Department of Electrical and Electronic Engineering

Key words Laser chaos, terahertz technology, nonlinear physics

Doctor of Engineering / Associate Professor

Fumiyoshi Kuwashima

Education

Sophia University, Graduate School of Science and Technology, Department of Physics (Master's Program)
Fukui University, Graduate School of Engineering, Department of system engineering (Doctral Program)

Professional Background

Assistant Professor/Associate Professor, Kagoshima National collage of technology
Project general manager, Laser Society of Japan, Technical Committee on Chaos, Noise and Dynamics of Lasers and their Applications

Consultations, Lectures, and Collaborative Research Themes

Generation of THz waves using laser chaos, THz spectroscopy, chaos applications

e-mail address

kuwashima@fukui-ut.ac.jp

Main research themes and their characteristics

「Chaotic oscillations on Single mode class A lasers」

The minimum condition for the onset of deterministic chaos in a dissipative system with continuous variable is the presence of at least three degrees of freedom. The single-mode laser is a typical dissipative system with three degree of freedom under specific conditions. With regard to laser dynamics, lasers are classified based on decay rate (or life time) of three relevant variables, electric field population inversion and polarization, which are given by the relaxation rates κ,γ‖ and γ⊥, respectively. The dynamical behavior of the single mode laser is described by three equations for these three relevant variables that usually decay on very different time scales. If one of these rates is larger than others, corresponding variable relaxes very fast and consequently follows to the other adiabatically. Thus, the number of the laser equations, that is degree of freedom is reduced. Lasers whose population inversion and polarization decay faster than the electric field are called class A laser. The laser equations for a class A laser can be reduced to one (Electric field). In order to generate chaos in this laser at least two external force must be added. This class laser is difficult to yield chaotic oscillations. We first observed chaotic oscillation in this single mode class A laser using optical feedback, which makes system to infinity degree of freedom.

Tab.1 Classification of lasers by relaxation constants

Single mode ← → (good cavity condition ... bad cavity condition)		
class A	class B	class C
$\kappa \ll \gamma_{//} < \gamma_{\perp}$	$\gamma_{//} \leqq \kappa < \gamma_{\perp}$	$\kappa \geqq \gamma_{\perp},\ \gamma_{//}$
He-Ne(6328Å) Ar^{+}(4880Å), Dye	Rb, YAG, Nd^{3+}, Glass, CO_2, semiconductor	He-Ne(3.39 μm) He-Xe(3.51 μm) FIR gas laser
High order stability	Sensitive to external force relaxation oscillation	Higher order instability
N=1 : E P,D : adiabatic elimination	N=2 : E,D P : adiabatic elimination	N=3 : E,D,P Non adiabatic elimination

「THz wave generations using laser chaos」

Terahertz time-domain spectroscopy systems (THz-TDS) are extensively used for material characterization and chemical identification. They usually use a mode-locked Ti:sapphire laser or a mode-locked fiber laser to excite a photoconductive antenna (PA). However, the high cost and bulky nature of these mode-locked lasers limit the scope of the potential uses of THz-TDS systems in many application settings. Low-cost and compact continuous-wave (CW) multimode laser diodes (MLDs) are preferable for use in THz-TDS systems . If a CW-MLD is employed, the spectrum of the generated terahertz signal consists of discrete lines at optical beat frequencies of the CW-MLD, i.e. the frequency spacings between the longitudinal modes in the optical spectrum. Various types of MLDs have been employed as the optical pump source for THz-TDS systems. However, some of the obtained signals are not stable because of intermittent mode hopping in free-running continuous-wave (FRCW) MLDs. Moreover, small differences between individual FRCW-MLDs make it very difficult to obtain the same performance from two similar systems even when employing LDs with the same model number. To overcome these problems, we proposed using a chaotically oscillating laser diode (COLD) for stable and highly efficient THz-TDS systems operating over a wide terahertz frequency range. And also we develop the V-grooved wave guide for the high sensitive THz wave detection.

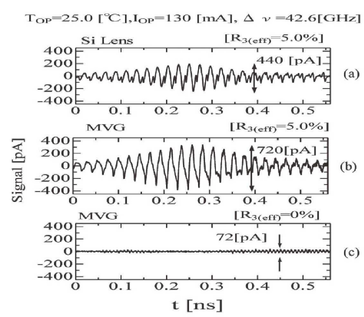

Fig.1 Time series of generated THz waves under the condition of (a)Si lens,$R_{3(eff)}$=5%,(b)MVG, $R_{3(eff)}$=5%, and (c) MVG, $R_{3(eff)}$=0%.

Major academic publications

F. Kuwashima, I. Kitazima and H.Iwasawa : "Theory of chaotic Dynamics on class A laser with optical delayed feedback", Jpn.J.Appl.Phys. Vol.40,No.2A, pp.601-608 (2001)

Kei Inoue and Fumiyoshi Kuwashima :"Evolution of Time Series Obtained from an Experiment of a Laser Chaos by Chaos Degree", INFORMATION, Vol.20, No.10(A),2017,pp.7093-7100.

Fumiyoshi Kuwashima, Mona Jarrahi, Semih Cakmakyapan, Osamu Morikawa, Takuya Shirao, Kazuyuki Iwao, Kazuyoshi Kurihara, Hideaki Kitahara, Takashi Furuya, Kenji Wada, Makoto Nakajima, and Masahiko Tani "Evaluation of high-stability optical beats in laser chaos by plasmonic photomixing", Opt. Express ,28(17) 24833- 24844