## Abstract Title

# Two-dimensional microcavity lasers

## Symposium Track

**Fundamental Modeling in Nanomechanics**


## Authors' names

*Takahisa Harayama*

## Authors' affiliations

*Department of Nonlinear Science, ATR Wave Engineering Laboratories, 2-2-2 Hikaridai, Seika-cho, Soraku-gun, Kyoto 619-0288, Japan*



## Abstract body

Various kinds of devices such as lasers and musical instruments utilize stationary wave oscillations in resonant cavities. In order to maintain the stationary oscillation in these devices, nonlinearity is essential in the mechanism for balancing the pumping of the external energy and the decay of the wave of the quasi-stable resonance in the resonant cavity. Besides, the interaction between nonlinearities and the morphology of the boundary condition imposed on a resonating wave system by the shape of the cavity is also very important for determining the modes of oscillation.

One-dimensional (1D) simple shapes have been used for laser cavities because they are suitable for fabrication as well as application of directional emission. However, recent advances in processing technology of dry-etching for semiconductor laser diodes have made it possible to fabricate two-dimensional (2D) microcavity lasers of arbirary 2D shapes with potential applications of 2D emission of laser light in optical communications, optical integrated circuits, and optical sensing. We will present the theory of 2D mcirocavity lasers, and show the fabrication technique as well as the lasing characteristics of the actually realized 2D microcavity laser diodes.

The conventional theory of 1D lasers is based on the expansion of the electromagnetic field by modes which are obtained as bound states with an approximation of the boundary condition of the closed cavity. These modes are orthonomal and can expand arbitrary wave functions. However, laser cavities are open systems where only resonances or quasi-stable states exist as eigen-states of which eigen-frequencies are comlex instead of stable bound eigen-states of real eigen-frequencies. It is not clear that the approximation by a closed cavity works even in the case of 2D microcavity lasers because they are quite different from 1D lasers in the sense that the light can emit from 2D edges in all directions in the plane. We present a nonlinear theory of 2D microcavity lasers described by including the effect of the active medium without any kind of modal description [1-6].

The lasing characteristics of 2D microcavity lasers strongly depend on their shapes. Accordingly, fabrication by dry-etching technique is crucially important to a realize vertical and smooth edge of the cavity. The wavelength of GaAs/AlGaAs quantum-well laser is

around 850 nm and the effective refractive index is 3.3, which means that the wavelength inside the microcavity is around 250 nm. Therefore, the precision of the smoothness of the cavity edge less than 80 nm is necessary to observe the 2D shape effects on the lasing characteristics. We will show that the experimentally observed far field patterns of the 2D lasers excellently correspond to the numerically calculated ones [7,8].

Examples of applications of 2D microcavity lasers will be also presented [9,10].


## Keywords

2D Microcavity lasers, Nonlinear interacton, Resonance, Dry-etching, Quantum-well lasers


## References


[1] T. Harayama, P. Davis, and K. Ikeda,“Stable Oscillations of a Spatially Chaotic Wave Function in a Micro-stadium laser”, Phys. Rev. Lett., vol.90, 063901-1-4, 2003.
[2] T. Harayama, T. Fukushima, S. Sunada, and K. S. Ikeda,“Asymmetric Stationary Lasing Patterns in 2D Symmetric Microcavities”, Phys. Rev. Lett., vol.91, 073903-1-4, 2003.
[3] S. Sunada, T. Harayama, and K.S. Ikeda, “Nonlinear whispering gallery modes in a micro-ellipse cavity”, Opt. Lett., vol. 29, 718-720, 2004.
[4] T. Harayama, S. Sunada, and K. S. Ikeda, “Theory of Two-dimensional Microcavity Lasers”, Phys. Rev. A, vol. 72, 013803-1-12, 2005.
[5] S. Sunada, T. Harayama, and K. S. Ikeda, “Multiple-mode Lasing in 2D Fully Chaotic Cavity Lasers”, Phys. Rev. E, vol. 71, 046209-1-5, 2005.
[6] S. Shinohara, S. Sunada, T. Harayama, and K. S. Ikeda, “Mode expansion description of stadium-cavity laser dynamics”, Phys. Rev. E, vol. 71, 036203-1-6, 2005.
[7] T. Fukushima, T. Harayama, T. Miyasaka, and P. O. Vaccaro, “Morphological dependence of lasing modes in two-dimensional quasi-stadium laser diodes”, J. Opt. Soc. Am. B, vol. 21, 935-943, 2004
[8] T. Fukushima andT. Harayama, “Stadium and Quasi-Stadium Laser Diodes”, IEEE J.Select. Topics Quantum Electron., vol.18, 1039-1051, 2004.
[9] T. Fukushima, T. Tanaka, and T. Harayama, “Unidirectional beam emission from starined InGaAsP multiple-quantum-well quasistadium laser diodes”, Appl. Phys. Lett., Vol. 86, 171103-1-3, 2005
[10] T. Fukushima, T. Tanaka, and T. Harayama, “Ring and axis mode switching in multielectrode strained InGaAsP multiple-quantum-well quasistadium laser diodes”, Appl. Phys. Lett., Vol. 87, 191103-1-3, 2005


## Corresponding author contact information


Takahisa Harayama, Department of Nonlinear Science, ATR Wave Engineering Laboratories, 2-2-2 Hikaridai, Seika-cho, Soraku-gun, Kyoto 619-0288, Japan
Phone: +81 774 95 1588
Fax: +81 774 95 1508
Email: harayama@atr.jp