ciative memory. In the hybrid associative memory, feedback and nonlinear processing of the reference beams are provided by vidicon detectors, image processors, and liquid crystal light valves. The electronics allows interfacing to a host computer that can also program the particular associations to be made. Successful operation of the system as a closed resonator was recently demonstrated.[3] The error-correction properties of the system were evident as the input image could be rotated over a range of 10° with no observable degradation in the output image.

Such optical associative memories, with their high degree of parallelism and interconnectivity, have applications in high speed implementations of multi-layer neural network models. The use of volume holograms in photorefractive crystals will permit the rapid updating of interconnection weights, which is necessary for the implementation of neural network learning algorithms such as backpropagation.

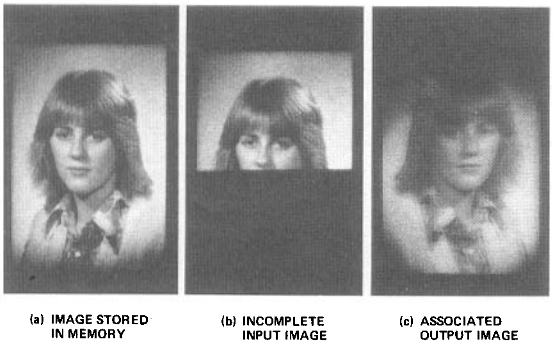

FIGURE 2. Photographs of experimental results: (a) Image stored in memory, (b) Incomplete input image, (c) Associated output image (inversion due to mirror reflection).

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New mechanism for generating redshifts of spectral lines

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According to current cosmological theories, the universe came into existence some 15 to 20 billion years ago. Since then, the large scale four-dimensional fabric of the world has continued to drag matter and radiation further and further apart. The available theories and observational evidence suggest that the recessional velocity of the visible and presumably also the invisible features increases linearly with the separation between the observer and the observed structures. This statement, known as Hubble's law, plays a central role in our current interpretation of the universe and in our understanding of its distant past. The observed red shift of the distant galaxies fits nicely with the picture of an expanding dynamical universe.

While most professional cosmologists appear to feel comfortable with the conceptual framework of the standard model and are inclined to seek a resolution of the many open problems within the existing theories, forceful objections have also been raised. For example, Halton C. Arp of the Max Planck Institute for Physics and Astrophysics in Munich and formerly of Mount Wilson and Las Campanas Observatories, views Hubble's law as "the single, frail assumption on which so much of the modern astronomy and cosmology is built" and believes that the observed red shift may be explained, at least in part, by effects other than recessional motion.

The replacement of the Doppler hypothesis with an alternative explanation would have been viewed as an extremely difficult task as little as two years ago. Now, as a result of a remarkable series of theoretical predictions and related experimental tests, perhaps this issue can be reopened with some assistance from the laws of traditional optics.

Emil Wolf of the University of Rochester promoted these efforts by questioning the common belief that the spectrum of light emitted by a source remains unchanged on propagation. General arguments based on the propagation properties of the field correlation functions show that the spectrum of light in general depends not only on the source spectrum but also on the location of the observer.[1,2] Only under certain conditions on the functional form of the degree of spectral coherence of the light across the source plane (when the so-called scaling law is satisfied) does the measured spectrum maintain its form throughout empty space.

Why was the issue not raised a long time ago? According to Wolf, the answer lies in the fact that ordinary thermal sources can be shown to satisfy the scaling law so that the requirements for spectral invariance are actually fulfilled. G. Michael Morris and Dean Faklis of the Institute of Optics in Rochester provided experimental support for the theoretical conclusions.[3] They created two secondary sources with different coherence properties: one was designed to obey the scaling law, while the other violated it. The measured spectra at the source planes and at some distance from the sources were found to possess the invariance property in the first case, but not in the latter.

Having established that spectral invariance on propagation is not a general property of statistically stationary fields, Wolf went on to explore the kind of modifications that a spectrum could undergo if the scaling relation was not valid at the source plane and proposed that, in addition to shape variations, the peak of spectral lines could undergo a frequency shift to the red or to the blue, depending on the correlation properties of the source.[4,5] Perhaps the most intriguing aspect of this prediction is that even a modest correlation length at the source can produce significant and measurable frequency shifts in the far field. While an optical demonstration of this phenomenon is still waiting to be performed, a convincing test was carried out by Mark F. Bocko, David H. Douglas, and Robert S. Knox[6] using acoustic sources with controllable correlation properties. In the opinion of this reporter, we have not heard yet the final word on this interesting subject.

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Simulated annealing and lens design

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Based on theoretical work done by Metropolis in the 1950s,[1] Bohachevsky, Viswanathan, and others at the Los Alamos National Laboratories pioneered the application of simulated annealing to lens design.[2,3] More recently, efforts by Yang and Hopkins,[4] Hearn,[5] and Weller[6] have advanced this technology toward commercial use by designers.

Simulated annealing is a stochastic approach to the solution of complex systems, not unlike the more familiar Monte Carlo methods. It is essentially a search method driven by a biased random walk. As applied to lens design, the method is based on the idea that a given lens can be thought of as being in some energy state. This energy state is lower when the lens is "better," and is higher when the lens is "worse," i.e., has more aberrations. What we want then is for the lens to be in the lowest possible energy state, where the overall image aberrations will be at a minimum.

The lens variables allow the lens to move from one energy level to another, within boundaries set by the lens designer. Rather than change variables under the guidance of Damped Least Squares (DLS) or ortho-normalization, the variables are changed in a random fashion. The set of changing variables can be likened to a hiker wandering over a hilly meadow—the hilly meadow being the multidimensional solution space of the lens, whose "height" at any point is just the value of the merit function. The hiker can move in any direction, but his walk is biased, as follows.

If the hiker steps down hill, that step is accepted. If he takes a step uphill, he must decide whether to accept that course, or go back and try another step in some other direction. His decision is based on how far uphill he stepped relative to where he was and on a coin toss. Theoretically, there is always a probability that the hiker will take an uphill step.

This biased random walk is based on the Boltzmann Equation that describes the energy state of a system of particles (typically fermions or bosoms) as a function of temperature. The Boltzman Equation, modified in form, becomes the essence of the simulated annealing method. Mathematically speaking, we do the following:

a) Generate a set of normalized random numbers and multiply the elements of this set by a master step size Δr to yield a set of random steps (a step vector Γ).
b) Add the step vector Γ to the set of lens variables. This operation constitutes a random step in the lens variables.
c) Evaluate the lens—a one-number merit function value is returned. If the value of the merit function ϕ is better than the previous value ϕ_0, the random step is accepted, and we continue at a).
d) If the value of the merit function ϕ is higher than the previous value ϕ_0, we generate a unit normalized random number Ω, and accept this uphill step according to the following equation: