Volume Holographic Reconstruction of Bessel Beams using Multiple Wavelengths

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Outstanding Young Scientist in Physics 2013

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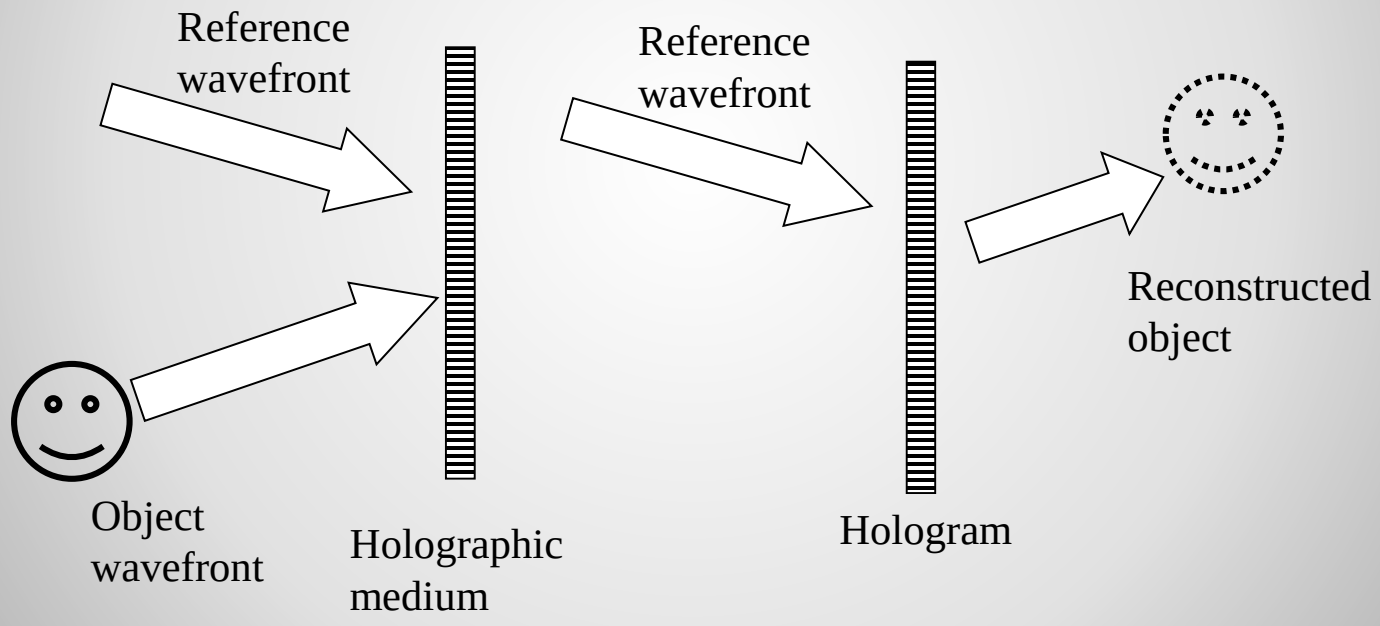
Holograms in a galaxy far, far away…

https://www.gizmodo.com.au/2018/01/inside-the-princess-leia-project-star-wars-holograms-are-real-now/



Holography here on Earth

Volume holography

5 Fundamental Processes:

1) Photoionization of impurities & generation of charge carriers

2) Charge carrier transport

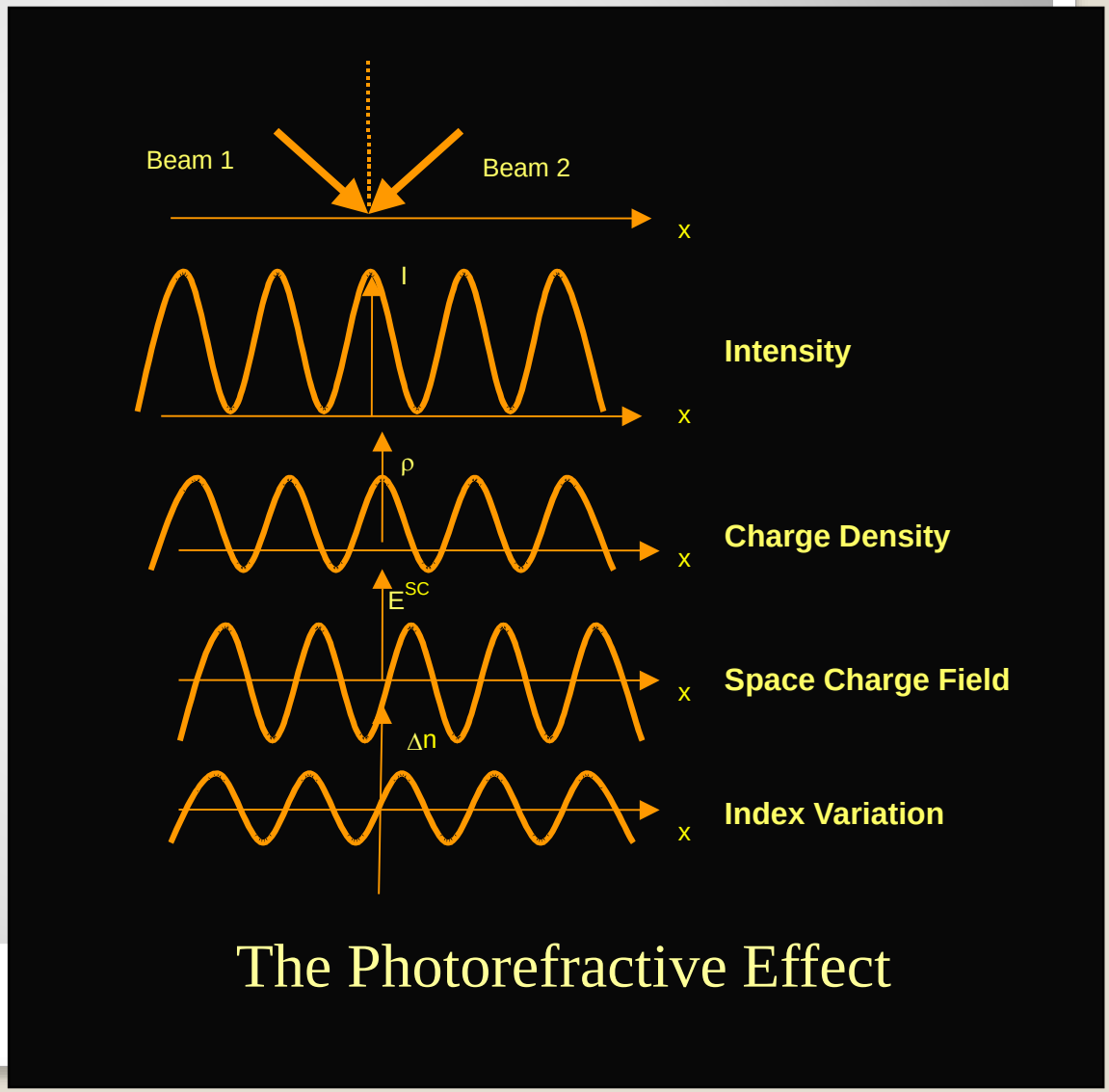
3) Trapping of charge carriers leading to formation of space-charge density

4) Formation of photo-induced space charge field

5) Formation of index grating

$$\Delta n(x,t) = \frac{1}{2} n_o{}^3 r_{eff} E_{sc}(x,t)$$

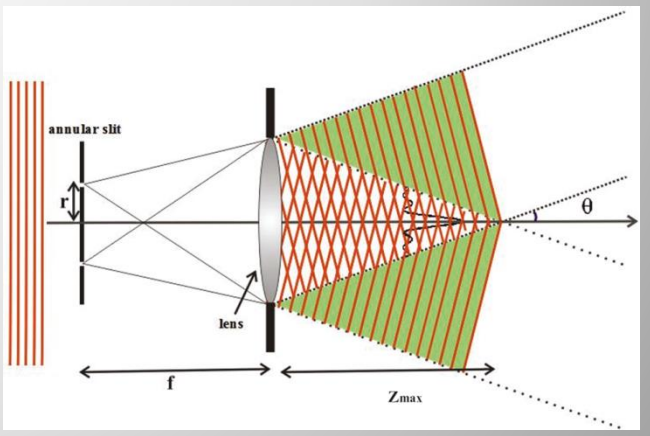
$$K = k_1 - k_2$$



The Photorefractive Effect

Introduction

- Volume holography
  - Massive data storage capacities
  - Multiplexing techniques
  - Nonplanar reference beams (phase-multiplexing)
- Bessel beams
  - Diffraction-free propagation and the capacity for self-healing
  - Optical micromanipulation



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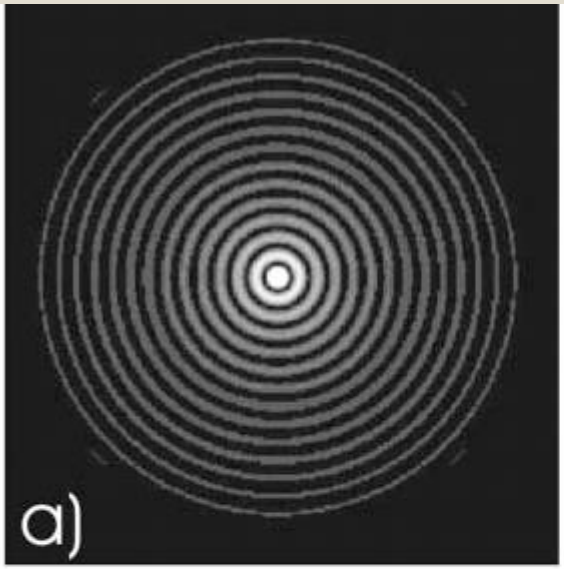
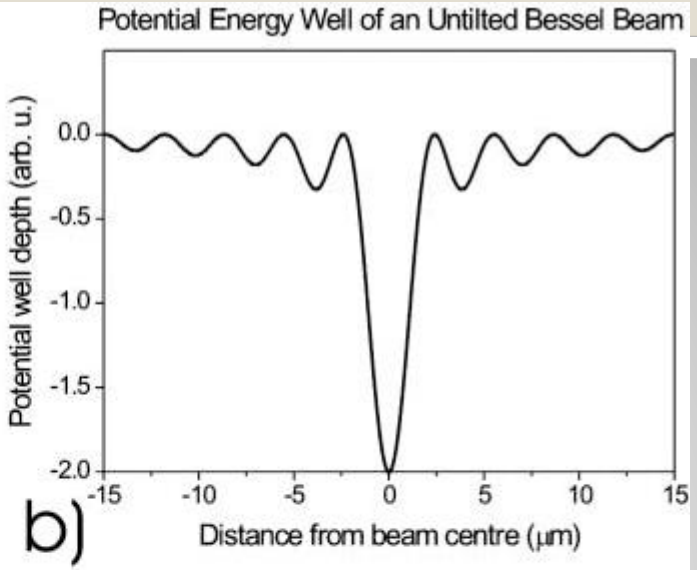
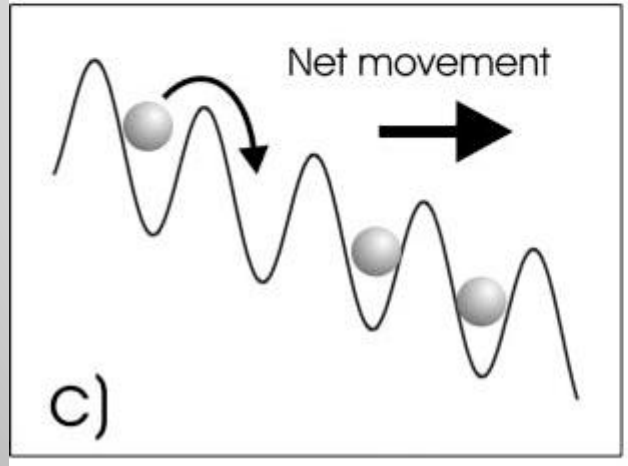
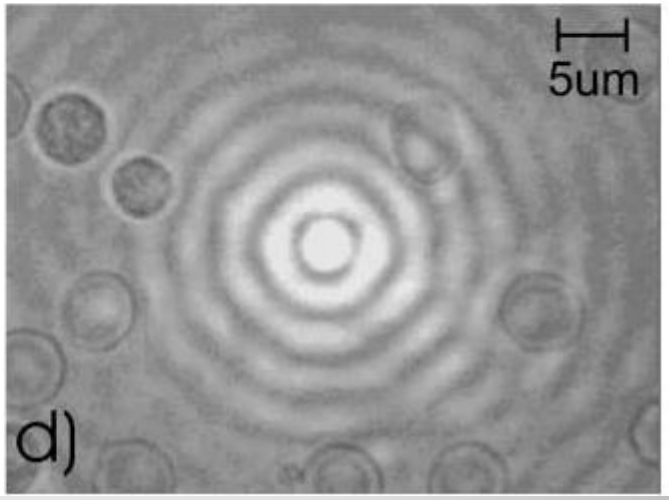








Bessel beam applications

https://www.semanticscholar.org/paper/Optical-micromanipulation.-Dholakia-Reece/56f3c6c7b990aa96938e1e77825d74f0ee0d2d22/figure/6

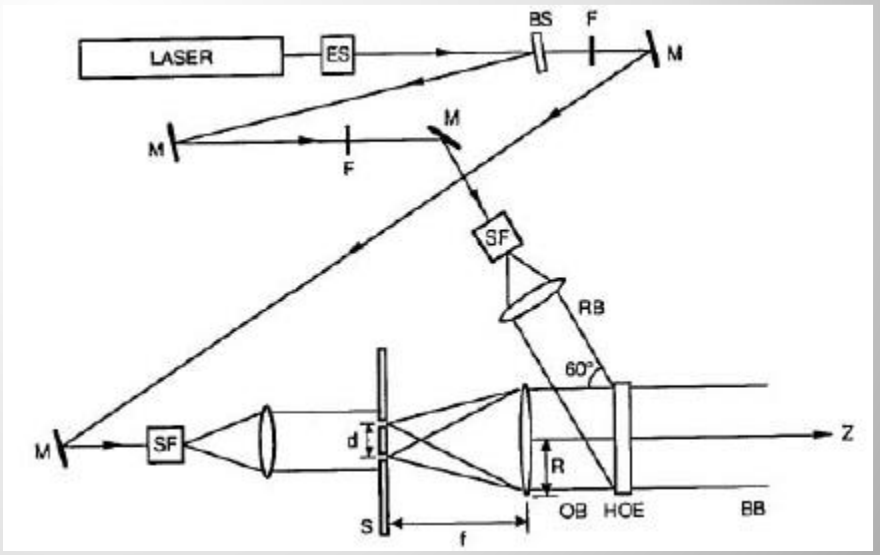
Introduction

- A simple holographic element could replace the bulky lens-annular slit Bessel beam apparatus

Holographic reproduction of a diffraction-free beam

A. J. Cox and Dean C. Dibble

APPLIED OPTICS / Vol. 30, No. 11 / 10 April 1991



- Bessel beams have been applied in recording volumetric lattices in photorefractive materials.

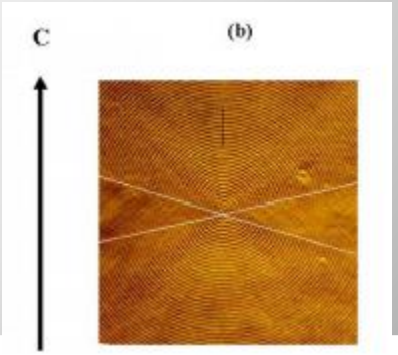
Eur. Phys. J. D (2014) 68: 82
DOI: 10.1140/epjd/e2014-40356-8

THE EUROPEAN PHYSICAL JOURNAL D

Regular Article

Nondestructive readout of holograms recorded by Bessel beam technique in $LiNbO_3$:Fe and $LiNbO_3$:Fe:Cu crystals

Anahit Badalyan, Ruben Hovsepyan, Paytsar Mantashyan, Vahram Mekhitaryan, and Rafael Drampyan[a]



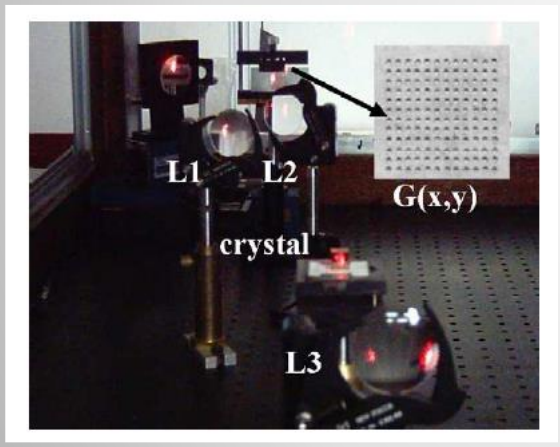
Introduction

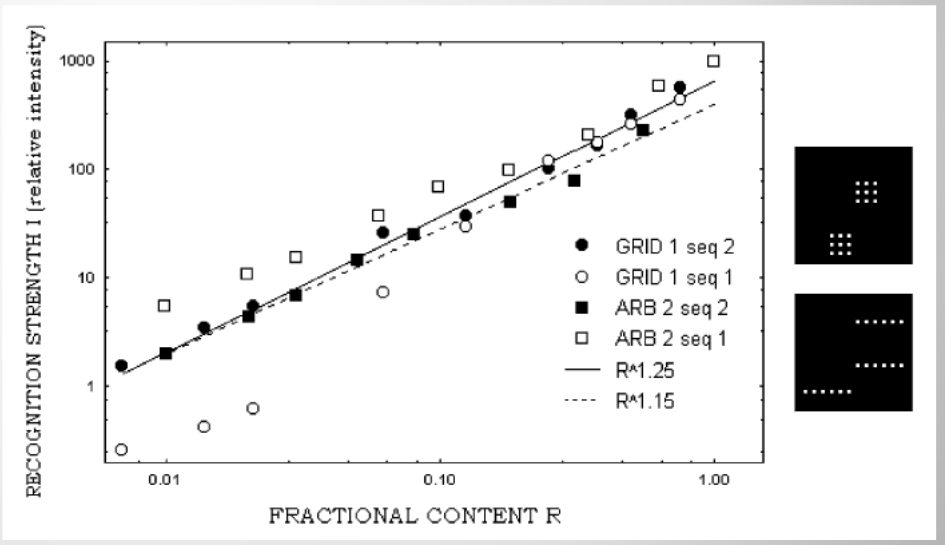
Power law response of volume holographic pattern recognition to partial images

Raphael A. Guerrero *

National Institute of Physics, University of the Philippines, Diliman, Quezon City, Philippines

R.A. Guerrero / Optics Communications 239 (2004) 303–310





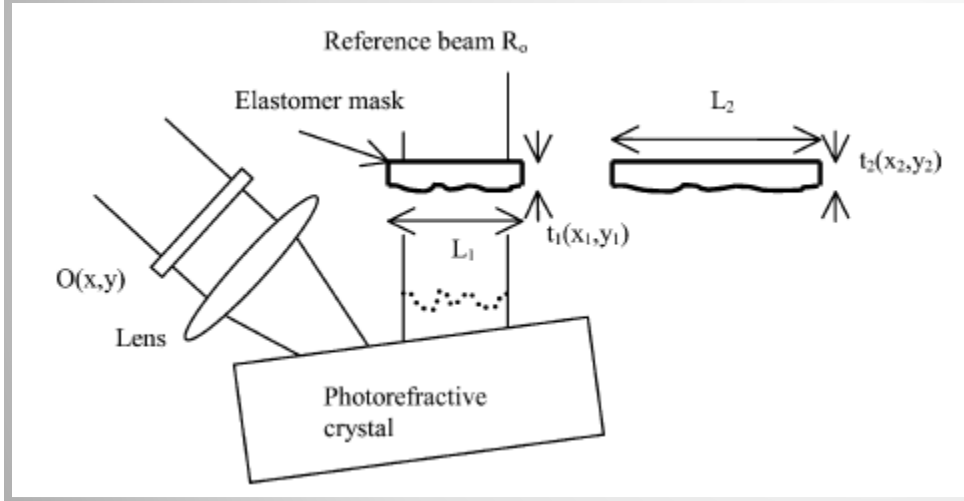
Volume holography in the Philippines

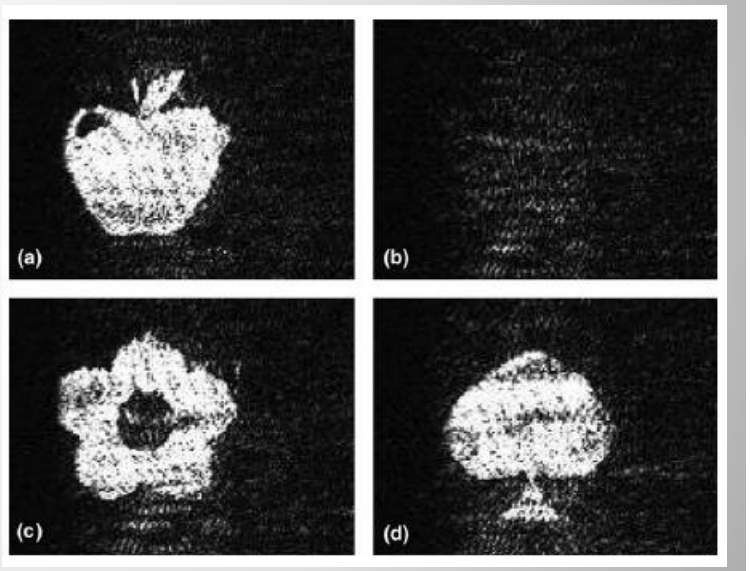
Volume holographic storage and animation based on addressing with an elastomer phase mask

Raphael A. Guerrero *

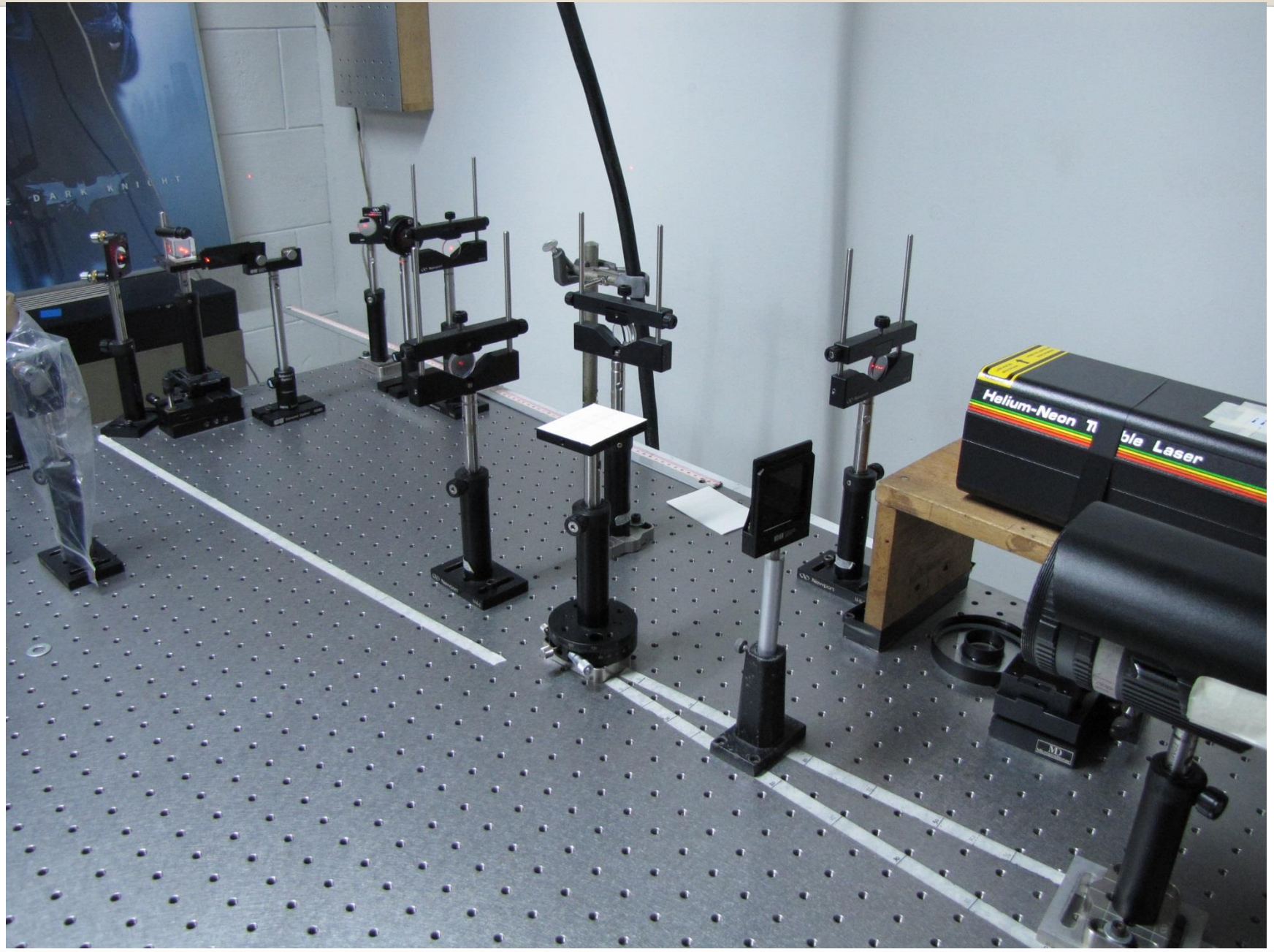
National Institute of Physics, University of the Philippines, Diliman, Quezon City, Philippines
Department of Physics, Ateneo de Manila University, Loyola Heights, Quezon City, Philippines

R.A. Guerrero / Optics Communications 245 (2005) 75–83





Volume holography in the Philippines

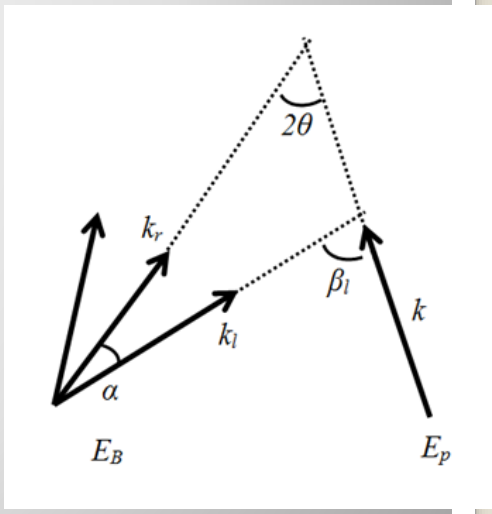

Helium-Neon
Laser

- We perform holographic storage of a Bessel beam as a refractive index modulation within a photorefractive crystal.
- Bessel beam $E_B = J_o(k_\rho \rho) e^{i\boldsymbol{k_r}\cdot\boldsymbol{r}} = \sum_l b_l \, e^{i\boldsymbol{k_l}\cdot\boldsymbol{r}}$
- Refractive index modulation

$$H = \left|E_p + E_B\right|^2 = \sum_l b_l e^{i(\boldsymbol{k}-\boldsymbol{k_l})\cdot\boldsymbol{r}} + \sum_l b_l e^{i(\boldsymbol{k_l}-\boldsymbol{k})\cdot\boldsymbol{r}}$$

- Using a readout plane wave

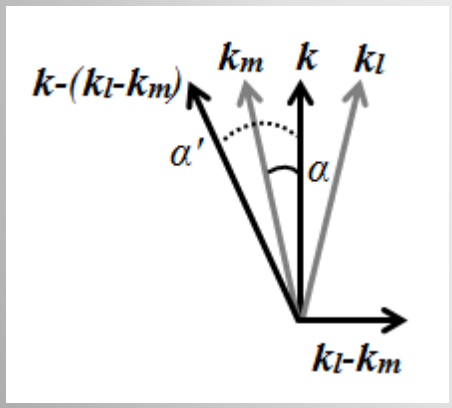
$$E_p H = e^{i\boldsymbol{k}\cdot\boldsymbol{r}} \sum_l b_l e^{i(\boldsymbol{k_l}-\boldsymbol{k})\cdot\boldsymbol{r}} = \sum_l b_l \, e^{i\boldsymbol{k_l}\cdot\boldsymbol{r}} = J_o(k_\rho \rho) e^{i\boldsymbol{k_r}\cdot\boldsymbol{r}}$$



Volume holography of Bessel beams

- Bragg-matching between a Bessel readout beam and the volume hologram reconstructs a plane wave and a modified Bessel beam.

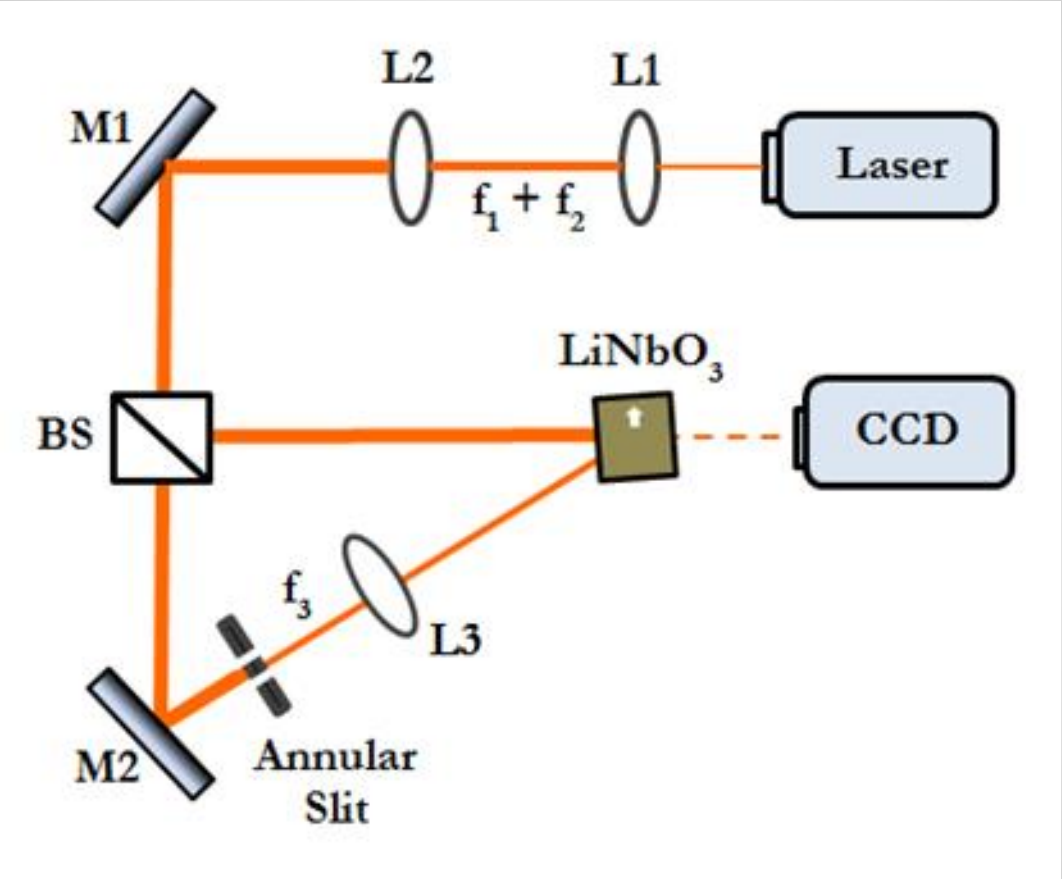
$$E_B H = \sum_m b_m\, e^{i\boldsymbol{k_m}\cdot\boldsymbol{r}} \sum_l b_l e^{i(\boldsymbol{k}-\boldsymbol{k_l})\cdot\boldsymbol{r}} = \sum_l b_l\, e^{i\boldsymbol{k}\cdot\boldsymbol{r}} + \sum_{l\neq m} b_l b_m\, e^{i\left(\boldsymbol{k}-(\boldsymbol{k_l}-\boldsymbol{k_m})\right)\cdot\boldsymbol{r}}$$



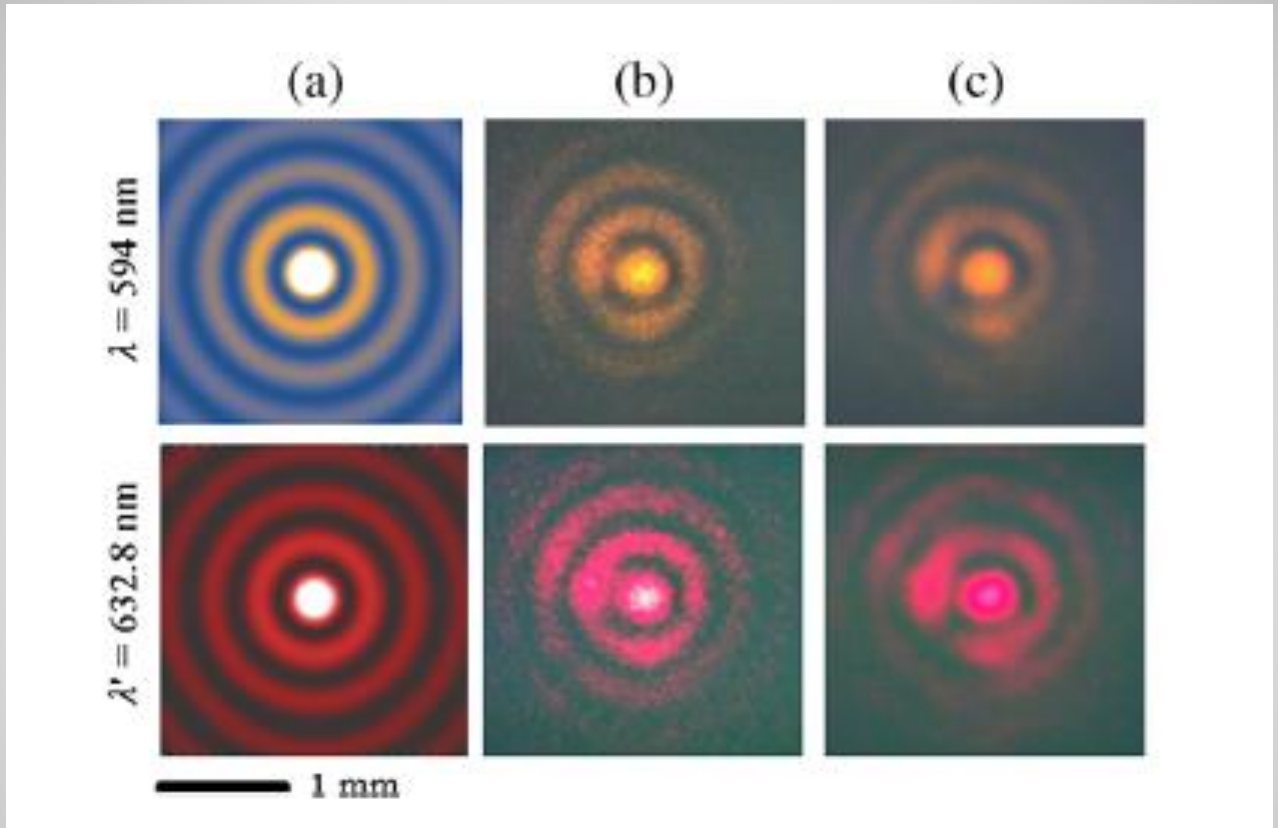
$$E_B H = B e^{i\boldsymbol{k}\cdot\boldsymbol{r}} + \sum_j b_j\, e^{i\boldsymbol{k_j}\cdot\boldsymbol{r}} = B e^{i\boldsymbol{k}\cdot\boldsymbol{r}} + J_o(k_\rho' \rho) e^{i\boldsymbol{k_r'}\cdot\boldsymbol{r}}$$

$$|E_B H|^2 = B^2 + J_o^2\left(k_\rho' \rho\right) + 2BJ_o(k_\rho' \rho) cos[(\boldsymbol{k} - \boldsymbol{k_r'})\cdot\boldsymbol{r}]$$

Volume holography with a Bessel reference beam

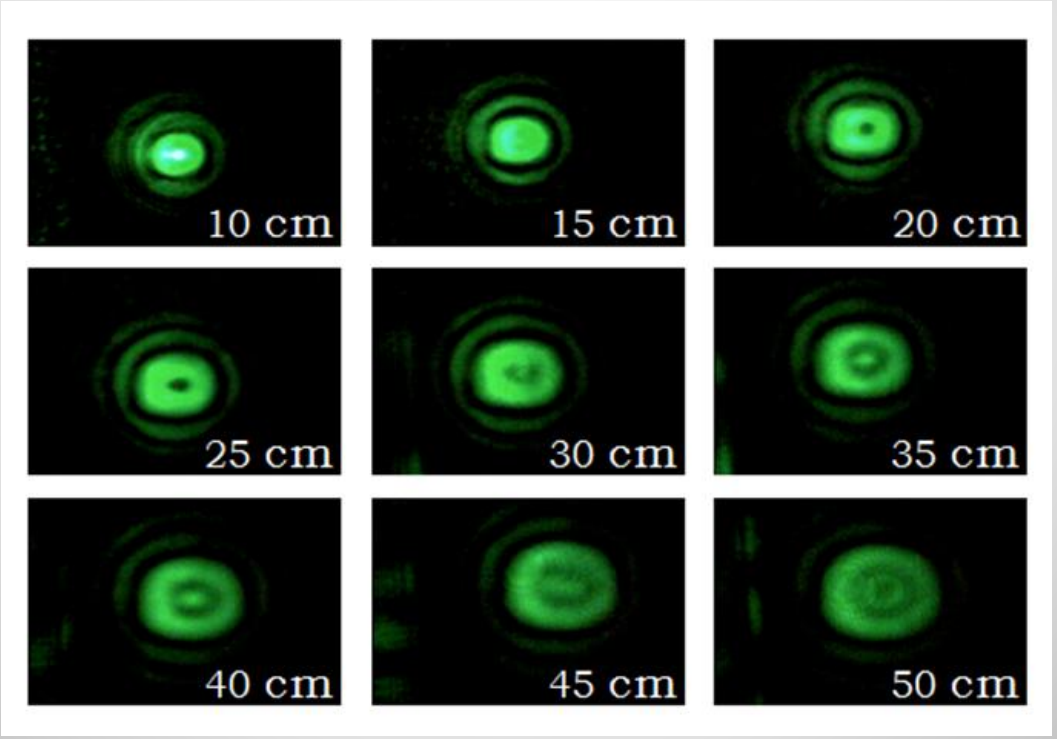


Volume holographic system



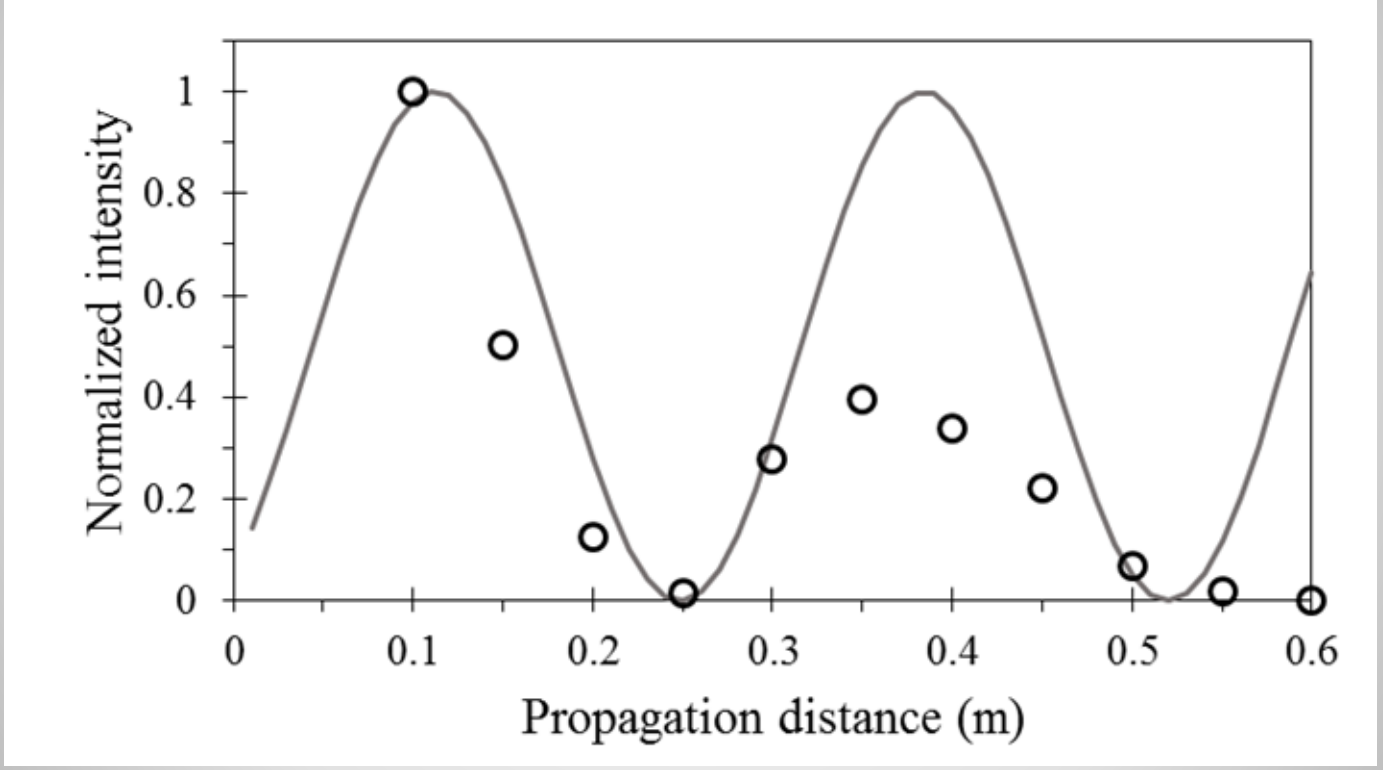
Multi-wavelength reconstruction of Bessel beams

- Our holographically generated beam exhibits self-imaging behavior, with periodic 3D intensity voids.
- The reconstructed beam may also be considered a volumetric optical lattice.

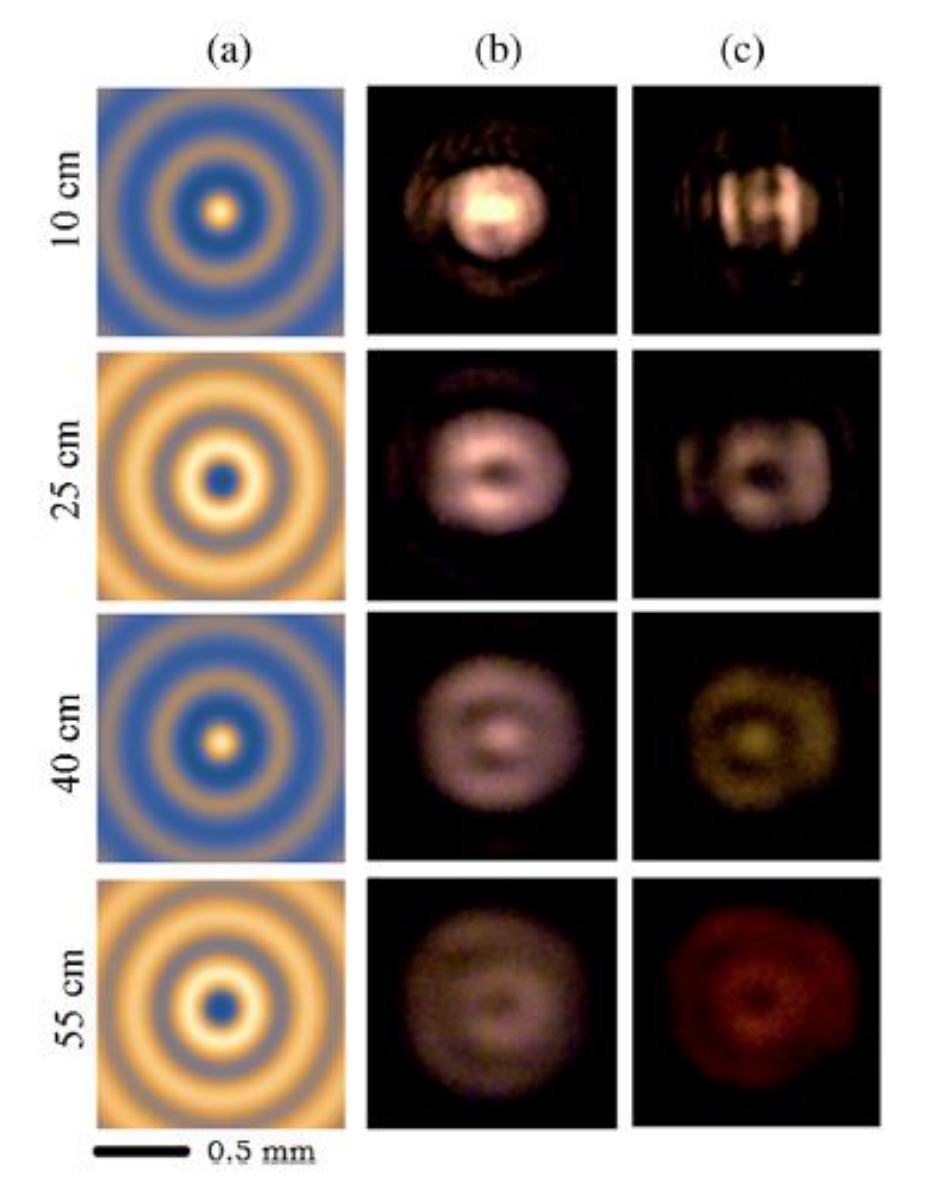


A self-imaging beam (543 nm)

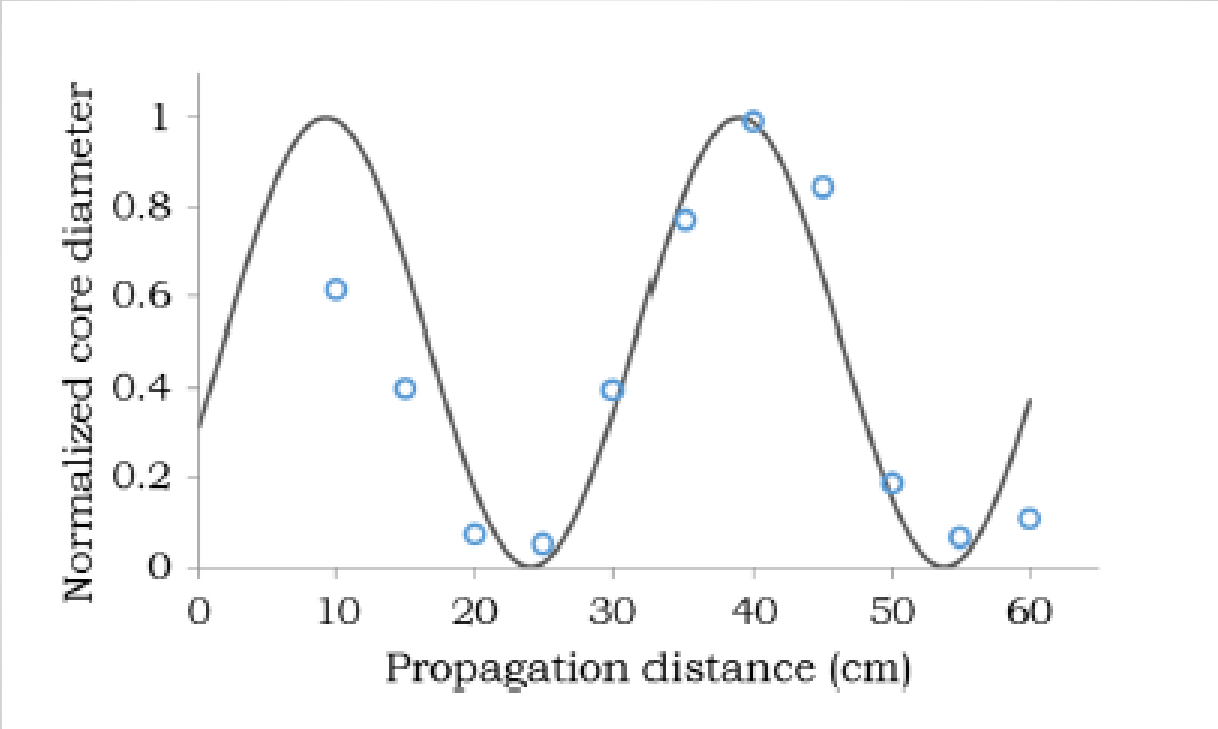
- Oscillation of the on-axis intensity is clearly seen within a propagation distance of 10 to 50 cm.



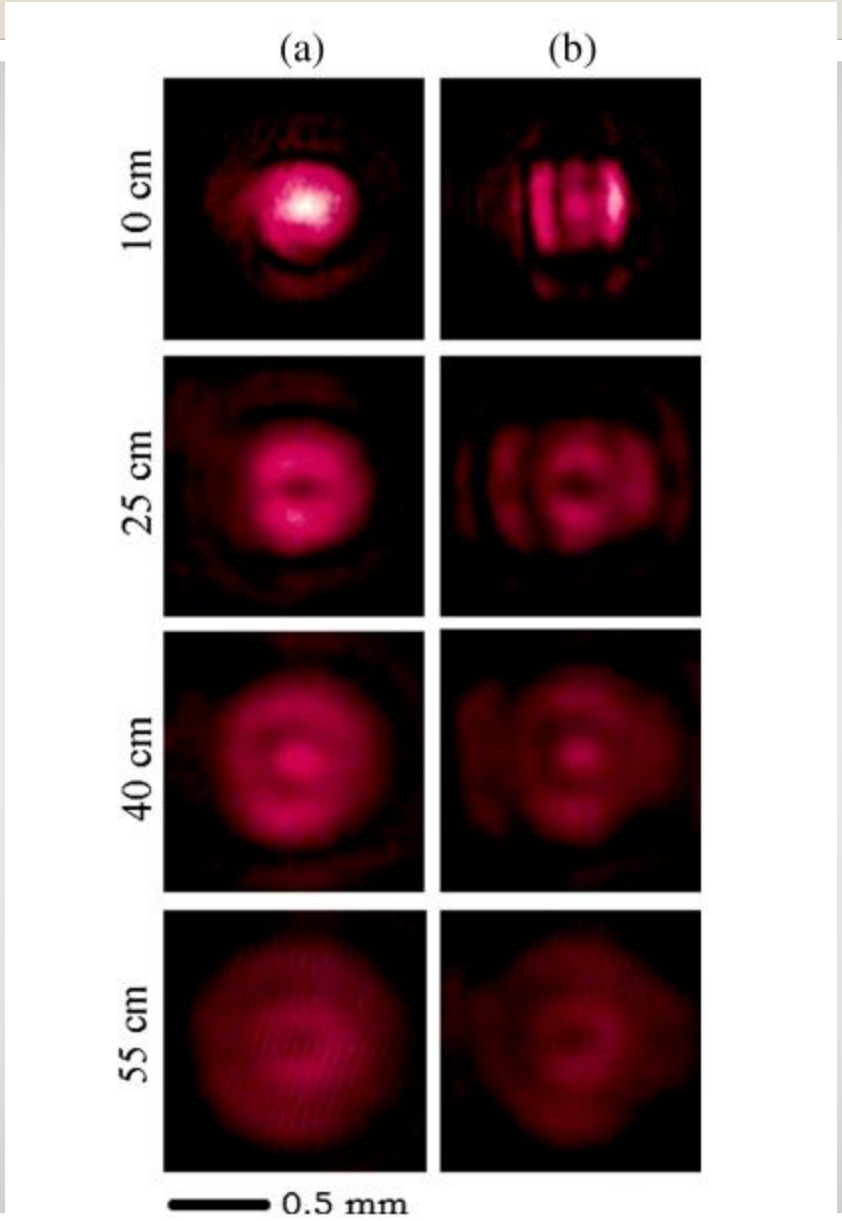
Experimental results



Self-imaging beam at 594 nm



Periodic propagation



Self-imaging beam at 632.8 nm

Optical Engineering 54(10), 104113 (October 2015)

Self-imaging, self-healing beams generated by photorefractive volume holography

Jonathan P. Manigo and Raphael A. Guerrero*
Ateneo de Manila University, Department of Physics, Loyola Heights, Quezon City 1108, Philippines

Abstract. Self-imaging beams consisting of three-dimensional intensity voids are generated via photorefractive volume holography. Reconstruction of a volume hologram recorded at 594 nm is performed with a Bessel read-out beam. The holographic output is similar in appearance to a Bessel beam, with the central spot oscillating between maximum and zero intensity over a propagation distance of 10 to 55 cm. The oscillation period for the on-axis intensity is 30 cm. The reconstruction is capable of self-healing, with a fully recovered central core after the beam propagates 40 cm. Dual-wavelength reconstruction at 632.8 nm produces an output beam with similar self-imaging and self-healing properties. A theoretical framework based on the interference of a plane wave and a Bessel beam simultaneously reconstructed from a volume hologram is able to describe our experimental results. [DOI: 10.1117/1.OE.54.10.104113]

Keywords: Bessel beams; volume holography; photorefractive effect.

Paper 151108P received Aug. 12, 2015; accepted for publication Sep. 25, 2015; published online Oct. 28, 2015.

ISI-indexed output

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applied optics

Generating superimposed Bessel beams with a volume holographic axicon

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2017 paper

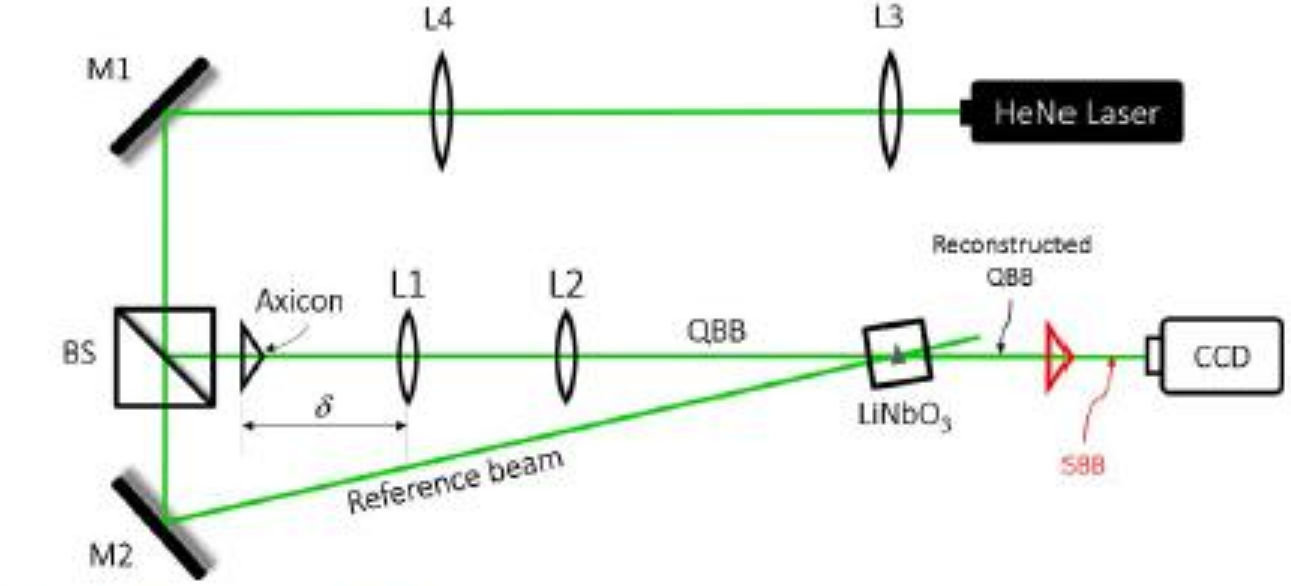
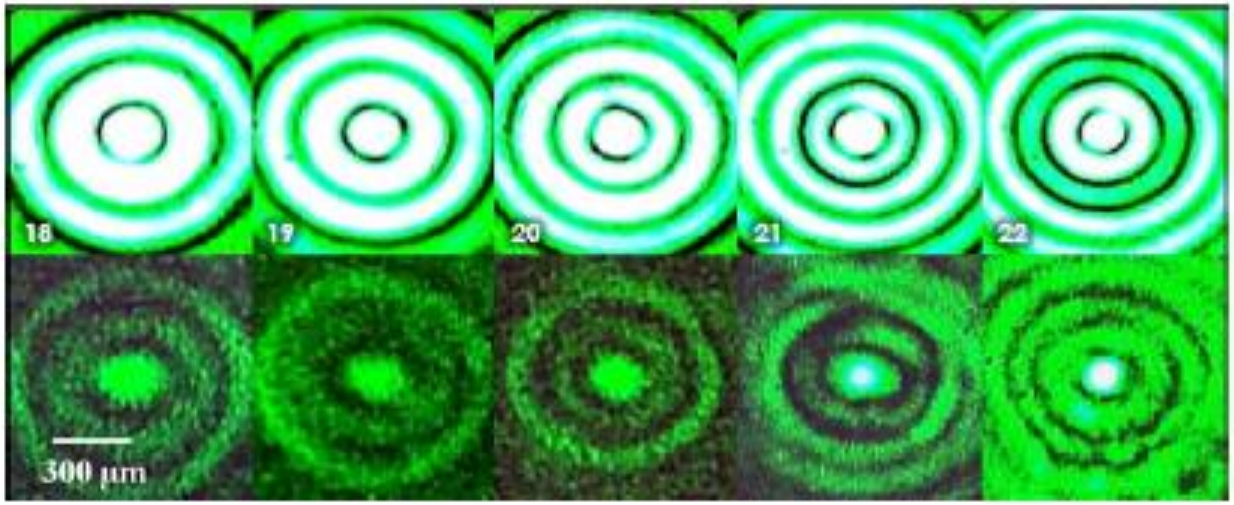
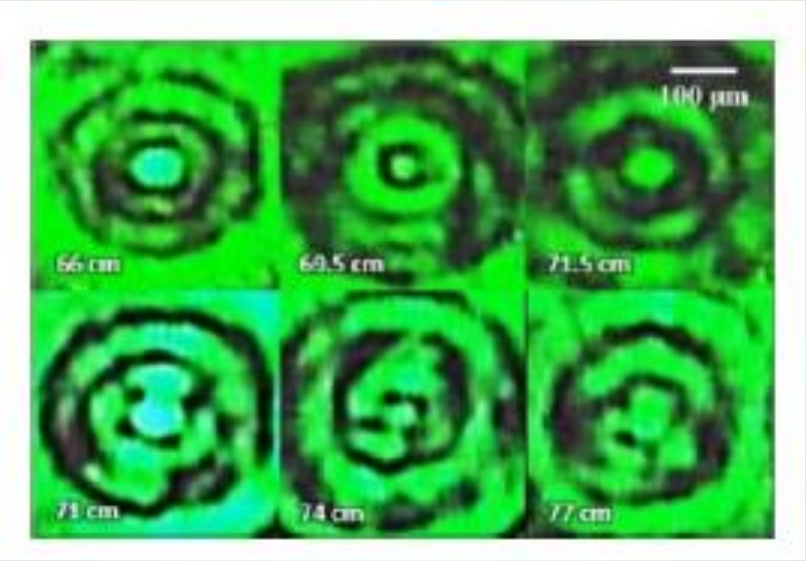


Fig. 4. Volume holography setup for recording QBBs generated by an a-t system.

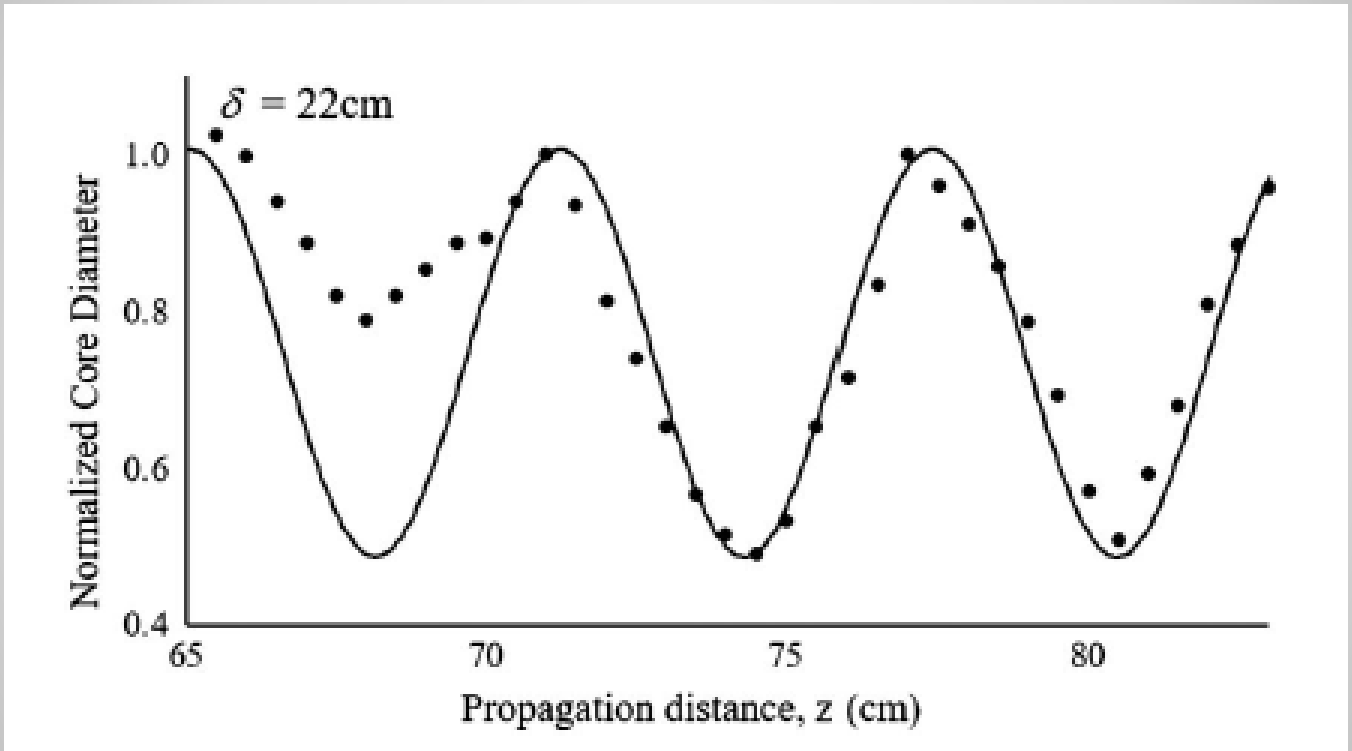
Volume holography with an axicon



Output Bessel beams



Oscillating core diameter



Periodicity

Dr. Alvie Asuncion
Philippine Nuclear Research Institute

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