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GENERALIZED INTERFERENCE AND OPTICAL PROCESSING

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Abstract

An electro-optic interferometer is used to determine complex interference patterns arising from N-slit transmission gratings. Corresponding interferograms calculated using universal computers are also generated. A time comparison between the two methods is given.

Introduction

For certain specific computational tasks, physical computers[1] can provide faster and smaller alternatives to conventional computers.[2] Here, an electro-optical interferometer is used to provide complex interferometric patterns arising from the interaction of coherent light with N-slit gratings where N could be as high as 2000.

The interferometer used in these computations has been described in detail elsewhere.[3,4] Briefly, a laser beam is expanded by a Galileon telescope and then is focused at a given plane, transverse to the plane of propagation, by a convex lens. Following the lens, a multiple-prism beam expander magnifies the beam in the plane of propagation. Thus, extremely elongated Gaussian beams can be rendered at the focal plane. Hence, large number of slits at a grating can be illuminated simultaneously. The interferometer uses a CCD detector at the interferometric plane. Hence, the resulting interferometric intensity pattern can be displayed in real time.

The physical computer, or interferometer, is mobile, compact, and rugged. It has a detection time limited by the electronics of ~30 ms. It uses the same time to characterize a grating with either 2 or 2000 slits. The wavelength range is limited by available laser sources and it demands TEM_{00} laser beam quality.

The two-dimensional interferometric probability distribution can be calculated using Dirac's notation[4]

$$|\langle x|s\rangle|^2_{2D} = \sum_{z=1}^{N}\sum_{y=1}^{N}\psi\left(r_{j_{zy}}\right)\sum_{q=1}^{N}\sum_{p=1}^{N}\psi\left(r_{j_{qp}}\right)e^{i\left(\Omega_{qp}-\Omega_{zy}\right)} \qquad (1)$$

that reduces to[3,4]

$$|\langle x|s\rangle|_{1D} = \sum_{j=1}^{N}\psi\left(r_j\right)^2 + 2\sum_{j=1}^{N}\psi\left(r_j\right)\left[\sum_{j=m+1}^{N}\psi\left(r_m\right)\cos\left(\Omega_m-\Omega_j\right)\right] \qquad (2)$$

for the one-dimensional case.

These equations have been programmed with the relevant exact geometrical expressions[3] using FORTRAN 77 in a mainframe 3090 IBM computer. A single-stage program that assumes a plane-wave illumination of the grating, contains 436 FORTRAN lines. A double-stage program that considers a realistic diffraction pattern of illumination of the grating contains 855 FORTRAN lines. A graph program contains 556 lines. It can be estimated that the possible number of calculations for a 2000-slit linear grating can be in excess of 10^{10}.

The single-stage program asks for the following information

- slit dimensions
- slit dimensions' standard of deviation
- interslit dimensions
- interslit dimensions' standard of deviation
- wavelength
- grating-screen distance
- number of slits

This program also gives options for the illumination profile.

Duarte[3,4] provides numerous comparisons of measured interferometric profiles with patterns calculated using the universal computer. Agreement between the two approaches varies from good to excellent. For a particular class of grating, the universal computing times as a function of the number of slits are listed in Table 1. It can be seen that there is a vast difference between the time needed to achieve a 2-slit calculation and the time needed to complete a 1500-slit calculation.

Table 1
Universal Computer Times

Slit width: 30 μm ± 0 μm
Interslit width: 30 μm ± 0 μm
Grating-screen distance: 75 cm
Laser wavelength: 632.8 nm

Number of Slits N	*Time (s)*
2	0.96
10	1.14
50	7.03
100	14.33
300	119.49
500	354.20
700	735.40
1000	1528.68
1500	3111.02

Time = CPU time + Transmission time.

Conclusions

A physical (or optical) computer for specific interferometric/diffraction calculations has been built. The input/output optical process is completed in some 30 ms for gratings composed of any number of slits. This time is mostly used by the electronics. Very good agreement has been established with universal computer calculations based on a generalized interference equation derived using Dirac's notation. Universal computer calculations can take in excess of 3000 s for a grating composed of 1500 slits. Thus, this optical computer has significant size and temporal advantages relative to the mainframe IBM. Several diverse applications have been identified for this new interferometer, which suggests that this class of physical computer does offer versatility. However, as an instrument based on quantum principles, we are limited to observe only the initial and final stages of the computation. The universal computer retains its vastly superior versatility and allows observation of intermediate stages of computation.

References

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