



Packaged Diamond Shaped Diode Ring Laser Switch (Paper)

Describes the development of a unique semiconductor ring laser (SCRL). It is packaged and characterized with injection locked time-varying input signals. Also discusses applications.

WORLD-CLASS
MEMS INNOVATION

PACKAGED DIAMOND SHAPED DIODE RING LASER SWITCH

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Abstract

The development of a unique semiconductor ring laser (SCRL) is described. It is packaged and characterized with injection locked time-varying input signals. Applications are discussed.

Laser Description

The diamond shaped cavity with four fiber-coupled access ports distinguishes this from all prior related work suitable for application in the 1550 nm regime. The design permits a time encoded *optical* input signal to influence all of the output signals via the interaction in the laser gain medium. In this particular prototype, response was observed to exceed 12 GHz without optimizing cavity dimensions.

Technical advances were required to implement the waveguide's geometry so as to access all active ports with optical fiber. The research effort involved Binoptics Corporation, Infotonics Technology Center and the Air Force Research Laboratory. Binoptics' novel fabrication technology generated the facets by a chemical assisted ion etch, defined by precision photolithography rather than conventional cleaving. This enabled flexible and reproducible monolithic integration of precise structural features [1], in particular the air-gapped trench fold mirrors illustrated in Figure 1 (Left). A custom package design, Figure 1 (Right), by Infotonics Technology Center incorporated metal-ferruled, polarization-maintaining (PM), lensed fibers in a TE temperature stabilized housing [2]. The device's performance was characterized at AFRL [3].

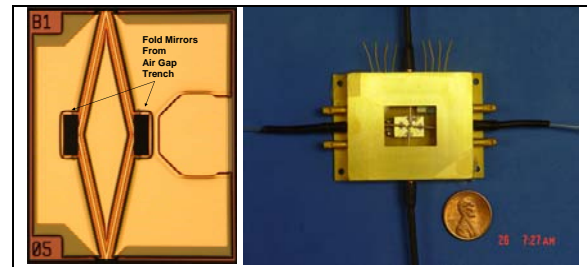


Figure 1. (Left) diamond cavity configuration [1]. (Right) packaged device.

The ninety degree separation of the four optical access ports permits a wide variety of input/output protocols. The input signal was modulated externally with a high speed optical modulator and injected from a narrow line width tunable diode, which locked the diamond laser's operation at a single longitudinal mode. The ring laser propagation is inherently bidirectional, but unidirectional propagation is forced upon injection, and an induced intensity inversion of the mode counter-propagating (CCW) relative to the input, or "switching" effect, is observed over a wide range of frequencies from steady state to modulation rates in excess of 12 GHz. The fact that ring lasers naturally exhibit traveling wave operation, as opposed to standing waves characteristic of Fabry-Perot lasers, also permits independently propagating optical signals to be synchronized and controlled by co-propagating signals. This approach overcomes a major difficulty in prior attempts at applying diode ring lasers in signal processing, which was the inability to separately access multiple input/output signals. Sampled performance characteristics and signal fidelity was monitored at two output ports as shown in Figure 2.

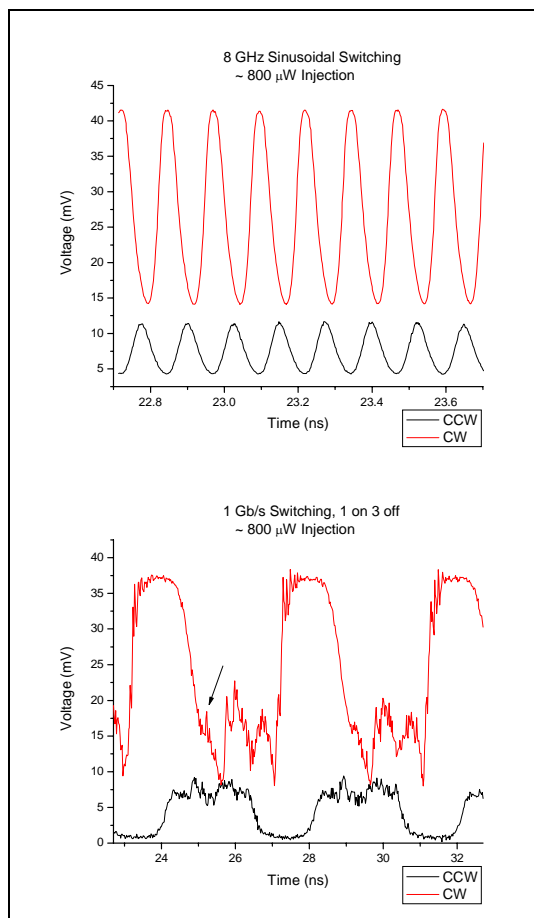


Figure 2. (Top) Sinusoidal 8 GHz Input Induced Switching in CCW Signal. (Bottom) Digital Encoded 1 Gb/s (1 On, 3Off) Switching with Extinction Ratio 9 dB.

Application to Sensing and Signal Processing

Ring diode lasers, bistable VCSELs and other optically coupled two mode laser systems, allow for the exchange of both energy and phase information between modes. Accessing the vector nature of these signals enables certain control over signals, which was not previously available in simpler laser structures. The nonlinear dynamics in a traditional diode laser with such additional degrees of freedom have not been examined to date, so the SCRL system offers a platform for full theoretical analysis of new operational mechanisms.

* **Digital Photonic Logic/Signal Routing.** Encoded digital signals exiting the optical

modulator also encode the output signals from the ring. This can be used in conventional digital signal processing or routing.

* **Optical Analog/Digital Conversion.** This SCRL has exhibited switching effects at inputs as low as $2 \mu\text{W}$. The magnitude of the switched intensity inversion is controlled by the input signal level and could allow an array of these devices properly stepped in threshold values to operate in principle as a converter.

* **Laser Gyros, Inertial Sensors.** The two counter propagating laser modes provide a direct means for realizing the Sagnac effect, which has been well established in gyro technology with gas and fiber lasers. The SCRL here offers an ultra compact geometry for potential applications.

* **Stochastic Resonance (SR).** A requirement in many applications is the extraction of weak signals from the noise floor. With SR the addition of random noise to the spontaneous emission noise can significantly improve the signal-to-noise level of an externally modulated bi-stable nonlinear system relative to one with no injected noise. A SCRL port allows an all-optical approach to this, in contrast with prior ones that were [4] constrained to manipulate the electrical drive power.

Conclusion

A newly developed SCRL device has been described and its performance characterized at high data rates. It offers unprecedented multi-port access to optical signals, as well as the flexibility to support new applications.

References

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