18a-C7-12

Spontaneous Four-Wave Mixing Mediated Mid-IR Entangled Photon Pair Generation in Dispersion Engineered Chalcogenide Optical Fibers

V. Mishra[1], S. P. Singh[1], and Shailendra K. Varshney[1, 2]
[1]Department of Physics, [2]Department of E&ECE, IIT Kharagpur, India
E-mail: vishwatoshmishra34@gmail.com; skvarshney@ece.iitkgp.ernet.in

We have theoretically investigated the effect of the fiber dispersion profile on the factorability of the two -photon states produced through birefringent Spontaneous Four Wave Mixing (SFWM). The dispersion profiles studied here, correspond to a capillary-assisted chalcogenide optical fiber (CCOF) reported in [1]. We have found that the shape of the dispersion profile plays a crucial role in achieving the perfectly factorable two-photon states. Thus if the fiber dispersion is normal throughout the whole pump wavelength range, the pure signal and idler photon states are generated only for the pump polarization along the slow axis of the fiber and if there is an anamolous dispersion region along with one or two normal dispersion regions, the pure states may be possible either for slow or fast axis pump polarizations, or there might not be pure states, depending upon the height of the anamolous dispersion region.

SFWM is a nonlinear optical process in which two pump photons (either degenerate or non-degenerate) interact spontaneously to produce two photons at different wavelengths. The generated signal and idler photons is highly correlated (entangled) in spectral and temporal domain [2-4]. Photon pairs generated in SFWM are not attractive for linear quantum optics computation, which relies on the availability of completely uncorrelated (factorable) photon pairs in which the individual signal and idler photons are in pure quantum states. In order to generate completely factorable photon pairs one has to engineer the fiber dispersion profile in such a way that the contribution to the correlation in two-photon state due to energy conservation is exactly balanced by momentum conservation. The entanglement of the two-photon states is characterized by the joint spectral amplitude (JSA) function [5], which is given by

$$F(\nu_s,\nu_i)=\alpha(\nu_s,\nu_i)\phi(\nu_s,\nu_i) \qquad (1)$$

where $\alpha(\nu_s,\nu_i)$ accounts for the energy conservation and is always inclined at -45^0 to ν_s axis in $\{\nu_s, \nu_i\}$ space. The pure signal and idler photon states can then be realized by reshaping $\phi(\nu_s,\nu_i)$ (which accounts for the momentum conservation) via the dispersion profile so that it makes an angle of 45^0 with ν_s and hereby counteracts the contribution to the entanglement from $\alpha(\nu_s,\nu_i)$, and ν_s, ν_i are the detuning of the signal and idler frequencies from their perfect phase matched values.

The dispersion profiles corresponding to particular structural parameters of the CCOF and different values of the capillary refractive index (n_{hole}) are shown in Fig 1. The refractive index of the capillary is varied from air to high-index of 1.8 from solid blue curve to solid magenta curve. It is clearly evident that dispersion profile varies from anomalous to normal dispersion regimes. In case of air, there is a factorable state at a pump wavelength of 2.93 μm for the pump polarization along the fast axis, as shown in the figure (right panel). For similar dispersion profile, corresponding to n_{hole} = 1.2, there is no factorable state for any pump polarization. For n_{hole} = 1.4 which has the similar dispersion profiles as the previous two cases, but the width of anomalous dispersion region is reduced considerably, factorable two photon state occurs for the pump polarization along the slow axis. For the remaining two all-normal dispersion profiles (in the range of pump wavelengths), factorability is possible only for the pump polarization along slow axis. To conclude, it has been verified that dispersion profile has a decisive role in determining that whether the factorability is possible corresponding to a specific dispersion profile or not.

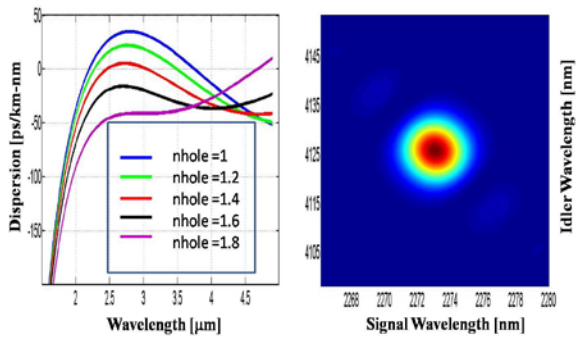

Fig 1. Left panel: Dispersion characteristics of CCOF (core radius: 2 μm, capillary radius: 600 nm for different values of capillary refractive index; Right panel: factorable JSA corresponding to the solid blue curve in dispersion profile at left.

V. Mishra would like to express sincere thanks to CSIR-INDIA for financial support through JRF scheme.

[1] S. P. Singh, *et al.*, ‘‘Theoretical investigation of chalcogenide capillary optical fiber with three zero dispersion wavelengths for parametric gain in Mid-IR region,” ICOL, Dehradun, 5-8 March 2014, India
[2] L. Zhang, *et al.*, “Heralded generation of single photons in oure quantum states,” J. Mod. Optics **59** (2012) 1525-1537.
[3] L. Zhang, *et al.*, “Generation of highly entangled photon pairs for continuous variable Bell inequality violation,” J. Mod. Optics **54** (2007) 707-719.
[4] B. Fang, *et al.*, “State engineering of photon pairs produced through dual-pump spontaneous four-wave mixing,” Optics Express **21** (2013) 2707-2717.
[5] K. Garay-Palmett, *et al.*, “Ultrabroadband photon pair preparation by spontaneous four-wave mixing in a dispersion-engineered optical fiber,” Physical Review A **78** (2008) 043827.