Such patterned surfaces could be used for confining and guiding surface-phonon polaritons in nanoscale devices, or to create materials with a negative index of refraction that would form the basis of optically perfect lenses. For data storage, ion implantation could be localized to spots of about 10-nm diameter, resulting in storage densities of up to a terabyte per square centimeter. Using ion beams to write ordinary data on an ordinary compact disk may not be practical; however, for storing unique data of cultural importance with longterm requirements, it may be worth further investigation.

When tunable IR lasers or quantum-cascade lasers become more widely available, more applications of s-SNOMs will become possible, such as identifying the chemical and structural composition of many materials by their mid-IR spectra, as well as direct visualization of Cooper-pair breaking, plasmon-phonon coupling, and cyclotron resonance in solid-state materials.

Uwe Brinkmann

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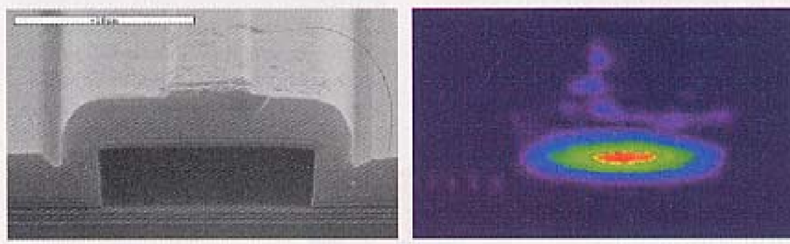
PHOTONIC INTEGRATED CIRCUITS

ARROW principle yields fluid-core waveguides

A desire to optically detect molecules one at one time has led researchers at the University of California, Santa Cruz (UC Santa Cruz), and at Brigham Young University (Provo, UT) to collaboratively develop micron-scale single-mode integrated optical waveguides with fluid or gas cores based on the antiresonant-reflecting-optical-waveguide (ARROW) principle.

The researchers fabricated and operated wavelength-selective rectangular waveguides, 3.5-µm tall and varying in width from 6 to 50 µm, using methods and cladding materials compatible with standard silicon microfabrication technology (see figure).[1] The best propagation losses observed to date were on the order of 1.2 dB/cm at 633 nm in a 15-µm-wide liquid-filled waveguide. The researchers believe that the design will yield losses as low as 0.1 dB/cm over waveguide lengths encompassing fluid volumes on the order of picoliters and nanoliters.

"Liquids and gases are the natural environment for molecules in biology and chemistry," said lead investigator Holger Schmidt at UC Santa Cruz. "If you can guide light through water and air, all of the fields that rely on nonsolid materials can take advantage of integrated-optics



UC SANTA CRUZ

A hollow rectangular core in an integrated optical waveguide measures 3.5 × 12 µm. The top ridge layer, intended for lateral confinement by effective-index guiding, measures 0.57 µm high by 5 µm wide (left). The intensity profile (full width at half maximum) of the mode propagating in the waveguide is 1.32 µm in the transverse direction and 6.4 µm in the lateral direction for a mode area of 6.64 µm² (right).

technology." These fields include environmental sensing.

Conventional optical fibers guide light using total internal reflection within a high-index core surrounded by a low-index cladding, while the ARROW principle is based on choosing layer thicknesses of high-index cladding materials to create an antiresonant Fabry-Perot resonator around a low-index core.

Photonic-bandgap structures such as holey fibers also guide light along low-index cores within high-index cladding, but rely on relatively thick periodic structures that are not compatible with the small sizes needed for integrated circuitry or with the materials and processes of established silicon microfabrication techniques.

Smallest waveguide

While Schmidt's research team is not the first to fabricate ARROW waveguides, they believe that their demonstration, reported earlier this year, of a 3.5×12-μm cross-section air-filled ARROW waveguide (6.5-dB/cm propagation loss at 785 nm) constitutes the smallest to date.[2] The propagation losses of their waveguides depend upon structural features such as

IN DESIGNING THEIR DEVICES, THEY SOUGHT AN OPTIMAL BALANCE OF PROPAGATION LOSSES AND COMPLEXITY.

the number of cladding layers, which do not have to be placed periodically as do components of photonic-crystal or Bragg devices. In designing their devices, they sought an optimal balance of propagation losses and fabrication complexity.

For cladding materials, the researchers chose silicon nitride and silicon dioxide because of their compatibility with microfabrication techniques and potential for integration with silicon-based electronics. The cladding layers are deposited above and below a sacrificial slab that is later etched away to create a hollow rectangular core. The researchers have also fabricated 2-D arrays with waveguides intersecting at 90° angles. The fabrication of what Schmidt described as "an enabling technology" was performed at Brigham Young University.

"We can make waveguides in parallel on a chip, so you can imagine probing 20 to 30 channels at one time, with each channel containing a different sample," he said.

The primary thrust at present is on developing a planar optical platform for measurements of single DNA molecules in solution. Schmidt is working with David Deamer, also at UC Santa Cruz, to combine liquid-core waveguides with a nanopore device developed in Deamer's lab that can feed linear molecules such as single-stranded DNA through a 1.5-nm channel one at a time.

"The idea is to use the nanopore to feed single molecules one by one into a very small volume in the core of the waveguide and capture the photons released by each molecule," said Deamer, who chairs the biomolecular-engineering department at UC Santa Cruz.

Schmidt is also applying the concept to creating an integrated platform for quantum-interference measurements based on electromagnetically induced transparency of rubidium atoms. "Specifically, we are exploiting the high intensities afforded by the small mode area to investigate nonlinear optical effects such as phase modulation in the few- to single-photon limit," he said.

Hassaun A. Jones-Bey

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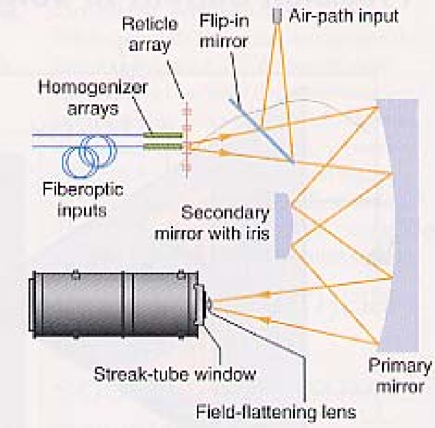
HIGH-SPEED IMAGING

Remotely operated streak camera is self-calibrating

Researchers at the University of Rochester Laboratory for Laser Energetics (LLE; Rochester, NY) have developed a remotely operated stand-alone streak camera with comprehensive autofocus and self-calibration capabilities.[1] The camera was developed to satisfy a need for improved measurement of implosion and basic physics experiments in support of the National Inertial Confinement Fusion program. A prototype of the Rochester Optical Streak System (ROSS) camera has been tested by a team at the Lawrence Livermore National Laboratory (LLNL; Livermore, CA) and found to have a spatial resolution of 20 line pairs per millimeter (lp/mm), temporal resolution of



Input optics for the ROSS camera are based on an Offner triplet system. An air path for signals from external sources can be selected with a flip-in mirror, or the homogenizer arrays for fiberoptic signals and internal calibration sources can be used.