東北大学 電気通信研究所

研究室外部評価資料

(2013 年度-2018 年度)

Activity Report of Research Laboratory for External Review

April 2013 - March 2019
(FY.2013-2018)

Research Institute of Electrical Communication

Tohoku University

応用量子光学研究室

Applied Quantum Optics

A. 研究室名 / Research Laboratory

応用量子光学研究室
Applied Quantum Optics

B. 構成員 / Faculty and Research Staff (as of May 1, 2019)

※ 欄を適宜追加削除等調整して下さい．期間内に異動等があった場合には，在籍期間を記載して下さい．

教授 / Professor	
氏名 Name	八坂 洋 Hiroshi Yasaka (April 2008 -)
分野名 Research Field	高機能フォトニクス研究分野 Highly Functional Photonics
准教授 / Associate Professor	
氏名 Name	吉田 真人 Masato Yoshida (April 2018 -)
分野名 Research Field	高精度光計測研究分野 High Accuracy Optical Measurement
助教 / Assistant Professor	
氏名 / Name	横田 信英 / Nobuhide Yokota (April 2014 -)
他 / Others	

C. 研究目的 / Research Purpose

本研究室では、光通信システムの処理能力を飛躍的に増加するための光デバイス技術、及び新世代光情報通信ネットワークシステムを実現するための革新的な新機能光デバイスやレーザ光源の実現を目標として研究を進めている。本研究室では、あわせて光エレクトロニクス的手法による情報通信・超精密計測や、半導体光デバイスの超高速動作とその演算処理への応用など、新しい光エレクトロニクス分野の開拓をはかっている。

Our research group is investigating novel, highly functional semiconductor photonic devices and laser light sources, which is indispensable to realize new generation optical information communication network systems. Furthermore, our research interests cover ultrafast photonic devices including laser sources, opto-electronic semiconductor devices and their applications to optical computing and signal processing areas.

D. 主な研究テーマ / Research Topics

1. 光信号による半導体光デバイス超高速制御の研究
2. 高機能半導体光源の研究
3. 高機能半導体光変調器の研究
4. 新機能半導体光集積回路の研究

1. Ultra-high speed control of semiconductor photonic devices by signal light injection
2. Highly functional semiconductor light sources
3. Highly functional semiconductor optical modulators
4. Novel functional semiconductor photonic integrated circuits

E. 学術論文等の編数 / The Number of Research Papers							
	2013	2014	2015	2016	2017	2018	Total
(1) 査読付学術論文 Refereed journal papers	1	4	3	3	3	4	18
(2) 原著論文と同等に扱う 査読付国際会議発表論文 Full papers in refereed conference proceedings equivalent to journal papers	0	0	0	0	0	0	0
(3) 査読付国際会議 Papers in refereed conference proceedings	1	2	2	5	1	2	13
(4) 査読なし国際会議・シンポジウム等 Papers in conference proceedings	1	2	2	0	3	0	8
(5) 総説・解説 Review articles	1	0	0	0	0	0	1
(6) 査読付国内会議 Refereed proceedings in domestic conferences	0	0	0	0	0	0	0
(7) 査読なし国内研究会・講演会 Proceedings in domestic conferences	5	11	8	10	9	4	47
(8) 著書 Books	0	0	0	1	0	0	1
(9) 特許 Patents	1	1	1	0	1	2	6
(10) 招待講演 Invited Talks	1	1	3	4	3	0	12

F. 特筆すべき研究成果 / Significant Research Achievements (FY.2013-2018)

See Ref. 1. "#" mark indicates research carried out at a former organization.

2013-2018 年度の研究成果（論文・特許など）のうち，前半（2013-2015 年度）と後半（2016-2018 年度）それぞれで代表的な数件（2-3 件程度ずつ）について，参考資料を引用して，その特徴と学術的意義などを簡単に紹介する．英文のみ，もしくは和文と英文で記載．要約は 300 字程度．論文誌の要約/Abstract のコピー可．学術面での国際的インパクトならびに社会的影響を 100 字程度で記載．
必ずしも当該期間内に発表・出版したものに限るのではなく，例えば過去に発表したものでもこの期間内に成果が得られたり，評価されるようになったりしたものも含むものとする．
インパクトファクターや被引用件数など，できる限り第三者が定量的に評価できる指標を用いてアピールすること．それらの指標にはそぐわない場合には，その事情とそれに変わる適当な評価指標・尺度を示すこと．

[2013-2015]

1. K. Aoyama, R. Yoshioka, N. Yokota, W. Kobayashi, and H. Yasaka, "Experimental Demonstration of Linewidth Reduction of Laser Diode by Compact Coherent Optical Negative Feedback System," Applied Physics Express, vol. 7, p. 122701, 2014. [IF: 2.772], [Times Cited: 9]

   Abstract: We demonstrate the linewidth reduction of a laser diode from 6.4MHz to 6.5 kHz using a compact coherent optical negative feedback system, which consists of only a lens and an optical filter. The FM noise power spectral density (PSD) and the relative intensity noise (RIN) of the laser output are measured to discuss the performance of the system. The FM noise PSD is reduced by -30 dB at <100 MHz. The RIN of -130 dB/Hz is not found to be increased by the feedback at <7 GHz, where the system is driven under negative feedback conditions.

   International impact on both academic and social aspects：これまでの狭線幅半導体レーザでは共振器のQ値を上げることで線幅の低減を図っていたが、光源が大きくなるという問題があった。共振器のQ値を上げることによらず、小型な狭線幅半導体レーザ光源を実現する技術として光負帰還法を提案し、その実用性を示した成果である。Nature Photonicsでhighlightedされた論文である。 / So far reduction of spectral linewidth of semiconductor laser have been realized by heightening the Q-value of the laser cavity. But it became the cause of enlarging device size. To overcome this problem and realize compact narrow linewidth semiconductor laser, we proposed optical negative feedback technology, where frequency noise of the laser is reduced by optical filter which acts as optical frequency discriminator. In this technique, optical filter does not compose the laser cavity and small size narrow linewidth semiconductor laser source can be realized by minimizing the size of the optical filter. This paper proposed the optical negative feedback technology for realizing compact narrow linewidth semiconductor laser source and showed its practicality for the first time.

2. S. Mieda, S. Shiratori, N. Yokota, W. Kobayashi, and H. Yasaka, "Ultra-high-speed Operation of Laser Diode by Cross-gain Modulation using external cavity," Applied Physics Express, vol. 8, No. 2, 022701, 2015. [IF: 2.772], [Times Cited: 3]

   Abstract: An optically controlled laser diode with an intensity- and phase-controllable external cavity was studied in order to achieve an increased bandwidth. The external cavity functions as the feedback section for the laser diode, using time-delayed laser light. A 3-dB bandwidth of over 70 GHz was numerically predicted, using rate equations that include cross-gain modulation and multiple optical feedback from the external cavity. A 3-dB bandwidth of more than 40 GHz was experimentally achieved with a fabricated device.

   International impact on both academic and social aspects： データセンタでの通信容量増大に対応するためには高速動作が可能な半導体レーザの実現が不可欠である。半導体レーザの超高速動作を可能とする光子・光子相互作用を導入した光制御型半導体レーザの提案と、その高速動作特性を明らかにした

論文である。 / Realizing Ultra-high speed semiconductor lasers is indispensable to enlarge transmission capacity in data centers. In this paper we propose high-speed optically controlled semiconductor laser introducing photon-photon resonance effect and demonstrate experimentally its high-speed operation characteristics.

3. S. Mieda, S. Shiratori, N. Yokota, W. Kobayashi, and H. Yasaka, "Intra-cavity Loss Modulation for Ultra-High-Speed Direct Modulation Lasers Based on Photon-Photon Resonance," Applied Physics Express, vol. 8, No. 8, 082701, 2015. [IF: 2.772], [Times Cited: 6]

   Abstract: The characteristics of the intra-cavity loss modulation laser diode (ICLM-LD) proposed in this paper were numerically and experimentally evaluated. A lower modulation sensitivity degradation rate (MSDR) of -0.30 dB/GHz and a wider 3 dB bandwidth of 49GHz compared to those of direct modulation lasers (-0.49 dB/Hz, 16GHz) were numerically confirmed. In addition, an MSDR of -0.29 dB/GHz and a 3 dB bandwidth wider than 30GHz were experimentally confirmed using the fabricated ICLM-LD. The ICLM-LD will thus become a key part of ultrahigh-speed direct modulation lasers with external cavities whose modulation sensitivity is enhanced by the photon–photon resonance effect.

   International impact on both academic and social aspects： 50GHz程度に制限された直接変調半導体レーザの応答速度を飛躍的に増大するために、光子・光子相互作用を効率よく利用するための新奇な技術として半導体レーザの応答特性を制御可能な共振器内部損失変調法を提案した論文である。本技術と直接電流変調をミックスすることで自由に周波数応答特性を操作可能とした混合変調半導体レーザを実現するために大切な知見を与えた論文である。 / In this paper we propose an intra-cavity loss modulation method which realizes to control the modulation response characteristic of a semiconductor laser. The method enables to use photon-photon resonance effect in directly modulated semiconductor laser effectively and realizes further enhancement of operation speed of the laser up to 100 GHz.

[2016-2018]

1. N. Yokota, K. Abe, S. Mieda, and H. Yasaka, "Harmonic superposition for tailored optical frequency comb generation by Mach-Zehnder modulator," Optics Letters, vol. 41, No. 5, pp. 1026-1029, 2016. [IF: 3.589], [Times Cited: 15]

   Abstract: This Letter demonstrates tailored optical frequency comb (OFC) generation using a LiNbO3 Mach–Zehnder modulator driven by a combination of first- and second-order harmonics of the RF signal. A quasi-rectangular-shaped OFC with less than 1 dB flatness among 11 lines was experimentally obtained when a slight second-order harmonic of the RF signal (0.1 times the half-wavelength voltage) was introduced. Good agreement was obtained between the measured and calculation results for OFCs. We discuss conditions to obtain flat OFCs using this method along with details concerning OFC conversion efficiency and bandwidth.

   International impact on both academic and social aspects： WDM技術を革新する多波長光源の実現や、パルス形状を自由に操ることを可能とする技術として重要な役割を担うことのできる、MZ変調器への高調波同時印加による変調技術を提案した論文で、将来的にも重要な知見を与えている。 / In this paper we propose and demonstrate experimentally the harmonic superposition technique with Mach-Zehnder modulator which enables to realize multi-wavelength light sources and pulse shape controllable light sources.

This novel technique will use to enlarge the functionality of light source for next generation optical communication systems.

2. K. Aoyama, N. Yokota, and H. Yasaka, "Strategy of optical negative feedback for narrow linewidth semiconductor lasers," Optics Express, vol. 26, No. 16, pp. 21159-21169, 2018. [IF: 3.356], [Times Cited: 1]
Abstract: The coherent optical negative feedback scheme is systematically investigated by calculating rate equations that model a noise-added semiconductor laser coupled to a Fabry-Perot optical filter for the FM noise reduction. The calculated results indicate that the FM noise is minimized when a lasing frequency of the free-running laser matches a valley frequency of the filter (the point where power reflectivity becomes zero) under a specific feedback phase, where the slope of the electric field reflectivity for the lasing light and frequency discrimination efficiency to electric field amplitude of the feedback light becomes maximum. And the linewidth is also minimized at a lasing frequency corresponding to the valley frequency of the Fabry-Perot optical filter. It is also made clear that the laser frequency becomes less sensitive to the fluctuation of the injection current of the laser under optical negative feedback.
International impact on both academic and social aspects: 共振器特性の向上に依らずに、小型な超狭線幅半導体レーザ光源を実現可能な光負帰還原理を解明した論文で、光負帰還半導体レーザの設計論を構築する上で重要な知見を与える論文である。 / In this paper we clarify the principle of optical negative feedback scheme for realizing compact and ultra-narrow linewidth semiconductor lasers without heightening the performance of laser cavities by increasing scale of light source. The results give important information to constructing design theory of optical negative feedback semiconductor lasers.

3. N. Yokota, K. Nisaka, H. Yasaka, and K. Ikeda, "Spin polarization modulation for high-speed vertical-cavity surface-emitting lasers," Applied Physics Letters, vol. 113, Issue 17, 171102, 2018. [IF: 3.495], [Times Cited: 0]
Abstract: The spin polarization modulation in birefringent vertical-cavity surface-emitting lasers (VCSELs) is investigated theoretically and experimentally for obtaining tailored polarization modulation characteristics suitable for high-speed data communications. A spin-flip rate equation analysis reveals that the spin polarization modulation response of VCSELs is flattened by shortening the electron spin relaxation time and its 3-dB bandwidth is broadened to a range determined by a frequency split between two orthogonal polarization modes. Optical modulations of spin polarized electrons in commercially-available InAlGaAs quantum well VCSELs demonstrate a wide 3-dB bandwidth of 23 GHz determined by the frequency split, which indicates that the spin relaxation time in the InAlGaAs quantum well VCSEL is around 20 ps at room temperature and suitable for use in high-speed data communications at a telecom wavelength of 1.55 μm.
International impact on both academic and social aspects: 発振光の偏光方向を高速に切り替える新奇な技術の提案を行った論文である。100GHzを超える超高速強度変調光や位相変調光の発生にも応用できる将来的に重要な技術である。 / In this paper we propose a novel technique to switch polarization rotation direction of lasing circular polarization mode in electron spin controlled VCSEL. We show that the polarization switchable VCSEL can generate ultra-high speed intensity modulated light or phase modulated light beyond 100 GHz. This laser technology will play an important roll in the research on next generation high speed and high function semiconductor laser source.

G. 特筆すべき活動 / Significant Activities (FY.2013-2018)

See Ref. 2-9. "#" mark indicates research carried out at a former organization.

研究室外部評価参考資料の 2 以降を参照しながら，2013-2018 年度のなどの活動の中から特筆すべきものを取り出し，前半（2013-2015 年度）と後半（2016-2018 年度）に分けて簡単に紹介する．英文のみ，もしくは和文と英文で記載.

[2013-2015]

1. TPC member for international conference: IPRM2013, CLEO2013
2. Committee member for international conference: MWP/APMP2014
3. Reviewer for academic journals: 14

[2016-2018]

1. TPC member for international conference: IPRM2016
2. Domestic Executive Committee member for international conference: ISLC2016
3. Reviewer for academic journals: 10