Tecnológico de Monterrey

Optical coherence tomography based on induced coherence with a pulsed pump

ICFO The Institute of Photonic Sciences

Poster - Abstract ID: 299, page 155

Arturo Rojas-Santana[1,*], Gerard J. Machado[2], Dorilian Lopez-Mago[1] and Juan P. Torres[2,3]

[1]Tecnologico de Monterrey, Mexico. [2]ICFO - Institut de Ciencies Fotoniques, Spain. [3] Universitat Politecnica de Catalunya, Spain.

[*]A00825456@itesm.mx

1. Graphical Abstract

OCT based on induced coherence with a pulsed pump

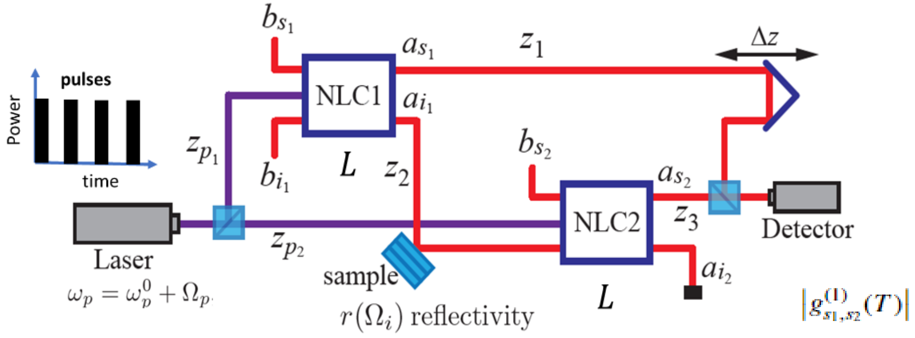
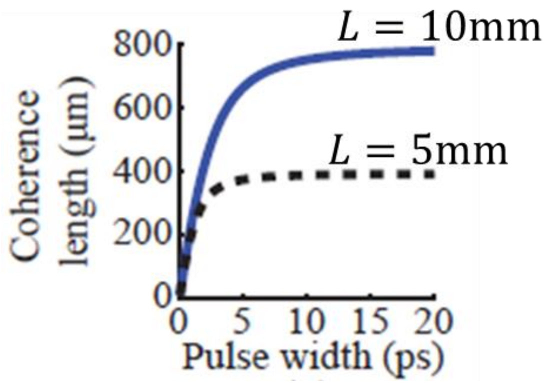
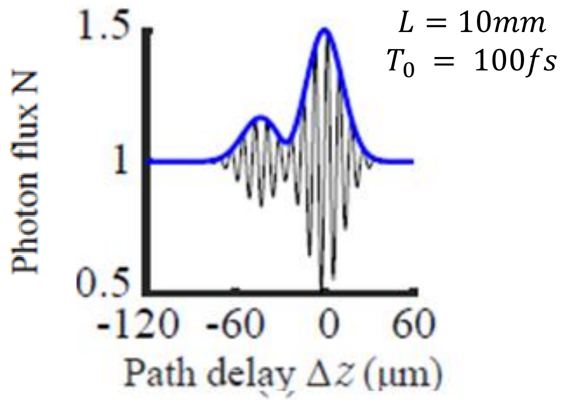


Fig. Simplified sketch of ICT. We considered MgO-doped LiNbO3 crystals. $\lambda_p = 532\ nm$ -> $\lambda_s = 810\ nm$ and $\lambda_i = 1550\ nm$ with $D = -263.50\ fs/mm$ and $D_+ = 780\ fs/mm$. $T_2 = 0$.

The first-order correlation function:



Optical depth sectioning of a Bi-layer sample



2. Introduction

Optical Coherence Tomography based on induced coherence is an optical depth sectioning technique based on the interference of the signal photons from two downconverters. In this regime the down-converted photons show frequency anticorrelation.

Photons s_1 and s_2 never interact with the object.

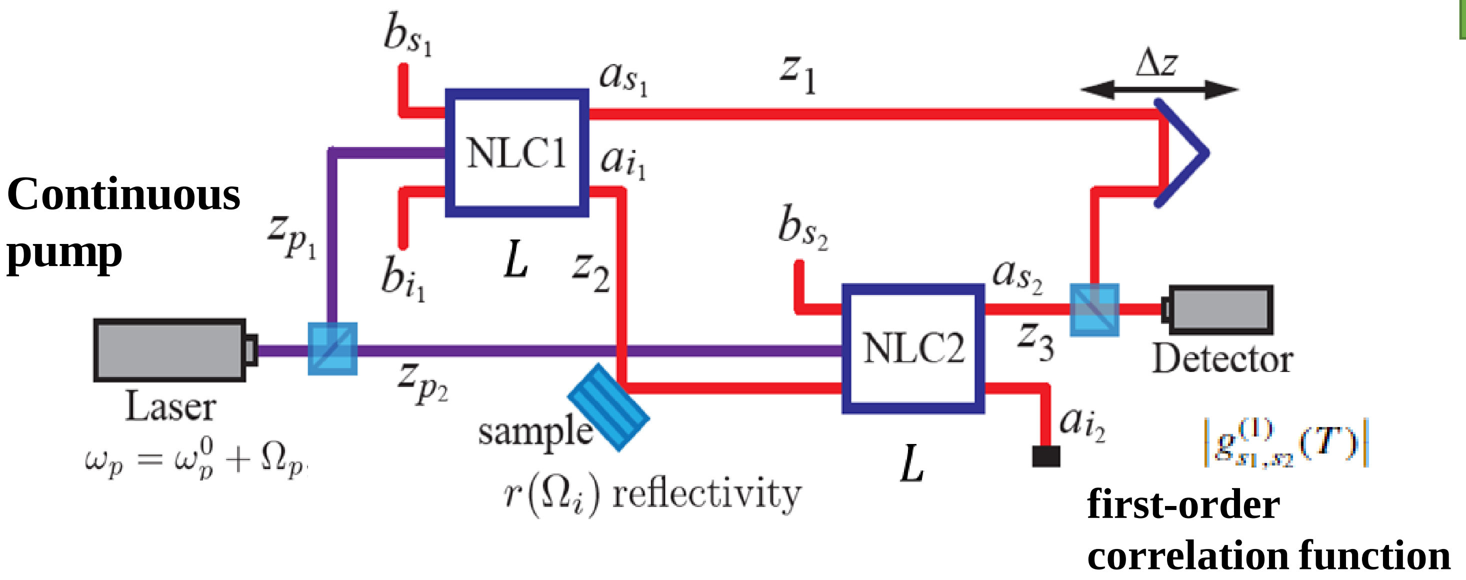


Fig. Simplified sketch of ICT. NLC stands for nonlinear crystal, s and i are labels that designate signal and idler modes, b and a represent input/output quantum operators.. $D = N_i - N_s$: $N_{s,i}$ inverse group velocities

Bi-layer object $|g^{(1)}_{s1,s2}(T)| = \text{tri}\left\{\frac{1}{DL}[T - T_0]\right\}$

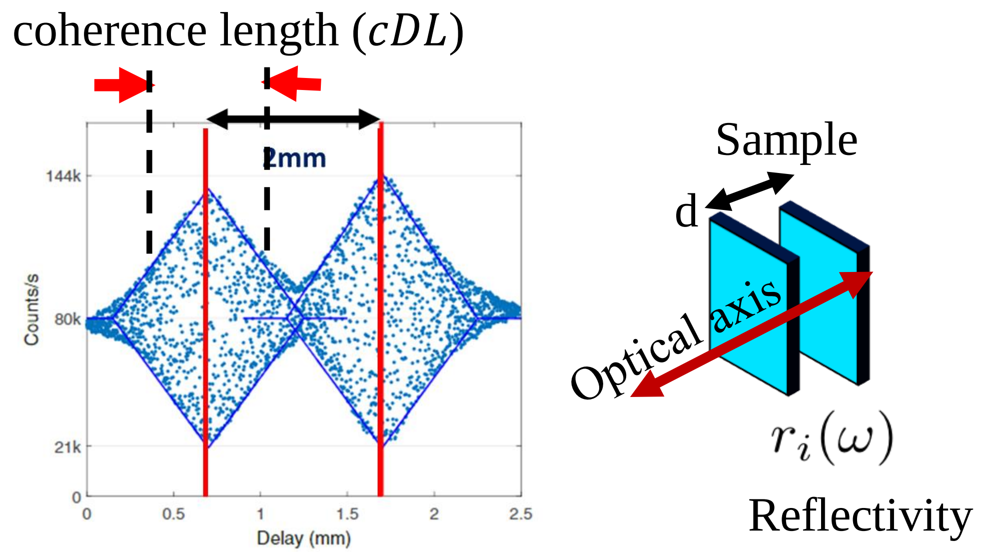


Fig. Interferogram from two layers separated 1 mm apart with a resolution of 600µm

[Phys. Rev A. **97**, 023824 (2018)]

3. Is the frequency anticorrelation provided by continuous Parametric Down Conversion a requisite to do OCT based on induced coherence?

NO. We show that one can do OCT with pulsed pump

The correlation function
is very weakly dependent on the laser pulse width (T_0)

$$\left|g^{(1)}_{s1,s2}(T)\right| = \mathrm{Tri}\left(\frac{T}{DL}\right)\exp\left[-\frac{1}{16}\left(1-\frac{2D_+}{D}\right)^2\frac{T^2}{T_0^2}\right]$$

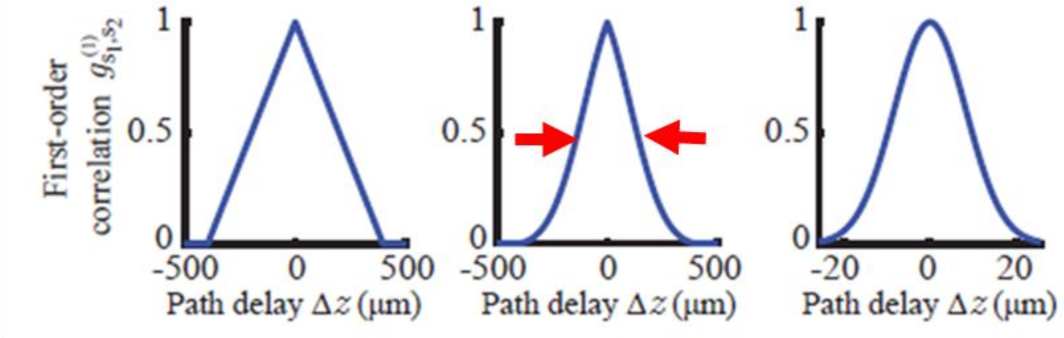
$D = N_i - N_s$: $N_{s,i}$ inverse group velocities of the photons

Frequency-entangled photons
We observe coherence for all values of the degree of entanglement between the signal and idler beams.

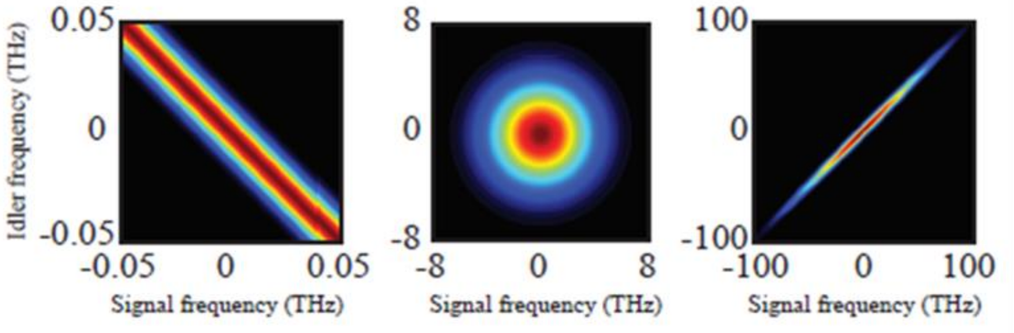
Biphoton function

$$\Phi(\Omega_s,\Omega_i) = \left(\frac{\alpha T_0 DL}{\sqrt{2\pi}}\right)^{1/2}\exp\left[-\frac{(\Omega_s+\Omega_i)^2T_0^2}{2}\right]$$
$$\times\exp\left[-\frac{\alpha^2(DL)^2}{16}(\Omega_s-\Omega_i)^2\right].$$

Degree of entanglement $\gamma = \frac{cDL}{2\sqrt{2}T_0}$



$T_0 = 100\text{ps}$ $T_0 = 2\text{ps}$ $T_0 = 100\text{fs}$



$\gamma \gg 1$ $\gamma = 1$ $\gamma \ll 1$

Fig. (Up) First order correlation function. (Down) Normalized biphoton function $|\Phi|^2$.

Tecnológico de Monterrey

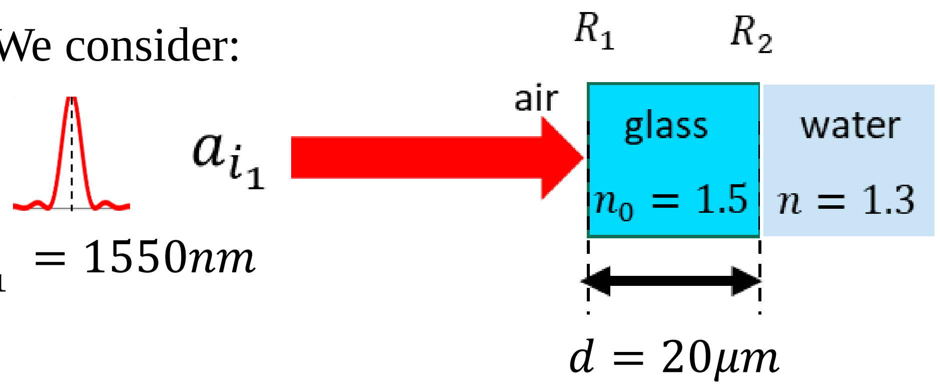
Arturo Rojas-Santana

[Preprint arXiv:2005.03741]

4. Can the use of pulsed pumps allow the use of longer crystals without reducing the bandwidth?

Bi-layer sample resolution.

We consider:



R_1 and R_2 are the reflectance of the first and second layer of the sample.

The signal detected at one output port of the beam splitter is

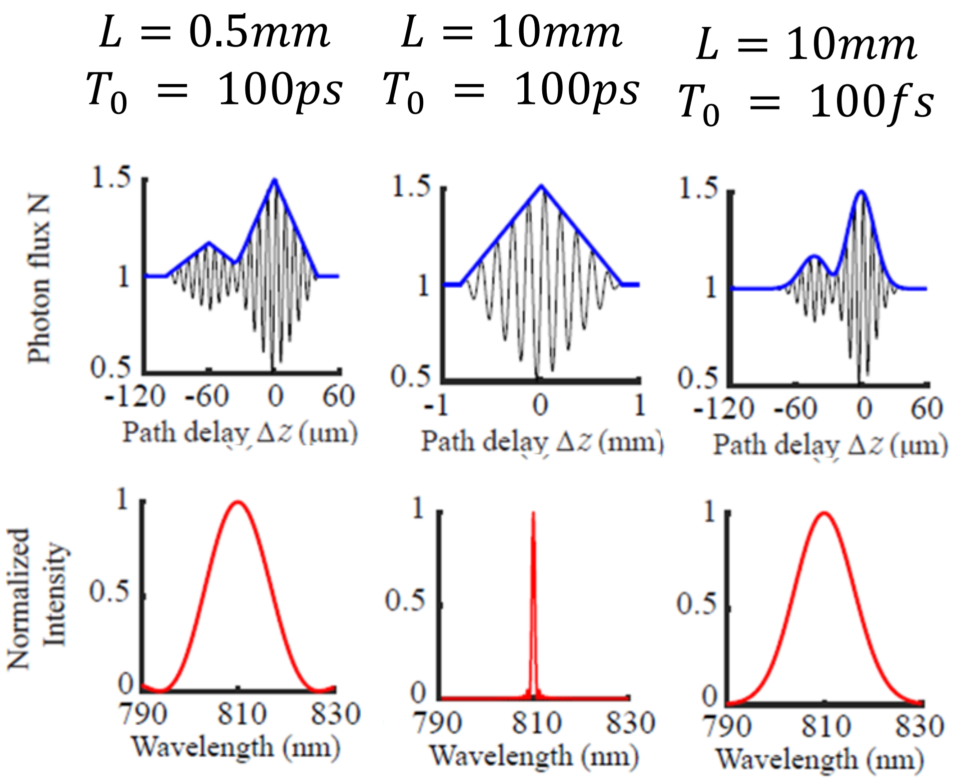


Fig. (Up) Signal detected, In blue the first order correlation function. (down) Normalized spectrum of the signal photon. thickness $2n_0d$.

$$N = N_{s_1}\Big\{1 + r_0 g^{(1)}_{s_1,s_2}(T_1,T_2)\sin\left[(\omega_p^0/c)(z_{p_2}-z_{p_1}) \;-(\omega_i^0/c)(z_2+n_iL) - (\omega_s^0/c)(z_1-z_3)\right]$$
$$+ r_1 g^{(1)}_{s_1,s_2}(T_1',T_2')\sin\left[(\omega_p^0/c)(z_{p_2}-z_{p_1}) \;-(\omega_i^0/c)(z_2+n_iL+2n_0d_0) - (\omega_s^0/c)(z_1-z_3)\right]\Big\},$$

Tecnológico de Monterrey

5. Conclusions

- We observe coherence for all degrees of entanglement between the signal and idler beams.
- It's possible to achieve high axial resolution and high photon emission rates by combining ultrashort pumping with millimeter length crystals in an induced coherence tomography system.
- The method maintains its salutary features, i.e., probing the sample with photons centered at the most appropriate wavelength while using the optimum wavelength for silicon-based photodetectors.

References in the Preprint arXiv:2005.03741
Paper accepted in Physical Review A

Arturo Rojas-Santana A00825456@itesm.mx

Thanks for the support

CONACYT

Tecnológico de Monterrey

ICFO
The Institute of Photonic Sciences