stylus." Next, we will add metallic nanoparticles (e.g., gold) to the liquid crystals, which will act as miniature heaters, potentially increasing the precision and efficiency of the process. In parallel, we will develop advanced computer models to simulate and better predict the outcomes of our experiments.

The most important and exciting goal of the project will be the final stage: attempting to create working prototypes. Using our new method, we will try to "draw" miniature, tunable lenses and diffraction gratings—key components of future optical devices.

The completion of this project will open up entirely new possibilities. On one hand, it will give scientists a powerful tool to study the fundamental properties of matter at the nanoscale. On the other, it could revolutionize the way we produce advanced photonic systems. Developing a technology for precise "drawing" in liquid crystals is a step towards devices that today exist mainly in the realm of science fiction—from invisible, smart contact lenses with displays to ultra-efficient optical communication systems.