A single photon is the smallest particle of light, and light, when properly processed, can be used to transmit information. This property is utilised in fibre-optic networks, where countless photons travel around the globe in the smallest fraction of a second, carrying information from place to place. Among other things, fibre-optic networks are used to transmit protected information between a computer and a bank during banking sessions. Is this information safe? Such information is encrypted and can be easily intercepted. Thus far, the existing encryption is highly effective, but this confidence may diminish as science progresses. The development of quantum mechanics could lead to computers capable of breaking a classical secret key in mere moments. Consequently, an information security issue may arise.

Quantum mechanics comes to our aid. A photon is the smallest particle of light. Some people do not realise it is a quantum particle. As such, it is subject to the laws of quantum mechanics. Suppose Alice produces a quantum photon, embeds some information within it, and sends it to the bank. In that case, someone may intercept this photon and attempt to read the information, which is impossible without knowledge of the properties of the device that produced the photon. Furthermore, if someone wishes to retain this stolen information, they must produce a photon in their device identical to Alice's photon and send it to the bank. Such an operation is impossible in the realm of quantum mechanics. The bank will promptly inform Alice that someone is listening and sever the connection, establishing a new method for Alice to encode information in the quantum state of her photon.

Today we have photon transmission channels, commonly referred to as optical networks. We can manufacture lasers that produce vast amounts of photons for these networks. However, what is particularly interesting is our limitation in generating a single photon precisely when we desire it, along with the parameters that enable its use in encrypted quantum communication between Alice's terminal and the Bank.

In this project, we focus on developing a technology to produce devices that generate single photons with remarkable properties. First, we want photons to travel long distances in optical networks. Hence, the device is designed to create photons of a specific "colour". In a fibre-optic network, such photons travel in the so-called C-band, which is invisible to the human eye. Secondly, we want the device to produce precisely one photon within a strictly defined time after the device is triggered (purity of single-photon emission on demand). Thirdly, we want the generated photons to always be identical in "colour" and other properties (photons indistinguishability). Fourthly, the photons should be generated one after the other very quickly (high emission rate), and finally, fifthly, the generator must be bright (brightness), optimally producing a photon each time the device is triggered. So far, a device with such properties does not exist.

The device will be based on semiconductor technology and will utilise light-matter interaction. The light source will be an island composed of indium (In) and arsenic (As) atoms, surrounded by indium (In) and phosphorus (P) atoms or inherited materials. Such an island in the InAs/InP material configuration, approximately 100 nanometres in size, is referred to as a quantum dot. It can generate photons upon proper illumination. However, we require more than this for our device to exhibit the desired properties. The emitted photons must appropriately react with the dot's environment, and the environment must suitably modify how the dot generates the photons. This modification process can be regulated by placing a quantum dot in a well-defined space known as a resonant cavity. In our proposal, the cavity is formed by concentric rings of the InP material with holes surrounding the InAs/InP quantum dot. These rings constitute the so-called circular resonator mimicking the Sunflower that can be adjusted to obtain the appropriate parameters of the photon generator. Creating such rings is not straightforward. First, it is necessary to locate a dot beneath the surface of the material in order to create rings in this location using modern electron lithography tools, which operate on the nanometre scale. Moreover, we need to ascertain the location of the dot when working with material containing an InAs/InP quantum dot, as it is embedded within the InP material. Therefore, the dot must first be located before the ring can be constructed. We intend to utilise a super-resolution object emission imaging tool to locate the dots. By examining the light emitted from the material, the position of the source can be identified with a resolution of <50 nm. In the subsequent step, it will be possible to produce rings and further modify them. This method yields predictable, i.e., deterministic, sources of single photons with similar properties, thereby allowing for scaling of the production process with a success rate exceeding 50%.

We anticipate that the proposed technology will provide Alice with an appropriate photon generator to exchange information with the Bank server via a silica fibre-based network in the C-band. The device will generate pure single-photon states with high indistinguishability, along with high brightness and a regulated emission rate controlled by light-matter coupling.