Optoelectronics

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1. Wavelength-graded laser array

(P.O. Kellermann, N. Finger and E. Gornik (cooperation with University Stuttgart))

The wavelength division multiplexing (WDM) scheme is utilized to increase significantly the transmission rate of optical communication systems. Monolithic arrays of wavelength-graded laser diodes are considered as a compact choice for WDM light sources.

Fig. 1: Wavelength graded laser array.

We are developing a wavelength-graded surface-emitting laser array, which is based on contradirectional surface-mode coupling. The wavelength of single array elements can be adjusted after the processing by just changing the optical thickness of a surface waveguide. Phase matching of the surface-mode and the laser-mode (propagating in the dielectric surface waveguide and in the horizontal cavity respectively) is achieved by a surface relief grating in the top cladding of the laser waveguide. The grating causes radiation losses of the laser-mode (dominated by the emission into the substrate). The losses are reduced significantly in a narrow spectral range by the excitation and feedback process of the surface-mode. The linewidth of this resonance is comparable to the longitudinal Fabry-Perot mode spacing of the laser cavity, thus providing an effective mode selection mechanism, which leads to single-mode emission. The surface-mode couples both to the active region and into the vacuum light cone resulting in surface emission.

This surface-mode coupling concept is now used to realize a wavelength-graded array with visible red GaInP/AlGaInP lasers. Lasers in the visible regime are suitable to be used as emitters in optical short-range data transmission since the attenuation minimum of polymethylmethacrylate (PMMA) fibers lies near 650 nm. Holographic lithography and ion milling define the surface grating. Different thicknesses of the SiO/SiN surface waveguides are etched by ion milling yielding a wavelength spacing between the individual lasers. The total range across the array is a few nanometers. The fabrication process allows etching one element type of many arrays in one step..

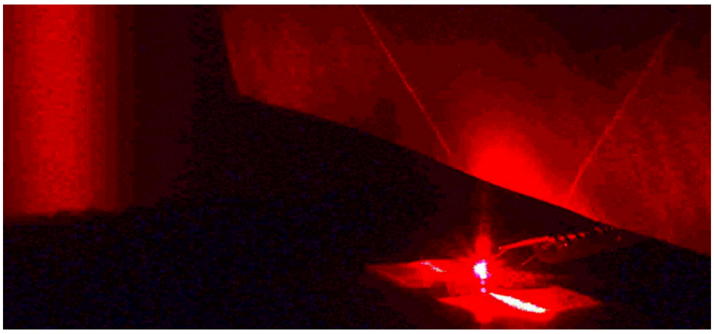

Fig. 2: The array elements emit via the surface. The intensity emitted per solid angle via the surface beam is five times larger than the one at the edges. Farfield pattern of a surface mode coupled laser: Two narrow surface beams and divergent spontaneous emission strike a paper screen (top) that is orientated parallel to the laser stripe contact. The divergent edge emission can be seen on the thermo electric cooling element and on a second paper screen (left-hand), which is orientated parallel to the cleaved facets.

2. A compact sensor for interferometric displacement measurements

(T. Maier and E. Gornik)

Interferometers based on the self-mixing effect in a single-mode laser diode are a low-cost solution for precise measurements of displacements, vibrations or absolute distances. Due to their inherent single-mode behavior and their homogenous far field patterns, vertical-cavity surface emitting lasers (VCSELs) appear especially suitable for this kind of application. Furthermore, by monolithic integration of a high-efficiency resonance-enhanced photodetector (REPD) which is used to read out the interferometric signal, a simple and compact interferometric sensor can be realized.

Our sensor consists of a GaAs-VCSEL which is surrounded by a large-area REPD (Fig. 3). The laser's 3 µm oxide aperture ensures single transverse mode operation throughout the pumping range. The top Bragg mirror of the VCSEL consists of 16.5 periods SiO_2/Si_3N_4. The detector efficiency is maximized by removing 5.5 periods of the top mirror, resulting in a peak efficiency of 62%.

The laser light is collimated and reflected back on the VCSEL with a retroreflector mounted on a piezoelectric transducer (PZT) which is driven by a sine voltage. The laser power is monitored with the integrated REPD. Due to self-mixing, the output power of the laser depends on the length of the external cavity and is modulated with a period of λ/2. The actual shape of the interferometric signal is determined by the strength of the feedback. Figure 4 shows the detector signal for several feedback levels, which are obtained by inserting various density filters in the optical path. For moderate feedback (a) the laser exhibits bistable switching between two external cavity modes, resulting in a hysteresis of the output power. The different switching levels indicate the direction of the retroreflector's movement. For decreasing feedback, the hysteresis disappears (b), and the sawtooth-like shape of the photosignal approaches a sine waveform (c). A first estimation of the dynamic range of the interferometer gives a minimum value of 15 cm.

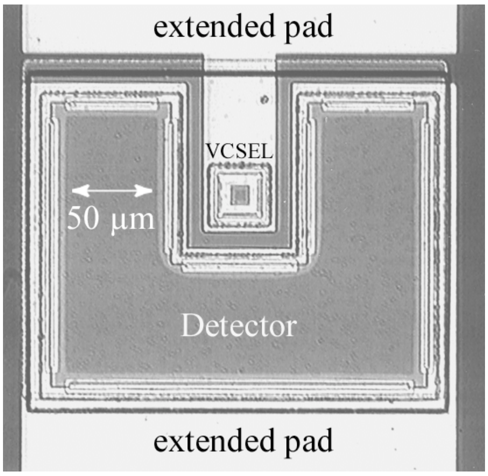

Fig. 3: Photograph of the sensor chip.

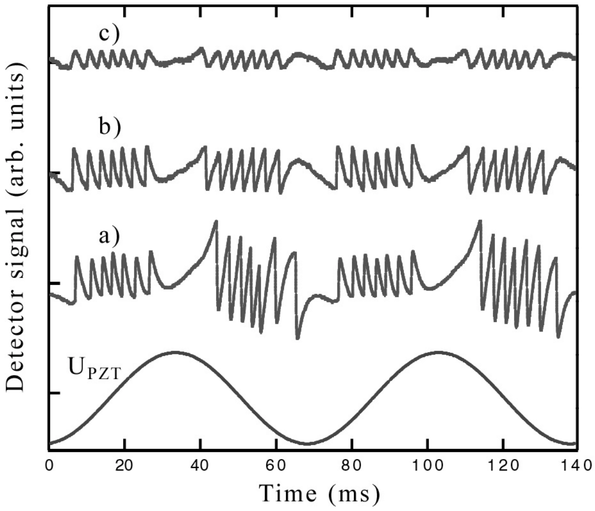

Fig. 4: Detector signals for various feedback levels (a, b, c). UPZT is the drive voltage applied to the PZT. The length of this external cavity is 20 cm.