Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Response to comments on "Slowing of Bessel light beam group velocity"

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We respond here to the comments made on our recent publication "Slowing of Bessel light beam group velocity", Optics Communications, 361, 25–27(2016).

We are happy that Saari [2] noticed and commented on our paper [1] which described theory of the slowing of Bessel Beam in free space. The salient message provided by Alfano and Nolan [1] was that structured beams such as Bessel light -a pencil like shaped beam -acts as a natural cylindrical waveguide as the beam propagates in free space or in dielectric media. Most of us know that when optical beam propagates in optical fiber or waveguide, light slowing occurs due to zig- zag paths taken by rays over the collinear direction. Most recently, in support of the concept presented in [1], experiments were performed in free space to measure Bessel [3] and Laguerre Gaussian [4] beam group velocity slowing in a femtosecond region. In particular, the group of Padgett reported Bessel light signal arrival times that implied a signal propagation speed less than c in free space [3]. The "subluminal" speed on the femtosecond scale (light delay as large as ~27 fs) is attributed to the transverse spatial structure of the slowed beam. Karimi and Boyd's groups [4] studied the propagation speed of subluminal twisted light in vacuum. The measurements of Laguerre Gaussian modes related the slow speed of propagation to the mode indices l producing light delay of 23 fs for L=6. Thus, according to these works, light propagation of a finite sized structured light beam undergoes group velocity slower than c. In addition, calculation of the dispersion and reduction of Laguerre-Gaussian group velocity in free space performed in [5] further confirmed results obtained in [3].

Maybe we were little over zealous in [1] to propose a 100 ps slowing time for Bessel beam of micrometer spot size and a long traveling length for optical buffers. However, one should not close one's eyes as to what may be achieved in future with advances in photonics technology. Multiple- photon Gaussian beams are indeed smaller in spot size [6].

Saari's comment was spawn by us overlooking some past works by Saari and others related or not related. They are now referenced in [2]. More scientists will be now aware of possibility of slowing structured light in free space to advance photonics. Any structured beam in space will be propagating at a speed less than c due to spatial traverse confinement.

The idea by Alfano and Nolan [1] regarding structured light slowing and possible use of it as an optical buffer depending on the beam parameters such as spot size W_o and beam Rayleigh length Z_o is correct.

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http://dx.doi.org/10.1016/j.optcom.2016.12.079
Received 2 December 2016; Received in revised form 27 December 2016; Accepted 29 December 2016
Available online 04 February 2017
0030-4018/