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Entangled photonic qudits encoded in 21GHz spaced frequency bins generated on-chip using a silicon microring for Quantum Communications with telecom devices.

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High dimensional quantum states, qudits, leverage the ability to store more information in a single photon. They can be used for quantum computing and quantum cryptography, as they are also enable more tolerant to noise [1]. Frequency domain, for example, grants access to a high dimensional Hilbert space. It is furthermore compatible with integration and can leverage multiplexing, since all frequency components can travel in a single fiber. Recent works demonstrated on-chip generation of frequency entangled qudits using micro-ring resonators [2, 3] with a dimension up to D = 8, at telecom wavelengths. The generation of qudits of dimension up to D = 4 has also been demonstrated with an array of four Silicon-On-Insulator (SOI) micro-resonators [4].

In this work, we use a SOI micro-ring resonator to generate frequency-bin entangled photon pairs through four-wave mixing (FWM) non linear process. The frequency bins are separated by a free spectral range (FSR) of 21GHz (see Fig.1 a). The FSR smaller than the 200 GHz FSR harnessed in [3] allows us to manipulate the photon pairs using off-the-shelf electro-optic modulators (EOM) and programmable filters (PF) (see Fig. 1 b). Commercial EOMs are limited to 40 GHz. The PFs select the frequency modes of interest while the EOM enable scattering in a supperposition of modes. We measure quantum interferences of qudits up to D = 5 (see Fig. 1 c and d).

The broadband emission of our source allows us to generate up to 9 pairs of frequency entangled qutrits (qudits with D = 3) over a 5 THz bandwidth, each displaying two-photon interference visibility higher than 90% (see Fig. 1 e). Therefore we can create a fully connected Quantum Key Distribution (QKD) network between up to five users, using high dimensional quantum states.

Fig. 1: https://i.postimg.cc/s2GJZw9r/Figure-1.png

a) Sketch of the emission spectrum of the microring resonator. **b)** Setup for manipulation of frequency entangled qudits. **c)** and **d)** Two-photon interferences of qudits, **e)** visibility of qutrit (D = 3) interferences over the emission bandwidth. FWM : four wave mixing, ωp : Pump frequency, Sn and In : Signal and Idler entangled photons, FSR : free spectral range, EOM : electro-optic modulator, PF : programmable filters.

References:

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