面発光レーザーと微小光学：この小さな光から

VCSEL and Microoptics: From Tiny Light

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1. Introduction

In this talk, we like to discuss on a Vertical Cavity Surface Emitting Laser (VCSEL) and microoptics. Figure 1 shows the skectch of VCSEL idea [1977IGA].

Fig. 1 A sketch of VCSEL idea

2. Birth of VCEL

The author invented a vertical cavity surface emitting laser in March 22, 1977 [1977IGA]. Its motivation is to realize laser with; (i) monolithic process, (ii) single mode, and (iii) wavelength-reproducibility [2018IGA]. The first presentation of idea was in 1978 and the initial device came out in 1979 operating at 77K by GaInAsP/InP material. The primary breakthrough was a 10-micron cavity VCSEL demonstrating clear VCSEL mode even at 77 K in 1982; i.e., single mode, circular beam, linear polarization, and so on. The first room temperature CW operation was achieved in 1988 by GaAs system with F. Koyama exhibiting a possibly engineered semiconductor laser. Also, we achieved a near room temperature CW in a 1,300 nm VCSEL in 1993.

The other important event in 1992 was the demonstration of a continuously tunable VCSEL by mechanically changing the cavity length. Later, this concept led to a MEMS tunable VCSEL by Chang-Hasnain et al.

Since the beginning of 1990's, a lot of research sectors started the development of VCSEL and very low threshold devices reaching several micro-Amperes were reported.

Since 1992, 850, 780, and 980 nm devices were commercialized into lightwave systems. Aiming at exploring applications, 1300-1550 nm long-wavelength, red color AlGaInAs, and blue GaN devices had been developed.

In the author's group, some key concepts have been proposed such as; Quantum-well VCSEL, MQB (Multi-Quantum Barrier), 1200 nm GaInAs/GaAs VCSEL, modulation schemes, phased array VCSEL, Talbot-cavity VCSEL, tunneling injection, tandem VCSEL, and so on [2020IGA].

Some value-added technologies have been proposed by successors such as; continuous tuning, wavelength-temperature insensitive VCSELs, MEMS integration, phased array, beam steering, high frequency modulation (>40 GHz), DBR-waveguide integration (modulator/amplifier), spontaneous emission control, and so on.

3. Microoptics

Microoptics is an area that deals with small optical devices. The author invented a "planar microlens" in 1979 [2018IGA].The typical size is as small as 250 μm in diameter. We made a bowl-shaped refractive index distribution by a diffusion method that provided a monolithic lens array. The microlens array was applied to LCD that helped to increase its brightness. Also, the author presented a concept of vertical stacked optics in 1982 that was the initiation of 3D integrated optics.

4. VCSEL and Microoptics Applications

From 1999, the VCSEL was applied to high speed LANs such as Gigabit Ethernet and its mass-production started [2018IGA]. In 2001, a computer mouse and laser printers were developed. In 2017, VCSEL was also adopted for iPhoneX face recognition together with microoptics elements.

Until now VCSELs have been applied to various IoT technical fields as shown in Fig. 2. The market size of production is postulated to be 2,500 M$ in 2020 [2020 IGA].

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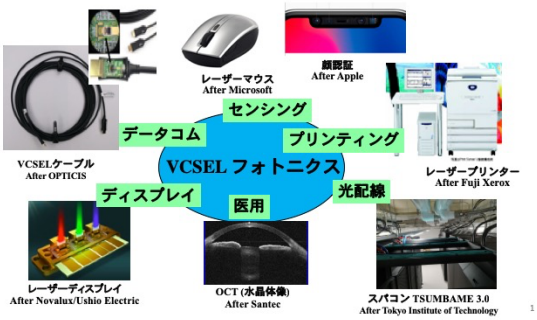

Fig. 2 The application areas of VCSELs

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