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A NEW COUPLED QUANTUM WELL SWITCHING LASER (PREPRINT)

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NOTICE

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14. ABSTRACT
A new thyristor VCSEL is reported. It incorporates two independent sets of modulation-doped quantum wells. Threshold currents for 12 μm and 8 μm apertures are 2.2 mA and 1.6 mA, respectively, with corresponding peak powers of 1.7 mW and 0.16 mW.

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A New Coupled Quantum Well Switching Laser

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Abstract: A new thyristor VCSEL is reported. It incorporates two independent sets of modulation-doped quantum wells. Threshold currents for 12μm and 8μm apertures are 2.2mA and 1.6mA respectively with corresponding peak powers of 1.7mW and 0.16mW.

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1.Introduction

Monolithic integration of electronic and optical components is the critical step towards the implementation of optical interconnect which the microelectronics industry now regards as essential to the continued evolution of the integrated circuit according to Moore's law. Currently the only approach is optoelectronic hybrid integration [1] which is both costly and non-scalable. The obstacles to monolithic integration may be reduced to the problems of compatibility of transistor and laser structures. In GaAs, the laser as a VCSEL is available but an electronics base, suitable for digital logic, is not. In Si , CMOS is a mature electronics platform, but the laser is not possible due to the indirect bandgap. Recent reports of an optically pumped Si Raman laser have created much interest [2]. However this is far from the goal of an electrically pumped VCSEL which is regarded as a benchmark optical source for a successful integration platform[3].

This paper reports the first operation of a new VCSEL structure which is designed for optoelectronic integration. The layer structure and fabrication technique for the VCSEL are shown in Fig.1a and the energy band diagram is shown in Fig.1b taken vertically through the cavity. It consists of two physically separated sets of

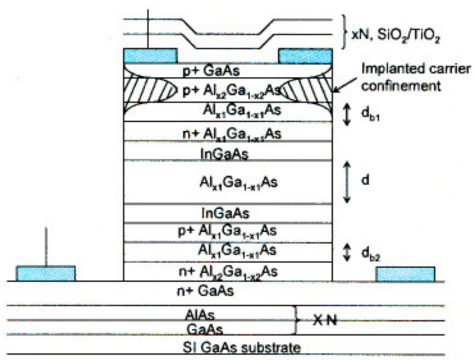

Fig.1a Layer structure and fabricated cross-section for the DDOES VCSEL

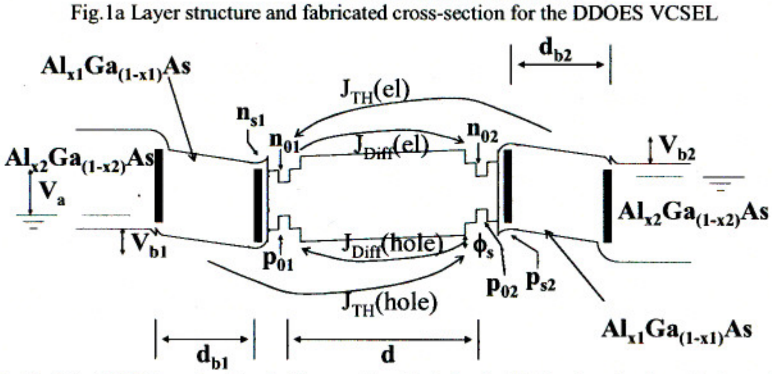

Fig.1b Energy bands for the thyristor VCSEL under bias in the on-state. Majority feed is by thermionic emission and minority feed by diffusion from the coupled well

modulation doped quantum wells, with n type and p type doping respectively, having majority and minority carriers in each set of quantum wells. The two sets of wells are mutually interactive electrically in the sense that each quantum well creates a thermionic barrier to control the injection current which feeds the majority carrier to the opposite well. In addition, each majority population becomes the source of carriers to supply minority charge to the opposite quantum well. The theory of this conduction has recently been published[4]. With each quantum well designed to lase at the same wavelength, the total photon population in the cavity produces stimulated emission simultaneously in both sets of quantum wells. These electrically and optically mutually interactive quantum wells form the basis for optoelectronic integration. The VCSEL functions electrically as a thyristor device with detector operation in a high impedance off state and laser operation in a low impedance on state. The quantum wells are accessed electrically to control the state of the thyristor. The device is termed the DDOES (Dual Double Heterostructure Optoelectronic Switch), based on its predecessor, the DOES[5]

2.Epitaxial Growth and Fabrication

The growth was performed by MBE on 3" SI GaAs wafers in a Varian GEN II system. The growth consists of a lower DBR mirror of AlAs and GaAs of thicknesses designed for oxidation. The layer sequence consists of 2000A of N+ GaAs, 700A of N doped AlGaAs(70%), 300A of undoped AlGaAs(15%), 80A of p doped $3x10^{18}$ cm^{-3} AlGaAs(15%), 3 QW/B's of InGaAs and GaAs, 5000A of 15%AlGaAs, 3 QW/B's of InGaAs and GaAs, 80A of n doped $3x10^{18}$ cm^{-3} AlGaAs (15%), 300A of undoped AlGaAs(15%), 700A of p doped $5x10^{17}$ cm^{-3} AlGaAs(70%), 700A of p doped $5x10^{19}$ cm^{-3} GaAs. These layer thicknesses are designed for a cavity of 4 wavelengths at 1000nm. Fabrication consisted of an ion implanted aperture, a refractory top metal contact, mesa etch to bottom contact, RTA , oxidation, metallization, anneal and top mirror deposition.

VCSEL operation was obtained with 1µs current pulses and a 1:30 duty cycle. For 12µm aperture devices, the

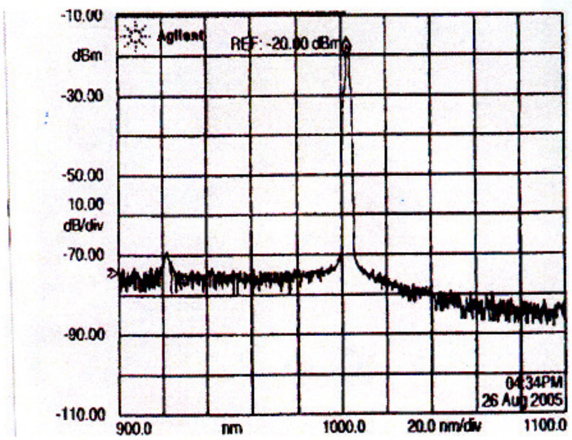

Fig. 2 Lasing spectrum from the thyristor two terminal laser under pulsed operation at 300K

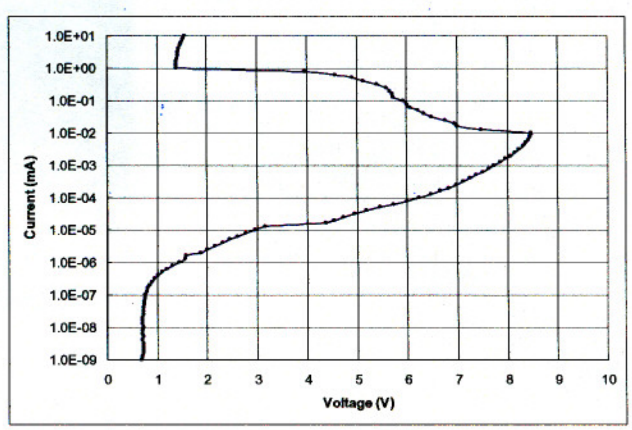

Fig.3 Two terminal switching characteristic of a 20um thyristor VCSEL

lasing parameters were I_{th}=2.2mA, I_{max}=9.1mA, P_{max}=1.7mW and R_{on}=200Ω and the optical spectrum is shown in Fig.2. A suppression ratio of >55dBm was obtained with a mode wavelength of 1004 nm. For the 8um apertures, the corresponding results were I_{th}=1.6mA, I_{max}=6.5mA, P_{max}=0.13 mW and R_{on}=280Ω. Electrically a typical measured characteristic is shown in Fig.3

3. References

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