6-2007

Analysis of Beam Propagation in 90-degree Holographic Recording and Readout Using Transfer Functions and Numerical 2-D-Laplace Inversion

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OCIS Codes: 050.0050, 090.0090

Abstract:

Recently, 2D-Laplace analysis of recording and readout of edge-holograms was reported. Numerical Laplace inversion was examined for simple test cases. In this paper, inversion algorithms are applied to examine beam shaping and distortion in photovoltaic and photorefractive materials.

SUMMARY:

In a recent paper, several numerical algorithms were tested in order to verify the efficiency and suitability of performing 2-D Laplace transforms in the (s_1, s_2) domain [1]. As shown in Fig.1(a-c) for the known 2-D Laplace pair:

$$F(p,q)=\frac{e^{-p}}{pq+1} \quad ; \qquad f(x,z)=J_0\left[2\sqrt{(x-1)z}\right] \quad ,$$

the Brancik algorithm appears to follow the analytical result more closely than the Abate algorithm. On the other hand, further numerical analyses indicated that depending on the specific inversion problem, both algorithms have relative advantages as well as limitations.

2-D Laplace transforms arose as a mathematical problem of interest in the context of a pre-recorded cross-beam hologram under edge-lit readout. In an earlier work, profiled optical beam readout under propagational diffraction was analyzed using a transfer function approach [2]. Under weak propagational diffraction, the standard Bessel function diffracted profiles undergo modifications. Two specific refractive index modulation versus intensity relationships were considered: (i) index profile proportional to intensity, as in photorefractive materials with photovoltaic features; and (ii) index profile proportional to the derivative of intensity, as in predominantly diffusive photorefractive materials.

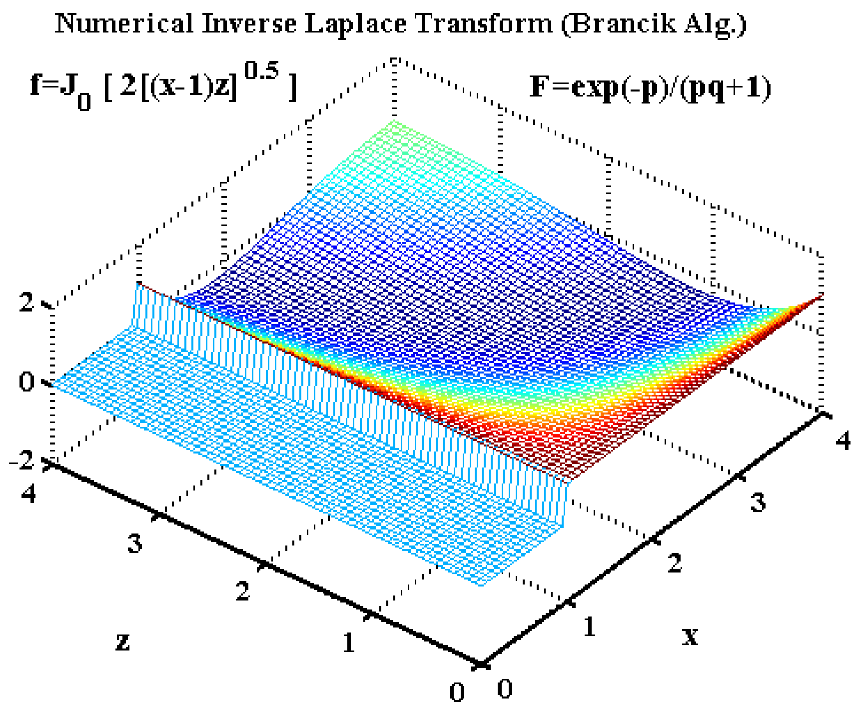
Analytical solutions obtained for the first type of index profile exhibited nonlinear self- and cross-phase coupling. Analytical solutions for the second type of index profile were intractable, but experiments in photorefractive lithium niobate indicated profile distortion (thereby likely affirming diffusive behavior).

Additionally, it turns out that when propagational diffraction is included, the analytical solutions for pre-recorded cross-beam holograms require the inversion of complex 2-D Laplace transforms. In the previously reported work, numerical inversion algorithms due to Abate *et al.* [3] and others were tested for some simple cases. In this paper, the numerical 2-D Laplace inversion techniques are applied to the specific transfer functions obtained for the two types of profiles mentioned above, without and with propagational diffraction. The intention is to verify if the expected self- and cross-phase modulation effects occur for the photovoltaic case, and beam distortion occurs for the diffusive case.

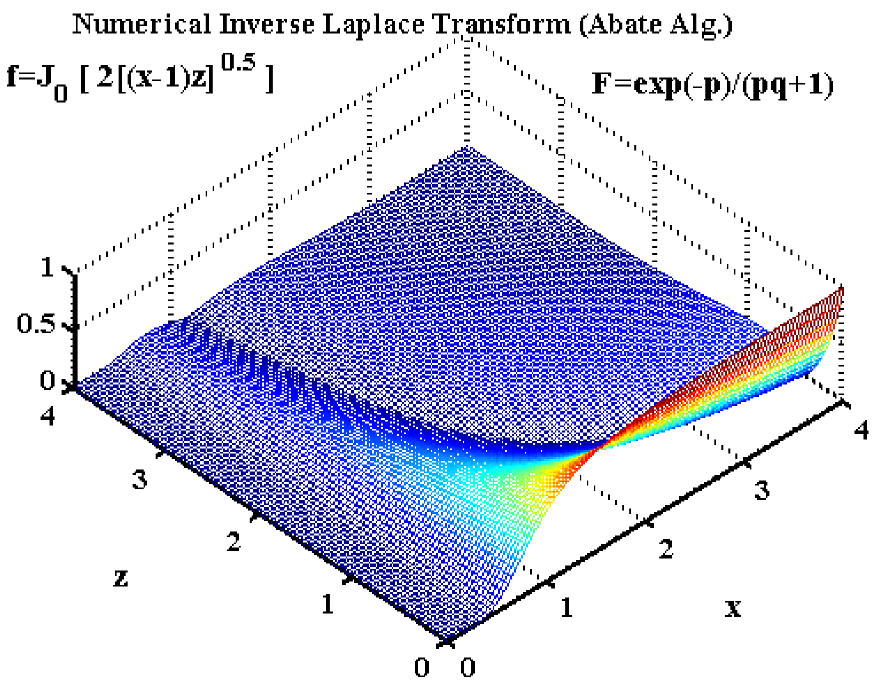
[1] M.R. Chatterjee, P.P. Banerjee, and G. Nehmetallah, "2-D Laplace approach to beam shaping and distortion for 90-degree holographic recording and readout," Opt. Soc. Am. Annual Meeting, Tucson, AZ, October 2005.

[2] P.P.Banerjee, M.R.Chatterjee, N.V.Kukhtarev, and T.Kukhtareva, "Volume holographic recording and readout for 90-degree geometry," Opt.Eng., vol.43, no.9, pp. 2053-2060 (Sept. 2004).

[3] J. Abate, G.L. Choudhury, and W. Whitt, "Numerical inversion of multidimensional Laplace transforms by the Laguerre method," Perfor. Eval., vol. 31, pp. 229-243, 1997.



(a)



(b)

Fig. 1. Numerical inverse 2-D Laplace using Brancik and Abate algorithms.