Integrated AlGaAs Source of Highly Indistinguishable and Energy-Time Entangled Photons

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Entangled states are key resources for quantum information science. In particular, on-chip fully integrated quantum photonic circuits will play an important role for future quantum technologies. In this domain, the maturity of semiconductor technology offers a huge potential in terms of ultra-compact devices including the generation, manipulation and detection of many quantum bits. Among the different semiconductor platforms AlGaAs present the advantage of a high second order nonlinearity, a mature clean room technology, and a direct band-gap having recently led to the integration of the laser source and the spontaneous parametric down conversion (SPDC) process within the same device [1].

In this paper we report the first demonstration, up to our knowledge, of an AlGaAs source, based on spontaneous parametric down-conversion process, emitting highly indistinguishable and energy-time entangled photon pairs. The device is an AlGaAs Bragg reflection waveguide emitting twin photons at room temperature and telecommunication wavelengths. It is based on a modal phase-matching scheme, in which the velocity mismatch is compensated by multimode waveguide dispersion. The structure includes two Bragg mirrors providing both a photonic band gap confinement for a TE Bragg pump mode at 780 nm and total internal reflection claddings for TE and TM modes at 1560 nm.

The source has a brightness of 7.2 $10^6$ pairs/s with a signal-to-noise ratio of 141. Indistinguishability between the photons is demonstrated through a Hong-Ou-Mandel experiment displaying a visibility of $89\pm 3\%$ (Fig 1a). The exploitation of a type II SPDC process makes the device able to produce polarization entanglement [2]. In this work we have chosen to test energy-time correlations, since this is a very convenient format of entanglement, as it can be easily manipulated with integrated circuits and can be preserved over long distances in standard optical fibers [3]. The generated photon pairs are sent through a standard Franson interferometer and the resulting fourth order quantum interference is recorded (Fig 1.b); the obtained Bell type curve has a net visibility of $V_{\text{net}} = 95.6 \pm 3.7\%$.

These measurements are a key step for energy-time entanglement and indistinguishable photons generation of electrically driven devices on chip.

References