cern for eye safety — provided, of course, that one observes the usual precaution of not looking directly into the laser beams.

The tool can readily be attached to almost any camera by use of the standard tripod nut on the underside of the camera. Once the tool is thus attached and properly aligned, it projects the laser scale marks wherever the camera is aimed.

The basic principle of operation of this tool is amenable to a number of potential variations of its design. For example, the number of laser beams could be different from four. For another example, one of the laser beams could be aimed at a known angle relative to the others so that the different dis-tances between laser-beam spots in an image can be used to estimate the distance between the camera/tool combination and the target.

For yet another example, one could reduce the cost of the tool by using a single laser in conjunction with a non-optimum inexpensive simple beam-splitting device to generate all four beams. In this case (see Figure 2), the beam-splitting device would be a flat glass plate coated to be partially reflective on one surface and highly reflective on the other surface. Because the parallelism of the output laser beams would depend only on the parallelism of the glass surfaces and the dis-tance between successive beams would depend only the thickness of the glass surfaces and would vary uncritically with the tilt of the plate, this design would offer the advantage of simplification of alignment. The one shortcoming of this design is that the four laser beams would not be of equal power.

This work was done by Charlie Stevenson, Jorge Rivera, and Robert Youngquist of **Kennedy Space Center** *and Robert Cox and William Haskell of Dynacs, Inc. For further information, contact the Kennedy Space Center Technology Commercialization Office at (321) 867-8130. KSC-12201*

Compact Interconnection Networks Based on Quantum Dots

These networks would exploit the crossing of coplanar signal paths.

NASA's Jet Propulsion Laboratory, Pasadena, California

Architectures that would exploit the distinct characteristics of quantum-dot cellular automata (QCA) have been proposed for digital communication networks that connect advanced digital computing circuits. In comparison with networks of wires in conventional very-large-scale integrated (VLSI) circuitry, the networks according to the proposed architectures would be more compact. The proposed architectures would make it possible to implement complex interconnection schemes that are required for some advanced parallel-computing algorithms and that are difficult (and in many cases impractical) to implement in VLSI circuitry.

The difficulty of implementation in VLSI and the major potential advantage afforded by QCA were described previously in "Implementing Permutation Matrices by Use of Quantum Dots" (NPO-20801), *NASA Tech Briefs*, Vol. 25, No. 10 (October 2001), page 42. To recapitulate: Wherever two wires in a conventional VLSI circuit cross each other and are required not to be in electrical contact with each other, there must be a layer of electrical insulation between them. This, in turn, makes it necessary to resort to a noncoplanar and possibly a multilayer design, which can be complex, expensive, and even impractical. As a result, much of the cost of designing VLSI circuits is associated with minimization of data routing and assignment of layers to minimize crossing of wires. Heretofore, these considerations have impeded the development of VLSI circuitry to implement complex, advanced interconnection schemes.
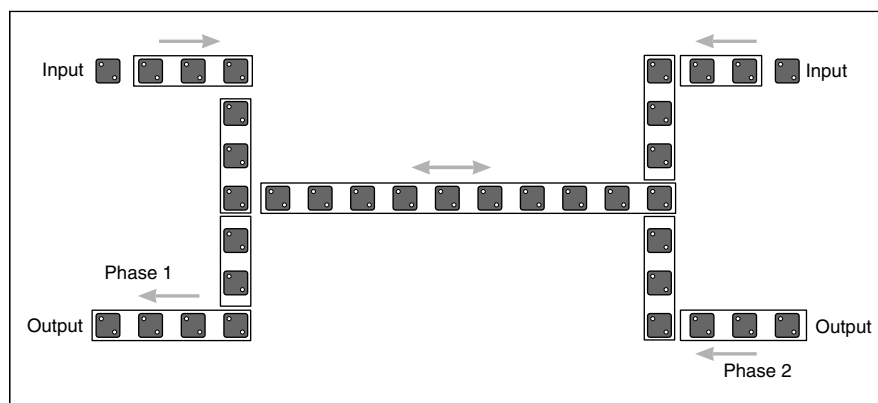

Figure 1. A **QCA-Based Wire for Bidirectional Communication** would be terminated in input and output branches at both ends.
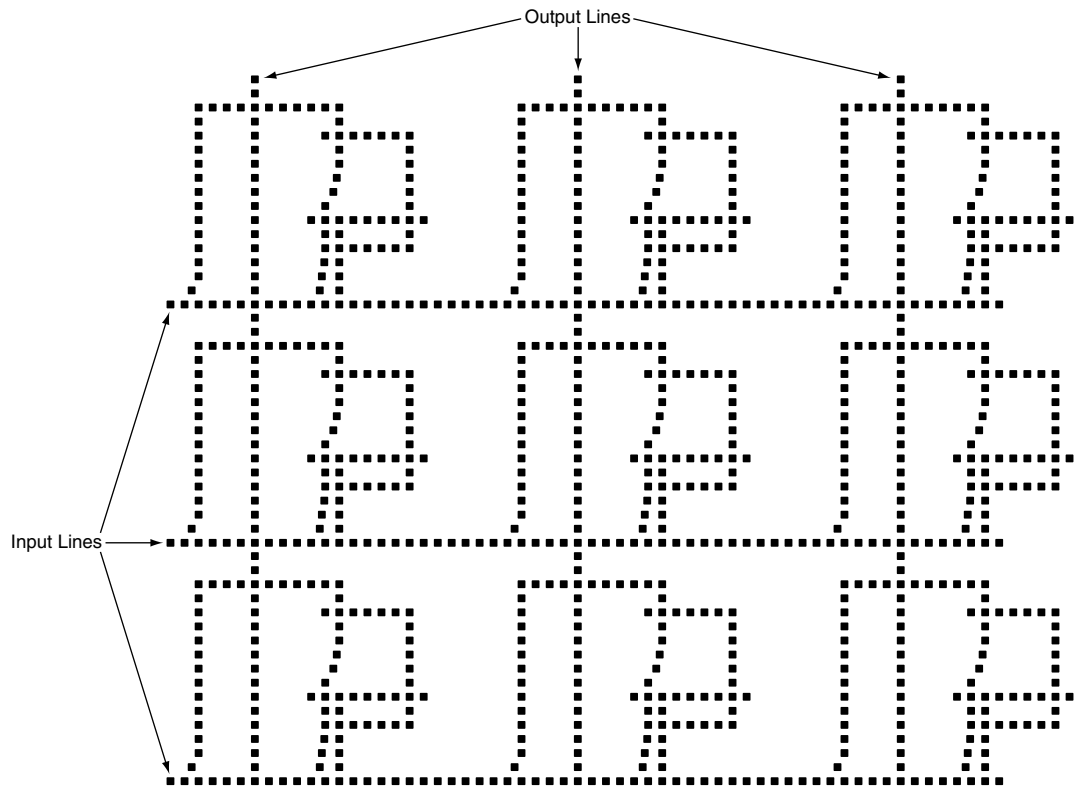
On the other hand, with suitable design and under suitable operating conditions, QCA-based signal paths can be allowed to cross each other in the same plane without adverse effect. In principle, this characteristic could be exploited to design compact, coplanar, simple (relative to VLSI) QCA-based networks to implement complex, advanced interconnection schemes.

The proposed architectures require two advances in QCA-based circuitry beyond basic QCA-based binary-signal wires described in the cited prior article. One of these advances would be the development of QCA-based wires capable of bidirectional transmission of signals. The other advance would be the development of QCA circuits capable of high-impedance state outputs. The high-impedance states would be utilized along with the 0- and 1-state outputs of QCA.
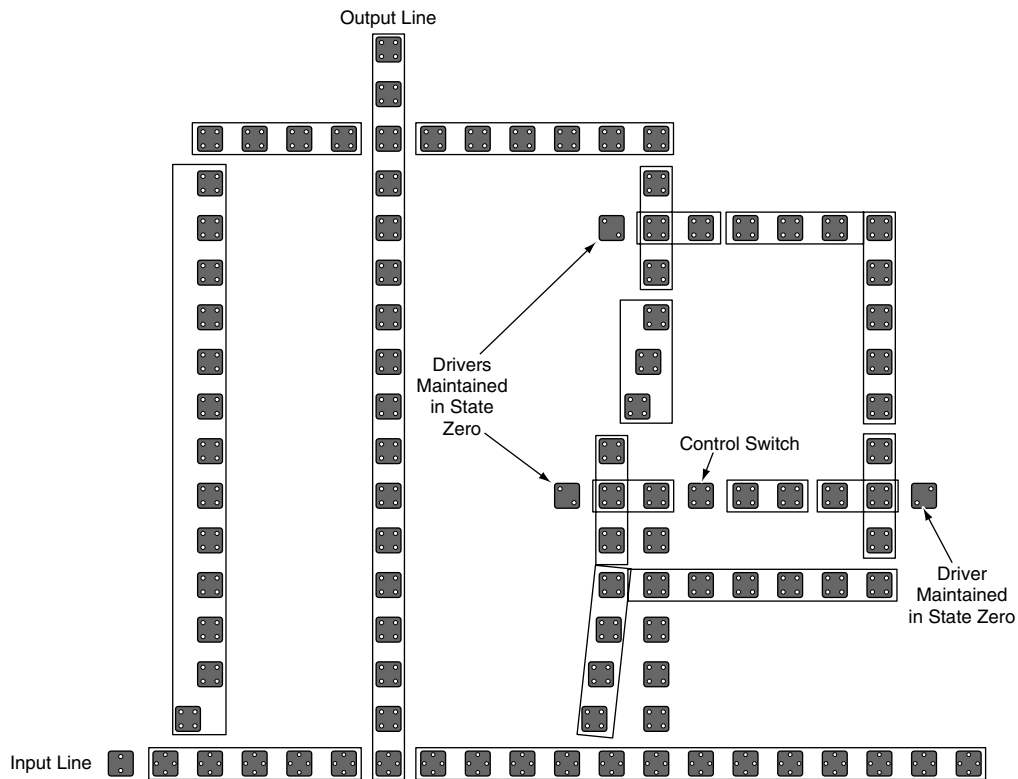
A QCA-based wire for bidirectional communication (see Figure 1) would be terminated in two branches at each end — one branch for input, the other for output. To enable binary signals to propagate both from the left input to the right output terminal and from the right input to the left output terminal, it would be necessary to apply suitably phased clock signals (bias voltages) to QCA subarrays at various positions along the main wire and the end branches. (For complex reasons that must be omitted from this article for lack of space, such clocking is needed in any event to prevent spurious outputs. Here, the clocking would be exploited for the additional purpose of bidirectional communication.)

One especially useful interconnection network is an $N \times N$ crossbar network. A QCA circuit capable of a high-impedance output state would be needed to implement a crosspoint switch in a crossbar network. This is because while all N input

Output Lines

3×3 CROSSBAR NETWORK

Output Line

Drivers
Maintained
in State
Zero

Control Switch

Input Lines

Driver
Maintained
in State Zero

Input Line

DETAIL OF A CROSSPOINT SWITCH

Figure 2. A **Crossbar Network** would be a coplanar assembly of QCA-based wires subdivided into QCA arrays excited by suitably timed clock signals.

lines cross a given output line, only one input line is allowed to put a signal on that output line; in other words, the connections between the other input lines and the given output line are required to be of high impedance in order to block signals.

Figure 2 depicts a proposed QCA-based crosspoint switch and a 3×3 crossbar network. The crosspoint switch would contain several branched QCA subarrays excited by suitably phased clock signals, and one of the quantum cellular automatons would serve as a control switch. The input signal I_i would propagate toward the output line along one branch and, by suitable clocking and coupling, would be converted to another signal, I_f, propagating toward the output line along another branch. The application of a "0" signal to the control switch would cause I_i and I_f to be of the same state (both 0 or both 1), thereby causing the signal I_i to be coupled onto the output line; in effect, the crosspoint switch would be in a low-impedance state. On the other hand, the application of a "1" signal to the control switch would cause I_f to be the opposite of I_i, thereby preventing coupling of either I_i or I_f onto the output line; in effect, the crosspoint switch would be in a high-impedance state.

This work was done by Amir Fijany, Nikzad Toomarian, Katayoon Modarress, and Matthew Spotnitz of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* **free on-line at www.nasatech.com**.
NPO-20855

Laterally Coupled Quantum-Dot Distributed-Feedback Lasers

These lasers show promise for single-frequency, single-spatial mode operation.

NASA's Jet Propulsion Laboratory, Pasadena, California

InAs quantum-dot lasers that feature distributed feedback and lateral evanescent-wave coupling have been demonstrated in operation at a wavelength of 1.3 µm. These lasers are prototypes of optical-communication oscillators that are required to be capable of stable single-frequency, single-spatial-mode operation.

A laser of this type (see figure) includes an active layer that comprises multiple stacks of InAs quantum dots embedded within InGaAs quantum wells. Distributed feedback is provided by gratings formed on both sides of a ridge by electron lithography and reactive-ion etching on the surfaces of an AlGaAs/GaAs waveguide. The lateral evanescent-wave coupling between the gratings and the wave propagating in the waveguide is strong enough to ensure operation at a single frequency, and the waveguide is thick enough to sustain a stable single spatial mode.

In tests, the lasers were found to emit continuous-wave radiation at temperatures up to about 90 °C. Side modes were found to be suppressed by more than 30 dB.

This work was done by Yueming Qui,

Pawan Gogna, Richard Muller, Paul Maker, and Daniel Wilson of Caltech and Andreas Stintz and Luke Lester of the University of New Mexico for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* **free on-line at www.nasatech.com**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to
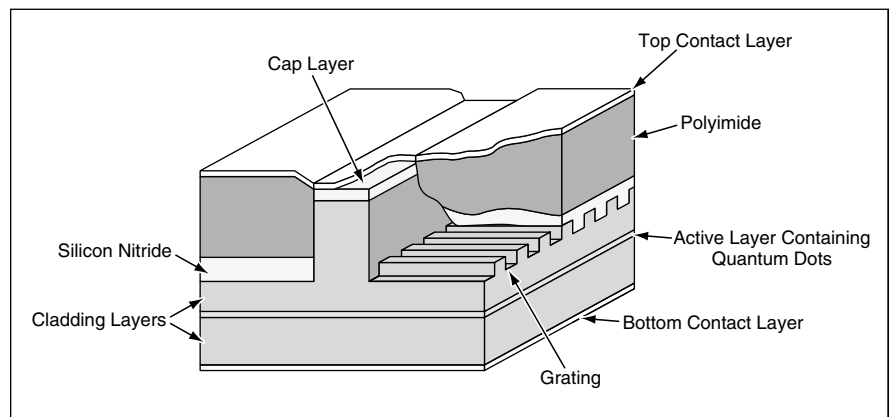
A **Laterally Coupled Quantum-Dot Distributed-Feedback Laser** contains structures that favor oscillation at a single frequency in a single spatial mode.

Bit-Serial Adder Based on Quantum Dots

Adders like this could be used to develop advanced, compact computers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed integrated circuit based on quantum-dot cellular automata (QCA) would function as a bit-serial adder. This circuit would serve as a prototype building block for demonstrating the feasibility of quantum-dots computing and for the further development of increasingly complex and increasingly capable quantum-dots computing circuits. QCA-based bit-serial adders would be especially useful in that they would enable the development of highly parallel and systolic processors for implementing fast Fourier, cosine, Hartley, and wavelet transforms.

The proposed circuit would complement the QCA-based circuits described in "Implementing Permutation Matrices by Use of Quantum Dots" (NPO-20801), *NASA Tech Briefs*, Vol. 25, No. 10 (October 2001), page 42 and "Compact Interconnection Networks Based on Quantum Dots" (NPO-20855), which appears elsewhere in this issue. Those