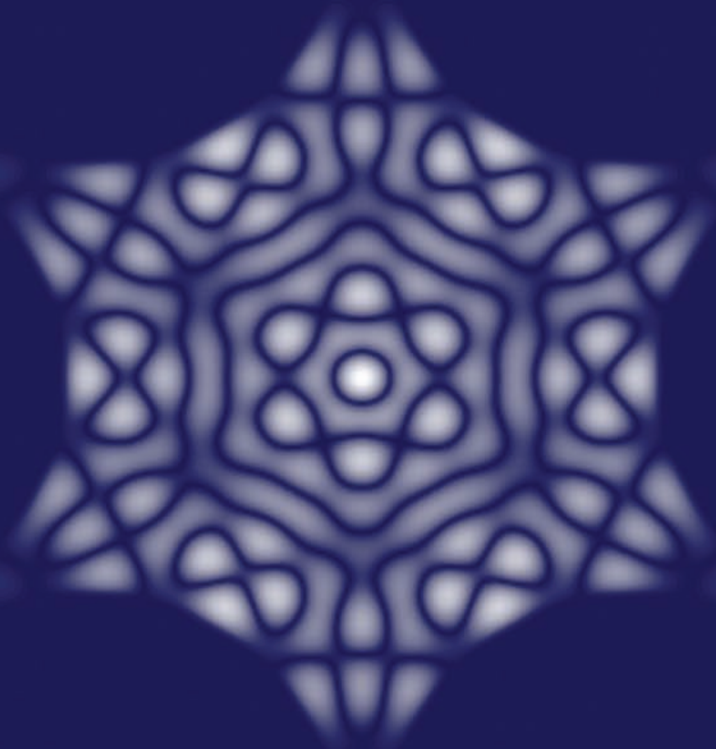
Optics in 2001



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Every December, *Optics & Photonics News* (OPN) highlights the year's most exciting developments in the fast-paced world of optics. Our special December issue, "Optics in 2001," presents key research in the form of summaries of articles that have appeared in peer-reviewed journals over the course of the past 12 months.

The overwhelming number of submissions received in 2001 signals another groundbreaking year for the world of optics. The increase in the number of submissions—almost twice as many were received this year as last—is vibrant testimony to the vitality of the optics community and to the importance of the work being carried out by optics researchers all over the world. The 58 summaries that compose this year's issue represent the work of nearly 200 scientists.

Submissions included in "Optics in 2001" are judged according to the following selection criteria:

- the accomplishments described must have been published in a refereed journal in the year prior to publication in OPN;
- the work must be illustrated in a clear, concise manner, comprehensible to the at-large optics community;
- the topical area as a whole must be described, and the importance of the research must be detailed.

Although we make every effort to insure that progress in all optics subfields is recognized, there are no requirements in the selection process for inclusion of specific topical areas. When a large number of submissions are received for a specific area, this is taken as evidence that the topic has been fertile ground for activity and research over the course of the preceding year. OPN strives to ensure that engineering, science, and technology are all represented. The number of papers accepted overall is limited by space. This year, a significant increase in submissions in the field of bio-optics reflects the rapid growth registered in this area of research.

OPN and OSA would like to thank the hundreds of researchers from all over the world who submitted summaries to "Optics in 2001."

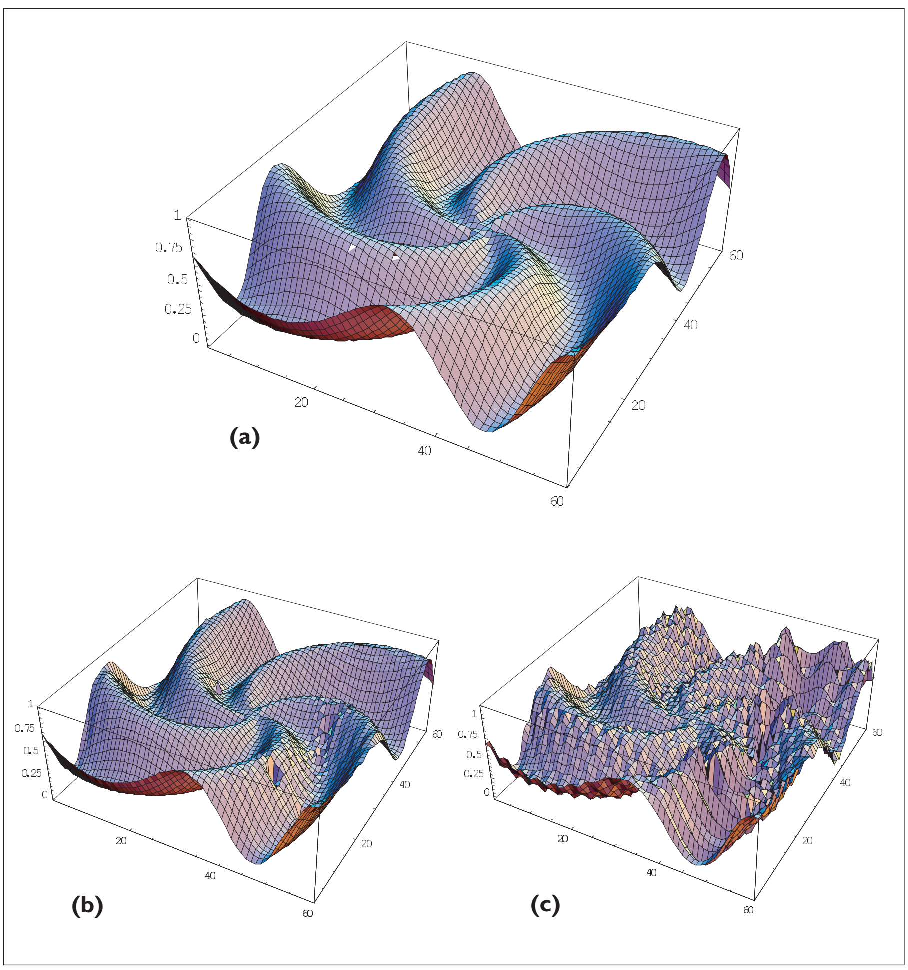
An Isotropic Hilbert Transform in Two Dimensions: Fearful Symmetry?

Kieran G. Larkin and Michael A. Oldfield

Hilbert transform (HT) relations occur frequently in optics. In communication theory, HT arises naturally in the study of signal demodulation. Given a modulated carrier wave, it is always possible to retrieve the modulation using the signal's HT.

The idea of modulation naturally extends to higher dimensions in the areas of interferometry and holography. Rather surprisingly, the theory of demodulation has not extended in a similarly natural manner. The disparity has been most evident in the analysis of inteferometric fringe patterns where two dimensional (2D) phase-modulation is intrinsic. For many years, the introduction of extreme asymmetry in fringe patterns known as "carrier fringes" has side-stepped the problem. In essence, carrier fringes ensure that a 2D problem becomes a one-dimensional (1D) problem and that the 1D HT allows full demodulation of the fringes. In 1982, Takeda introduced a Fourier transform (FT) implementation of the 1D HT that revolutionized fringe analysis. However, this method still required carrier fringes. Over the past 20 years, a considerable amount of research has been devoted to the demodulation of carrier-free fringe patterns with varying amounts of success. Methods using wavelets, filters, phase-locked loops, and rotating 1D HTs have been tried. Since the necessary anti-symmetry seems counter-intuitive, none of the methods have defined an isotropic 2D HT.

Figure 1. Comparison of demodulated magnitudes for spiral phase Hilbert transform and half plane Hilbert transform. The spiral phase transform derives a close estimate of the complex image magnitude, failing only at discontinuities in the phase. The half-plane Hilbert transform derives a highly oscillatory estimate of the magnitude with substantial errors in all regions.



The symmetry problem is at the very core of the 2D HT. In 1D, the FT of the HT is the signum function. This scenario raises the question of how the signum function can be defined in higher dimensions. The most popular solutions are the half-plane signum and the quadrant signum. Since neither solution is isotropic, unwarranted directional artifacts influence the analysis. Larkin, Bone, and Oldfield recently proposed a new twist on the isotropic signum function.[1] The idea is based on a smooth spiral phase function that almost paradoxically has odd (180°) symmetry. Another way to view the signum function as a normalized vector makes the 2D extension obvious:

1D signum: $\mathrm{sgn}(x) = x/|x|$.
In 2D, let $z = x + iy$, then $\mathrm{sgn}(z) = z/|z| = \exp(i\theta)$: spiral phase signum.

Many unsolved problems in 2D demodulation become soluble once the spiral phase signum function replaces the conceptual barrier of the conventional linear signum function.[1, 2] A mathematical justification of the spiral phase HT has been achieved using asymptotic methods.[2, 3] Initial simulations and error analysis indicate that the method can be applied quite generally with remarkably accurate demodulation of typical fringe patterns.

References

1. K. G. Larkin, D. Bone, and M. A. Oldfield, J. Opt. Soc. Am., **8**, 1862-70 (2001).
2. K. G. Larkin, "Topics in multi-dimensional signal demodulation," Ph.D. Thesis, University of Sydney, 2001. http://setis.library.usyd.edu.au/~thesis/adt-NU/ public/
3. K. G. Larkin, J. Opt. Soc. Am., **8**, 1871-81 (2001).

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