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### ► **To cite this version:**

A Chambinaud, M Cordier, A Reigue, Y Asselah, G Bonamis, et al.. High brightness single photon source at the telecom wavelength based on inhibited-coupling hollow-core fiber. Conference on Lasers and Electro-Optics (CLEO US), May 2022, San Jose, United States. pp.FW1A.4. <hal-03681733>

**HAL Id: hal-03681733**

**<https://hal.science/hal-03681733v1>**

Submitted on 30 May 2022

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# High brightness single photon source at the telecom wavelength based on inhibited-coupling hollow-core fiber

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**Abstract:** We report on a Raman-free heralded single-photon source based on xenon-filled hollow-core fiber pumped with GHz-repetition rate femtosecond laser. The measured brightness of 720 kHz is one order of magnitude improvement over our previous demonstration. © 2022 The Author(s)

## 1. Introduction

The emerging second quantum revolution entails the development of several key quantum and photonic components and devices with stringent specification requirements [1]. For example, single photon sources, which are required in quantum information, must combine high signal-to-noise ratio, high brightness, high purity and integrability in the telecommunications network. A combination that is yet to be achieved. Recently Cordier *et al.* [2] demonstrated that the generation of photon-pairs by spontaneous four-wave mixing (SFWM) in inhibited-coupling hollow-core photonic crystal fiber (IC-HCPCF) filled with an inert gas is a very promising platform for the generation of both noise-free pure single photon and entangled photon-pairs. This configuration stands out with three enabling features: i) the IC-HCPCF can be designed and fabricated in such a way that the dispersion meets very strict phase matching conditions to generate the photon-pairs with tailored spectral correlations, ii) the fiber can be designed to operate at wide ranges of wavelengths, as illustrated in [2,3] whereby the idler wavelength lies in the telecom wavelength range ( $\sim 1550$  nm), and the signal wavelength is in the range of atomic transitions and Silicon single photon detectors ( $\sim 780$  nm), and iii) the gas-filled HCF does not suffer from the Raman scattering effect, which has hitherto been an obstacle in the development of a noise-free fiber-based single-photon sources. However, despite all these promising results, the maximum brightness of the source was found to be 50 kHz, mainly limited by the time regime of the pump beam used. Here, we report on a SFWM based heralded single photon at 1550 nm pumped with GHz-repetition rate femtosecond laser, with the brightness corresponding to a photon-pair rate of 720 kHz, and a maximum signal-to-noise ratio given by the coincidence-to-accidentals ratio (CAR) of 7400, resulting in a new state-of-the-art of fiber photon-pairs sources.

## 2. Experimental set-up and quantum state preparation

Figure 1 summarizes the set-up used in the present work and the photon-pair correlation properties obtained [3]. Here, we use a femtosecond laser source delivering light pulses of 16 W maximum average power at 1033 nm with a duration of 280 fs and a repetition rate of 1 GHz. The generated light pulses are then coupled to a 93 cm long gas-filled IC-HCF. The fiber used is a IC-HCPCF with tubular cladding lattice, a core diameter of 44  $\mu\text{m}$  and a silica thickness of 628 nm. The fiber was designed so the SFWM induced photons are emitted near 1550 nm and 780 nm (Fig. 1b).

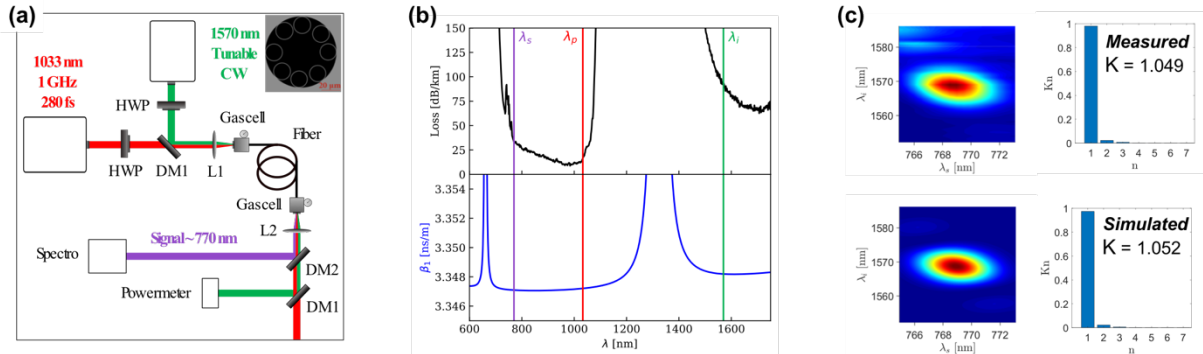


Fig. 1. (a) Experimental set-up (b) Loss and phase matching curves of the Xe-filled IC-HCF. (c) Measured and simulated JSI of the source associated with the Schmidt decomposition (assuming a flat phase).

In order to set the SFWM photon-pair in the desired separable quantum state, the gas pressure is varied for fine dispersion control. This was demonstrated by the reconstructed JSI using stimulated emission tomography technique as in [4], with the seed laser being a continuous-wave laser tunable in the telecom range. The average power of the pump and the seed is then set respectively to 5.8 W and 10 mW. The results of this quantum state preparation show a JSI with a Schmidt number  $K$  of 1.049, corresponding to a high purity factorable pair states of 95% (Fig. 1c). This state was achieved with a gas pressure of 4.3 bar, a signal wavelength of 769 nm and an idler wavelength of 1570 nm.

### 3. Heralded single photon source

The resulted separable photon-pairs are then implemented to demonstrate a high brightness heralded single photon source. Here, the set-up described in Fig. 1a is modified by blocking the seed laser (spontaneous scheme) and adding Si and InGaAs single-photon detectors at the fiber output. The signal and idler photons are filtered and detected individually using standard coincidence correlation scheme (see the inset of Fig. 2a). Figure 2 shows the occurrences obtained for both photons and the associated CAR as a function of the average pump power ranging between 0 to 10 W. The evolution with a quadratic polynomial ( $\propto P^2$ ) demonstrates photon-pair generation with negligible Raman Scattering as expected. This is further confirmed by the measured CAR reaching a record for any fiber architecture of 7400 at 1 W over 250 mW. Finally, the photon-pair rate was found to a maximum of 720 kHz, value corresponding to an improvement of more than one order of magnitude compared to our previous work based on a 2 MHz pump laser. This figure is in good agreement with the theoretical calculations which predicts an enhancement factor of 16 for the laser powers considered (100 mW at 2 MHz and 10 W at 1 GHz). This improvement of the brightness will be a strong advantage for future experiments, especially for correlations measurements which will experience a time reduction factor of two orders of magnitude.

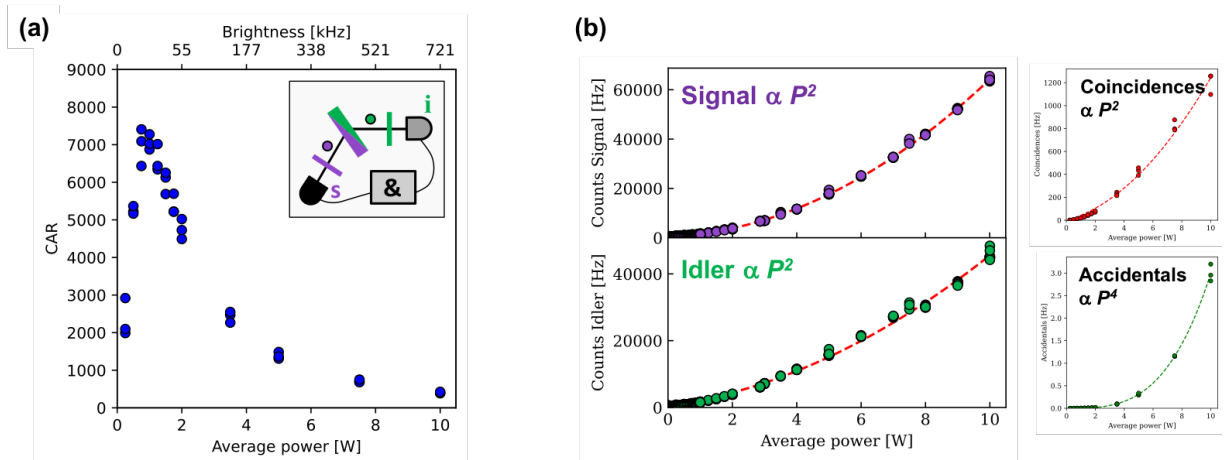


Fig. 2. (a) CAR and brightness of the heralded single photon source. In inset, the detection protocol is added. (b) Signal and idler counts as a function of the average pump power. The measured coincidences and accidentals are also plotted.

### 4. Conclusion

To conclude, by pumping a Xe-filled IC-HCF with a GHz-repetition rate femtosecond laser, we improved the current state-of-the-art in signal-to-noise and brightness of fiber photon-pairs sources. This result is a new step to configure our platform as an entangled pair generator to demonstrate quantum key distribution.

The authors acknowledge support from la Région Nouvelle Aquitaine.

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