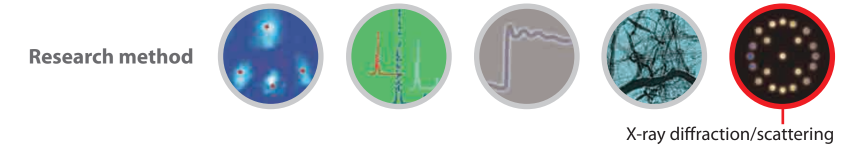
Development of Photonic Integrated Devices with High Luminescent Efficiency

Clarification of factors improving luminescent characteristics

Research method



Beamline used at SPring-8: Hyogo ID (BL24XU)

Achievements

- Measurements of the composition of the laser active layer in **photonic integrated devices*** at high accuracy
- Contribution to the improvement of the luminescent efficiency of photonic devices by approximately 40% through optimization of the composition and the commercialization of high-performance photonic integrated devices

R&D facility: NEC Corporation and Himeji Institute of Technology (now University of Hyogo)

***Photonic integrated device:** A device comprising various optical elements, such as semiconductor lasers, optical waveguides, optical switches, optical modulators, and optical detectors. The photonic integrated element introduced here incorporates a modulator and a semiconductor laser on a single semiconductor substrate. This is a key device for optical communication systems to realize higher capacity optical communications because multiple signals with different wavelengths can be superimposed on a fiber.

****Lattice constant:** Six constants that represent the lengths and angles between crystal axes.

Role of SPring-8

Background

The luminescent characteristics of photonic integrated elements (luminescence intensity for each wavelength) depend on the quality of the laser structure. A **selective-area growth method**, in which the crystals of the laser active layer (InGaAsP layer) are grown between SiO_2 masks, has been developed as a method of fabricating laser structures. This method enables us to shorten the fabrication process compared with conventional methods, resulting in a low production price.

However, it was impossible to accurately control the quality of crystals of InGaAsP layers, because the layer width is as narrow as 1.5 µm and thus there was no method of measuring the composition of the layers with high accuracy.

Results

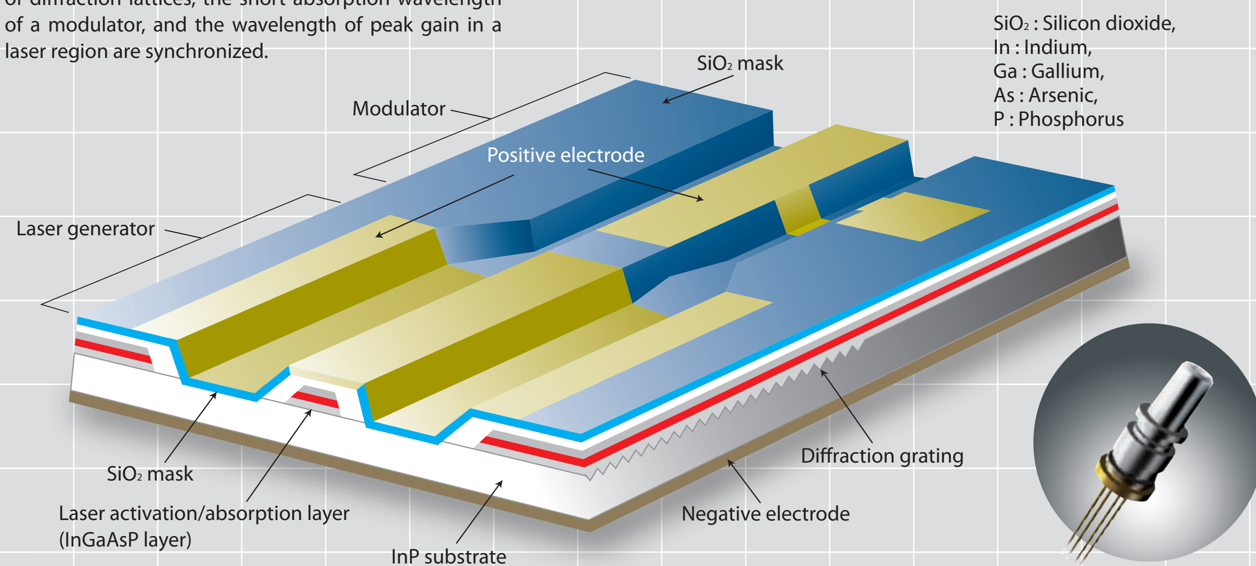
It is necessary to measure the **lattice constants**** to determine the composition of InGaAsP layers. For this, an X-ray diffraction measurement method with a spatial resolution of a few µm or higher is required. This measurement was realized using the synchrotron radiation of SPring-8. As a result, the composition of InGaAsP layers, which depends on the mask width, was analyzed with an accuracy at least one order higher than before. In addition, we unveiled an unconventional result that the composition ratio of group V elements (As and P) in InGaAsP layers changes depending on the mask width.

Using the above results, it became possible to control the composition and lattice constants of crystals selectively grown in devices as designed.

Publication: S. Kimura et al.; Applied Physics Letters **77** (9), 1286-1288 (2000)

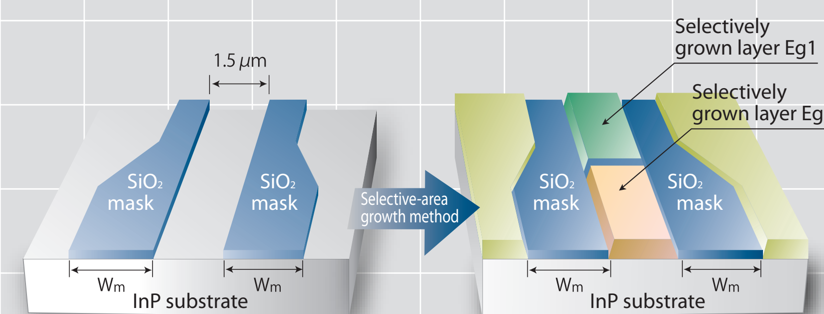
Structure of photonic integrated device with modulator and laser

It is necessary to fabricate elements such that the pitch of diffraction lattices, the short absorption wavelength of a modulator, and the wavelength of peak gain in a laser region are synchronized.



Selective-area growth of laser activation layer

When the compounds of source gases are diffused onto the surface of an InP substrate partially masked with SiO_2 or other films, crystals grow on the surface via a thermal decomposition reaction. This is a selective-area growth method that enables the selective-area growth of the crystals of InGaAsP layers in regions other than the masks. The method can also be used to realize waveguides (Eg1 and Eg2) with different compositions.



Change in SiO_2 mask width and composition ratio of group V elements (As and P) in InGaAsP layer

The lattice constants of an InGaAsP layer (0.1-0.2 µm thick, 2-30 µm wide) that acts as a laser activation layer were measured using an X-ray microbeam generated from high-brilliance synchrotron radiation. The results revealed that the composition ratios of not only group III elements (Ga and In) but also group V elements (As and P) in the InGaAsP layers change depending on the SiO_2 mask width (Wm).