

Focal-Plane Arrays of Quantum-Dot Infrared Photodetectors

Electron-beam lithography would be used to make arrays sufficiently uniform.

NASA's Jet Propulsion Laboratory, Pasadena, California

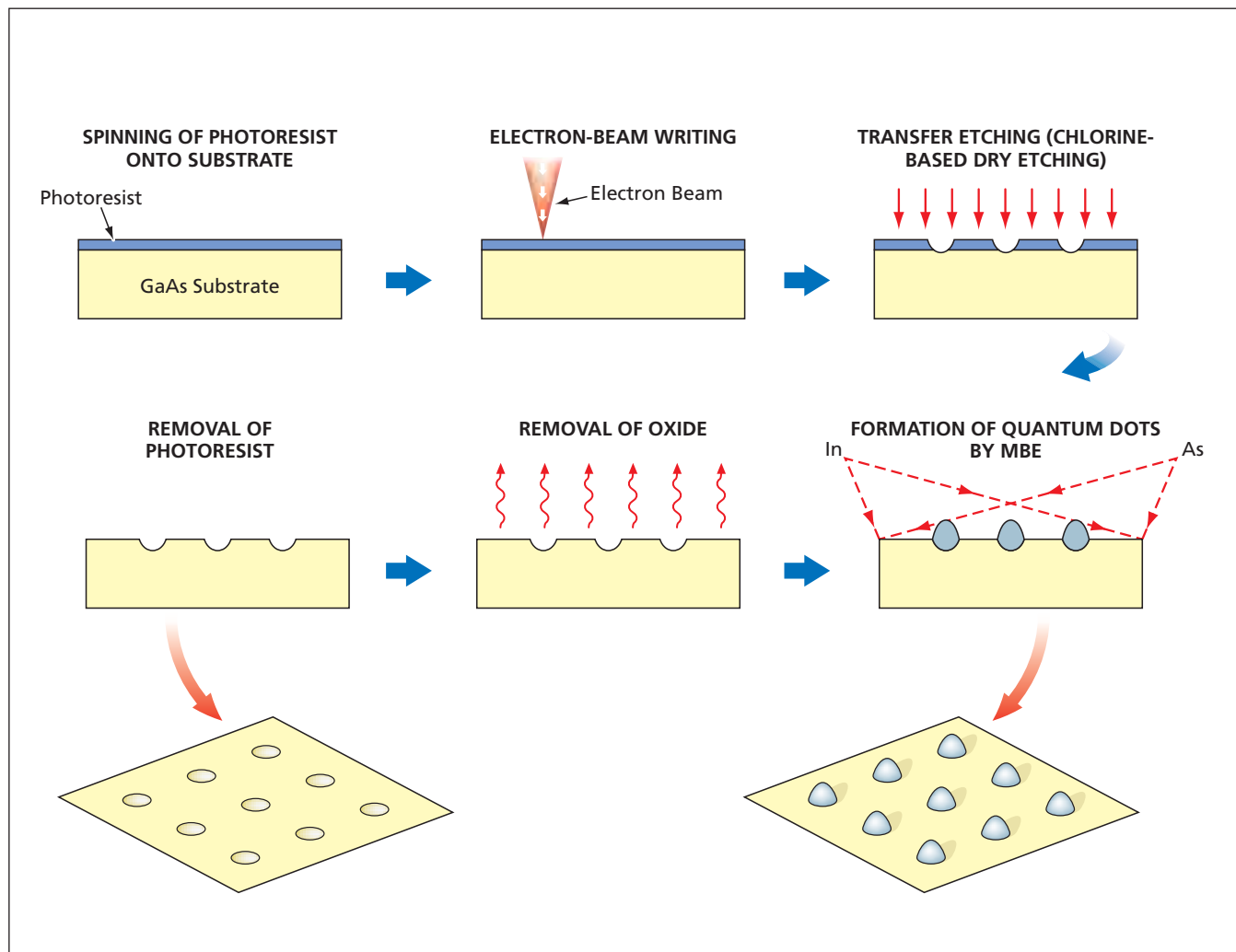
Focal-plane arrays of semiconductor quantum-dot infrared photodetectors (QDIPs) are being developed as superior alternatives to prior infrared imagers, including imagers based on HgCdTe devices and, especially, those based on quantum-well infrared photodetectors (QWIPs). HgCdTe devices and arrays thereof are difficult to fabricate and operate, and they exhibit large nonuniformities and high $1/f$ (where f signifies frequency) noise. QWIPs are easier to fabricate and operate, can be made nearly uniform, and exhibit lower $1/f$ noise, but they exhibit larger dark currents, and their quantization only along the growth direction prevents them from absorbing photons at normal incidence, thereby limiting their quantum efficiencies. Like QWIPs,

QDIPs offer the advantages of greater ease of operation, greater uniformity, and lower $1/f$ noise, but without the disadvantages: QDIPs exhibit lower dark currents, and quantum efficiencies of QDIPs are greater because the three-dimensional quantization of QDIPs is favorable to the absorption of photons at normal or oblique incidence. Moreover, QDIPs can be operated at higher temperatures (around 200 K) than are required for operation of QWIPs.

The main problem in the development of QDIP imagers is to fabricate quantum dots with the requisite uniformity of size and spacing. A promising approach to be tested soon involves the use of electron-beam lithography to define the locations and sizes of

quantum dots (see figure). A photoresist-covered GaAs substrate would be exposed to the beam generated by an advanced, high-precision electron-beam apparatus. The exposure pattern would consist of spots typically having a diameter of 4 nm and typically spaced 20 nm apart.

The exposed photoresist would be developed by either a high-contrast or a low-contrast method. In the high-contrast method, the spots would be etched in such a way as to form steep-wall holes all the way down to the substrate. The holes would be wider than the electron-beam spots — perhaps as wide as 15 to 20 nm, but may be sufficient to control the growth of the quantum dots. In the low-contrast method, the resist would be etched in such a way as to form dimples,



Electron-Beam Lithography and Molecular-Beam Epitaxy would be used to grow quantum dots with a relatively high degree of uniformity in size and spacing.

the shapes of which would mimic the electron-beam density profile. Then by use of a transfer etching process that etches the substrate faster than it etches the resist, either the pattern of holes or a pattern comprising the narrow, lowest portions of the dimples would be imparted to the substrate. Having been

thus patterned, the substrate would be cleaned. The resulting holes or dimples in the substrate would serve as nucleation sites for the growth of quantum dots of controlled size in the following steps. The substrate would be cleaned, then placed in a molecular-beam-epitaxy (MBE) chamber, where native

oxide would be thermally desorbed and the quantum dots would be grown.

This work was done by Sarath Gunapala, Daniel Wilson, Cory Hill, John Liu, Sumith Bandara, and David Ting of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-41236

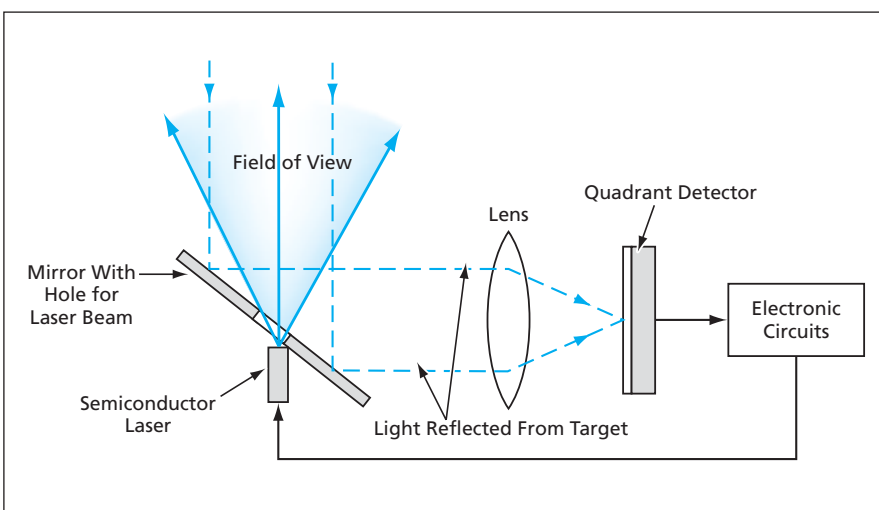
Laser Range and Bearing Finder With No Moving Parts

This instrument would locate a nearby target, without scanning.

Marshall Space Flight Center, Alabama

A proposed laser-based instrument would quickly measure the approximate distance and approximate direction to the closest target within its field of view. The instrument would not contain any moving parts and its mode of operation would not entail scanning over of its field of view. Typically, the instrument would be used to locate a target at a distance on the order of meters to kilometers. The instrument would be best suited for use in an uncluttered setting in which the target is the only or, at worst, the closest object in the vicinity; for example, it could be used aboard an aircraft to detect and track another aircraft flying nearby.

The proposed instrument would include a conventional time-of-flight or echo-phase-shift laser range finder, but unlike most other range finders, this one would not generate a narrow cylindrical laser beam; instead, it would generate a conical laser beam spanning the field of view (see figure). The instrument would also include a quadrant detector, optics to focus the light returning from the target onto the quadrant detector, and circuitry to synchronize the acquisition of the quadrant-detector output with the arrival of laser light returning from the



An Unusually Wide-Beam Laser Range Finder would be combined with a quadrant detector so that the distance and direction to a target could be measured simultaneously.

nearest target. A quadrant detector constantly gathers information from the entire field of view, without scanning; its output is a direct measure of the position of the target-return light spot on the focal plane and is thus a measure of the direction to the target.

The instrument should be able to operate at a repetition rate high enough to enable it to track a rapidly moving tar-

get. Of course, a target that is not sufficiently reflective could not be located by this instrument. Preferably, retroreflectors should be attached to the target to make it sufficiently reflective.

This work was done by Thomas C. Bryan, Richard T. Howard, and Michael L. Book of Marshall Space Flight Center. Further information is contained in a TSP (see page 1). MFS-31705

Microrectenna: A Terahertz Antenna and Rectifier on a Chip

Microscopic rectennas would supply DC power to microdevices.

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A microrectenna that would operate at a frequency of 2.5 THz has been designed and partially fabricated. The circuit is intended to be a prototype of an extremely compact device that could be used to convert radio-beamed power to DC to drive microdevices (see Figure 1).

The microrectenna (see Figure 2) circuit consists of an antenna, a diode rectifier and a DC output port. The antenna consists of a twin slot array in a conducting ground plane (denoted the antenna ground plane) over an enclosed quarter-wavelength-thick resonant cavity (de-

noted the reflecting ground plane). The circuit also contains a planar high-frequency low-parasitic Schottky-barrier diode, a low-impedance microstrip transmission line, capacitors, and contact beam leads. The entire 3-D circuit is fabricated monolithically from a single