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Millimeter-Wave Signal Generation Using an Integrated Mode-Locked Semiconductor Laser and
Photodiode

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Millimeter-Wave Signal Generation Using an Integrated Mode-Locked Semiconductor Laser and Photodiode

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A compact optoelectronic integrated circuit (OEIC) for generation of mm-wave frequencies has been demonstrated. This new OEIC integrates a passively mode-locked semiconductor ring laser, optical amplifier and high-speed photodiode for generation, amplification and detection of an optical pulse train with 30 to 90 GHz pulse-repetition frequency. Output of the OEIC is an electrical signal, generated by the photodiode, whose fundamental frequency is the pulse repetition rate of the mode-locked laser.

The mm-wave generation OEIC, Fig. (1), uses (Al,Ga)As double-heterostructure rib waveguides with a single-quantum-well active region. Multi-lateral-moded ring waveguides with y-junction output couplers are etched to form passive mode-locked lasers¹ monolithically integrated with an optical amplification section and waveguide photodiode (WGPD) at the laser output. Pulse repetition frequency is fixed by the ring diameter to be nominally 30, 60 and 90 GHz for the three circuits fabricated. The WGPD is formed using a trench etch around the rib waveguide and is integrated with an electrical transmission line for efficient removal of the output signal.

The RF output spectrum of each OEIC is plotted in Fig. (2). Fundamental pulse repetition frequency of the 860, 430 and 290 μm diameter of rings were 29.1, 57.5 and 85.2 GHz respectively. Frequency generation close to the desired value was achieved for all three laser diameters. The observed linewidth is dominated by the approximate 900 psec rms pulse-to-pulse timing jitter. Such values are not unusual for passively mode-locked semiconductor lasers. Peak mm-wave power levels are -12, -23 and -27 dBm at 29.1, 57.5 and 85.2 GHz respectively.

The focus of this work has been to demonstrate the feasibility of mm-wave signal generation using a mode-locked ring laser OEIC. Output power of these circuits is influenced by a number of factors including the internal circulating power of the ring, the amount of power coupled out of the ring, gain of the amplifier and the efficiency of the photodiode. Use of an optimal output coupler for power extraction from the ring and a traveling-wave photodiode^{2, 3} (TWPD) would increase the output by as much as a factor of 100 at these demonstration frequencies. A TWPD may be required above 100 GHz due to the poor WGPD efficiency. A flared amplifier with one or more photodiodes operating in parallel at the wide amplifier output end may result in further power enhancements.

In conclusion, we have demonstrated a new type of OEIC for direct generation of mm-wave frequencies. This OEIC integrates a passively mode-locked semiconductor ring laser with an optical amplifier and high-speed waveguide photodiode. OEICs using this concept can be used in a wide variety of applications where a very compact, lightweight mm-wave source is required. This work was supported by United States Department of Energy under Contract DE-AC04-94AL85000. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed-Martin Company, for the United States Department of Energy.

1) J. P. Hohimer and G. A. Vawter, *Appl. Phys. Lett.* **63**, 1598-1600 (1993).

2) V. M. Hietala, G. A. Vawter, T. M. Brennan and B. E. Hammons, *IEEE Trans. on Microwave Th. and Tech.* **43**, 2291-2297 (1995).

3) K. S. Giboney, R. L. Nagarajan, T. E. Reynolds, S. T. Allen, R. P. Mirin, M. J. Rodwell and J. E. Bowers, *IEEE Phot. Technol. Lett.* **7**, 412-414 (1995).

Figure 1: Schematic and electron micrograph views of millimeter-wave generation OEIC.

During normal operation the two separately-contacted sections of the amplifier are biased together.

Figure 2: Measured electrical output spectrum of three different millimeter-wave generation OEICs. Ring laser diameter determines the output frequency of circuit.

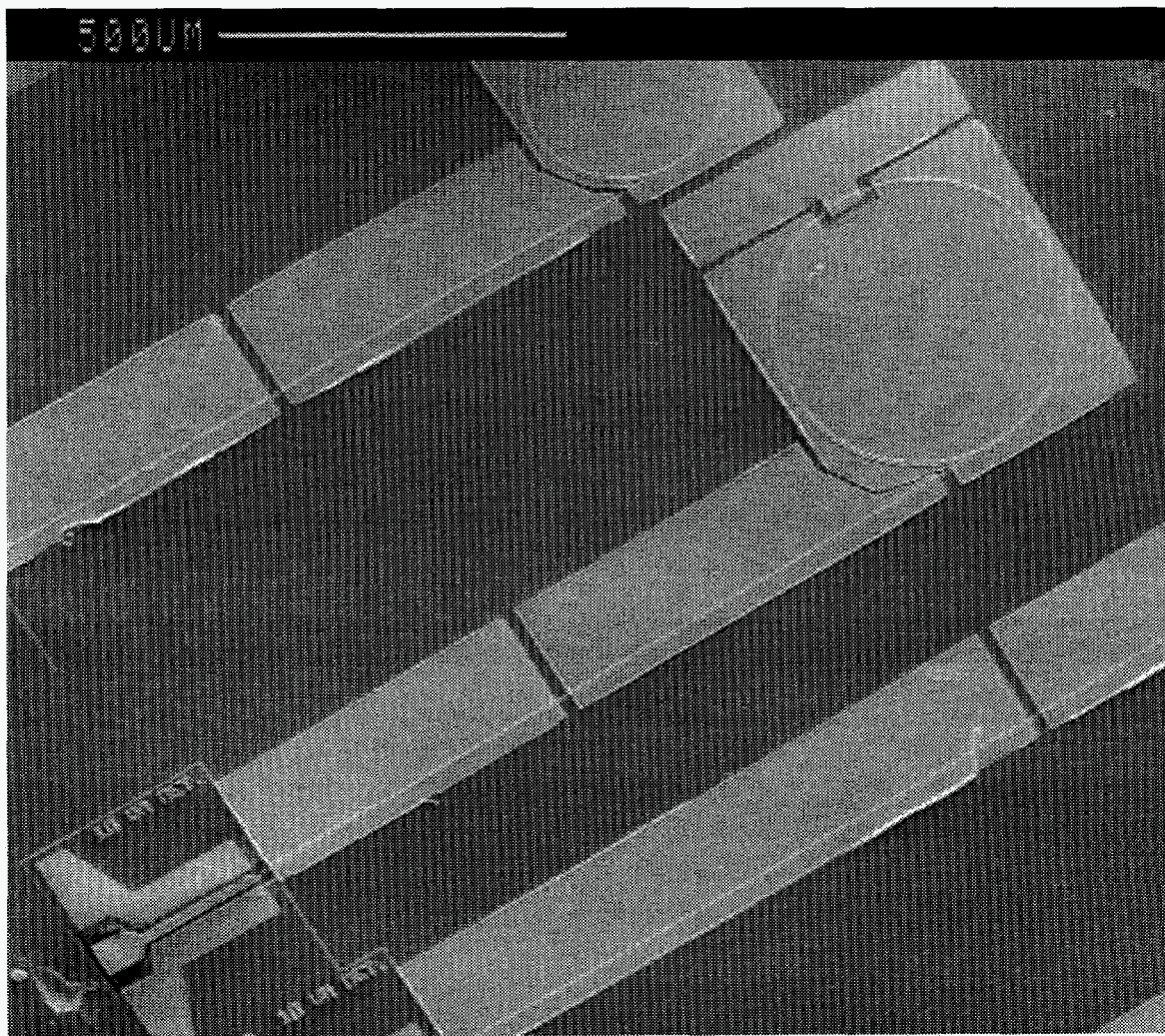
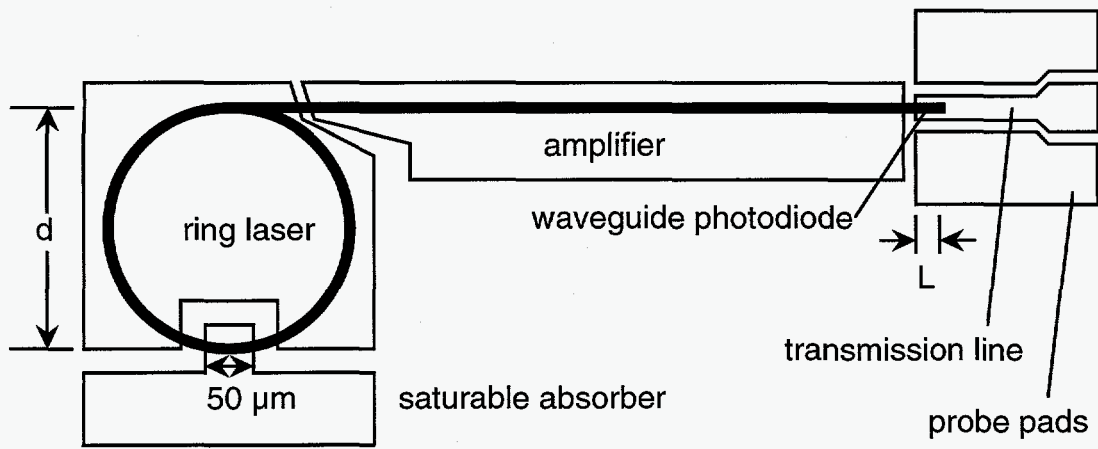


Figure 1

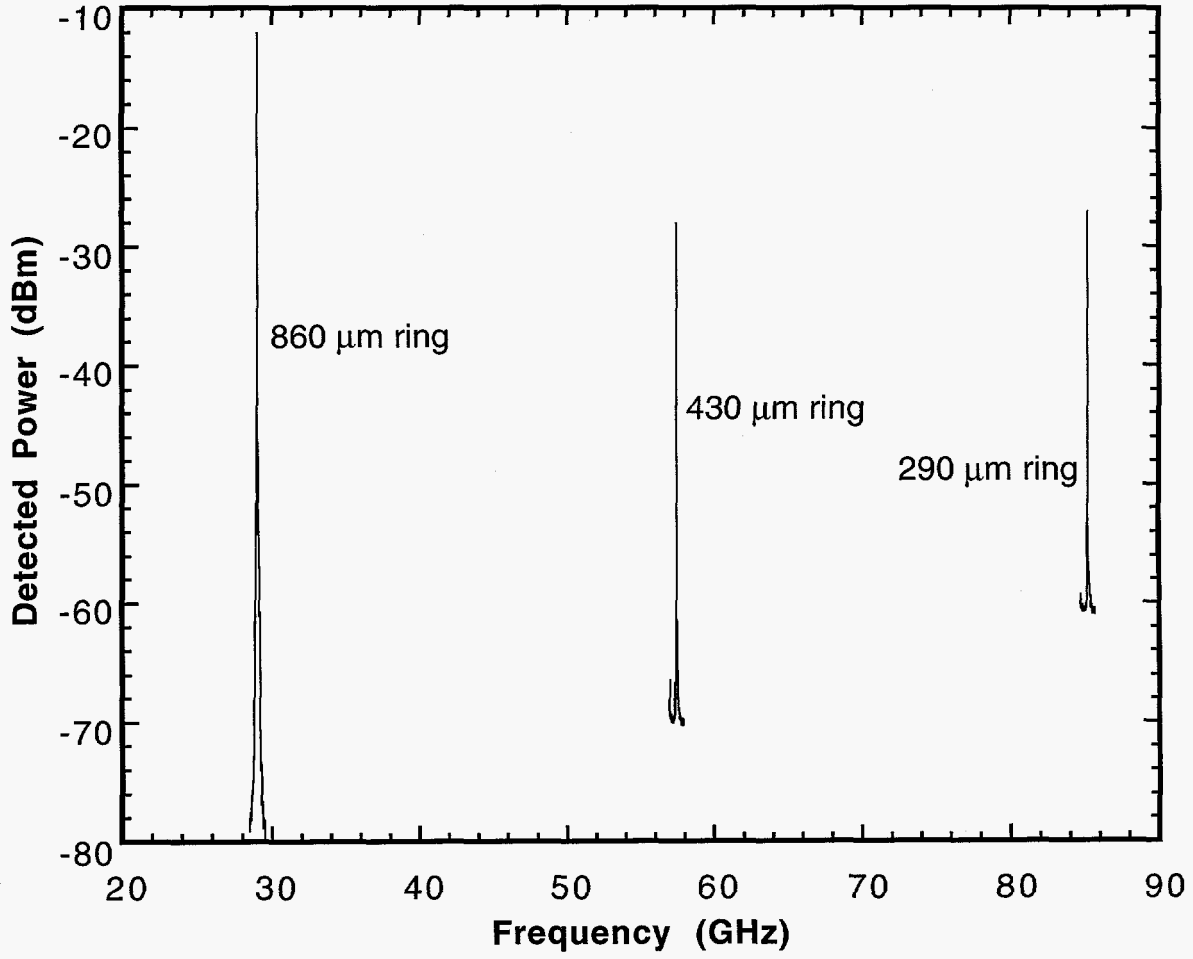


Figure 2