BRight EntAnglement vIa Dark States (BRAIDS)

In BRAIDS project, we deal with the fascinating world of quantum physics. We focus on particles of light called *photons* that can carry *quantum information*. Quantum physics not only describes the fundamental building blocks of our universe, but it also has big potential for future technologies that will transform our everyday life. Some of them are quantum computing and *secure communication* that cannot be eavesdropped.

One of the purely quantum phenomena is *entanglement*. Imagine a toy consisting of two spinning tops connected by a very special string. When you spin one top, the other one starts spinning as well, no matter how far apart they are. These two tops are a lot like *entangled photons*. Studying entangled particles may help to answer fundamental questions about quantum physics. It will also enable quantum technologies including *secure telecommunication*.

In the BRAIDS project, we are working together at four universities in three European countries to produce entangled photons using semiconductor *quantum dots*. Those quantum dots can be imagined as raisins in a cake, where both are made of different semiconductors. They are so small that they behave in the specific quantum way. Thanks to this, they can emit a single photon at a time. These photons can also be entangled and used to carry information in secure *quantum networks*.

However, polarization entanglement, the most common type of entanglement used so far, is not ideal. This is because it *decoheres*, *i.e.*, gets partially destroyed in optical fibers. So there is room for improvement. In earlier work, strides in generating a more robust type of entanglement have been made. *Time-bin entanglement* of photons from quantum dots and optical schemes to control them have been shown. This means that we can entangle a photon that comes earlier with a one that is emitted later. Building on that progress, in BRAIDS we aim to pave new ways towards producing entangled states. Our central idea is to use a *dark exciton* to generate the mentioned time-bin entanglement. *Exciton* is another quantum object in which an electron interacts with a missing electron. They can disappear (we say they annihilate) together to emit light — a photon. In principle the dark exciton should not interact with light and, thanks to this, it remembers its state for longer, which is beneficial.

Still, we know how to control the dark exciton with (bright!) *optical techniques*. We will combine technological, experimental, and theoretical efforts hand in hand to force our quantum dots to produce the best possible entangled photon pairs. To achieve this, we will use chirped laser pulses (they change the frequency on the fly just as the name says!) and specialized filters to eliminate unwanted light interference. Calculations and experimental findings will allow us to refine our techniques. We will carefully tailor quantum-dot properties and put them into tiny boxes called *photonic structures* that act a bit like antennas and enhance interaction with light. As a result, our source of these photon pairs will be bright and efficient enough for use in quantum communication.

Who knows, maybe one day, the dots and ideas developed in this project will power a quantum network that connects the world.