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 InAs quantum dot structures, which when excited by an external laser will produce indistinguishable single photons on demand. The emitted photons are collected by a nanophotonic 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.

The chip comes in two versions: i) non-resonant version where the quantum dot is excited with laser light at a higher frequency than the emitted photons and ii) resonant version where the excitation laser is tuned to the transition frequency of the quantum dot and electrical contacts stabilize the quantum dot transition. The latter chip offers world leading specifications in terms of the indistinguishability of the emitted single-photon train.

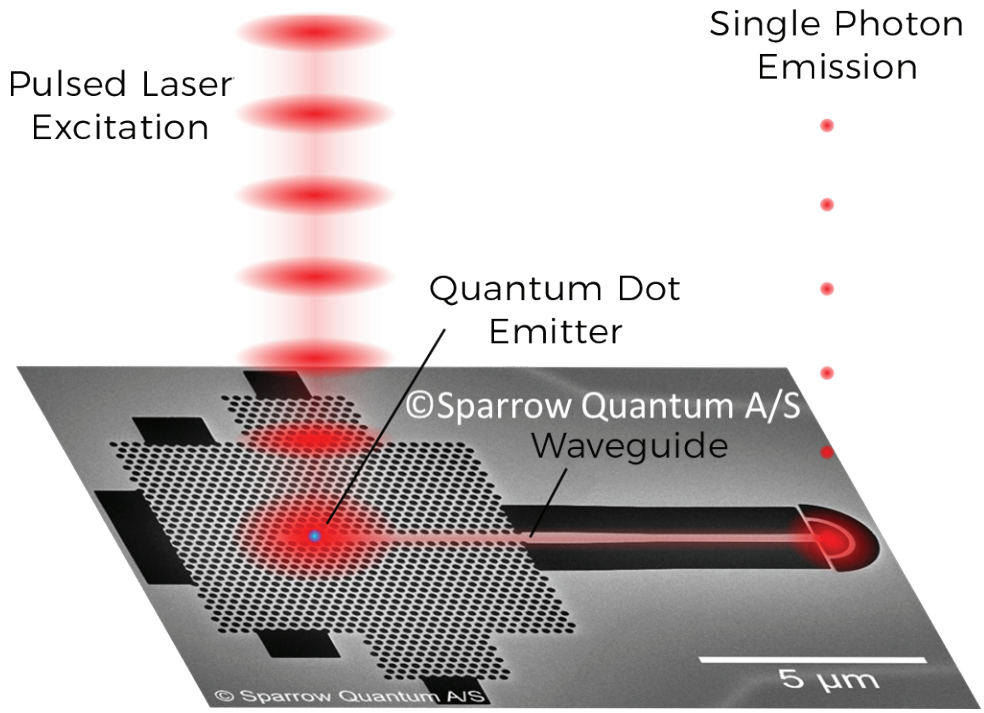

Figure 1. The quantum dot embedded in a photonic-crystal waveguide. The quantum dot is excited by an external laser and emits indistinguishable single photons.

Specifications

Specifications	Sparrow Chip 2021 Non-Resonant	Sparrow Chip 2021 Resonant
Excitation mechanism	Non-Resonant	Resonant
Single-photon purity (1-$g^{(2)}(0)$)	95-98%	>98%
Single-photon coherence indistinguishability	60-90%	95-98%
Single-photon efficiency in fiber	20 MHz *	>100 MHz *
Emission wavelength	920-980 nm	920-980 nm
Excitation wavelength	700-920 nm	Same as emission wavelength
Operating temperature	< 6°K	< 6°K
Excitation power	Typ. 1-10 µW	Typ. 1-10 µW
Excitation pulse width (recommended)	10-30ps	10-30ps
Single-photon pulse duration	100 ps – 1 ns	100 ps – 1 ns

**** For 0.5 GHz repetition rate pulsed operation of the source***

Table 1. Specifications for the Sparrow non-resonant and resonant coupled chip.

References

1. R. Uppu, H. T. Eriksen, H. Thyrrestrup, A. D. Uğurlu, Y. Wang, S. Scholz, A. D. Wieck, A. Ludwig, M. C. Löbl, R. J. Warburton, P. Lodahl, and L. Midolo, On-chip deterministic operation of quantum dots in dual-mode waveguides for a plug-and-play single-photon source, Nature Communications 11, 3782. (2020).
2. R. Uppu, F. T. Pedersen, Y. Wang, C. T. Olesen, C. Papon, X. Zhou, L. Midolo, S. Scholz, A. D. Wieck, A. Ludwig, and P. Lodahl, Scalable integrated single-photon source, Science Advances 6, 8268 (2020)
3. 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).
4. 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).
5. 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).
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Optical setup for the free space SPS non-resonant chip

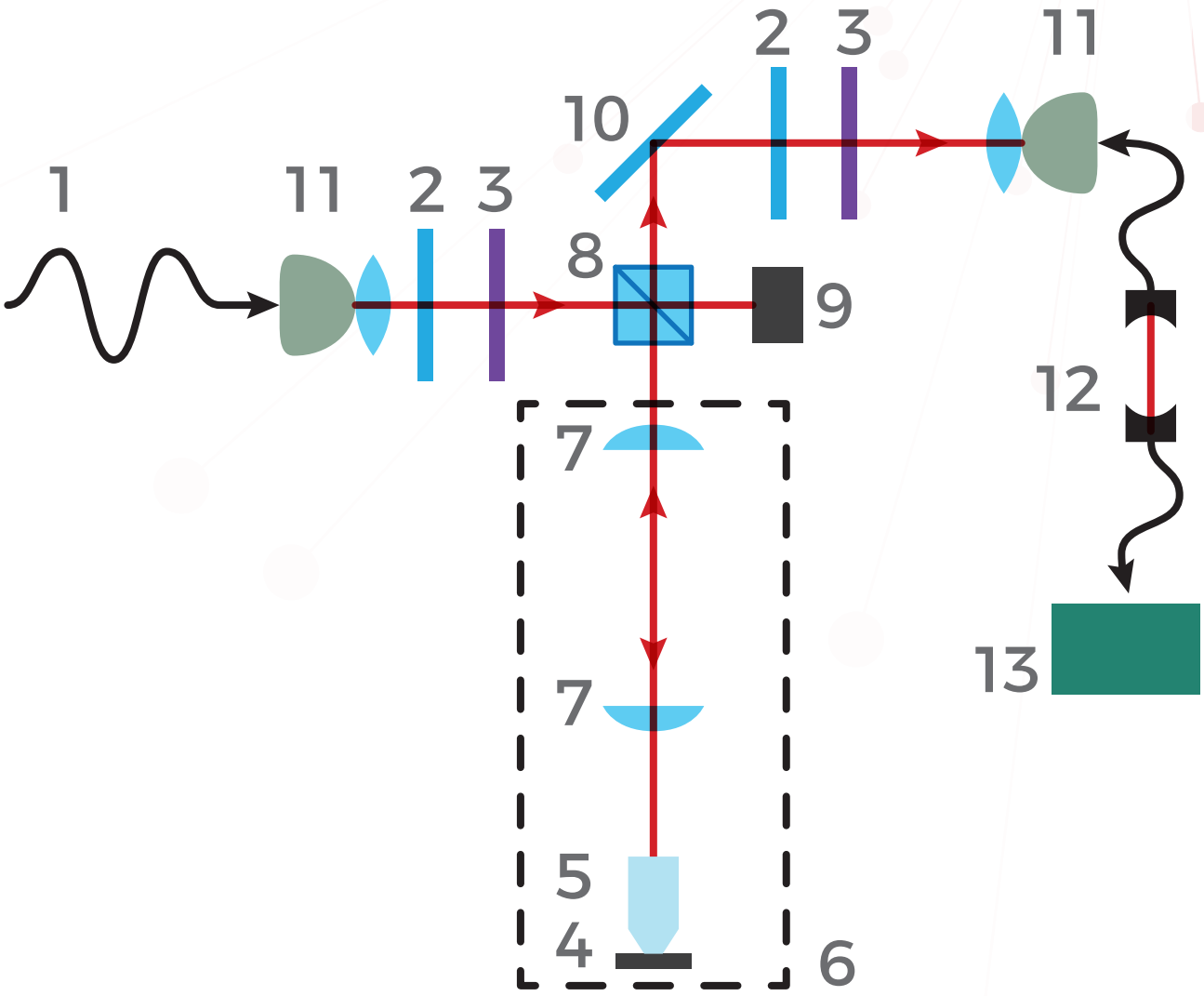

Figure 2. The optical setup for the SPS non-resonant chip, the dashed line represents the cryostat. For description of each component, see table 2.

List of components in the optical setup for non-resonant chip

Item	Component	Recommended Supplier
1	Pulsed tunable laser delivering ~20ps pulses, ~mW average power, repetition rate below 2 GHz, and emission wavelength of typically 800 – 900 nm.	Coherent Mira
2	Quarter wave plate mounted on motorized rotation stage	Thorlabs
3	Half wave plate mounted on motorized rotation stage	Thorlabs
4	Sample mounted on micro manipulators	Sample holder and micromanipulator from Attocube
5	Confocal microscope with wide field-of-view confocal microscope with a high numerical aperture objective (NA = 0.81).	Attocube
6	Cryostat cooled to ~4°K	Attocube, Attodry-2100 Different options could be considered as well, e.g., Attodry-1000 or cryo from Montana Instruments
7	Focal lenses with focal length f = 300 mm	Thorlabs
8	Reflection/transmission beam splitter 5/95 %	Thorlabs
9	Light Dump	Thorlabs
10	Mirror	Thorlabs
11	Lens for coupling with fiber	Thorlabs
12	Spectral filter Fabry-Perot etalon with 3 GHz linewidth and 100 GHz free spectral range	Light Machinery
13	Spectrometer	Princeton Instruments

Table 2. Details of the components in the optical setup around the non-resonant single photon chip illustrated in figure 2.

Optical setup for the free space SPS resonant chip

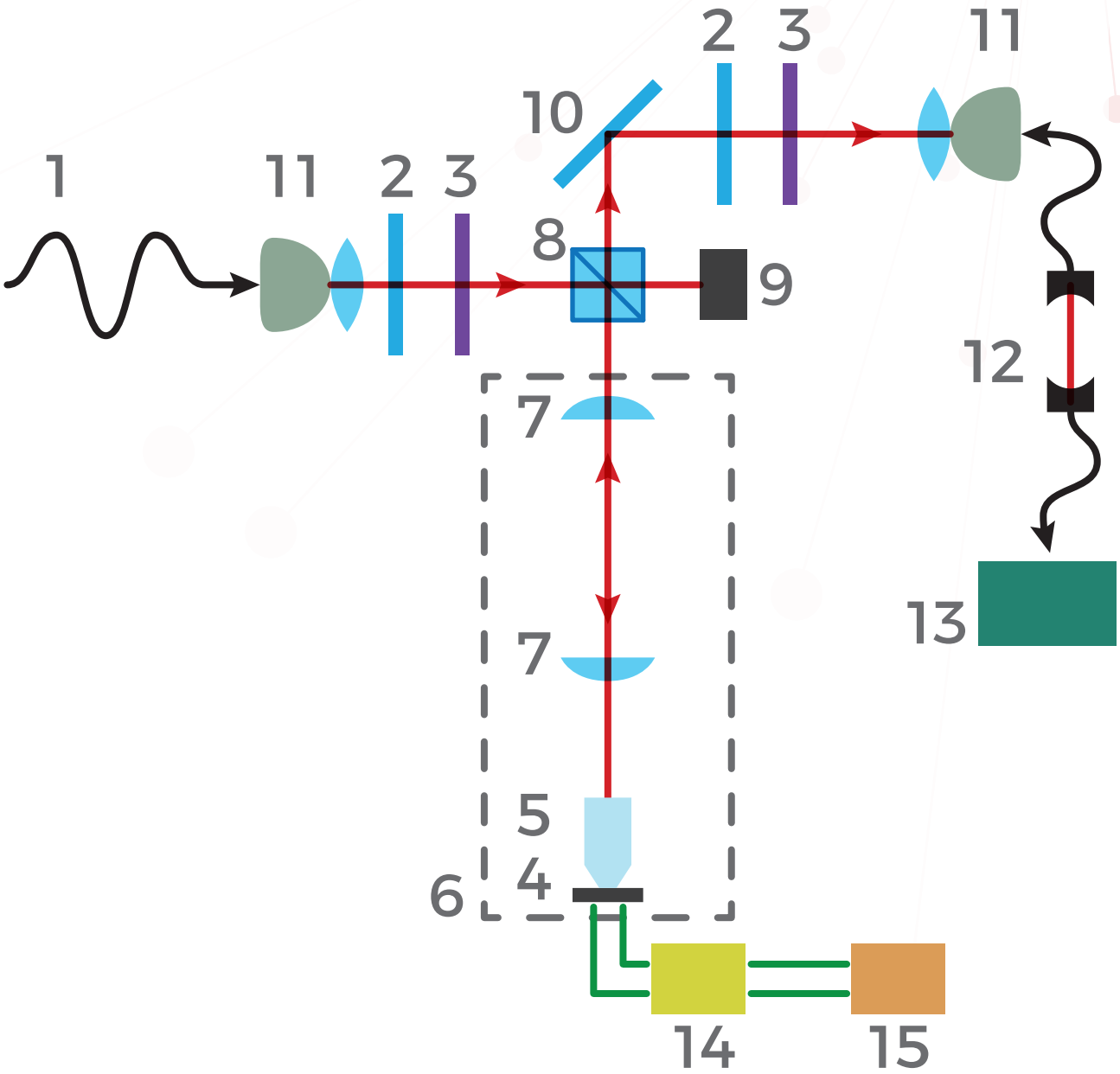

Figure 3. The optical setup for the SPS resonant chip.
Each component is detailed in Table 3.

List of components in the optical setup for non-resonant chip

Item	Component	Recommended Supplier
1	Pulsed tunable laser delivering ~20ps pulses, ~mW average power, repetition rate below 2 GHz, and emission wavelength of typically 800 – 900 nm.	Coherent Mira
2	Quarter wave plate mounted on motorized rotation stage	Thorlabs
3	Half wave plate mounted on motorized rotation stage	Thorlabs
4	Sample mounted on micro manipulators	Sample holder and micromanipulator from Attocube
5	Confocal microscope with wide field-of-view confocal microscope with a high numerical aperture objective (NA = 0.81).	Attocube
6	Cryostat cooled to 2-4°K	Attocube, model Attodry-2100. Different options could be considered as well, e.g., Attodry-1000 or cryo from Montana Instruments
7	Focal lenses with focal length f = 300 mm	Thorlabs
8	Reflection/transmission beam splitter 5/95 %	Thorlabs
9	Light Dump	Thorlabs
10	Mirror	Thorlabs
11	Lens for coupling with fiber	Thorlabs
12	Spectral filter Fabry-Perot etalon with 3 GHz linewidth and 100 GHz free spectral range	Light Machinery
13	Spectrometer	Princeton Instruments
14	Ultra-low noise low-pass filter	Keysight (N1294A-021)
15	DC voltage source	Keithley 2450

Table 3. Details of the components in the optical setup, as illustrated in figure 3.

Product list 2021

The Sparrow chip is available in a resonant and non-resonant version as described in the previous pages and listed in the table below.

Product:
Sparrow SPS non-resonant free space chip.
Pretested with guaranteed specifications.
1 week offsite support and 3 days onsite support.

Time of Delivery:
2-4 months

Product:
Sparrow SPS resonant free space component.
Pretested with guaranteed specifications.
2 week offsite support and 1 week onsite support.

Time of Delivery:
4-6 months

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