The Sparrow Single Photon Chip

The Sparrow Single Photon Chip is a patented technology for deterministically generating single photons. It is based on ultra-precise GaAs Quantum dot structures, which when excited by an external laser will produce single photons. The photons emitted by the quantum dot are collected by a nano-photonic waveguide. The on-demand photon stream is subsequently directed to an out coupling grating that emits the photons vertically off the chip. To obtain a high purity and coherence of the single photon, the chip must be cooled down to below ~6 K.

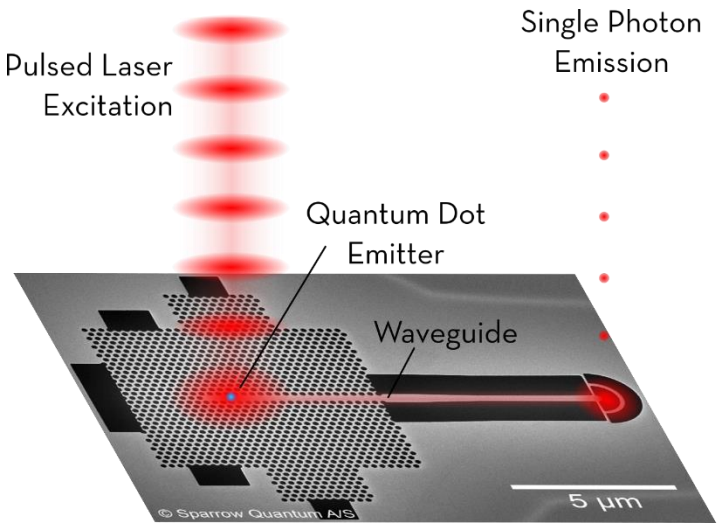

Figure 1. The quantum dot embedded in a photonic-crystal waveguide. The quantum dot is excited by an external laser and emits single photons.

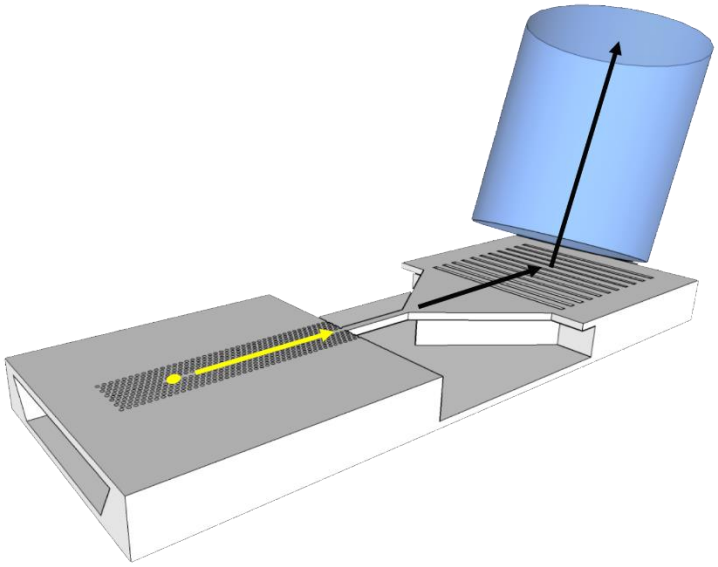

Figure 2. The guided path of the collected single photons. A nano-photonic waveguide directs the photons from the quantum dot to an out coupling grating.

SPARROW QUANTUM

Specifications

Quantity	Sparrow Chip 2019[7]	Lodahl best Lap Chip 2019[2,3]	Sparrow Chip 2020 target
Single-photon purity ($1-g^{(2)}(0)$)	95-98%	98%	98%
Single-photon coherence indistinguishability	60-90%	Publication in preparation	>90%
Single-photon efficiency in fiber	1.3 MHz	Publication in preparation	>20 MHz
Emission wavelength	910-950 nm	910-950 nm	910-950 nm
Excitation wavelength	800-960 nm	Resonant excitation	800-960 nm
Operating temperature	< 6 K	1.6 K	< 6 K
Excitation power	Typ. 1-4 µW	Typ. 1-4 µW	Typ. 1-4 µW
Excitation pulse width (recommended)	10-30ps	25 ps	10-30ps
Decay time	Typ. 500 ps	Typ. 500 ps	Typ. 500 ps

The second column in the table shows the specifications of the Sparrow chips shipped in 2019 (Ref. 7). The third column shows the specification currently obtained in our research lab (see Refs. 2, 3). The last column shows the target specifications of the updated chip which will be released in 2020.

References

1. Lodahl, Mahmoodian & Stobbe, *Interfacing single photons and single quantum dots with photonic nanostructures* Rev. Mod. Phys. **87**, 347 (2015).
2. Dreessen, Plamondon, Tighineanu, Zhou, Midolo, Sørensen & Lodahl, *Suppressing phonon decoherence of high performance single-photon sources in nanophotonic waveguides* Quantum Science & Technology **4**, 015003 (2018).
3. Uppu et al. https://arxiv.org/abs/2003.08919
4. Lund-Hansen, Stobbe, Julsgaard, Thyrrestrup, Sunner, Kamp, Forchel & Lodahl, *Experimental realization of highly efficient broadband coupling of single quantum dots to a photonic crystal waveguide* Phys. Rev. Lett. **101**, 113903 (2008).
5. Arcari, Sollner, Javadi, Hansen, Liu, Thyrrestrup, Lee, Song, Stobbe & Lodahl, *Near-unity coupling efficiency of a quantum emitter to a photonic crystal waveguide*, Phys. Rev. Lett. **113**, 093603 (2014).
6. Daveau, Balram, Pregnolato, Liu, Lee, Song, Verma, Mirin, Woo Nam, Modolo, Stobbe, Srinivasan, and Lodahl, *Efficient fiber-coupled single-photon source based on quantum dots in a photonic-crystal waveguide*, Optica **4**, 178 (2017).
7. Zhou, Kulkova, Hansen, Hansen, Lodahl, and Midolo, *High-efficiency shallow-etched grating on GaAs membranes for quantum photonic applications*, Appl. Phys. Lett. **113**, 251103 (2018).

Sparrow SPS Free Space component

- The Sparrow Single-Photon Source (SPS) free space component supplies the SPS chip in a housing that allows for integrating with most standard cryogenic setups and a window gives visual inspection possible and allows for in and outcoupling of the laser signal. The operating temperature of the chip is 0-6 K and must be obtained by placing the housing in a cryostat. The housing is open with direct optical access for excitation of the chip and collection of the SPS signal. The excitation source must have a wavelength 800-960 nm. The chip is aligned relative to the housing, such that both excitation and emission can be done perpendicular to the housing. Figure 2 shows a typical optical setup around the component.

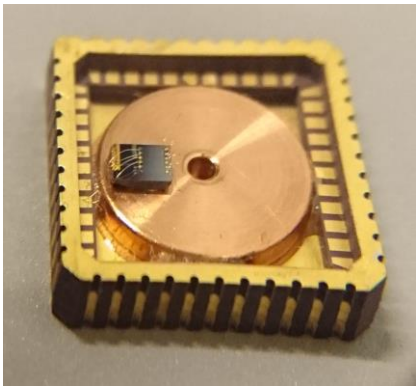

Fig. 3. Free space housing of the SPS chip. The chip is placed on metal plate which allows for coupling to a cryostat. In the free space version a transparent top lid allows for in and outcoupling of an optical signal. The chip is placed at an angle relative to the housing window which allows for in and outcoupling through the same optical path perpendicular to the housing. The table shows the specifications for the component.

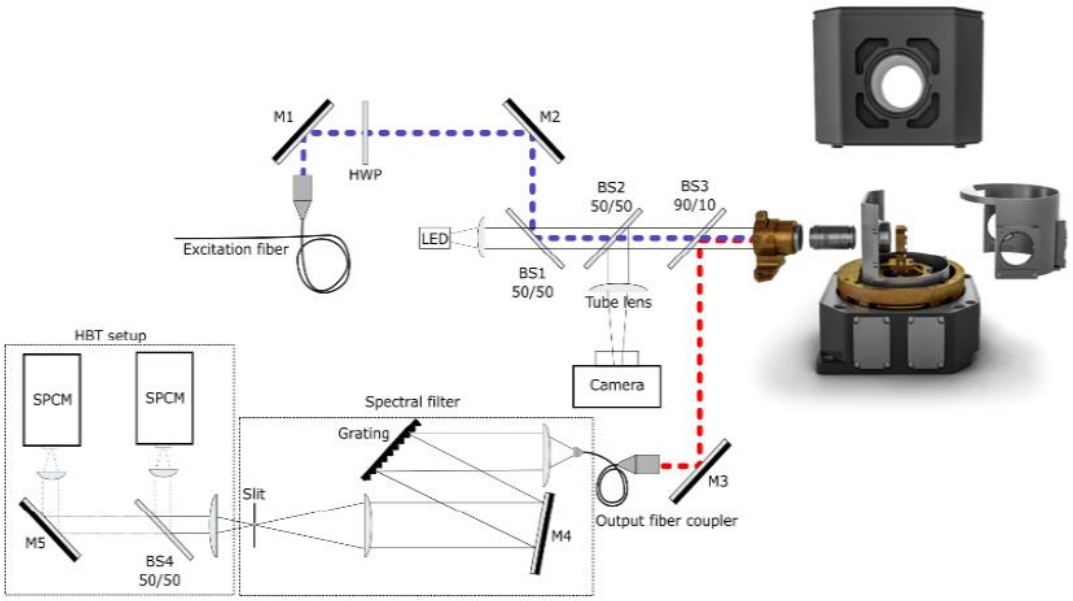

Figure 4: Typical optical setup around the SPS free space component. The component is placed in the cryostat at the right. A laser excitation source is coupled perpendicular to the component. The emission signal is collected from the same path, and an optical setup ensures the separation between the excitation and emission signal, as well as filtering the single photon source from excitations from other quantum dots on the chip.

Sparrow SPS fiber coupled component

The Sparrow Chip will in 2020 be available in a fiber coupled version. The Single Photon Source (SPS) fiber coupled component supplies the SPS chip in a housing with a single mode fiber for the input and another fiber for the output signal. The chip is placed on a thermal anchor that allows for integrating with most standard cryogenic setups. In this setup it is not possible to visually inspect the chip and all integration with the chip is through the tapered fibers. The only difference with the free space version is that in the fiber coupled version the optical coupling with the chip is through a fiber coupling. We note that the optical setup illustrated in Fig. 4 is also required for the fiber coupled chip.

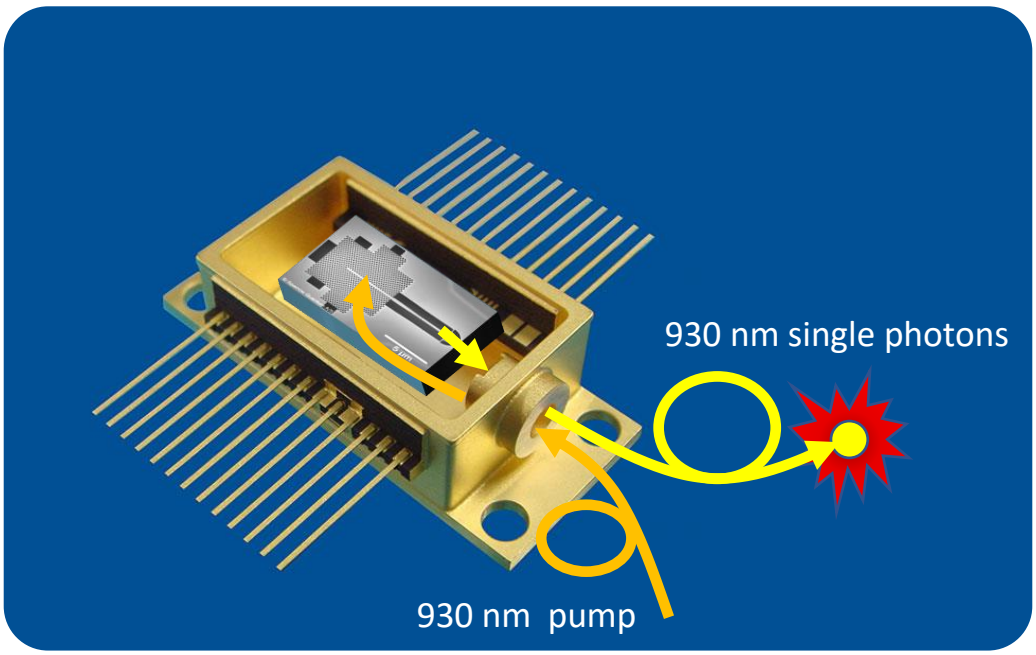

Fig. 5. Schematics of the fiber coupled housing of the SPS chip. The chip is placed on a metal plate which allows for coupling to a cryostat. Two fibers are tapered to the chip, for providing the excitation signal and the other fiber collecting the output photons.

Sparrow SPS 930 nm module

The Sparrow SPS 930 nm module is a fully integrated plug and play solution that supplies single photons at 930 nm wavelength. The system includes the excitation laser, the Sparrow chip, a Montana cryo-optic cryostat and an optical setup for filtering the signal. The setup is integrated in a practical box with a fiber output for easy input of the single photons to an external optical circuit.

Fig. 6. The Sparrow 930 nm plug and play SPS module, including the Montana cryostat to the right and the optical circuitry in the box to the left.

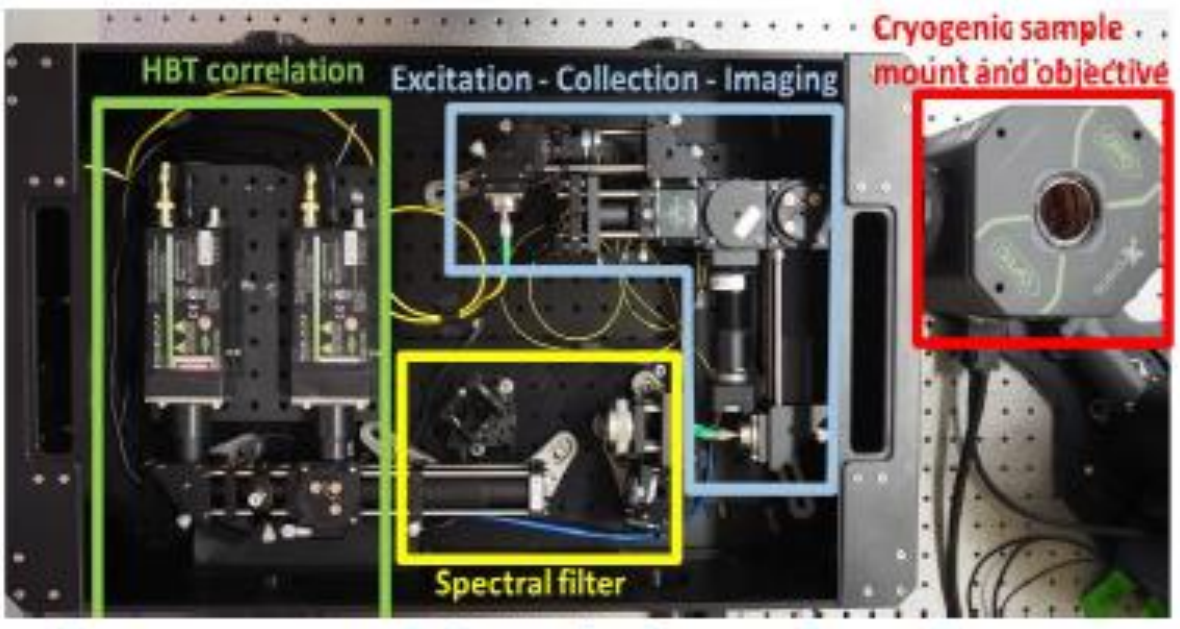

Fig. 7 Top view of the Sparrow SPS 930 nm module.

Sparrow SPS 1550 nm module

The Sparrow SPS 1550 nm module is a fully integrated plug and play solution that supplies single photons with 1550 nm wavelength for compatibility with standard telecommunication equipment. The module is an extension of the 930 nm module with a wavelength up-conversion component.

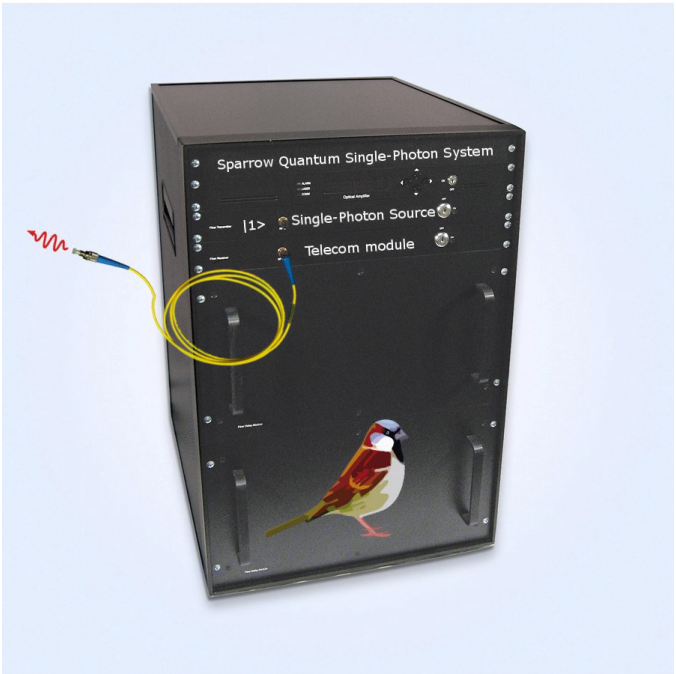

Fig. 8. The Sparrow 1550 nm plug and play SPS module. The module is an extension of the Sparrow 930 nm module with a wavelength up-conversion component.

Product list autumn 2019

The Sparrow chip is available in four different embeddings as described in the previous pages and listed in the table below.

Product	Time of Delivery	Price
Sparrow SPS free space component	1-2 months	
Sparrow SPS fiber coupled component	6-8 months	
Sparrow 930 nm module	8-10 months	
Sparrow 1550 nm module	10-12 months	

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