ZnO photonic-crystal laser emits in the UV

Topic Index

View Laser Focus World articles by topic, A-Z

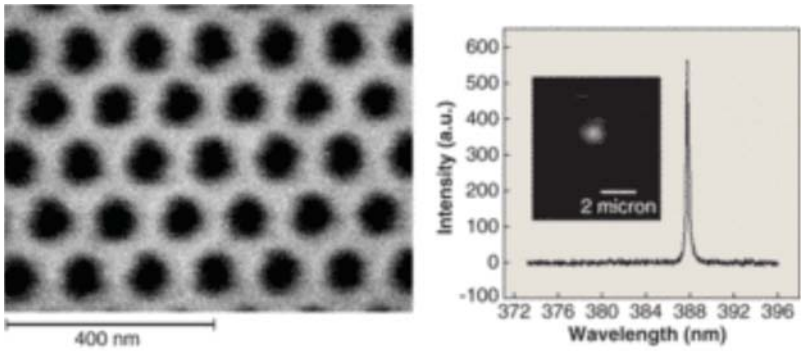
Laser Focus World Article Archive

View Laser Focus World past articles now.

01/01/2005

Although low-threshold lasing in the IR has been realized in photonic-crystal slabs made of III-V semiconductor materials, a UV photonic-crystal laser represents a special challenge because of the different materials and the smaller feature sizes required for the crystal. Although the small feature size is difficult to achieve in commonly used wide-bandgap materials such as gallium nitride (GaN) and zinc oxide (ZnO), demands for compact blue and UV light sources have prompted much research in this area. Building on a recent demonstration of photonic-crystal UV light-emitting diodes fabricated with III nitrides, a team of researchers from the Materials Research Center at Northwestern University (Evanston, IL) has demonstrated an optically pumped ZnO photonic-crystal laser operating in the near-UV at room temperature.

The photonic-crystal structure was prepared by growing 200-nm-thick ZnO films on c-plane sapphire substrates by plasma-enhanced metal-organic chemical-vapor deposition. Next, arrays of cylindrical columns were removed by focused-ion-beam (FIB) etching at 30 KeV (see figure). Structural damage caused by the FIB process was then removed by annealing the films in oxygen at 600°C for one hour. By adjusting the lattice constant a, and the radius of the air cylinders r, the ZnO gain spectrum can be made to overlap the photonic bandgap.



A ZnO triangular-lattice photonic-crystal slab (left) with lattice constant a = 130 nm and air-cylinder radius r = 33 nm produces laser emission when pumped with a modelocked Nd:YAG laser. Lasing is observed at 387.7 nm (right) and is caused by structural disorders that are unintentionally introduced during the focused-ion-beam etching process for the photonic crystal.

Click here to enlarge image

In the experimental setup, a 10×-microscope objective lens is used to focus a modelocked Nd:YAG laser (355-nm wavelength, 10-Hz repetition rate, 20-ps pulse length) at room temperature to a 4-μm spot on the patterned ZnO film. A beamsplitter routes the emission through another lens and into a UV fiber connected to a spectrometer with 0.13-nm spectral resolution. Because the sapphire substrate is transparent in both visible and UV frequencies, a 20×-microscope objective lens is placed at the backside of the sample for measurement of the spatial distribution of emission intensity. The sample was also illuminated by a white-light source to identify the position of the lasing modes in the photonic lattice.

Although the ZnO-patterned films had structures with lattice constants a varying from 100 to 160 nm, only the patterns with a = 115 nm and 130 nm were able to lase. The spectral emission from a pattern with a = 115 nm andr/a = 0.25 was a single sharp peak at 387.7 nm with a spectral width of 0.24 nm above the lasing threshold. The near-field image of the lasing mode showed spatial localization to a small region approximately 1 μm in diameter inside the 8 × 8-μm patterned region of the film (see figure).

Calculation of the photonic band structures using a 3-D plane-wave-expansion method revealed a bandgap from 396 to 415 nm for the structure with *a* = 130 nm and a narrower gap from 363 to 372 nm for the structure with *a* = 115 nm. With the gain spectrum for ZnO ranging from 373 to 397 nm, the calculated photonic bandgaps for these two structures do not exactly overlap the gain spectrum. The team surmised that the unavoidable imperfections in the structures created during the fabrication process broadened the bandgaps and made them shallower, allowing overlap and lasing modes to occur on the lower-frequency side of the bandgap (near the dielectric band edge) for the *a* = 115 nm structure and on the higher-frequency side of the bandgap (near the air band edge) for the *a* = 130 nm structure. The lasing threshold of the structure with *a* = 115 nm is lower than that of the latter because the defect modes are concentrated inside ZnO and experience more gain.

The research team now understands that the lasing modes are basically spatially localized defect states near the edge of the photonic bandgap that are formed by structural disorders unintentionally introduced during the fabrication process. “It is very difficult to make the intentionally introduced defect modes repeatable, especially in the UV regime,” says researcher Hui Cao. For this reason, the team plans to focus on minimizing the structure disorder so that they can get lasing in intentionally introduced defect modes.

REFERENCE

X. Wu et al., *Appl. Phys. Lett. 85*, 17 (Oct. 25, 2004).

Recent Articles

Recent announcement by NASA of nanotube ultrablack absorber is predated by other work, says independent researcher

Hamamatsu deuterium light sources for UV applications

Silicon photonics maker Lightwire to be acquired by Cisco

Experimental "metatronic" circuits imitate electronics, but at optical frequencies

Topic Centers

Biophotonics

Most Commented

OSA Foundation, ICO donation partnership to

Most Recommended

ASPHERES: Fabrication choices impact IR asphere

Detectors and Imaging
Fiber Optic Components & Systems
Lasers & Sources
Optical Components & Systems
Positioning, Support & Accessories
Science and Research
Software
Test & Measurement

support optics education
RPMC DPSS laser series emits at 532 nm
TILL Photonics fluorescence microscope for live tissue imaging
Handheld lensless microscope identifies malaria parasites

design
Resolve Optics compact HD zoom lens focuses up to 450 mm
CMOS DETECTORS: Terahertz imaging achieved with low-cost CMOS detectors
Intertronics opto-mechanical adhesive suits bonding optical components
Rigol Technologies spectrum analyzers offer DANL of -148 dBm

Most Popular Articles

Corning drops on high volatility
LIDAR used to map Mexicali magnitude 7.2 earthquake zone in 3D
Weekly: Corning Inc increases 2.1%
SENSOR FUSION: AFM-IR characterizes photovoltaics at the nanoscale
EMCORE REPORTS DISPOSITION BY CHIEF FINANCIAL OFFICER WEINSWIG (New Mexico)

ABOUT US & SUPPORT
Laser Focus World World Magazine
Contact Us
About Us
Advertising
Subscribe
Login
Register
RSS

RESOURCES
Webcasts
White papers
Editorial Digests
Video
Blogs
Events
PennWell Events
PennWell Websites
OptoIQ
Strategies Unlimited

PRODUCTS
Products
Focus on Products

SECTOR PUBLICATIONS
Laser Focus World
Laser Focus World Japan
Laser Focus World China
Industrial Laser Solutions
Industrial Laser Solutions China
Industrial Laser Solutions Japan
BioOtpics World Magazine

TOPICS
Biophotonics
Detectors and Imaging
Fiber Optics Components & Systems
Lasers & Sources
Optical Components & Systems
Positioning, Support & Accessories
Science and Research
Software
Test & Measurement

CURRENT ISSUE
Current Issue
Online Archives
Digital Archives

STAY CONNECTED
Twitter
Facebook
Linked In

CLICK TO EXPAND