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Femtosecond Optical Correlation Using Four-Wave Mixing

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Abstract

A matched-filter optical correlator was built using four-wave mixing in an air-stable degenerate ground state conjugated polymer. The four-wave mixing architecture results in a highly parallel optical computer which completes an image correlation in less than 160 fs. The images correlated were each 5000 pixels in size, resulting in a peak data processing rate of 3×10^{16} operations per second. The results demonstrate the application of the large third order nonlinear optical susceptibilities of conjugated polymers in optical computing, achieving data processing rates that cannot be approached by current electronic computers.

1. Summary

A four-wave mixing correlator was built using poly(1,6-heptadiester) as the nonlinear material.[1] This materials readily forms optical quality thin films that are air-stable and readily soluble.

A drawing of the four-wave mixing correlator is shown below. The nematic liquid crystal spatial light modulators (SLM) convert an image on a mask (illuminated by a collimated HeNe laser) into an intensity image on the main beam. Two of the beams are modulated: the object beam (ob) and the read beam (re); the reference beam is unmodulated. The four-wave mixing operation produces a signal that is equivalent to the correlation of the two images; the correlator "finds" images.[2]

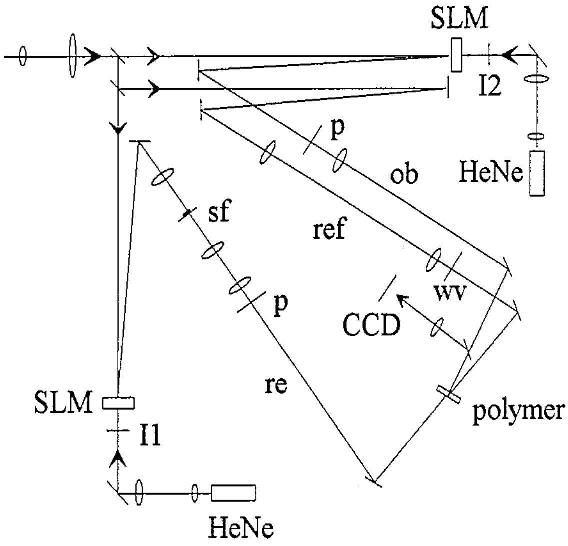

Figure 1 shows the result of a correlation between images of U.S. President George Washington (the reference image) and images of George Washington, Thomas Jefferson, and John Adams, as well as a rotated image of Washington (the data image). The correlation peaks shown below these two sets of images demonstrate that the correlator is able to find George Washington, as well as to calculate that the image of Thomas Jefferson resembles that of Washington more closely than the image of Adams does. The signal to noise is better than 10:1.

The temporal profile of the degenerate four-wave mixing signal was measured by stepping a motorized delay line while measuring the four-wave mixing signal. When pumped with 90 fs pulses, the FWHM of the signal was 160 fs. A separate measurement revealed the spatial resolution of the system to be 1.6 lp/mm over the 25.4 mm apertures of the spatial light modulators, equivalent to 5,000 pixels per image. The resulting peak processing rate is greater than 3×10^{16} operations per second. For comparison, the current best Cray supercomputer, the C916, attains a peak rate of 1.55×10^{10} operations per second.

The results demonstrate that ultrafast optical computing is possible with current materials if the spatially modulated four-wave mixing machine architecture is used.

2. Acknowledgements

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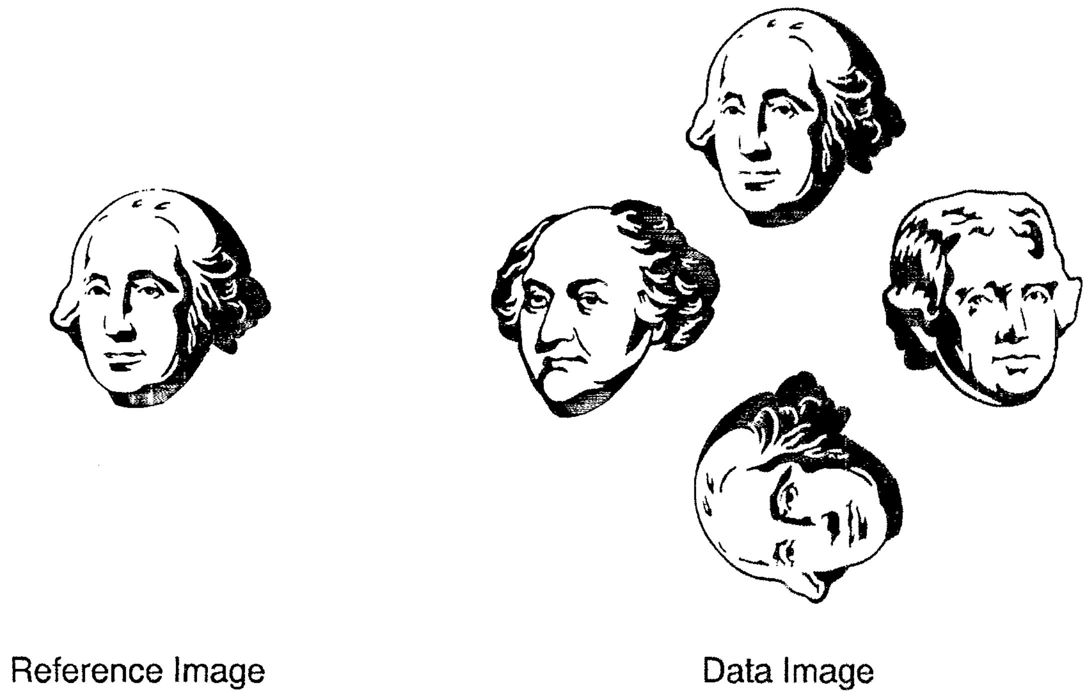
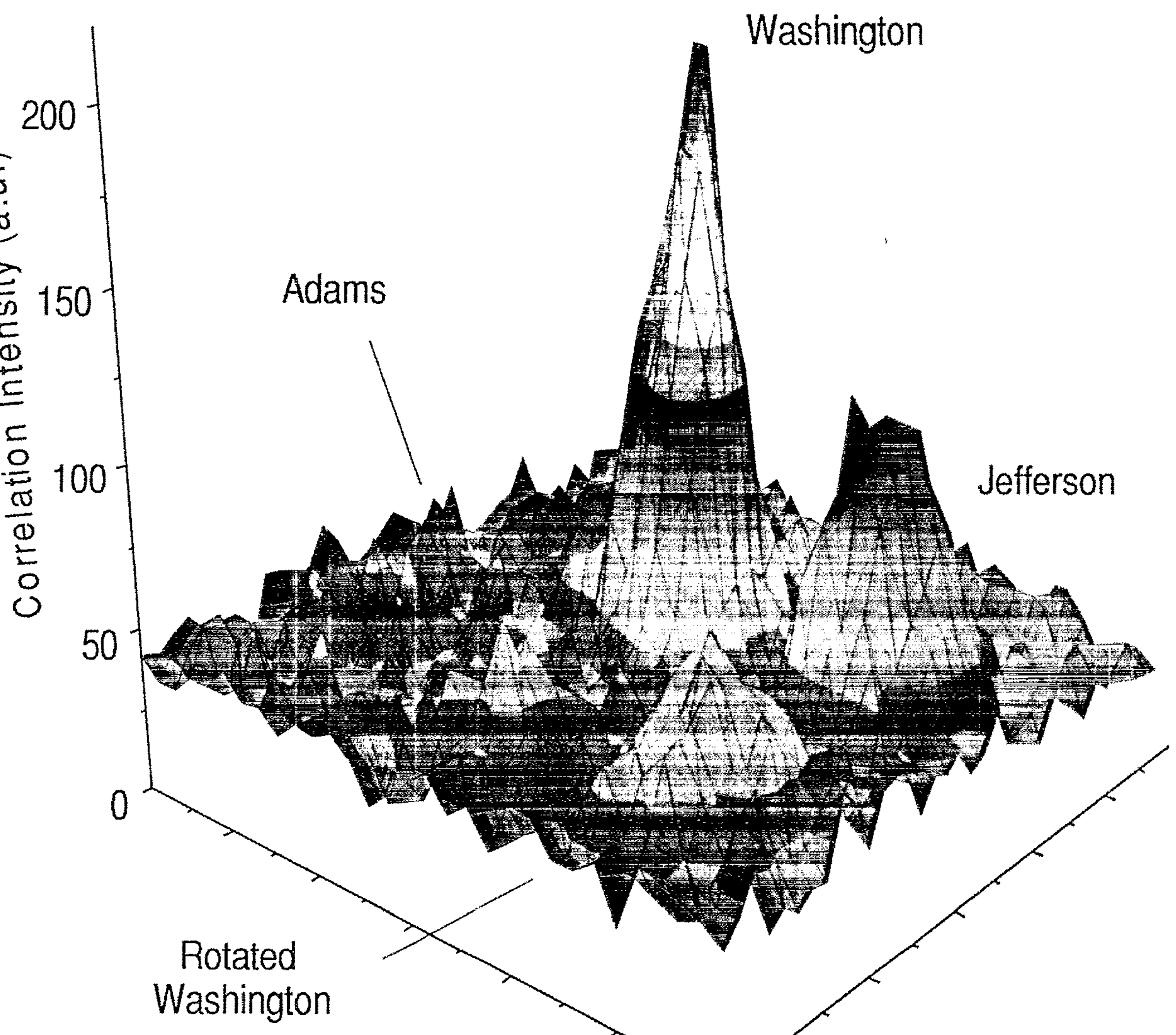
3. References

1. C. Halvorson, R. Wu, D. Moses, F. Wudl and A.J. Heeger, Chem. Phys. Lett. 212, 85 (1993).
2. J. O. White and A. Yariv, Appl. Phys. Lett. 37, 5 (1980).


Reference Image
Data Image


Washington
Adams
Jefferson
Correlation Intensity (a.u.)
200
150
100
50
0
Rotated
Washington