Low intensity inelastic photon scattering in silicon wire waveguide below the bandgap

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Abstract: We study the spontaneous photon scattering that arises in silicon waveguides at low power. Power dependence, temperature dependence, spectrum and response time point out its origin as pump scattering on a thermal bath of excitons.

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Introduction. When a pump beam is propagated through a silicon nanophotonic waveguide, a very small fraction of the light is scattered to other frequencies. At very low intensity, the amount of scattered light is proportional to the power of the pump beam. This may impact on the quality of photon pairs generated through the Kerr nonlinearity in silicon [1–3]. This scattering has been observed before [3], but never studied in detail. Here we characterise this scattering and investigate its origin via spectral measurements, time, power and temperature response.

Experiments. Our sample is a 11.3 mm long silicon wire waveguide (SWW) whose section is 500×220 nm². This SWW is optically pumped by a monochromatic beam at telecom wavelength. The scattered light is isolated from the pump by appropriate filtering stages and is detected with single photon detectors. The collection bandwidth is ω ∈ [0.4,2.4] THz. A time to digital converter allow for measuring time/frequency correlation and emission response time. The spectral properties are investigated with an additional tunable filter. The silicon chip temperature T is controlled between 300 and 575 K.

Results. As previously reported [3], the photon flux exhibits both a quadratic and a linear contribution (Fig.1a). The quadratic part is attributed to photon pair generated via spontaneous four wave mixing, and is in good agreement with the theoretical expectation. The aim of this work is to study the linear contribution. It could be explained by nonlinear loss on the quadratically generated flux but it is excluded as nonlinear losses are too low (absent within our measurement error of 2.5% and for power less than 3 mW) and not compatible with Fig.1a. A small contribution to the flux comes from imperfect filtering operation. This contribution is measured by replacing the SWW by a fiber-attenuator. It is found to be weak in comparison to the flux generated into the SWW in every experimental condition that we investigated.

The evolution of the flux as a function of the temperature is studied at low power (0.5 mW) such that the dominant contribution is the linear scattering. Fig.1b shows that the flux grows linearly with the absolute temperature in the interval [300,575] K.

Fig.1c presents our spectral measurements. Again, the pump power was set at low power (250 µW) to minimize the photon pair generation. Both the photon pair generation spectrum and the noise due to imperfect filtering were measured as well. As predicted by theory [3], the photon pair generation spectrum showed a sinc² profile. The noise