



Quantum-Dot Laser for Wavelengths of 1.8 to 2.3 μm

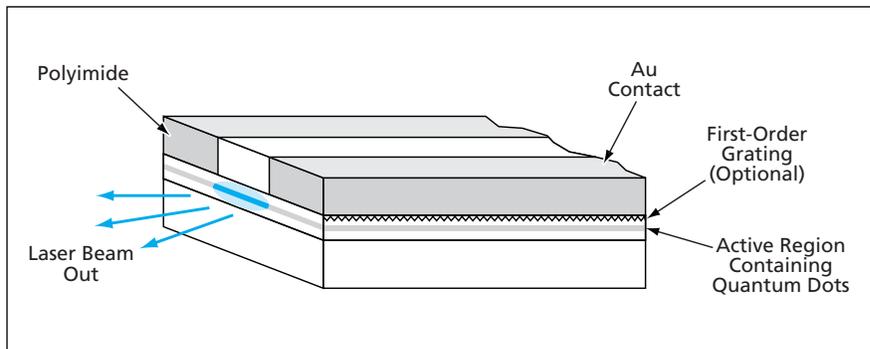
Process conditions must be controlled to form quantum dots at sufficient density.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure depicts a proposed semiconductor laser, based on In(As)Sb quantum dots on a (001) InP substrate, that would operate in the wavelength range between 1.8 and 2.3 μm . InSb and InAsSb are the smallest-bandgap conventional III-V semiconductor materials, and the present proposal is an attempt to exploit the small bandgaps by using InSb and InAsSb nanostructures as mid-infrared emitters.

The most closely related prior III-V semiconductor lasers are based, variously, on strained InGaAs quantum wells and InAs quantum dots on InP substrates. The emission wavelengths of these prior devices are limited to about 2.1 μm because of critical quantum-well thickness limitations for these lattice-mismatched material systems.

The major obstacle to realizing the proposed laser is the difficulty of fabricating InSb quantum dots in sufficient density on an InP substrate. This difficulty arises partly because of the weakness of the bond between In and Sb and partly because of the high temperature needed to crack metalorganic precursor compounds during the vapor-phase epitaxy used to grow quantum dots: The mobility of the weakly bound In at the high growth temperature is so high that In adatoms migrate easily on the growth surface, resulting in the formation of large InSb islands at a density, usually



In the Proposed Semiconductor Laser, the active region would contain In(As)Sb quantum dots, which emit at wavelengths from 1.7 to 2.3 μm . The first-order grating would be included, optionally, to select operation at a single wavelength.

less than $5 \times 10^9 \text{ cm}^{-2}$, that is too low for laser operation.

The mobility of the In adatoms could be reduced by introducing As atoms to the growth surface because the In-As bond is about 30 percent stronger than is the In-Sb bond. The fabrication of the proposed laser would include a recently demonstrated process that involves the use of alternative supplies of precursors to separate group-III and group-V species to establish local non-equilibrium process conditions, so that In(As)Sb quantum dots assemble themselves on a (001) InP substrate at a density as high as $4 \times 10^{10} \text{ cm}^{-2}$. Room-temperature photoluminescence spectra of quantum dots formed by this process indicate that they emit at wavelengths from 1.7 to 2.3 μm .

This work was done by Yueming Qiu of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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:

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Refer to NPO-40653, volume and number of this NASA Tech Briefs issue, and the page number.

Tunable Filter Made From Three Coupled WGM Resonators

This is a prototype of high-performance filters for photonic applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

A tunable third-order band-pass optical filter has been constructed as an assembly of three coupled, tunable, whispering-gallery-mode resonators similar to the one described in "Whispering-Gallery-Mode Tunable Narrow-Band-Pass Filter" (NPO-30896), *NASA Tech Briefs*, Vol. 28, No. 4 (April 2004), page 5a. This filter offers a combination of four characteristics that are desirable for

potential applications in photonics: (1) wide real-time tunability accompanied by a high-order filter function, (2) narrowness of the passband, (3) relatively low loss between input and output coupling optical fibers, and (4) a sparse spectrum. In contrast, prior tunable band-pass optical filters have exhibited, at most, two of these four characteristics.

As described in several prior *NASA Tech*

Briefs articles, a whispering-gallery-mode (WGM) resonator is a spheroidal, disklike, or toroidal body made of a highly transparent material. It is so named because it is designed to exploit whispering-gallery electromagnetic modes, which are waveguide modes that propagate circumferentially and are concentrated in a narrow toroidal region centered on the equatorial plane and located near the outermost edge.