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Progress of GaInNAs Long Wavelength Lasers

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1. Introduction

Next generation optical network systems, such as LAN, MAN and interconnects, requires low cost and temperature stable light sources with high transmission performances. A vertical cavity surface emitting laser (VCSEL) is a candidate due to its low fabrication cost, low power consumption and high-speed modulation capability. Though GaAs-based 0.85μm VCSELs have been commercialized for short distance networks, long wavelength (1.3-1.55μm) VCSELs are strongly desired for a high transmission capacity of more than 10Gbps with a long distance over 10km. Low operation voltage and eye safety of the long wavelength is also advantageous for short distance networks.

A GaInNAs/GaAs proposed by Kondow et al. is an attractive material for long-wavelength lasers [1] and suitable for applying GaAs-VCSEL technologies [2]. An excellent temperature characteristic is another advantage of the GaInNAs system. These characteristics are also beneficial for edge emitting lasers.

In this presentation, the issues for realization of GaInNAs lasers are discussed and the current lasing performance of GaInNAs lasers are reviewed.

2. Issues of GaInNAs systems

Establishment of high quality GaInNAs growth is a key for high performance lasers. Because of the large atomic radius difference between the arsenic (As) and nitrogen (N), the GaInNAs has narrow growth parameter window and the careful optimization of the growth condition is isuue for the high quality epitaxy. The crystal quality has been improved enough to fabricate laser devices by both MBE and MOCVD technologies.

Recent topics on the GaInNAs growth are utilization of the surfactant for suppression of the growth mode change from 2D to 3D [3] and a post growth thermal annealing [4]. These technologies will improve the crystal quality to a comparable level with conventional material systems.

3. Lasing Properties of GaInNAs FP-Lasers

Figure 1 shows progress of the threshold of GaInNAs lasers. After the first lasing by Kondow et al. in 1996, improvement of the crystal quality reduced the threshold rapidly. We have fabricated GaInNAs QW lasers by MOCVD and the minimum threshold was as low as 200A/cm^2/well as shown in Fig. 2. The recent GaInNAs laser performances become comparable or better than conventional lasers.

These lasers showed a characteristic temperature T_0 of about 200K and the maximum operating temperature was up to 180°C with a little change in the slope efficiency. Such an excellent temperature characteristics are advantageous for temperature control free systems and simplify of the control circuits. A large conduction band offset of the GaInNAs improves temperature characteristics. It is also effective for reduction of the threshold, increase of the gain coefficient, and high differential gain. A high differential gain dg/dn of 1×10^{-15}cm^2 was reported from Shimizu et al. [5] and this indicates the possibility of a high-speed modulation.

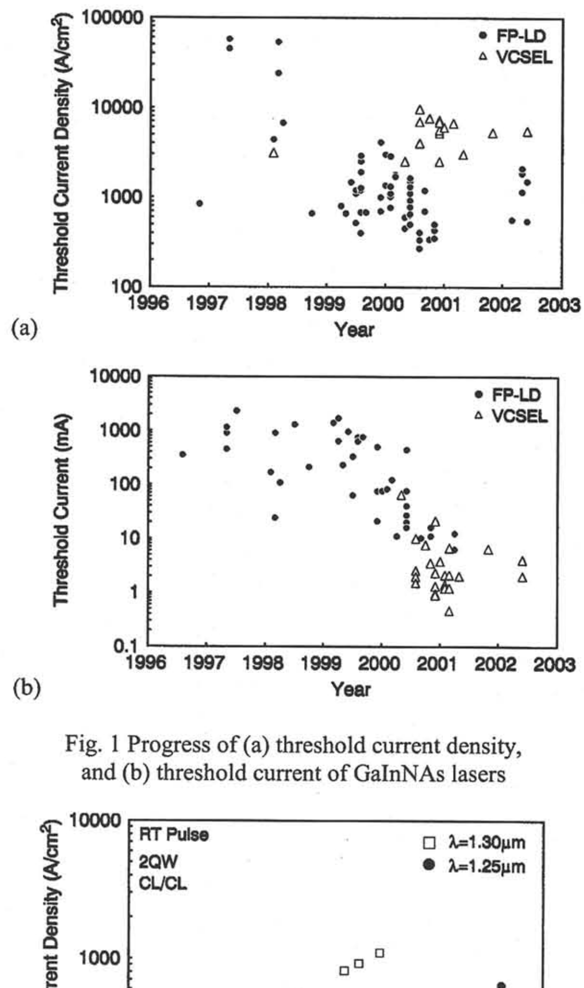

Fig. 1 Progress of (a) threshold current density, and (b) threshold current of GaInNAs lasers

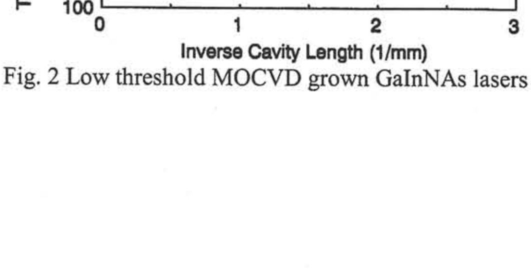

Fig. 2 Low threshold MOCVD grown GaInNAs lasers

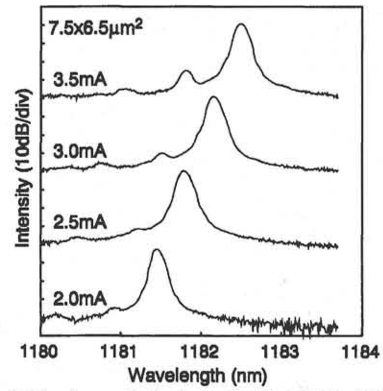

Fig. 3 Single mode lasing of a GaInNAs VCSEL

As high performance edge emitting lasers, the output power of 8W [6] and a metal-gratings DFB laser [7] have been demonstrated. The wavelength elongation is a next important target for the GaInNAs system and 1.4-1.52μm lasers have been reported [8, 9].

4. GaInNAs VCSEL

The first VCSEL was reported in 1998. We also realized a VCSEL grown by chemical beam epitaxy (CBE) [10]. The CBE growth was utilized for the growth of the GaInNAs cavity and DBRs were grown by MOCVD. Room temperature cw operation was observed with a threshold current of 1.2mA and the threshold current density was as low as 2.6 kA/cm^2. A single transverse mode operation was observed for a relatively large current aperture because of the long wavelength as shown in Fig. 3.

In recent years, many groups demonstrated the VCSEL lasing and performances have been improved as shown in Table 1. A low threshold of less than 0.5mA were reported. The threshold current reduction was clearly achieved by VCSELs as shown in Fig. 1(b).

Transmission characteristics have been also investigated such as 10Gbps operation, 2.5Gbps-20km and 5Gbps-10km transmissions [11, 12]. The results indicate applicability of GaInNAs VCSELs to high capacity networks.

5. Summary

The recent progresses of the GaInNAs lasers are reviewed. The laser performances have been improved by the crystal quality improvement. The lasers show a low threshold, good temperature characteristics and high-speed modulation capability. The GaInNAs lasers have a potential of replacing the light sources used in optical networks.

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Table 1 Lasing characteristics of GaInNAs VCSELs (* single mode output power)

Reported by	Growth	λ (nm)	I_{th} (mA)	J_{th} (kA/cm^2)	P_{max} (mW)	T_{max} (°C)	Publish
Hitachi	GSMBE	1186	22.3	4.5	1.1	95	1998.2
Stanford	GSMBE	1215	65	2.5	17		2000.5
Sandia, Cielo	MBE	1294	1.95	9.6	0.06*	55	2000.8
Ricoh, Tokyo Tech	MOCVD	1262	7.6	7.6	0.1		2000.11
Stanford	MBE	1201	0.89	6.9	0.08*		2000.12
Infineon	MBE	1284	3.8	6	0.4*	60	2001.1
Tokyo Tech	CBE/ MOCVD	1185	1.2 2.1	6.0 2.6	0.25 0.34*	 55	2001.2
Cielo, Sandia	MBE	1268 1262	1.2 0.46	38 59	0.749*	107	2001.3
Infineon	MBE	1305	2.0	3	0.65*		2001.5
Cielo	MBE	1289	2	10	1	125	2001.5
Agilent	MOCVD	1305	1.5		0.7		2001.11
EMCORE	MOCVD	1275	1.5	3	0.4*		2002.1
Sandia	MBE	1284	0.9	5	0.7*		2002.1
Ricoh	MOCVD	1284	2	5.5	0.55		2002.5
Infineon	MOCVD	1293	1.25		1.4*	85	2002.6