

# Glass waveguide-semiconductor hybrid lasers

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Diode lasers with narrow spectral linewidth and wide spectral coverage are of high importance, such as in metrology, sensing, or as phase reference in optical beam-forming networks (OBFNs) [1]. These desired spectral properties can be achieved via feedback from long external cavities that comprise narrowband spectral filters, so-called external cavity diode lasers (ECDLs) [2]. However choosing free-space optics with bulk components as frequency-selective elements renders such lasers sensitive to acoustic perturbations, while a large physical size is unacceptable for most applications as well. Monolithically integrated lasers, such as distributed Bragg reflector (DBR) lasers and distributed feedback (DFB) lasers avoid such issues but show relatively large linewidths, typically, in the order of MHz [3].

Here we report on a novel type of laser (see Fig. 1a) where a glass-waveguide circuit provides frequency-selective external feedback to a semiconductor optical amplifier (SOA), forming a glass-semiconductor hybrid laser. In a first example, for operation in the 1.55  $\mu\text{m}$  wavelength range, we have chosen a SOA based on InP. The  $\text{Si}_3\text{N}_4/\text{SiO}_2$  glass waveguide circuit comprises two sequential ring resonators, which are thermally tunable via electric currents. The laser shows single-frequency oscillation with more than 50 dB side mode suppression (see Fig. 1b), and exhibits a record-narrow spectral linewidth of 24 kHz. Compared to our initial results [4], the output power is increased by a factor of ten to 5.7 mW, and the spectral coverage is enlarged to 46.8 nm (from 1531 to 1577.8 nm), which is achieved with adiabatically tapering the glass waveguides.

Employing glass waveguides, as compared to feedback from, e.g., Si waveguides [5], opens up unprecedented options. Glass waveguides can provide record-low propagation losses (0.045 dB/m [6]), which is central for further spectral narrowing of the laser bandwidth. Glass waveguides can provide feedback over a huge wavelength range, including the entire visible range, limited only by material transparency (400 nm to 2.35  $\mu\text{m}$ ). We exemplify this in Fig. 1c, which shows the tuning of a visible glass-semiconductor hybrid laser (AlGaInP) around 694 nm, which might be of interest, e.g., for exciting transitions in strontium optical clocks.

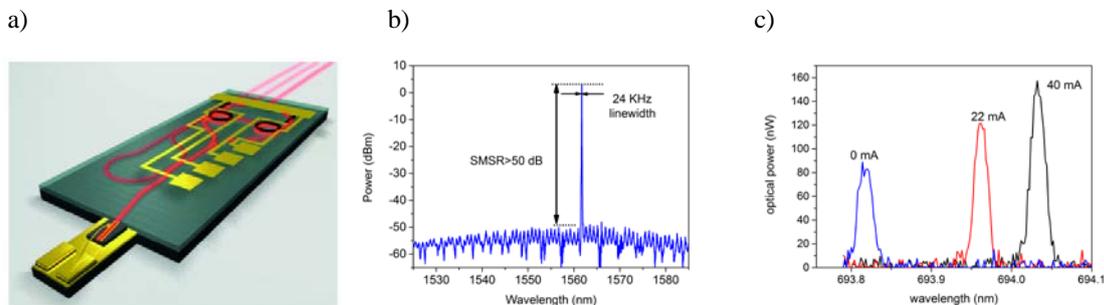


Fig.1 a) Schematic illustration of the glass-waveguides InP hybrid laser, b) typical single mode output spectrum in the 1.55  $\mu\text{m}$  range, c) tuning of a glass-AlGaInP hybrid laser around 695 nm.

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