Novel Design Simplifies VECSEL Fabrication

Intracavity microlens provides focusing and matches pump light to resonator mode.

There are several advantages in using the end facet of an optical fiber as the output mirror of a vertical external cavity surface-emitting laser (VECSEL). For one thing, it's easy to couple the VECSEL's output into the fiber. And if the VECSEL is optically pumped, the fiber provides an ideal mechanism to launch the pump power. Recently, Nicolas Laurand and his colleagues at the Institute of Photonics at the University of Strathclyde in Glasgow, UK, demonstrated such a laser that incorporates a unique intracavity microlens to stabilize the resonator (Figure 1). This type of laser is likely to find applications in spectroscopy, metrology and optical communications.

The idea of using a fiber facet as a VECSEL mirror is not new and has been explored previously. But a resonator with two flat reflectors — such as a fiber facet and a distributed Bragg reflector — cannot support a stable mode in the absence of any form of intracavity focusing. In some cases, thermal gradients within the laser itself can provide the necessary focusing.

However, these gradients and, hence, the resonator stability, are strongly dependent on power levels and are, therefore, unsatisfactory for many applications. As an alternative, researchers have polished a concave surface on the fiber facet, thereby providing intracavity focusing that is independent of power.

Now the Strathclyde researchers have substituted an intracavity microlens for the concave surface, a step that they say significantly simplifies device fabrication.

There are additional advantages to substituting a microlens for the concave facet. Because the VECSEL's output coupler (i.e., the fiber facet) is

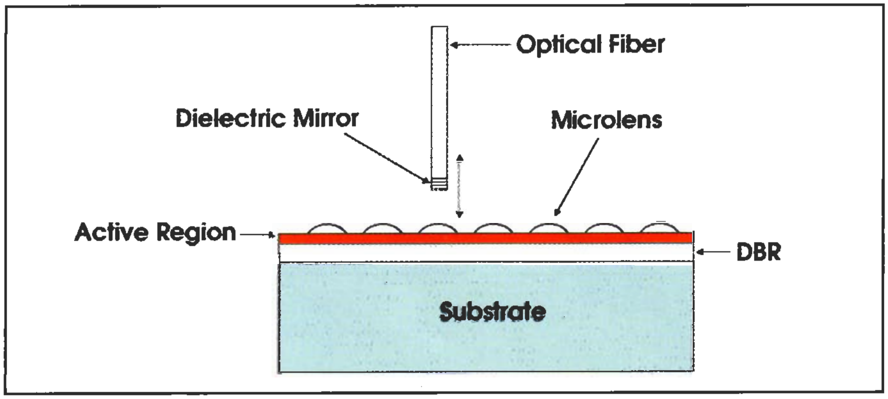

Figure 1. The VECSEL resonator is defined by its two reflectors, the distributed Bragg reflector (DBR) on the bottom and the dielectric mirror on the fiber facet, which is the laser's output coupler. The laser can be wavelength-tuned by displacing the fiber vertically. Images reprinted with permission of *Optics Letters*.

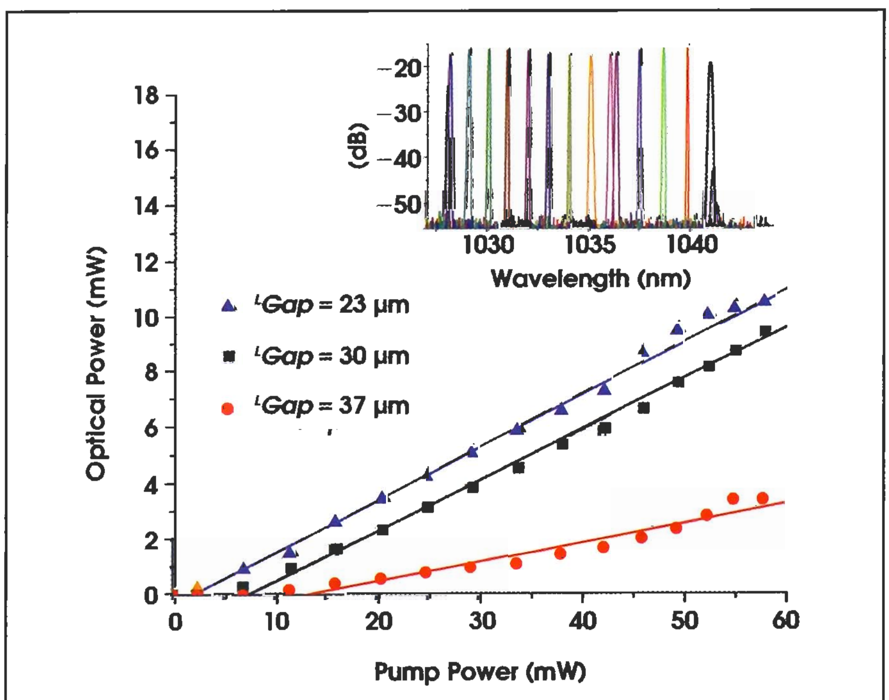

Figure 2. The output power was greatest for the smallest gap between the fiber facet and the microlens, even though that spacing didn't optimize coupling into the fiber. The explanation lies in the increased pump-power density accompanying the 23-µm gap. The inset shows a superposition of sequential spectra as the laser was tuned. Single longitudinal- and transverse-mode oscillation occurred except near the edges, where a second longitudinal mode reached threshold.

flat, there is necessarily a beam waist there, facilitating coupling into the fiber. Also, for an optically pumped VECSEL, the waist is inherently close in size to the fiber's mode, ensuring good overlap between the pump light and the intracavity laser mode.

The scientists fabricated their microlenses from a homemade epoxy but believe that commercial polymers alternatively could be used with no degradation in performance. For the results described here, they used microlenses of 44 μm in diameter. The laser gain was provided by 10 InGaAs strain-compensated quantum wells that were positioned at the maxima of the intracavity standing wave. The mirror coated onto the fiber facet reflected 95 percent of the 1.055-μm laser wavelength but was highly transmissive to the 810-nm pump light. The scientists mounted the fiber on a precision X-Y-Z translation stage so that they could carefully adjust the spacing between the fiber facet and the microlens.

By adjusting that spacing, they continuously tuned the laser between 1028 and 1041 nm (Figure 2). The resonator's longitudinal mode spacing was approximately as great as the gain spectrum, so only at the extremes of this tuning curve did they observe more than a single longitudinal mode oscillating. □

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