Available online at www.sciencedirect.com

ScienceDirect

Optics Communications 281 (2008) 2722–2726

OPTICS COMMUNICATIONS

www.elsevier.com/locate/optcom

First demonstration of a temporal coherence analysis through a parametric interferometer

L. Del Rio *, M. Ribiere, L. Delage, F. Reynaud

Department Photonique/XLIM – 123, UMR CNRS 6172 Av. Albert Thomas, 87060 Limoges Cedex, France

Received 3 October 2007; received in revised form 9 January 2008; accepted 11 January 2008

Abstract

We analyze the temporal coherence of an optical infrared radiation in the visible domain by using a Mach–Zehnder interferometer and a wavelength conversion stage in each arm. We exploit a sum frequency generation process in bulk PPLN crystal to convert the infrared radiation at 1.55 μm into 0.63 μm before the interferometric mixing. The applicability of the Wiener–Kintchine theorem through up-conversion processes is here demonstrated by direct comparisons among visible and infrared measurements.

Keywords: Sum frequency generation; Theorem of Wiener–Kintchine; Temporal coherence; Nonlinear optics; PPLN

1. Introduction

The conversion of frequencies through mixers is a fundamental data processing operation which is widely employed in the field of radio and microwave applications.

In the optical domain, this function can be provided by a parametric sum or difference frequency generation (SFG, DFG). Such optical signal processing becomes mature thanks to the development of specific nonlinear materials [1,2]. For instance, periodically poled lithium niobate (PPLN) crystals permit now very efficient SFG conversion from infrared to visible light with widespread application domains [3]. These optical functionalities have been deeply investigated in terms of energy conversion in a single nonlinear component. SFG at very low power levels and detection in photon counting regime has been recently reported and implemented in the frame of quantum communications [4–6].

More recently, the principles of nonlinear optics have been extended to interferometry. Hansch and co-workers have proposed to characterise ultra-violet radiation through third-order nonlinear effects in gases [7,8]. Their scope was to simplify the experimental coherence analysis by shifting the radiation wavelength towards the near infrared region. In doing so the mechanical tolerances of the interferometer are less critical at long wavelengths. Note that in their experiments, they used a single cell to process two spatially separated optical beams.

Our long term scope is to propose an alternative technique for high resolution imaging with nonlinear optics. Stellar interferometry uses array of telescopes with an interferometric mixing. This technique is based on the analysis of the spatial coherence of astronomical targets. In this framework, we need a total temporal coherence of the interfering beams. The primarily scope of our present study is then to prove the temporal coherence to be preserved when using a SFG process.

Differently from the case of Refs. [7,8], we are interested in up-conversion processes with two distinct SFG components. Our choice is based on the following points. First of all, visible wavelengths (i.e. the output of an SFG process) are preferable thanks to the better signal to noise ratio of silicon photodetectors [4,5]. Second, the SFG in second order nonlinear crystals in known to be a noiseless process [11]; this fact represents a crucial point in astronomy,

* Corresponding author. Tel.: +33 5 55 45 74 15; fax: +33 5 55 45 77 80. *E-mail address:* louis.delrio@free.fr (L. Del Rio).

0030-4018/$ - see front matter
doi:10.1016/j.optcom.2008.01.018

owing to the low power of astrophysical targets. Third, the frequency shift step, which takes place at the foci of separate telescopes, makes necessary to implement one nonlinear component per telescope.

The main goal of this study is to check the possibility to use the nonlinear up-conversion process in the frame of coherence analysis This first step devoted to temporal coherence is mandatory before to address the spatial coherence study.

The purpose of our present study is then to demonstrate that a temporal coherence analysis of an infrared radiation can be carried out in the visible domain. Our test bed avoids spatial coherence fluctuations by using spatially monomode guided optics.

Our experimental setup consists of a two arm interferometer fed by an infrared source with an adjustable spectrum. Parametric up-conversion modules, including PPLN crystals, allows the characterisation of an infrared radiation by detection in the visible radiation.

The interferometric analysis of a source temporal coherence allows us to determine its power spectrum. This method is commonly applied in Fourier spectroscopy [9,10]. We demonstrate, we believe for the fist time to our knowledge, that this technique may be compatible with SFG. The excellent agreement between our results in the infrared and in the visible domain, permits us to demonstrate the coherent properties of the up-conversion process. Such investigation could be of interest for a large number of applications such as Fourier spectroscopy, sensors or astronomy.

2. Experimental setup

Our experimental setup is based on a dual Mach–Zehnder interferometer (see Fig. 1). It is fed by a science signal at 1.55 μm, whose temporal coherence will be here analyzed, and by a coherent pump source at 1.064 μm.

The science source is composed by a set of two distributed-feedback (DFB) lasers with 1550 nm mean wavelength. We investigated two possible configurations:

- a single source for phase measurements;
- a spectral doublet to carry out an analysis of temporal coherence.

With the second option, we can finely adjust the spacing between the two spectral lines by using the thermal regulation units of the DFB lasers themselves.

In both cases, a polarisation maintaining optical fibre coupler (OFC, see Fig. 1) equally divide the input field into the two interferometric arms.

We insert an optical path modulator in one arm so to display the fringes pattern as a function of time. This device is driven by a triangular voltage in order to induce a linear optical path difference (OPD) as a function of time. in order to get a sinusoidal function as interferometric signal.

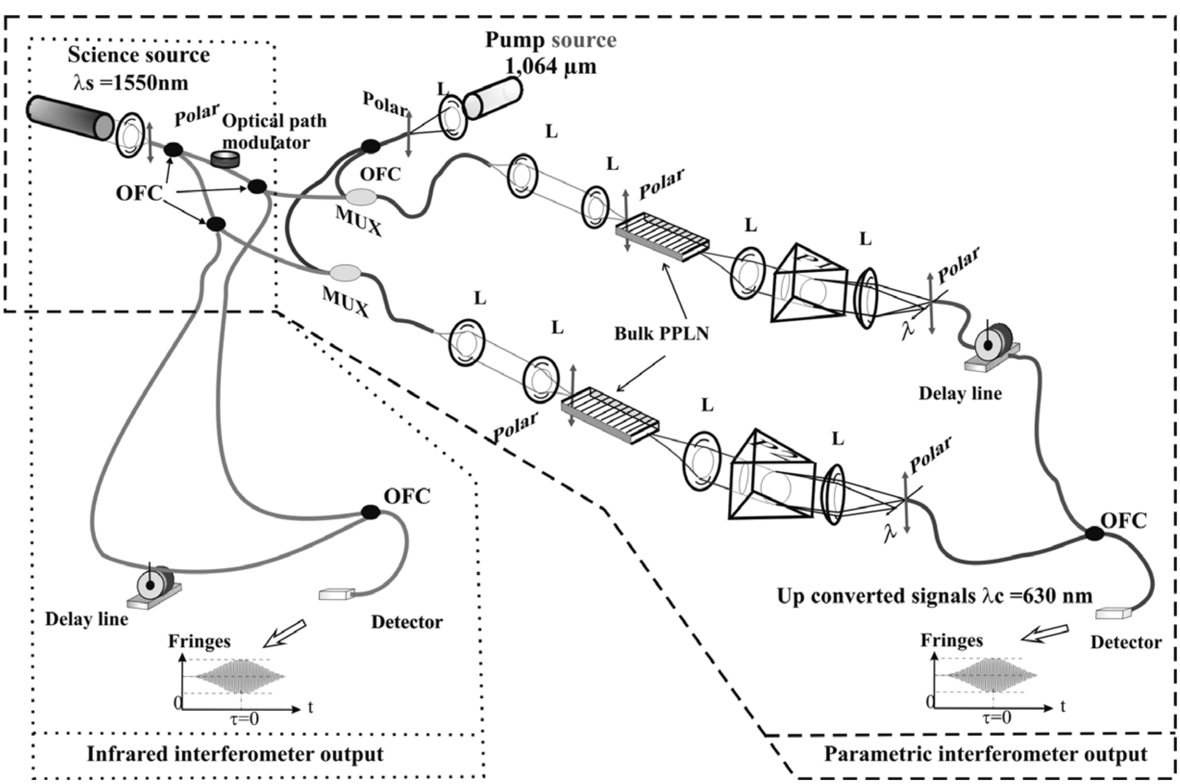

Fig. 1. Experimental setup: OFC: optical fiber couplers; L: lens; Mux: multiplexer. All the components are PM.