Optical responce of semiconductor nano-structures and device application

Faculty of Engineering
Tokushima University

Designated Professor Toshiro Isu

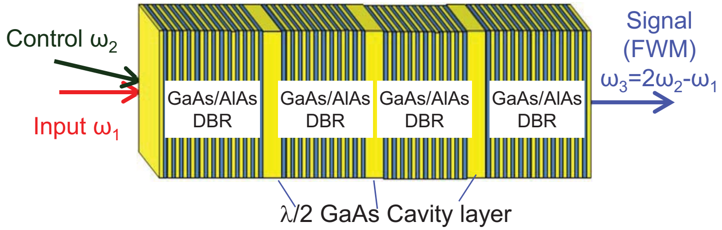

Fig.1 Triple-coupled cavity for wavelengh-conversion devices

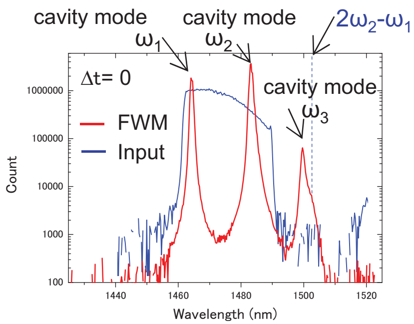

Fig.2 Spectra of FWM and input signals

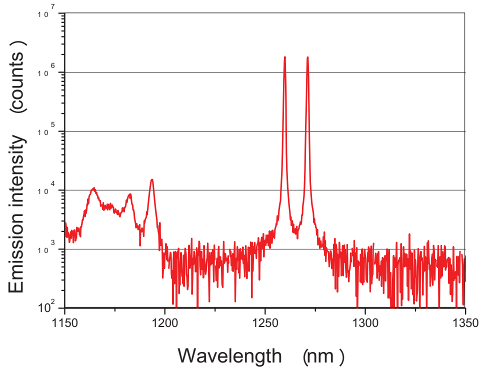

Fig.3 Spectrum of two-color emission of a coupled cavity structure for a THz light emitting device

We are investigating a planar-type ultrafast wavelength-conversion device operating at communication wave bands. A triple-coupled GaAs/AlAs multilayer cavity (Fig.1) enhances optical electric fields of its own three cavity-mode frequencies, wavelength conversion through the four-wave-mixing is realized with high efficiency. We have demonstrated wavelength-conversion signals 1.5μm bands.(Fig.2) We also demonstrated that InAs quantum dots (QDs) embedded in a strain-relaxed InGaAs layer showed large nonlinearity in the communication wave bands with ultrafast responses of 1ps in the semiconductor multilayer cavity. We are developing a device structure with such QDs in order to obtain more enhanced wavelength conversion signals.

We also investigate terahertz-light emitting devices operating by current injection at room temperatures. To realize the devices, we are developing a two-color surface emission laser with difference frequency of terahertz region. We have demonstrated two-color emission from InAs QDs in an active layer by optical pumping. (Fig.3)

These subjects are performed by collaboration of all staffs in our laboratory.

Keywords : optoelectronics, semiconductor technology, optical physics

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THz Emission Devices Based on Coupled Multilayer Cavity

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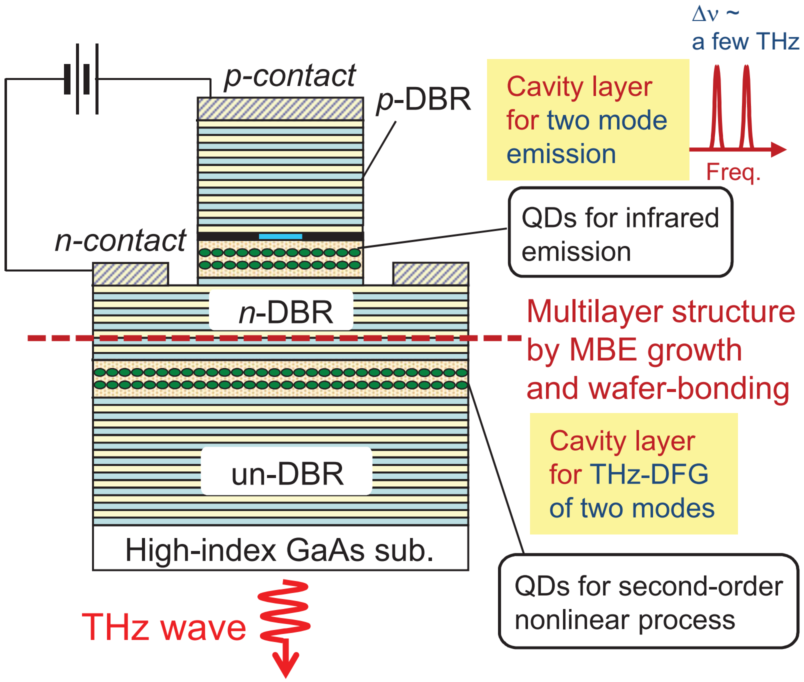
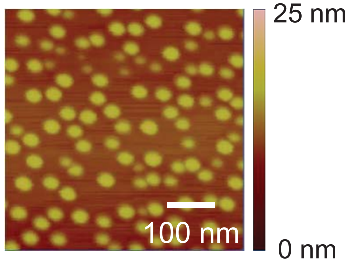


SEM image of GaAs/AlAs coupled multilayer cavity

AFM image of InAs QDs



Content:

Terahertz (THz) sources have been widely investigated due to the wide range of possible application, such as wireless communication, spectroscopy, and imaging. We have studied novel planar-type THz emission devices based on a coupled multilayer cavity.

The coupled multilayer cavity structure consists of three GaAs/AlAs distributed Bragg reflector (DBR) multilayers and two cavity layers containing self-assembled InAs quantum dots (QDs). The QDs in the top-side cavity with a pin junction are responsible for two mode emission in the infrared region, while the QDs in the bottom-side cavity on a high-index GaAs substrate allow difference frequency generation (DFG) of two cavity modes in the THz region. The coupled cavity structure should be fabricated by face-to-face bonding of two epitaxial wafers grown by molecular beam epitaxy (MBE) to produce a strong THz emission. The proposed planar-type device is very useful because it can emit monochromatic THz wave by current injection at room temperature.

Keywords: semiconductor device, nonlinear optical, quantum structure

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Growth of InAs quantum dots by molecular beam epitaxy

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①Fabrication of δ-doped p-InAs QD laser

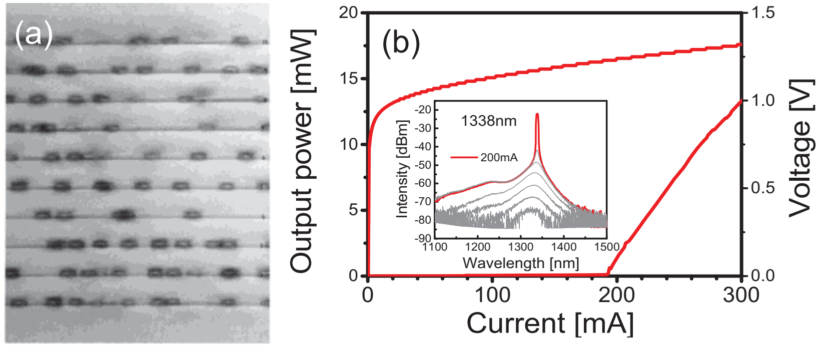

Fig.1 (a) Cross-sectional TEM image of 10 layer-stacked delta doped p-InAs QDs laser diode (b) 1.3μm lasing spectra of p- InAs QDs laser diode at RT.

②Fabrication of low density InAs QDs for single dot spectroscopy

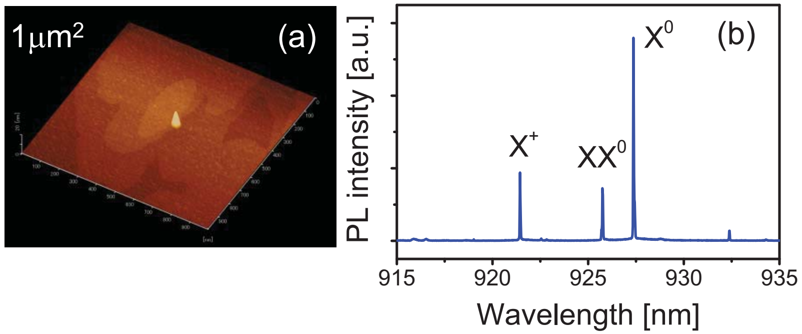

Fig.2 (a) AFM image of single InAs QD (b) micro PL spectra of single InAs QD at low temperature .

InAs quantum dot (QD) is attractive for gain medium of laser diode, and sources of single photon and/or entangled photon pair in quantum information technology.

InAs QDs are grown on GaAs substrates by molecular beam epitaxy (MBE).

①Comparing with usual modulation doping to InAs QDs in active layer, improvements of both J_{th} and its temperature insensitivity were achieved by δ-doping. The X-sectional TEM image of δ-doped InAs QDs laser diode and its 1.3 μm lasing spectra at RT are shown in Fig.1.

②Low density was achieved by very low growth rate of InAs. Growth temperature of initial GaAs cap on InAs QDs lead suppression of background emission as noises. Additionally, control of charge state in a QD was achieved by δ-doping. These QDs contributed generation of single photon and/or entangled photon pair, and lasing from single QD. AFM image of low density InAs QDs and micro PL spectra from excitonic states in a QD are shown in Fig.2.

Keywords：Quantum dot (QD), Molecular beam epitaxy (MBE)

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Field Electron Emission studies of Nanostructures

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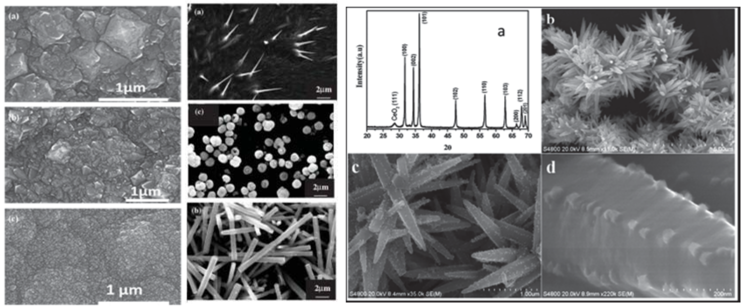

Figure (a) : Surface morphology of various nanostructures

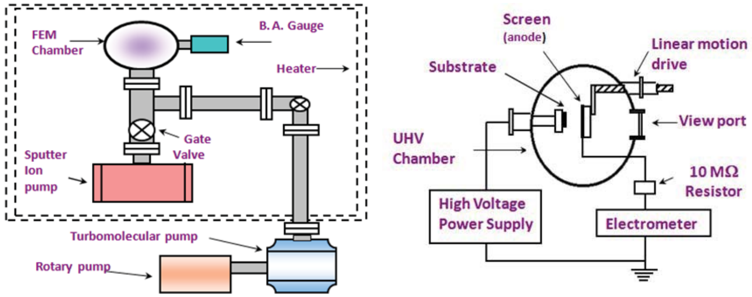

Figure (b) : Field Electron Microscope set up

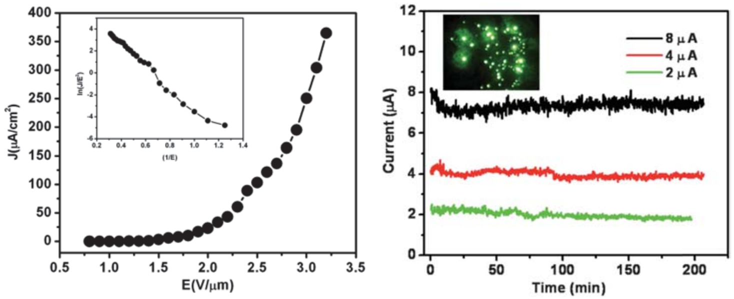

Figure (c) : Typical I-V and I-T plots with emission image

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The deposition of nanomaterials (such as diamond, carbon nanotube, oxides) and employ different surface treatments to study electrical properties as shown in figure (a). The surface treatment leads to favored surface properties useful for electrical properties.

The field emission studies from various nanomaterials like Carbon nanotubes, ZnO, SnO, GaN, InN and to investigate the effect of the structural modification on the field emission characteristics. We have carried out field emission investigations on PANI (nanofibers, nanotubes). The field emission (FE) current versus applied voltage (I–V) and emission current versus time (I–t) characteristics were measured in planar 'diode' configuration in an all-metal vacuum chamber evacuated to a base pressure of 1×10^{-8} mbar as shown in figure (b) and (c).

The promising field emission properties exhibited by nanostructures lead them to play excellent role in field emission displays (FEDs).

Keywords : Nanostructures, Field emission,
Field emission displays

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